STRUCTURAL MODIFICATIONS OF DALBERGIN USING BENZENESELENINIC ANHYDRIDE

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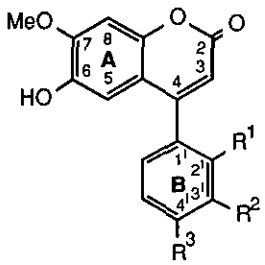
Dedicated to Professor Sir Derek Barton on the occasion of his 70th birthday.

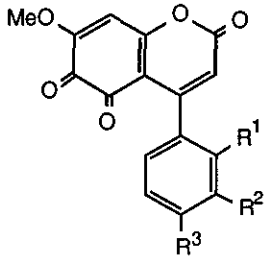
Abstract - Reaction of dalbergin (6-hydroxy-7-methoxy-4-phenylcoumarin) (**1**) with benzeneseleninic anhydride afforded two quinones, the major being an *o*-quinone (**2**) arising from oxidation of ring A of the chromanone moiety and the minor (**3**) resulting from a rearrangement of (**2**). The *p*-quinone (**3**) was isolated independently from benzeneseleninic acid oxidation of 8-hydroxy-7-methoxy-4-phenylcoumarin (**7**). The benzopyran-2-ones (**8**) and (**9**) when reacted with benzeneseleninic anhydride yielded the *o*-quinones (**10, 11**) only. Confirmation of the *o*-quinone structure (**2**) was obtained by single crystal X-ray analysis. The structures and chemistry of the compounds are discussed. The *o*-quinones displayed significant fungicidal properties.

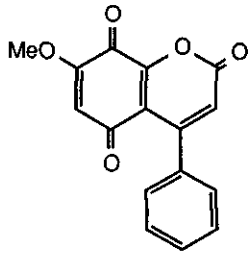
Part of our continuing work on 4-arylcoumarins (4-aryl-2H-1-benzopyran-2-ones, neoflavanoids) has been concerned with the preparation of antifungal compounds from inactive but relatively abundant co-metabolites. The neoflavanoids were isolated originally from the Guttiferae, where they are concentrated in the genera *Callophyllum*, *Mesua* and *Mammea* (contains mammeisin, the toxic principle of the seeds of *M. americana*). Later, a series of neoflavanoids including open-chain members were found in the Leguminosae sub-family Papilionoideae[1] : a characteristic 6,7-dioxygenated pattern is present in ring A of all the isolated neoflavonoids with the exception of those in *Macherium kuhlmanii* which carry an additional methoxyl group at C-8.

In our search for a direct method to convert the 6,7-dioxygenated neoflavanoids into 5,6,7- or 5,7,8-trioxygenated compounds, we were attracted by benzeneseleninic anhydride, a reagent, which has a wide versatility as was demonstrated by *Barton et al*[2]. *Thus among the wide variety of reactions* with this reagent one can cite *o*-hydroxylation of phenols, oxidations of a number of alicyclic alcohols to carbonyl derivatives and of enolisable ketones to enones[3].

We herein report that dalbergin (1), upon exposure to benzeneseleninic anhydride in methylene dichloride, afforded two products (2) and (3) in 76.5% and 2% yields respectively.







(1) $R^1 = R^2 = R^3 = H$ **(2)** $R^1 = R^2 = R^3 = H$ **(3)**

(8) $R^1 = R^2 = H$; $R^3 = OMe$ **(10)** $R^1 = R^2 = H$; $R^3 = OMe$

(9) $R^1 = R^2 = R^3 = OMe$ **(11)** $R^1 = R^2 = R^3 = OMe$

The major product (2) was a purple crystalline material, mp 195-197°C, which showed ir carbonyl absorption bands at 1750cm^{-1}, 1710cm^{-1} and 1680cm^{-1} consistent with an *o*-quinone structure. The EI-MS spectrum of 2 displays a M^+ ion at m/z 282 consistent with the molecular formula $C_{16}H_{10}O_5$. The base peak m/z 226 arises from the loss of two carbonyl groups. The CI-MS spectrum showed an MH^++2 signal characteristic of the quinone structure[4]. The ^1H nmr spectrum shows one methoxyl group (δ 3.97) and two signals δ 6.11 and δ 6.32, the latter is assigned to the olefinic proton of ring A which would contain an *o*-quinone function, and the former signal would account for the olefinic proton of the heterocyclic ring. When 2 was dissolved in methanol a methyl hemiketal was formed and the solution changed its colour rapidly from deep red to yellow and did not absorb in the region of the uv spectrum, characteristic of *o*-quinones (504-587nm). On evaporation of the solvent, the dark purple crystals were recovered and the uv spectrum in benzene gave a peak at 495nm. Thus the product (2) was tentatively assigned as 5,6-diketo-7-methoxy-4-phenylcoumarin and this structure was confirmed by single crystal X-ray analysis.

The crystals (needles from ethyl acetate) belong to the monoclinic system, space group $P2_1/n$, with parameters a = 35.947(2); b = 7.506(4); c = 9.370(4)A, β = 91.2(1)° and z = 8 (2 molecules in the asymmetric unit). The diffraction data were measured up to θ = 64° (see Experimental). The structure was solved by direct

methods using the MULTAN programme[5] and refined by block diagonal least squares to an agreement factor, R = 0.079 for 3466 reflections with unit weights. Anisotropic thermal factors were used only for non-hydrogen atoms. A perspective view of the *o*-quinone (2) showing crystallographic numbering scheme is shown in Figure 1.

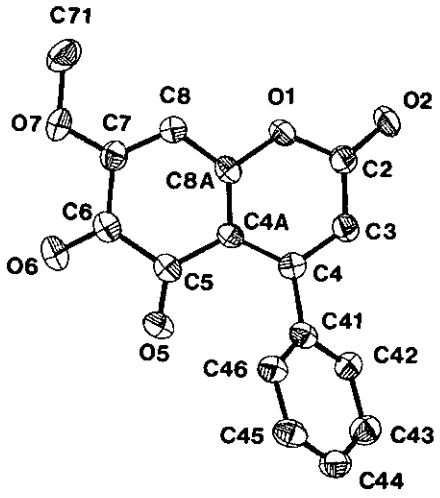
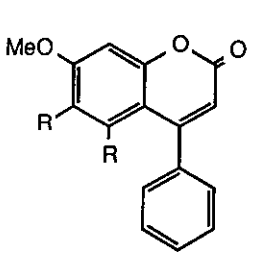


Figure 1. Perspective view of the *o*-quinone (2) showing crystallographic numbering scheme.

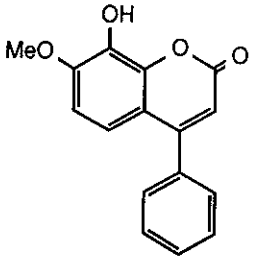
Aromatisation of 5,6-diketo-7-methoxy-4-phenylcoumarin (2) was achieved with sodium dithionite. The structure of 5,6-dihydroxy-7-methoxy-4-phenylcoumarin (4) was established from its spectral data (uv, ir, ^1H , and ^{13}C nmr). It notably had signals in the ^1H nmr spectrum at δ 5.53 and δ 5.26 (exchangeable with D_2O) in addition to signals at δ 6.07 (H-3) and δ 6.59 (H-8). The 0,0-diacetate (5) and 0,0-dimethyl (6) derivatives were also prepared.



(4) R = OH

(5) R = OAc

(6) R = OMe



(7)

The minor product (3) from the benzeneseleninic anhydride reaction was crystallised from ethyl acetate in yellow needles, mp 280-282°C and was assigned as 5,8-diketo-7-methoxy-4-phenylcoumarin on the basis of the elemental and the spectroscopic analysis. Its ir spectrum contains the carbonyl absorption bands at 1740cm^{-1}, 1700cm^{-1} , and 1660cm^{-1}. The ^1H nmr spectrum contained a methoxyl group

(δ 3.83) and two vinylic hydrogens, δ 6.10 and δ 6.53, the latter was assigned to C-6 proton and the former signal to the C-3 proton of the heterocyclic ring. The *p*-quinone (**3**) like the *o*-quinone (**2**) undergoes methyl hemiketal formation in the presence of methanol.

The presence of the *p*-quinone (**3**) as a minor product of the reaction of **1** with benzeneseleninic anhydride was considered to arise from **2** by opening of the hemiketal of **2** and subsequent recyclisation.

Oxidation of the isomeric 8-hydroxy-7-methoxy-4-phenylcoumarin (**7**) with benzeneseleninic derivatives[6] was expected to give the *p*-quinone directly. The coumarin (**7**) was synthesised by acid catalysed reaction of 1,2-dihydroxy-3-methoxybenzene with ethyl 3-oxo-3-phenylpropanoate. The *p*-quinone (**3**) was the sole product of the oxidation of **7**, although in low yield: 5% with $(PhSeO)_2O$ and 10% with $PhSeO_2H$. In both reactions, the starting material (**7**) was recovered.

The benzeneseleninic anhydride reaction was carried out on two additional 4-arylcoumarins, 6-hydroxy-7-methoxy-4-(4'-methoxyphenyl)coumarin (**8**) and 6-hydroxy-7-methoxy-4-(2',3',4'-trimethoxyphenyl)coumarin (**9**). The coumarin (**8**) was insoluble in methylene dichloride, therefore the oxidation reaction was carried out in THF. Both compounds gave only the corresponding 5,6-diketo products (**10**, **11**) in 84.5% and 73.5% yields respectively. The elemental analysis and spectral data were in both cases supportive of the structures proposed.

The coumarins (**8**) and (**9**) were not available from natural sources in sufficient quantity and therefore additional material was synthesised. Condensation of ethyl 3-oxo-3-(4'-methoxyphenyl)propanoate and ethyl 3-oxo-1-(2',3',4'-trimethoxyphenyl)propanoate with methoxyquinol afforded the coumarins (**8**) and (**9**) respectively in satisfactory yields. The ^1H nmr spectra of the 4-arylcoumarin (**8**) showed a characteristic singlet at δ 6.20 for the vinylic proton at C-3, and two singlets δ 6.90 and δ 7.10 due to the aromatic protons at C-8 and C-5 respectively. The protons in the B-ring were represented in coumarin (**8**) by an A_2B_2 system (two doublets at δ 7.02 and δ 7.40) and in (**9**) by a multiplet δ 6.81-6.96.

The bioassays were carried out using conventional antibiotic discs (1 μ 1). 5,6-Diketo-7-methoxy-4-phenylcoumarin (**2**) showed strong fungicidal activity against *Phytophthora cinamomi*. The coumarins (**10**) and (**11**) showed a reduction in growth inhibition compared with that observed in **2**.

EXPERIMENTAL

Mps were measured with a Kofler hot-stage apparatus and are uncorrected. ^1H Nmr (270 MHz, 100 MHz and 60 MHz) and ^{13}C nmr (67.8 MHz) spectral determinations were taken in $CDCl_3$ unless otherwise stated at 25° using TMS as internal standard. EI-MS were taken on an AEI MS 30 instrument and CI-MS and HR-MS were recorded on a modified MS-9 spectrometer. Merck Kieselgel 60 (70-230 mesh), Woelm dry silica TSC 04526 and Sephadex LH-20 were used as stationary phases for column chromatography.

Crystal structure analysis of the quinone (2). A crystal 0.4 x 0.3 x 0.1 mm was mounted on a Phillips PW1100 automatic diffractometer using the CuK α radiation. (λ = 1.5418 A) monochromatised by graphite. 5344 Reflections were scanned in the θ /2θ mode, with a speed of 0.04 deg sec^{-1} over a range of 1.2°, and were reduced to 4634 unique reflections with R sym = 9.2% on intensities. Among them, 3466 reflections were considered as observed ($I \geq 2\sigma$ (I)) after Lorentz and polarisation corrections. All calculations were performed on a VAX780 using the SHELX76[7] program. The atomic coordinates, bond distances and angles, and anisotropic thermal parameters are available on request from the Director of the Cambridge Crystallographic Data Centre, University Chemical Laboratory, Lensfield Road, CB2, AEW, Cambridge, UK.

Oxidation of dalbergin (1) with benzeneseleninic anhydride.

5,6-Diketo-7-methoxy-4-phenylcoumarin (2) - Benzeneseleninic anhydride (350 mg) was added to a stirred solution of dalbergin (1 , 252 mg) in dry methylene dichloride (18 ml) at 0°C. The resultant solution was stirred at room temperature for 18 h. The solution was evaporated to dryness to leave a residue which was purified by column chromatography [eluant: chloroform-ethyl acetate (9:1)] to give three fractions. Fraction 1 yielded diphenyl diselenide (203 mg), mp 60-61°C, lit.[8] 61-62°C. Fraction 2 on evaporation of the solvent gave a residue (203 mg, 76.5%) which upon crystallization from ethyl acetate afforded 5,6-diketo-7-methoxy-4-phenylcoumarin (2) as needles, mp 195-197°C. Ir $\nu_{max}(CHCl_3)$ 3025, 2935, 1750, 1710, 1680, 1630, 1605(sh), 1590, 1575(sh), 1510, 1395, and 1335 cm^{-1}. Uv λ_{max} (MeOH) : 246(11 766), 299(11 339), 320(11 060), and 376(7 494) nm (ε). $\lambda_{max}(C_6H_6)$: 301(11,739), 495(1,974) nm (ε). ^1H Nmr (60MHz) δ ($CDCl_3$) : 3.97 (3H, s, $-OCH_3$), 6.11 (1H, s, H-8), 6.32(1H, s, H-3), and 7.26-7.63 (5H, m, -Ph). Mass spectrum m/z (%) : 282(78, M^+), 268(2), 254(53), 239(38), 226(100), 211(63), 197(4), 183(13), 171(24), 155(10), 139(7), 127(12), 115(29), and 69(46). Found: C, 67.81; H, 3.42. $C_{16}H_{10}O_5$ requires: C, 68.09; H, 3.57%. Fraction 3 on evaporation of the solvent gave 5,8-diketo-7-methoxy-4-phenylcoumarin (3) which crystallized from ethyl acetate as needles (6 mg), mp 280-282°C, lit.[9] 278-279°C. Ir ν_{max}(KBr) : 3075, 1740, 1700, 1660, 1630, 1595, 1495, 1460, 1445, 1395, 1300, 1250, 1110, 1085, 1040, 1020, 865, and 780 cm^{-1}. Uv λ_{max} (MeOH) : 231(sh)(16 384) and 290(17 625) nm (ε). ^1H Nmr (100MHz) δ (DMSO-d_6) : 3.83 (3H, s, -OMe), 6.10 (1H, s, H-3), 6.53 (1H, s, H-6), and 7.35-7.40 (5H, m, -Ph). Mass spectrum m/z (%) : 282(80, M^+), 254(54), 239(36), 226(100), 211(60), 197(4), 183(16), 171(20), 155(12), 139(8), 127(13), 115(22), and 69(38). Found: C, 67.61; H, 3.42. $C_{16}H_{10}O_5$ requires: C, 68.09; H, 3.57%.

5,6-Dihydroxy-7-methoxy-4-phenylcoumarin (4) - A solution of 5,6-diketo-7-methoxy-4-phenylcoumarin (2, 89 mg) in ethyl acetate (100 ml) was shaken with $Na_2S_2O_4$ (10 g) and water (100 ml). Evaporation of the ethyl acetate gave a solid which was crystallised from benzene-acetone to give 5,6-dihydroxy-7-methoxy-4-phenylcoumarin (4, 59 mg) as plates, mp 103-104°C. Ir ν_{max}(KBr) : 3280, 1680, 1670, 1620, 1570, 1540, 1495, 1460, 1355, and 1135 cm^{-1}. Uv λ_{max}(MeOH) : 208(32 434) and 327(11 720) nm(ε). ^1H Nmr (100MHz) δ: 3.97 (3H, s, $-OCH_3$), 5.26 (1H, s, -OH,

exchanges with D_2O), 5.53(1H, s, -OH, exchanges with D_2O), 6.07 (1H, s, H-3), 6.59(1H, s, H-8), and 7.42-7.44 (5H, m, -Ph). ^{13}C Nmr δ(DMSO-d_6) : 60(q, $-OCH_3$), 95(d, C-8), 105(s, C-10), 116(d, C-3), 131,5*(d,C-2', C-6'), 132*(d, C-3', C-5'), 132.5(s, C-1'), 134(d, C-4'), 143.6(s, C-6), 148(s, C-5), 153(s, C-9), 156(s, C-7), 160(s, C-4), and 164(s, C-2). Mass spectrum m/z (%) : 284(100, M^+), 283(28), 269(1.5), 256(18), 241(23), 227(3), 213(4), 185(1.5), 171(4), 155(1.5), 139(5), 128(5), 115(10), 105(10), 89(1.5), 77(3), 69(9), 63(2), and 51(2). Found: C, 67.85; H, 4.3. $C_{16}H_{12}O_5$ requires: C, 67.6; H, 4.26%.

5,6-Diacetoxy-7-methoxy-4-phenylcoumarin (5) - Acetylation (Ac_2O (5 ml)- pyridine (0.5 ml)) of 5,6-dihydroxy-7-methoxy-4-phenylcoumarin (4, 300 mg) at room temperature for 18 h gave 5,6-diacetoxy-7-methoxy-4-phenylcoumarin (5, 210 mg) which was crystallised as needles from ethyl acetate, mp 191-192°C. Ir ν_{max}(KBr) : 3060, 1778, 1738, 1608, 1450, 1384, and 1210 cm^{-1}. Uv λ_{max}(MeOH) : 204(7 287), 222(sh)(12 458), and 322(27 789) nm(ε). ^1H Nmr (100MHz) δ: 1.35(3H, s, $-OCOCH_3$) , 2.24(3H, s, $-OCOCH_3$), 3.92 (3H, s, $-OCH_3$), 6.10(1H, s, H-3), 6.92 (1H, s, H-8), and 7.31-7.48(5H, m, Ph). ^{13}C Nmr δ: 19.0(q, $-CH_3$), 20.0(q, $-CH_3$), 56.6(q, $-OCH_3$), 98.8(d, C-8), 106.7(s, C-10), 115.4(d, C-3), 127.7*(d, C-2', C-6'), 128.2(d, C-3', C-5'), 128.6(d, C-4'), 129.9(s, C-1'), 137.4(s, C-5), 140.2(s, C-6), 153.2**(s, C-9), 153.5**(s, C-4), 154.9(s, C-7), 159.6(s, C-2), 167.2, and 167.6 2x(s, $-OCOCH_3$). Mass spectrum m/z (%) : 368(4, M^+), 326(26), and 284(100). Found: C, 65.70; H, 4.25. $C_{20}H_{16}O_7$ requires: C, 65.2; H, 4.37%.

5,6,7-Trimethoxy-4-phenylcoumarin (6) - Methylation [K_2CO_3 (170 mg) and dimethyl sulphate (120 mg)] of 5,6-dihydroxy-7-methoxy-4-phenylcoumarin (5, 175 mg) in dry acetone (25 ml) afforded the title compound (6, 134 mg, 69.8%) as needles from ethyl acetate, mp 140-141°C, lit.[10] 140-141°C. Ir ν_{max}(KBr) : 2922, 1717, 1595, 1402, and 1360 cm^{-1}. Uv λ_{max}(MeOH) : 231(sh)(17 238), 304(10 626), 330(sh)(9 446), and 390(5 431) nm(ε). ^1H Nmr (100MHz) δ: 3.26 (3H, s, 5-OCH_3), 3.79 and 3.94 2x(3H, s, $-OCH_3$), 6.07(1H, s, H-3), 6.72 (1H, s, H-8), and 7.32-7.48 (5H, m, Ph). ^{13}C Nmr δ: 56.2, 60.82, and 60.95 3x(q, $-OCH_3$), 96.2(d, C-8), 107.2(s, C-10), 114.0(d, C-3), 127.1*(d, C-2', C-6'), 127.4*(d, C-3', C-5'), 127.9(d, C-4'), 138.9(s, C-1'), 139.9(s, C-5), 150.9(s, C-6), 151.6(s, C-7), 155.3(s, C-9), 156.8(s, C-4), and 160.5(s, C-2). Mass spectrum m/z (relative intensity (%)) : 312(100, M^+), 297(57), 284(6), 269(13), 241(4), and 226(6). Found: C, 69.42; H, 5.14. $C_{18}H_{16}O_5$ requires: C, 69.23; H, 5.17%.

Synthesis and oxidation of 6-hydroxy-7-methoxy-4-(4'-methoxyphenyl)coumarin (8) and 6-hydroxy-7-methoxy-4-(2',3',4'-trimethoxyphenyl)coumarin (9).

6-Hydroxy-7-methoxy-4-(4'-methoxyphenyl)coumarin (8) - Dry HCl gas was bubbled through a solution of ethyl 3-oxo-3-(4'-methoxyphenyl)propanoate (6 g) and methoxyquinol (3.84 g) in ethanol (200 ml) at 0°C for 5 h and the resultant solution was stirred at room temperature for 2 days. The reaction mixture was poured onto ice and extracted with ethyl acetate. Evaporation of the solvent gave a solid which afforded 6-hydroxy-7-methoxy-4-(4'-methoxyphenyl)coumarin (8, 4.411

g; 55%) as orange needles from ethyl acetate, mp 228-229°C, lit.[11] 231-232°C. Ir ν_{max}(KBr) : 3160, 1660, 1600, 1560, 1505, and 1415 cm^{-1}. Uv λ_{max}(MeOH) : 262(6 489), 296(8 610), and 348(6 739) nm(ε). ^{1}H Nmr (100MHz) δ: 3.89 (3H, s, $-OCH_3$), 3.99 (3H, s, $-OCH_3$), 5.50(1H, s, exchanges with D_2O, -OH), 6.23 (1H, s, H-3), 6.90 (1H, s, H-8), 7.02 (2H, d, J = 9 Hz, H-3', H-5'), 7.06(1H, s, H-5), and 7.40 (2H, d, J = 9 Hz, H-2', H-5'). Mass spectrum m/z (%) : 298(100, M^+), 270(45), 255(43), and 227(4). Found: C, 68.09; H, 4.57. $C_{17}H_{14}O_5$ requires: C, 68.45; H, 4.73%.

5,6-Diketo-7-methoxy-4-(4-methoxyphenyl)coumarin **(10)** - Benzeneseleninic anhydride (210 mg) was added to a stirred solution of 6-hydroxy-7-methoxy-4-(4'-methoxyphenyl)coumarin (**8**, 130 mg) in dry THF (30 ml) at 0°C and the resultant solution stirred at room temperature for 48 h. Evaporation of the solvent gave a solid residue which was purified by flash chromatography [eluant : chloroform-ethyl acetate (8.5:1.5)] to afford two major fractions. The less polar was diphenyl diselenide whilst the more polar fraction afforded 5,6-diketo-7-methoxy-4-(4'-methoxyphenyl)coumarin (**10**, 115 mg; 84.5%) which crystallised from ethyl acetate in violet coloured needles , mp 210-212°C. Ir ν_{max}(KBr) : 1740, 1705, 1680, and 1640 cm^{-1}. Uv λ_{max}(C_6H_6) : 325(15 732) and 497(4 297) nm(ε). ^{1}H Nmr (100MHz)δ: 3.85 and 3.93, (2 x 3H, s, $-OCH_3$), 6.04(1H, s, H-3), 6.24 (1H, s, H-8), 6.91 (2H, d, J = 8.8 Hz, H-3', H-5'), and 7.21(2H, d, J = 8.8 Hz, H-2', H-6'). Mass spectrum m/z (%) : 312(73, M^+), 284(30), 256(100), and 241(33).

6-Hydroxy-7-methoxy-4-(2',3',4'-trimethoxyphenyl)coumarin **(9)** - Dry HCl gas was bubbled through a suspension of ethyl 3-oxo-3-(2,3,4-trimethoxyphenyl)propanoate (1.0 g) and methoxyquinol (finely ground; 0.6 g) in ethanol (50 ml) at 0°C for 4 h. The reaction mixture was stirred at room temperature for 18 h, saturated with dry HCl gas for a further 5 h at 0°C and was stirred at room temperature for 18 h. The reaction mixture was poured onto ice and extracted with chloroform. Evaporation of the solvent and purification of the residue by flash chromatography on silica gel [eluant : $CHCl_3$-MeOH-H_2O; (40:1:0.1)] gave 6-hydroxy-7-methoxy-4-(2',3',4'-trimethoxyphenyl)coumarin (9, 0.91 g; 57%) which crystallised from methanol as cubes, mp 180-182°C. Ir ν_{max}(KBr) : 3110, 1662, 1600, and 1433 cm^{-1}. Uv λ_{max}(C_6H_6) : 296(11 446), 343(sh)(11 446) nm(ε). ^{1}H Nmr (60MHz)δ: 3.79 (3H, s, $-OCH_3$), 3.98 (6H, s, 2x$-OCH_3$), 4.03 (3H, s, $-OCH_3$), 5.65 (1H, s, br, exchanges with D_2O, -OH), 6.30 (1H, s, H-3), and 6.81-6.96 (4H, m, H-5, H-8, H-5', H-6'). Mass spectrum m/z (%) : 358(100, M^+), 330(7), 327(68), 316(24), 301(8), and 269(5). Found: C, 63.92; H, 5.13. $C_{19}H_{18}RO_7$ requires: C, 63.69; H, 5.03%.

5,6-Diketo-7-methoxy-4-(2',3',4'-trimethoxyphenyl)coumarin **(11)** - Benzeneseleninic anhydride (78.5 mg) was added to a stirred solution of 6-hydroxy-7-methoxy-4-(2',3',4'-trimethoxyphenyl)coumarin (**9**, 76 mg) in dry methylene dichloride (3 ml). The resultant solution was stirred at room temperature for 60 h. The solvent was evaporated and the residue purified by preparative thin layer chromatography [Eluant; chloroform : ethyl acetate 5:1]. The more polar band yielded 5,6-diketo-7-methoxy-4-(2',3',4'-trimethoxyphenyl)coumarin (11, 58 mg,

73.5%), mp 160-162°C. Ir ν_{max}(KBr): 1740, 1677, 1629, and 1596 cm^{-1}. Uv λ_{max} (C_6H_6): 316(13 730) and 480(1 756) nm(ε). ^1H Nmr (270MHz)δ: 3.74, 3.86, 3.90 and 3.92 (4 x 3H, s, $-OCH_3$), 6.03(1H, s, H-3), 6.22 (1H, s, H-8), 6.69 (1H, d, J = 8.4 Hz, H-5'), and 6.82 (1H, d, J = 8.4 Hz, H-6'). Found: C, 60.92; H, 4.45. $C_{19}H_{16}O_8$ requires: C, 61.29; H, 4.33%.

Synthesis and oxidation of 8-hydroxy-7-methoxy-4-phenylcoumarin

8-Hydroxy-7-methoxy-4-phenylcoumarin (**7**) - Dry HCl gas was bubbled through a solution of ethyl 3-oxo-3-phenylpropanoate (17 g) and 1,2-dihydroxy-3-methoxybenzene (11.9 g) in ethanol (560 ml) at 0°C for 7 days. The reaction mixture was poured on ice-HCl and extracted with ethyl acetate. Evaporation of the solvent gave the coumarin (**7**, 4.2 g; 18%) as lustrous plates from ethyl acetate, mp 174°C, lit.[12] 174°-5°C. ^1H Nmr (100MHz) δ (DMSO-d6) : 3.97 (3H, s, $-OCH_3$), 6.30 (1H, s, H-3), 6.94 (1H, d, J = 9.6 Hz, H-6), 7.10 (1H, d, J = 9.6 Hz, H-5), and 7.58-7.66 (5H, m, Ph). ^{13}C Nmr δ (DMSO-d6) : 56.20($-OCH_3$), 108.31(C-3), 111.49(C-6)*, 112.86(C-10)*, 116.91, (C-5), 128.61(C-2', C-6'), 129.54(C-4'), 133.85(C-8), 135.25(C-1'), 142.97(C-9), 150.73(C-7), 155.58(C-4), and 159.89(C-2).

5,8-Diketo-7-methoxy-4-phenylcoumarin (**3**) - a) To a solution of 8-hydroxy-7-methoxy-4-phenylcoumarin (**7**, 300 mg) in dry methylene dichloride (10 ml) at 0°C was added benzeneseleninic anhydride (423 mg) and a further 3 ml of dry methylene dichloride. The resulting suspension was stirred at room temperature for 96 h. The solvent was evaporated and the residual oil purified by flash column chromatography [eluant: chloroform-ethyl acetate (4:1)-(1:1)] to give three major fractions in order of increasing polarity. Fraction 1 proved to be diphenyl diselenide and the most polar fraction was the starting material (94 mg, 31%). Fraction 2 afforded 5,8-diketo-7-methoxy-4-phenylcoumarin (17 mg, 5%) identical, mp and mmp with the rearranged product (**3**). b) When a similar reaction was performed with **7** (200 mg) and benzeneseleninic acid (155 mg) in dry THF (8 ml) for 72 h at room temperature the *p*-quinone (**3**) was obtained (21 mg, 10%).

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