

A one pot synthesis of fused chromenones

Kaushal P. Patel

Department of Advanced Organic Chemistry, P.D.Patel Institute of Applied Sciences, Charotar University of Science and Technology, Charusat, Changa-388 421, Gujarat, India
E-mail: kaus_chem@yahoo.com

Abstract

A new class of compounds, 7-hydroxy-9,10-dihydroindeno[5,4-*c*]chromene-6,11-dione **2a-e**, 7-hydroxy-10,11-dihydro-6*H*-naphtho[2,1-*c*]chromene-6,12(9*H*)-dione **2f-j** and 7-hydroxy-10,10-dimethyl-10,11-dihydro-6*H*-naphtho[2,1-*c*]chromene-6,12(9*H*)-dione **2k-o** have been synthesized by reacting various 1-(2-oxo-2-(2-oxo-2*H*-chromen-3-yl)ethyl)pyridinium bromides **1a-e** with 1,3-cyclopentandione, 1,3-cyclohexandione and dimedone respectively in the presence of sodium acetate in refluxing glacial acetic acid. Thus, new fused chromenones derivatives are synthesized and characterized by analytical and spectral data.

Keywords: 1-(2-Oxo-2-(2-oxo-2*H*-chromen-3-yl)ethyl)pyridinium bromide, indeno[5,4-*c*]chromene, naphtho[2,1-*c*]chromene

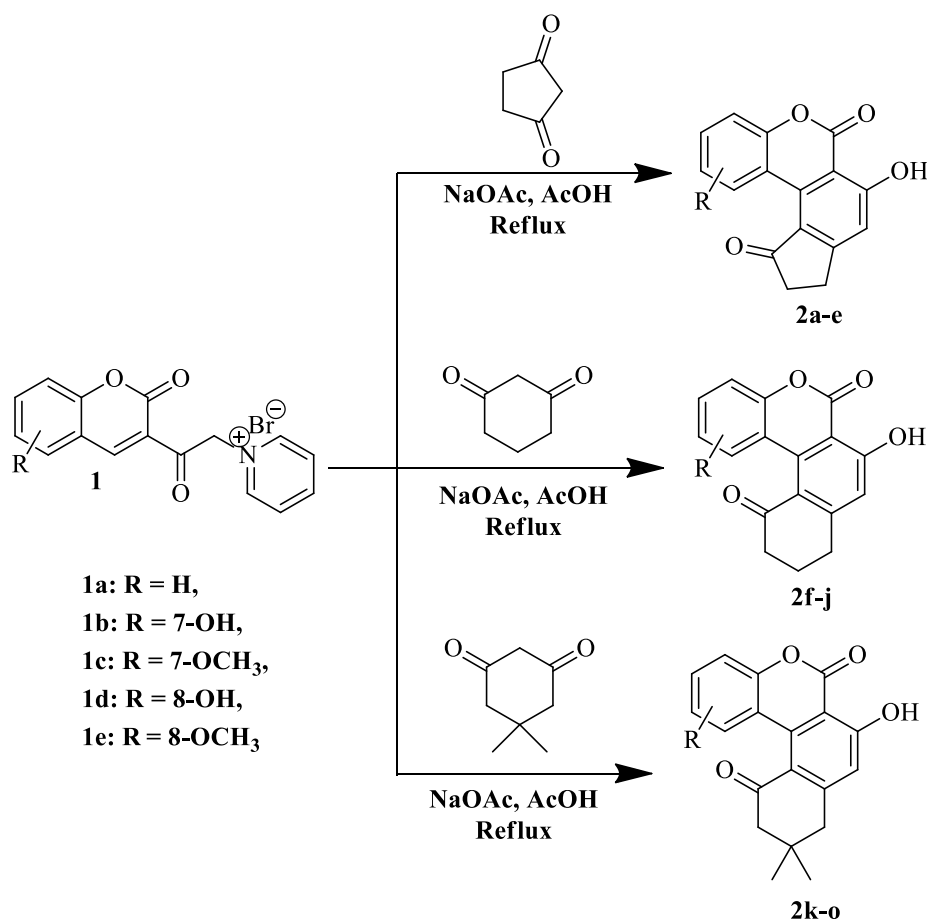
Introduction

During the last twenty years, the study of the biological activities of chromene derivatives has drawn the attention of many scientists.¹⁻¹⁰ Recently, the anticoagulant, antibacterial, anti-helminthic, hypothermic and vasodilatory properties of chromene have been reviewed.¹ Fused chromenones are interesting due to their significant antibacterial¹¹⁻¹⁵ and novobiocin^{16,17} activities. Recently, Selectfluor¹⁸ has been used as an alternative to conventional catalysts for the synthesis of substituted chromenones via Pechmann condensation of phenols with β -ketoesters under solvent-free conditions. Some of the co-workers developed simple and efficient synthesis of polyfunction heterocyclics from readily available starting materials.^{19,20} They have reported the synthesis of chromenopyridine and thiopyranochromene derivatives by cycloaddition of active methylene compounds with chromene-3-(4-aminosulfonyl) carbanilide¹⁹ or coumarin-3-thiocarboxamide.²⁰ Thus, considering the above synthetic methodology to prepare chromenones and its biological importance it was thought worthwhile to incorporate chromenone nucleus as a fuse group with indanone and naphthalenone. Therefore, in the present work we report a one pot synthesis of 7-hydroxy-9,10-dihydroindeno[5,4-*c*]chromene-6,11-dione **2a-e**, 7-hydroxy-10,11-

dihydro-6*H*-naphtho[2,1-*c*]chromene-6,12(9*H*)-dione **2f-j** and 7-hydroxy-10,10-dimethyl-10,11-dihydro-6*H*-naphtho[2,1-*c*]chromene-6,12(9*H*)-dione **2k-o** utilizing inexpensive and easily available starting materials.

Result and Discussion

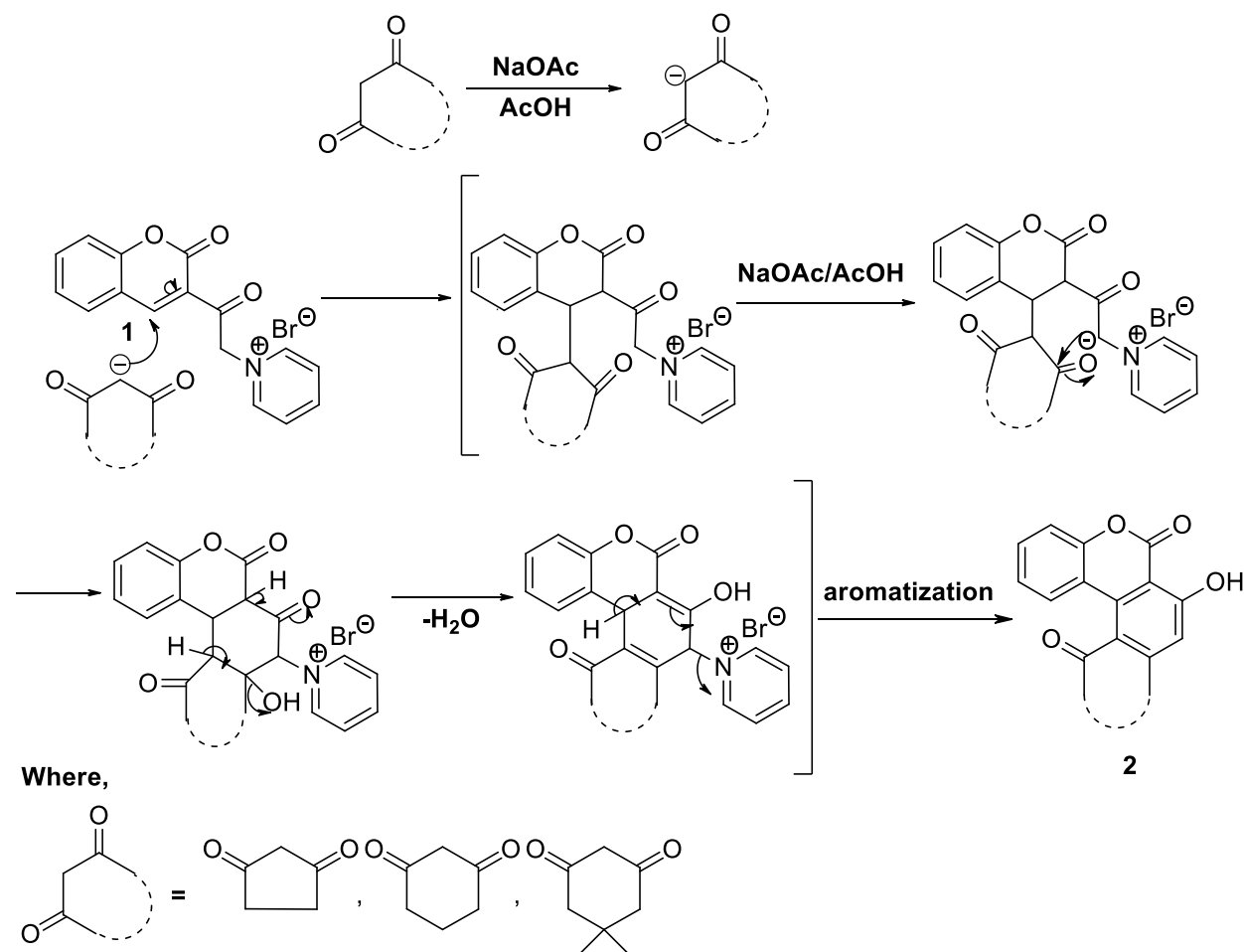
In this work, 1-(2-oxo-2-(2-oxo-2*H*-chromen-3-yl)ethyl)pyridinium bromide **1a-e** were reacted with appropriate diketone compound such as 1,3-cyclopentandione, 1,3-cyclohexandione and dimedone respectively in the presence of sodium acetate in refluxing acetic acid to afford 7-hydroxy-9,10-dihydroindeno[5,4-*c*]chromene-6,11-dione **2a-e**, 7-hydroxy-10,11-dihydro-6*H*-naphtho[2,1-*c*]chromene-6,12(9*H*)-dione **2f-j** and 7-hydroxy-10,10-dimethyl-10,11-dihydro-6*H*-naphtho[2,1-*c*]chromene-6,12(9*H*)-dione **2k-o** respectively (Scheme 1).



Scheme 1

Compound **1** was allowed to react with the 1,3-diketone under acidic conditions, to obtain fused chromenones **2**. The reaction pathway is assumed to proceed by Michael addition of the

active methylene function of 1-(2-oxo-2-(2-oxo-2*H*-chromen-3-yl) ethyl) pyridinium bromide on 1,3-diketone, resulting in the formation of intermediate having 1,5-dione functionality. The active methylene group (flanked by carbonyl ketone and pyridine moiety) then gets cyclized with carbonyl group of 1,3-diketone and the resultant intermediate finally aromatized to afford the product **2**. The proposed mechanism is shown in Scheme 2.



Scheme 2

The structures of all the synthesized compounds were established on the basis of IR, ¹H-NMR, ¹³C-NMR, DEPT-135 spectral data, elemental analysis and molecular weights of some selected compounds **2a**, **2f** and **2k** were confirmed by mass spectrometry.

The IR spectrum of **2a–o** showed characteristic bands around 1670, 1715, 2926, 1610, and 3020 cm⁻¹ for carbonyl stretching vibrations of δ-lactone ring, carbonyl stretching vibrations of 1,3-diketone ring, aliphatic C–H stretching vibrations of CH₂ groups, aromatic C=C and C–H stretching vibrations respectively. The decrease in C=O stretching frequency of δ-lactone ring from the normal value (~1710 cm⁻¹) is due to hydrogen bonding with C₇-OH. A broad band observed around 3440 cm⁻¹ is due to phenolic-OH stretching.

The NMR spectrum of compounds **2a–e** showed two triplets around δ 3.08 and δ 3.13 each integrating for two protons attached at C₉ and C₁₀ respectively. A singlet appeared around δ 8.10 is due to C₈–H and –OH proton was seen as a broad singlet around δ 11.35, which was conformed by D₂O exchanged spectrum. The remaining aromatic protons appeared at appropriate positions and with appropriate multiplicity. The ¹³C-NMR spectra of compounds **2a–e** showed signals around δ 28.0 and 29.0 due to C₉ and C₁₀, respectively. This was further confirmed by DEPT-135 spectra in which these signals got inverted. This supports the incorporation of indanone ring in the compounds **2a–e**. The carbonyl carbon signals in indanone ring and δ -lactone ring appeared around δ 200.0 and δ 163.0 respectively. The aromatic carbons appeared between δ 105.0 and 161.6. The signal around δ 161.6 is due to C₇–OH. Mass spectra of compound **2a** gave molecular ion peak at 266.0 (M⁺) corresponding to molecular formula C₁₆H₁₀O₄.

The NMR spectrum of compounds **2f–j** showed a multiplet around δ 2.25 integrating for two protons attached at C₁₀. Two triplets appeared around δ 2.70 and δ 2.95 each integrating for two protons attached at C₉ and C₁₁ respectively. A singlet appeared around δ 8.15 is due to C₈–H and –OH proton was seen as a broad singlet around δ 11.40, which was conformed by D₂O exchanged spectrum. The remaining aromatic protons appeared as expected. The ¹³C-NMR spectra of compounds **2f–j** showed signals around δ 23.0, 30.0 and 35.0 due to C₉, C₁₀ and C₁₁ respectively. This was further confirmed by DEPT-135 spectra in which these signals got inverted. This supports the incorporation of naphthalenone ring in the compounds **2f–j**. The carbonyl carbon signals in naphthalenone ring and δ -lactone ring appeared around δ 197.0 and δ 163.0 respectively. The aromatic carbons appeared between δ 107.0 and 161.9. The signal around δ 161.9 is due to C₇–OH. Mass spectra of compound **2f** gave molecular ion peak at 280.0 (M⁺) corresponding to molecular formula C₁₇H₁₂O₄.

The NMR spectrum of compounds **2k–o** showed three singlets around δ 1.11, 2.70 and 2.90 due to six protons of two methyl groups attached at C₁₀, two protons attached at C₉ and C₁₁ respectively. A singlet appeared around δ 8.20 is due to C₈–H and –OH proton was seen as a broad singlet around δ 11.40, which was confirmed as stated earlier. The remaining aromatic protons appeared as expected. The ¹³C-NMR spectra of compounds **2k–o** showed signals around δ 28.5, 33.6, 44.7 and 54.5 due to two methyl group attached at C₁₀, C₁₀ (itself), C₉ and C₁₁ respectively. This was further confirmed by DEPT-135 spectra in which C₉ and C₁₁ signals got inverted. The incorporation of naphthalenone ring in the compounds **2k–o** is this supported. The carbonyl carbon signals in naphthalenone ring and δ -lactone ring appeared around δ 200.0 and δ 163.0 respectively. The aromatic carbons appeared between δ 108.0 and 162.0. The signal around δ 162.0 is due to C₇–OH. Mass spectra of compound **2k** gave molecular ion peak at 308.1 (M⁺) corresponding to molecular formula C₁₉H₁₆O₄.

All other compounds gave satisfactory spectral data which are given in experimental section.

Conclusions

In summary, a simple, convenient and general method has been developed for the preparation of fused chromenes utilizing easily accessible and inexpensive starting materials. This synthetic approach includes some important aspects such as high yields and mild reaction conditions, which make this synthetic protocol a useful and an attractive procedure for the synthesis of indanone and naphthalenone fused chromenones derivatives. This reaction can be regarded as a new approach for the preparation of synthetically and pharmaceutically relevant heterocyclic systems.

Experimental Section

General. Reagents and solvents were obtained from commercial sources and used without further purification. All melting points were taken in open capillaries and are uncorrected. Thin-layer chromatography (TLC, on aluminum plates coated with silica gel 60 F₂₅₄, 0.25 mm thickness, Merck) was used for monitoring the progress of all reactions, purity and homogeneity of the synthesized compounds. Elemental analysis (% C, H, N) was carried out by Perkin-Elmer 2400 series-II elemental analyzer at Sophisticated Instrumentation Centre for Applied Research & Training (SICART), Vallabh Vidyanagar and result obtained for those elements are within $\pm 0.4\%$ of the theoretical values. The FTIR spectra were recorded using potassium bromide disc on a Shimadzu FTIR 8401 spectrophotometer and only the characteristic peaks are reported. ¹H-NMR and ¹³C-NMR spectra were recorded using DMSO-*d*₆ solvent on a Bruker Avance 400 (MHz) spectrometer using solvent peak as internal standard at 400 and 100 MHz, respectively. Chemical shifts are reported in parts per million (ppm). Mass spectra were scanned on a Shimadzu LCMS 2010 spectrometer. 1-(2-oxo-2-(2-oxo-2*H*-chromen-3-yl) ethyl) pyridinium bromide **1(a-e)** was prepared according the literature procedures²¹.

General procedure for the synthesis of fused chromenones (2a-o). In a round bottom flask (100 mL), a solution of appropriate diketone (1,3-cyclopentandione or 1,3-cyclohexandione or dimedone) (0.0058 mol) was taken in glacial acetic acid (15 mL). To this solution, sodium acetate (0.06 mol) and an appropriate 1-(2-oxo-2-(2-oxo-2*H*-chromen-3-yl) ethyl) pyridinium bromide **1a-e** (0.006 mol) in acetic acid (10 mL) were added with stirring. The reaction mixture was stirred at room temperature for 45 minutes and then refluxed in an oil bath at 140-145°C for 6 hours and left overnight. It was then poured in water (75 mL) and the crude solid obtained was extracted with chloroform (3 x 50 mL). The organic layer was washed with 10% sodium bicarbonate solution (50 mL), water (50 mL) and dried over anhydrous sodium sulfate. Distillation of chloroform in vacuum gave gummy material which was subjected to column chromatography using ethyl acetate-pet.ether (60-80) (2:8) as an eluent to afford product **2a-o** respectively. The product was recrystallized from chloroform-hexane.

7-Hydroxy-9,10-dihydroindeno[5,4-*c*]chromene-6,11-dione (2a). Yield 62%; mp 222-224 °C; white crystalline solid; Selected IR frequencies (KBr): 3445 (broad, -OH), 2926 (C-H, aliphatic), 1670 (C=O, δ -lactone), 1710 (C=O, indanone), 1615 (C=C, aromatic) cm^{-1} ; ^1H NMR (CDCl_3): δ 3.08 (2H, t, $\text{C}_9\text{-H}$, J 6.8 Hz), 3.15 (2H, t, $\text{C}_{10}\text{-H}$, J 6.8 Hz), 7.33-7.61 (4H, m, Ar-H), 8.07 (1H, s, $\text{C}_8\text{-H}$), 11.30 (1H, s, -OH proton, D_2O exchangeable); ^{13}C NMR: δ 28.0 (CH_2), 29.0 (CH_2), 105.0 (C), 114.7 (CH), 117.8 (CH), 118.4 (C), 123.3 (CH), 127.2 (CH), 129.8 (C), 130.6 (CH), 136.5 (C), 139.2 (C), 150.2 (C), 161.6 (C_7), 163.0 (C=O, δ -lactone), 200.0 (C=O, indanone); Anal. Calcd. for $\text{C}_{16}\text{H}_{10}\text{O}_4$: C, 72.18; H, 3.79%. Found: C, 72.08; H, 3.51%. MS: 266.0 (M^+).

3,7-Dihydroxy-9,10-dihydroindeno[5,4-*c*]chromene-6,11-dione (2b). Yield 57%; mp 176-178 °C; white crystalline solid; Selected IR frequencies (KBr): 3442 (broad, -OH), 2935 (C-H, aliphatic), 1680 (C=O, δ -lactone), 1720 (C=O, indanone), 1610 (C=C, aromatic) cm^{-1} ; ^1H NMR (CDCl_3): δ 3.05 (2H, t, $\text{C}_9\text{-H}$, J 6.7 Hz), 3.13 (2H, t, $\text{C}_{10}\text{-H}$, J 6.7 Hz), 7.34-7.59 (3H, m, Ar-H), 8.09 (1H, s, $\text{C}_8\text{-H}$), 11.30 (1H, s, -OH proton, D_2O exchangeable), 11.83 (1H, s, -OH proton, D_2O exchangeable); ^{13}C NMR: δ 28.5 (CH_2), 29.8 (CH_2), 105.7 (C), 113.2 (CH), 116.7 (CH), 118.7 (C), 123.4 (CH), 127.5 (CH), 129.8 (C), 135.7 (C), 140.3 (C), 150.2 (C), 159.7 (C), 160.7 (C_7), 163.3 (C=O, δ -lactone), 199.9 (C=O, indanone); Anal. Calcd. for $\text{C}_{16}\text{H}_{10}\text{O}_5$: C, 68.09; H, 3.57%. Found: C, 68.23; H, 3.42%.

7-Hydroxy-3-methoxy-9,10-dihydroindeno[5,4-*c*]chromene-6,11-dione (2c). Yield 63%; mp 228-230 °C; off-white solid; Selected IR frequencies (KBr): 3439 (broad, -OH), 2948 (C-H, aliphatic), 1670 (C=O, δ -lactone), 1730 (C=O, indanone), 1622 (C=C, aromatic), 1055 (asymmetric and symmetric C-O-C stretching) cm^{-1} ; ^1H NMR (CDCl_3): δ 3.07 (2H, t, $\text{C}_9\text{-H}$, J 6.8 Hz), 3.11 (2H, t, $\text{C}_{10}\text{-H}$, J 6.8 Hz), 3.94 (3H, s, OCH_3), 7.32-7.55 (3H, m, Ar-H), 8.11 (1H, s, $\text{C}_8\text{-H}$), 11.42 (1H, s, -OH proton, D_2O exchangeable); ^{13}C NMR: δ 28.4 (CH_2), 28.8 (CH_2), 56.2 (OCH_3), 106.7 (C), 114.1 (CH), 116.4 (CH), 119.5 (C), 122.2 (CH), 126.4 (CH), 129.2 (C), 136.8 (C), 140.1 (C), 150.4 (C), 158.8 (C), 161.7 (C_7), 163.5 (C=O, δ -lactone), 200.1 (C=O, indanone); Anal. Calcd. for $\text{C}_{17}\text{H}_{12}\text{O}_5$: C, 68.92; H, 4.08%. Found: C, 68.83; H, 3.97%.

4,7-Dihydroxy-9,10-dihydroindeno[5,4-*c*]chromene-6,11-dione (2d). Yield 64%; mp 195-198 °C; white crystalline solid; Selected IR frequencies (KBr): 3437 (broad, -OH), 2933 (C-H, aliphatic), 1680 (C=O, δ -lactone), 1715 (C=O, indanone), 1617 (C=C, aromatic) cm^{-1} ; ^1H NMR (CDCl_3): δ 3.08 (2H, t, $\text{C}_9\text{-H}$, J 6.7 Hz), 3.10 (2H, t, $\text{C}_{10}\text{-H}$, J 6.7 Hz), 7.30-7.57 (3H, m, Ar-H), 8.08 (1H, s, $\text{C}_8\text{-H}$), 11.35 (1H, s, -OH proton, D_2O exchangeable), 11.78 (1H, s, -OH proton, D_2O exchangeable); ^{13}C NMR: δ 28.8 (CH_2), 29.4 (CH_2), 105.2 (C), 113.2 (CH), 116.9 (CH), 118.7 (C), 122.1 (CH), 127.8 (CH), 130.2 (C), 135.2 (C), 140.5 (C), 151.8 (C), 159.1 (C), 160.1 (C_7), 163.8 (C=O, δ -lactone), 200.0 (C=O, indanone); Anal. Calcd. for $\text{C}_{16}\text{H}_{10}\text{O}_5$: C, 68.09; H, 3.57%. Found: C, 68.11; H, 3.71%.

7-Hydroxy-4-methoxy-9,10-dihydroindeno[5,4-*c*]chromene-6,11-dione (2e). Yield 67%; mp 173-176 °C; off-white solid; Selected IR frequencies (KBr): 3445 (broad, -OH), 2933 (C-H, aliphatic), 1670 (C=O, δ -lactone), 1720 (C=O, indanone), 1621 (C=C, aromatic), 1050 (asymmetric and symmetric C-O-C stretching) cm^{-1} ; ^1H NMR (CDCl_3): δ 3.03 (2H, t, $\text{C}_9\text{-H}$, J 6.8 Hz), 3.13 (2H, t, $\text{C}_{10}\text{-H}$, J 6.8 Hz), 3.97 (3H, s, OCH_3), 7.29-7.49 (3H, m, Ar-H), 8.13 (1H, s,

C₈-H), 11.44 (1H, s, -OH proton, D₂O exchangeable); ¹³C NMR: δ 28.2 (CH₂), 28.6 (CH₂), 56.24 (OCH₃), 105.9 (C), 114.3 (CH), 117.1 (CH), 120.3 (C), 122.2 (CH), 126.7 (CH), 128.9 (C), 136.9 (C), 139.9 (C), 150.7 (C), 152.7 (C), 162.3 (C₇), 163.0 (C=O, δ-lactone), 200.2 (C=O, indanone); Anal. Calcd. for C₁₇H₁₂O₅: C, 68.92; H, 4.08%. Found: C, 68.89; H, 4.11%.

7-Hydroxy-10,11-dihydro-6H-naphtho[2,1-c]chromene-6,12(9H)-dione (2f). Yield 61%; mp 180-182 °C; white solid; Selected IR frequencies (KBr): 3430 (broad, -OH), 2900 (C-H, aliphatic), 1665 (C=O, δ-lactone), 1720 (C=O, naphthalenone), 1610 (C=C, aromatic) cm⁻¹; ¹H NMR (CDCl₃): δ 2.25 (2H, m, C₁₀-H), 2.76 (2H, t, C₉-H, *J* 5.5 Hz), 2.95 (2H, t, C₁₁-H, *J* 5.5 Hz), 7.33-7.62 (4H, m, Ar-H), 8.15 (1H, s, C₈-H), 11.42 (1H, s, -OH proton, D₂O exchangeable); ¹³C NMR: δ 23.8 (CH₂), 30.2 (CH₂), 35.6 (CH₂), 107.9 (C), 111.3 (C), 116.3 (CH), 120.7 (CH), 122.6 (CH), 125.7 (C), 128.3 (CH), 135.4 (CH), 140.1 (C), 149.5 (C), 158.7 (C), 161.3 (C₇), 163.2 (C=O, δ-lactone), 197.2 (C=O, naphthalenone); Anal. Calcd. for C₁₇H₁₂O₄: C, 72.85; H, 4.32%. Found: C, 72.71; H, 4.25%. MS: 280.0 (M⁺).

3,7-Dihydroxy-10,11-dihydro-6H-naphtho[2,1-c]chromene-6,12(9H)-dione (2g). Yield 69%; mp 210-213 °C; white solid; Selected IR frequencies (KBr): 3440 (broad, -OH), 2930 (C-H, aliphatic), 1660 (C=O, δ-lactone), 1710 (C=O, naphthalenone), 1615 (C=C, aromatic) cm⁻¹; ¹H NMR (CDCl₃): δ 2.20 (2H, m, C₁₀-H), 2.71 (2H, t, C₉-H, *J* 5.5 Hz), 2.93 (2H, t, C₁₁-H, *J* 5.5 Hz), 7.34-7.59 (3H, m, Ar-H), 8.09 (1H, s, C₈-H), 11.39 (1H, s, -OH proton, D₂O exchangeable), 11.83 (1H, s, -OH proton, D₂O exchangeable); ¹³C NMR: δ 23.3 (CH₂), 29.8 (CH₂), 34.8 (CH₂), 107.3 (C), 111.7 (C), 116.8 (CH), 121.3 (CH), 121.8 (CH), 125.5 (C), 128.2 (C), 134.9 (CH), 140.8 (C), 151.4 (C), 158.9 (C), 161.7 (C₇), 163.8 (C=O, δ-lactone), 197.8 (C=O, naphthalenone); Anal. Calcd. for C₁₇H₁₂O₅: C, 68.92; H, 4.08%;. Found: C, 68.79; H, 4.18%.

7-Hydroxy-3-methoxy-10,11-dihydro-6H-naphtho[2,1-c]chromene-6,12(9H)-dione (2h). Yield 64%; mp 190-194 °C; off-white solid; Selected IR frequencies (KBr): 3435 (broad, -OH), 2940 (C-H, aliphatic), 1670 (C=O, δ-lactone), 1730 (C=O, naphthalenone), 1622 (C=C, aromatic), 1050 (asymmetric and symmetric C-O-C stretching) cm⁻¹; ¹H NMR (CDCl₃): δ 2.27 (2H, m, C₁₀-H), 2.73 (2H, t, C₉-H, *J* 5.5 Hz), 2.97 (2H, t, C₁₁-H, *J* 5.5 Hz), 3.40 (3H, s, OCH₃), 7.31-7.60 (3H, m, Ar-H), 8.08 (1H, s, C₈-H), 11.44 (1H, s, -OH proton, D₂O exchangeable); ¹³C NMR: δ 23.4 (CH₂), 30.1 (CH₂), 35.2 (CH₂), 56.4 (OCH₃), 107.8 (C), 111.5 (C), 116.7 (CH), 120.9 (CH), 122.3 (CH), 125.4 (C), 128.4 (C), 135.7 (CH), 141.2 (C), 151.5 (C), 157.8 (C), 161.9 (C₇), 162.8 (C=O, δ-lactone), 197.7 (C=O, naphthalenone); Anal. Calcd. for C₁₈H₁₄O₅: C, 69.67; H, 4.55%. Found: C, 69.79; H, 4.35%.

4,7-Dihydroxy-10,11-dihydro-6H-naphtho[2,1-c]chromene-6,12(9H)-dione (2i). Yield 67%; mp 203-207 °C; white crystalline solid; Selected IR frequencies (KBr): 3440 (broad, -OH), 2925 (C-H, aliphatic), 1650 (C=O, δ-lactone), 1715 (C=O, naphthalenone), 1610 (C=C, aromatic) cm⁻¹; ¹H NMR (CDCl₃): δ 2.22 (2H, m, C₁₀-H), 2.77 (2H, t, C₉-H, *J* 5.5 Hz), 2.95 (2H, t, C₁₁-H, *J* 5.5 Hz), 7.33-7.61 (3H, m, Ar-H), 8.11 (1H, s, C₈-H), 11.42 (1H, s, -OH proton, D₂O exchangeable), 11.86 (1H, s, -OH proton, D₂O exchangeable); ¹³C NMR: δ 22.9 (CH₂), 30.2 (CH₂), 35.1 (CH₂), 107.2 (C), 111.8 (C), 116.5 (CH), 120.8 (CH), 121.6 (CH), 125.3 (C), 128.4 (C), 135.1 (CH), 141.1 (C), 151.6 (C), 158.7 (C), 161.2 (C₇), 163.5 (C=O, δ-lactone), 197.2

(C=O, naphthalenone); Anal. Calcd. for C₁₇H₁₂O₅ : C, 68.92; H, 4.08%; Found: C, 68.75; H, 3.98%.

7-Hydroxy-4-methoxy-10,11-dihydro-6H-naphtho[2,1-c]chromene-6,12(9H)-dione (2j).

Yield 61%; mp 183-186 °C; off-white solid; Selected IR frequencies (KBr): 3450 (broad, -OH), 2930 (C-H, aliphatic), 1670 (C=O, δ -lactone), 1720 (C=O, indanone), 1621 (C=C, aromatic), 1055 (asymmetric and symmetric C-O-C stretching) cm⁻¹; ¹H NMR (CDCl₃): δ 2.20 (2H, m, C₁₀-H), 2.70 (2H, t, C₉-H, *J* 5.5 Hz), 2.96 (2H, t, C₁₁-H, *J* 5.5 Hz), 3.97 (3H, s, OCH₃), 7.28-7.67 (3H, m, Ar-H), 8.15 (1H, s, C₈-H), 11.40 (1H, s, -OH proton, D₂O exchangeable); ¹³C NMR: δ 23.3 (CH₂), 30.4 (CH₂), 34.9 (CH₂), 56.3 (OCH₃), 107.9 (C), 111.8 (C), 116.5 (CH), 121.2 (CH), 122.4 (CH), 125.3 (C), 128.7 (C), 136.2 (CH), 140.9 (C), 151.4 (C), 157.8 (C), 161.5 (C₇), 163.1 (C=O, δ -lactone), 197.8 (C=O, naphthalenone); Anal. Calcd. for C₁₈H₁₄O₅ : C, 69.67; H, 4.55 %. Found: C, 69.55; H, 4.72 %.

7-Hydroxy-10,10-dimethyl-10,11-dihydro-6H-naphtho[2,1-c]chromene-6,12(9H)-dione (2k).

Yield 66%; mp 180-182 °C; off-white solid; Selected IR frequencies (KBr): 3435 (broad, -OH), 3020 (C-H, aliphatic), 1660 (C=O, δ -lactone), 1715 (C=O, naphthalenone), 1605 (C=C, aromatic) cm⁻¹; ¹H NMR (CDCl₃): δ 1.11 (6H, s, 2 x CH₃), 2.70 (2H, s, C₉-H), 2.95 (2H, s, C₁₁-H), 7.30-7.59 (4H, m, Ar-H), 8.20 (1H, s, C₈-H), 11.44 (1H, s, -OH proton, D₂O exchangeable); ¹³C NMR: δ 28.2 (2 x CH₃), 33.6 (C), 44.7 (CH₂), 54.5 (CH₂), 108.6 (C), 112.4 (C), 117.5 (CH), 121.5 (CH), 123.6 (CH), 127.2 (C), 128.4 (CH), 137.3 (CH), 142.3 (C), 150.5 (C), 158.8 (C), 162.3 (C₇), 163.3 (C=O, δ -lactone), 200.9 (C=O, naphthalenone); Anal. Calcd. for C₁₉H₁₆O₄ : C, 74.01; H, 5.23%. Found: C, 74.21; H, 5.33%. MS: 308.1 (M⁺).

3,7-Dihydroxy-10,10-dimethyl-10,11-dihydro-6H-naphtho[2,1-c]chromene-6,12(9H)-dione (2l).

Yield 63%; mp 207-210 °C; white solid; Selected IR frequencies (KBr): 3440 (broad, -OH), 3030 (C-H, aliphatic), 1650 (C=O, δ -lactone), 1710 (C=O, naphthalenone), 1615 (C=C, aromatic) cm⁻¹; ¹H NMR (CDCl₃): δ 1.11 (6H, s, 2 x CH₃), 2.73 (2H, s, C₉-H), 2.90 (2H, s, C₁₁-H), 7.34-7.61 (3H, m, Ar-H), 8.18 (1H, s, C₈-H), 11.39 (1H, s, -OH proton, D₂O exchangeable), 11.81 (1H, s, -OH proton, D₂O exchangeable); ¹³C NMR: δ 28.3 (2 x CH₃), 33.4 (C), 44.5 (CH₂), 54.2 (CH₂), 108.9 (C), 113.5 (C), 117.3 (CH), 121.7 (CH), 124.2 (C), 127.6 (CH), 128.9 (C), 137.6 (CH), 143.5 (C), 151.2 (C), 158.4 (C), 162.7 (C₇), 163.8 (C=O, δ -lactone), 200.7 (C=O, naphthalenone); Anal. Calcd. for C₁₉H₁₆O₅ : C, 70.36; H, 4.97%. Found: C, 70.58; H, 5.20%.

7-Hydroxy-3-methoxy-10,10-dimethyl-10,11-dihydro-6H-naphtho[2,1-c]chromene-

6,12(9H)-dione (2m).

Yield 59%; mp 182-186 °C; white solid; Selected IR frequencies (KBr): 3435 (broad, -OH), 2990 (C-H, aliphatic), 1670 (C=O, δ -lactone), 1730 (C=O, naphthalenone), 1607 (C=C, aromatic), 1055 (asymmetric and symmetric C-O-C stretching) cm⁻¹; ¹H NMR (CDCl₃): δ 1.11 (6H, s, 2 x CH₃), 2.72 (2H, s, C₉-H), 2.96 (2H, s, C₁₁-H), 3.39 (3H, s, OCH₃), 7.35-7.69 (3H, m, Ar-H), 8.16 (1H, s, C₈-H), 11.40 (1H, s, -OH proton, D₂O exchangeable); ¹³C NMR: δ 28.4 (2 x CH₃), 33.4 (C), 44.3 (CH₂), 54.4 (CH₂), 56.4 (OCH₃), 109.4 (C), 113.3 (C), 116.7 (CH), 120.8 (CH), 124.3 (CH), 127.4 (C), 128.4 (C), 136.7 (CH), 143.2 (C), 151.3 (C), 158.8 (C), 162.9 (C₇), 163.5 (C=O, δ -lactone), 200.3 (C=O, naphthalenone); Anal. Calcd. for C₂₀H₁₈O₅ : C, 70.99; H, 5.36%. Found: C, 70.87; H, 5.55%.

4,7-Dihydroxy-10,10-dimethyl-10,11-dihydro-6H-naphtho[2,1-c]chromene-6,12(9H)-dione (2n). Yield 66%; mp 201-204 °C; white solid; Selected IR frequencies (KBr): 3440 (broad, -OH), 3033 (C-H, aliphatic), 1650 (C=O, δ -lactone), 1710 (C=O, naphthalenone), 1617 (C=C, aromatic) cm^{-1} ; ^1H NMR (CDCl_3): δ 1.11 (6H, s, 2 x CH_3), 2.72 (2H, s, C_9 -H), 2.92 (2H, s, C_{11} -H), 7.33-7.67 (3H, m, Ar-H), 8.15 (1H, s, C_8 -H), 11.40 (1H, s, -OH proton, D_2O exchangeable), 11.82 (1H, s, -OH proton, D_2O exchangeable); ^{13}C NMR: δ 28.2 (2 x CH_3), 33.7 (C), 44.7 (CH_2), 54.6 (CH_2), 109.2 (C), 113.2 (C), 117.8 (CH), 121.6 (CH), 123.8 (C), 127.9 (CH), 129.3 (C), 137.2 (CH), 143.2 (C), 151.7 (C), 158.8 (C), 162.3 (C_7), 163.6 (C=O, δ -lactone), 200.1 (C=O, naphthalenone); Anal. Calcd. for $\text{C}_{19}\text{H}_{16}\text{O}_5$: C, 70.36; H, 4.97%. Found: C, 70.20; H, 5.27%.

7-Hydroxy-4-methoxy-10,10-dimethyl-10,11-dihydro-6H-naphtho[2,1-c]chromene-6,12(9H)-dione (2o). Yield 55%; mp 193-197 °C; off-white solid; Selected IR frequencies (KBr): 3430 (broad, -OH), 3010 (C-H, aliphatic), 1665 (C=O, δ -lactone), 1730 (C=O, naphthalenone), 1615 (C=C, aromatic), 1045 (asymmetric and symmetric C-O-C stretching) cm^{-1} ; ^1H NMR (CDCl_3): δ 1.11 (6H, s, 2 x CH_3), 2.70 (2H, s, C_9 -H), 2.93 (2H, s, C_{11} -H), 3.40 (3H, s, OCH_3), 7.33-7.58 (3H, m, Ar-H), 8.19 (1H, s, C_8 -H), 11.44 (1H, s, -OH proton, D_2O exchangeable); ^{13}C NMR: δ 28.5 (2 x CH_3), 33.4 (C), 44.7 (CH_2), 54.8 (CH_2), 56.9 (OCH_3), 108.0 (C), 113.5 (C), 116.6 (CH), 121.1 (CH), 124.5 (CH), 127.7 (C), 128.3 (C), 136.7 (CH), 143.4 (C), 151.5 (C), 158.8 (C), 162.8 (C_7), 163.4 (C=O, δ -lactone), 200.6 (C=O, naphthalenone); Anal. Calcd. for $\text{C}_{20}\text{H}_{18}\text{O}_5$: C, 70.99; H, 5.36%. Found: C, 70.66; H, 5.10%.

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