Pergamon

*Tetrahedron* Vol. 51, No. 17, pp. 4909-4922, 1995

0040-4020/95 $9.50+0.00

0040-4020(95)00186-7

# A NEW ROUTE FOR THE SYNTHESIS OF FURANOFLAVONE AND FURANOCHALCONE NATURAL PRODUCTS

**Yong Rok Lee*,[1] and Andrew T. Morehead, Jr.**

Department of Chemistry, Duke University
P. M. Gross Chemical Laboratory
Durham, North Carolina 27708-0346 USA

*Key Words:* Total synthesis, lanceolatin B, pongaglabrone, isopongaglabol, isopongaglabol methyl ether, pongol, pongamol, ovalitenone, ovalitenin A, ovalitenin C, purpuritenin.

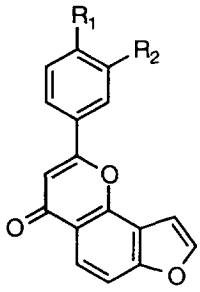
**Abstract:** An efficient synthesis of furanoflavones and furanochalcones has been carried out starting from a dihydrobenzofuran derivative.

Furanoflavones and furanochalcones are an abundant subclass of the flavonoid class of compounds and are widely distributed in nature.[2] The compounds of interest in our work have been isolated from *Tephrosia* Pers. (Galegeae, Lotoideae, Leguminosae), a tropical and subtropical plant genus of over 300 species found in India, northeastern Brasil, and the southern part of Africa, and *Pongamia* (Papilionodae), which is found in Japan, southeast Asia, west Pacific, and north Australia. Members of the furanoflavones and furanochalcones have been associated with a wide variety of biological activities such as insecticidal, pesticidal, antihelmintic, anticancer and antiulcer,[3] and are used in traditional medicines for the treatment of tumours, piles, skin diseases, wounds, ulcers, etc.[4] This wide range of biological properties has stimulated interest in the synthesis of naturally-occurring furanoflavones and furanochalcones. We have carried out the total syntheses of five furanoflavones: lanceolatin B (**1**), pongaglabrone (**2**), isopongaglabol (**3**), isopongaglabol methyl ether (**4**), pongol (**5**) and five furanochalcones: pongamol ( **6**), ovalitenone (**7**), ovalitenin A (**8**), ovalitenin C (**9**), and purpuritenin (**10**) (Figure I).

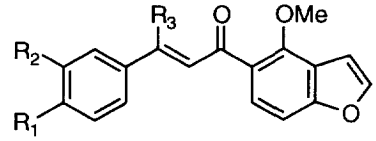
Lanceolatin B (**1**) has been isolated from *Pongamia pinnata,*[5] *Tephrosia purpurea,*[6] *Pongamia glabra*,[7] *Dahlstedtia pinnata,*[8] *Lannea acida,*[9] *Tephrosia lanceolata,*[10] and *Derris mollis.*[11] Only a partial synthesis of lanceolatin B has been accomplished by demethylation of pongamol with hydrochloric acid followed by cyclization.[12] Pongaglabrone (**2**) has been isolated from *Dahlstedtia pinnata,*[8] *Derris mollis,*[11] *Pongamia pinnata,*[5] and *Pongamia glabra.*[13] Isopongaglabol (**3**), isopongaglabol methyl ether (**4**), and pongol (**5**) were isolated from *Pongamia glabra.*[7,14] Pongamol (**6**) has been isolated from *Pongamia glabra,*[7,12] *Tephrosia purpurea,*[6] *Tephrosia lanceolota,*[10] *Tephrosia hamiltonii* [15] and *Dahlstedtia pinnata.*[8] A recent X-ray analysis has shown that **6** exists in the enol form.[16] Pongamol (**6**) has been synthesized by condensation of 5-acetyl-4-

methoxybenzofuran with ethyl benzoate and by resynthesis from its degradation product karanjic acid methyl ester.[17] Ovalitenone (**7**) was isolated from *Pongamia glabra,*[18] *Dahlstedtia pinnata,*[8] and *Pongamia pinnata.*[5] Ovalitenin A (**8**) and ovalitenin C (**9**) were isolated from *Milletia ovalifonia.*[19,20] Purpuritenin (**10**) was isolated from *Tephrosia purpurea.*[6]

**Figure I**



**1** $R_1$=$R_2$=H
**2** $R_1$=$R_2$=$OCH_2O$
**3** $R_1$=OH, $R_2$=H
**4** $R_1$=OMe, $R_2$=H
**5** $R_1$=H, $R_2$=OH



**6** $R_1$=$R_2$=H, $R_3$=OH
**7** $R_1$=$R_2$=$OCH_2O$, $R_3$=OH
**8** $R_1$=$R_2$=H, $R_3$=H
**9** $R_1$=$R_2$=$OCH_2O$, $R_3$=H
**10** $R_1$=$CH_3$, $R_2$=H, $R_3$=H

Although there are currently a number of methods available to synthesize flavones,[2] the synthetic approaches to furanoflavones and furanochalcones are few. The majority of the synthetic work on these flavonoids has involved partial resyntheses from degradation products formed by fission of naturally-occurring compounds such as pongamol and lanceolatin B.[12,21]

In a previous communication, we have described a simple and convenient method for benzofuran formation that is short and provides the desired products in moderate yield (41-71%) without contamination from undesired side products (Table 1).[22] This process involves cycloaddition of diazocyclohexane-1,3-diketones with vinyl acetates followed by acid-catalyzed dehydration (eq 1). For example, application of this method led to the synthesis of evodone, a furanomonoterpene isolated from *Evonia hortensis* Forst., in 41% overall yield.[23] We have used this method as the key step in the construction of natural furanoflavones and furanochalcones.

The synthesis of furanoflavones is shown in Scheme I. The crucial starting material **11** was readily prepared in two steps from diazocyclohexane-1,3-dione using vinyl acetate with a catalytic amount (2 mol %) of $Rh_2(OAc)_4$ in fluorobenzene and dehydration with *p*-TsOH in toluene in 69% overall yield (Table 1). Transformation of **11** into its sodium enolate with an excess of NaH in the presence of a catalytic amount of KH was followed by treatment with dimethyl carbonate to form **17** in 94% yield. The DDQ-mediated dehydrogenation of compound **17** in refluxing dioxane gives the aromatized compound **18** (83%), the methyl ester of karanjic acid, a degradation product that can be obtained from many of the flavonoids, such as karanjin, by treatment with alkali.

Currently, there are a number of methods available for the synthesis of the 4-pyrone ring of flavones, including the Allan-Robinson method,[24] the Baker-Venkataraman rearrangement,[25] synthesis from chalcones,[26] and synthesis via an intramolecular Wittig strategy.[27] We found that the von Strandmann approach was suitable for construction of the 4-pyrone ring.[28] Ester **18** was treated with dimsyl anion in DMSO to form the β-ketosulfoxide **19** (83%), which on treatment with the aldehydes **20, 21, 22, 23** and **24**, and piperidine, first at

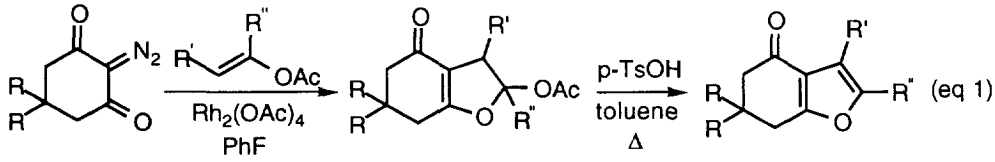
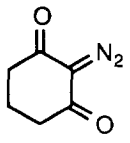
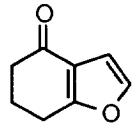
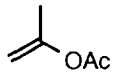
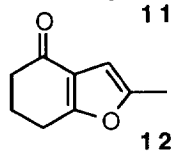
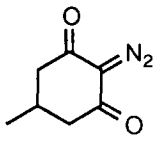
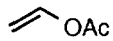
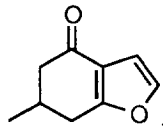
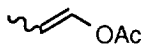
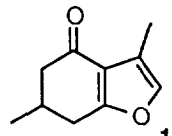
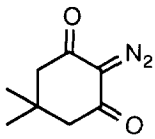
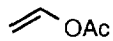
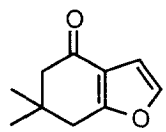
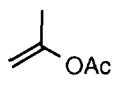
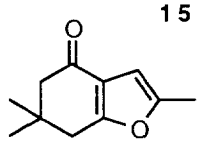
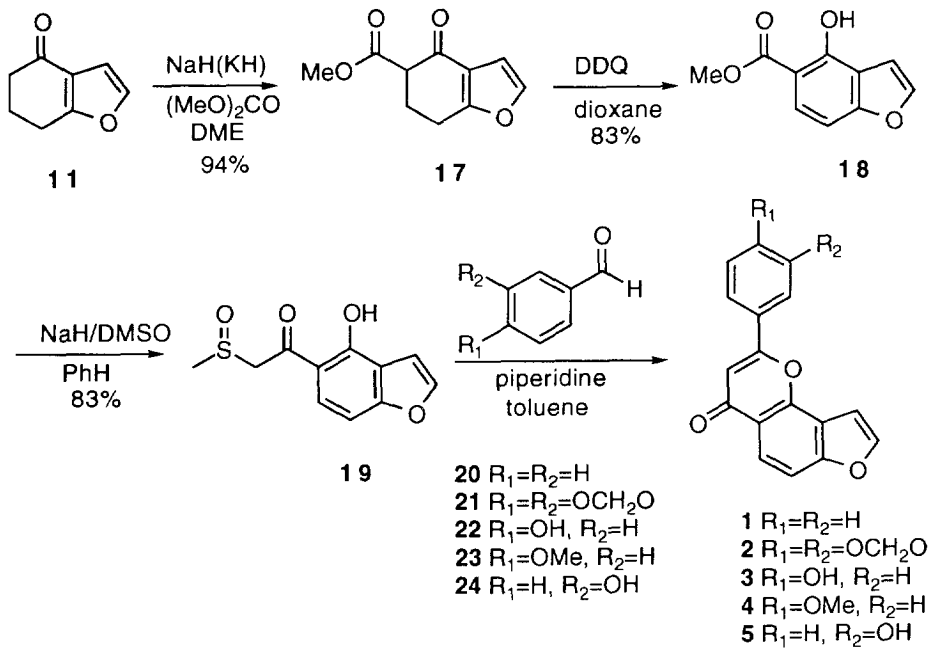



**Table 1**

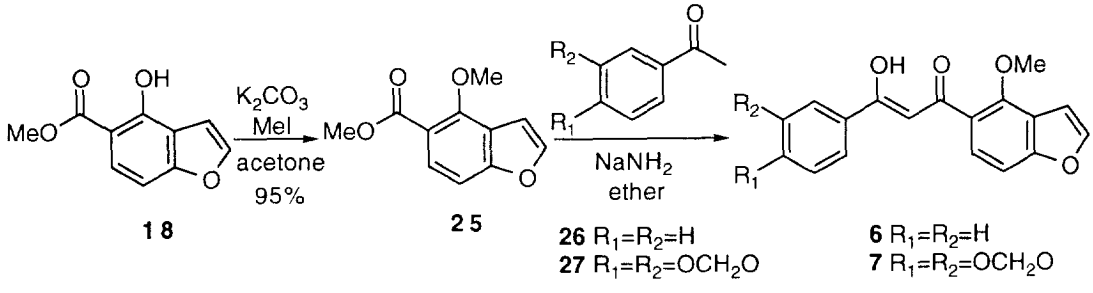
| 2-Diazo-1,3-dicarbonyl | Vinylic acetate | Product | Yield |
|---|---|---|---|
|  |  |  **11** | 69 |
| |  |  **12** | 62 |
|  |  |  **13** | 59 |
| |  (1:1 mixture) |  evodone **14** | 41 |
|  |  |  **15** | 71 |
| |  |  **16** | 64 |

**Scheme I**




40 °C and then at 110 °C, deliver the natural products lanceolatin B (**1**), pongaglabrone (**2**), isopongaglabol (**3**), isopongaglabol methyl ether (**4**), and pongol (**5**) in 79, 82, 79, 90 and 79% yields, respectively. Presumably, Knoevenagel condensation to produce a highly-activated benzylidine β-ketosulfoxide is followed by conjugate addition of the phenolic hydroxy and elimination of methanesulfenic acid. These synthetic natural furanoflavones exhibited physical (mp) and spectroscopic properties ($^1$H NMR, IR) consistent with those reported in the literature.

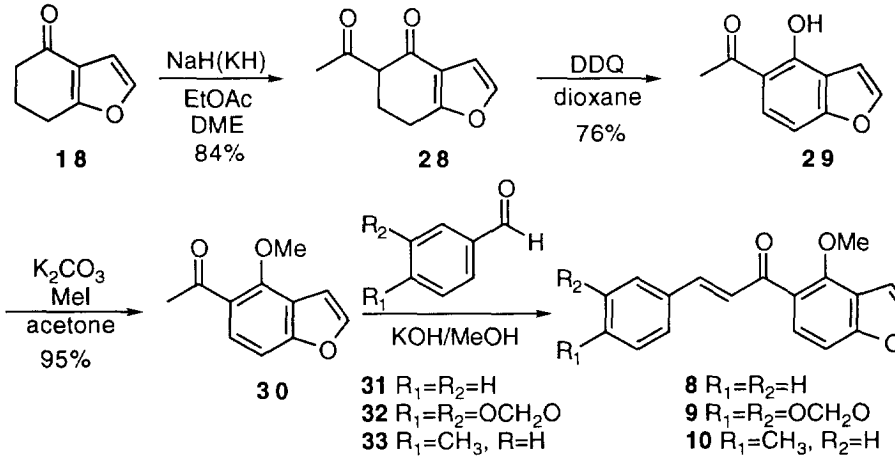
**Scheme II**



Our synthetic plan for the syntheses of the furanochalcones pongamol (**6**) and ovalitenone (**7**) is shown in Scheme II. They were synthesized by first methylation of the phenol **18** with MeI and $K_2CO_3$ in acetone in 95% yield, and then condensation with acetophenones **26** and **27** in the presence of sodium amide in 80 and 72% yield, respectively. These transformations have been reported without a yield by Seshadri in a resynthesis of pongamol from naturally-derived karanjic acid.[17] The spectroscopic properties of our synthetic material agreed well with those reported in the literature. The $^1H$ NMR spectrum of pongamol shows that it exists in the enol form by a chelated hydroxy signal at $\delta$ 16.92 and an olefinic proton signal at $\delta$ 7.17.

Finally, the syntheses of furanochalcones ovalitenin A (**8**), ovalitenin C (**9**) and purpuritenin (**10**), were achieved via aldol reaction as shown in Scheme III. Formation of the enolate of dihydrobenzofuranone **18** with NaH in the presence of KH followed by coupling with ethyl acetate gives **28** (84%) as a mixture of keto and enol tautomers in a 1 : 2.4 ratio. The diketone **28** is readily oxidized with DDQ in dioxane to 4-hydroxy-5-acetyl coumarone **29** (76%),[21] a fisson product that can be obtained from lanceolatin B by treatment with alkali. The spectroscopic properties of our synthetic material agreed well with those reported in the literature. Direct methylation of **29** with $CH_3I$ in the presence of potassium carbonate in acetone gives 4-methoxy-5-acetyl coumarone **30** in 95% yield. This coumarone **30** is easily converted by treatment with benzaldehyde **31**, piperonal **32**, and *p*-tolualdehyde **33** in methanolic KOH to the corresponding furanochalcones ovalitenin A (**8**), ovalitenin C (**9**), and purpuritenin (**10**) in 73, 72 and 79% yield, respectively. The spectroscopic properties of our synthetic materials agreed well with those reported in the literature.

**Scheme III**




In conclusion, a new entry to biologically-active polyketides has been gained from dihydro benzofuran **11** readly-available through a rhodium-catalyzed carbene transformation. The process has afforded efficient syntheses of five furanoflavones: lanceolatin B (**1**) (6 steps, 35% overall yield), pongaglabrone (**2**) (6 steps, 37% overall yield), isopongaglabol methyl ether (**3**) (6 steps, 35% overall yield), isopongaglabol (**4**) (6 steps, 40% overall yield), pongol (**5**) (6 steps, 35% overall yield) and five furanochalcones: pongamol (**6**) (6 steps,

41% overall yield), ovalitenone (**7**) (6 steps, 37% overall yield), ovalitenin A (**8**) (6 steps, 31% overall yield), ovalitenin C (**9**) (6 steps, 30% overall yield), and purpuritenin (**10**) (6 steps, 33% overall yield), which have desirable medicinal properties.

## Experimental

All experiments were carried out under a nitrogen or argon atmosphere. Tetrahydrofuran (THF), ether, and dimethoxyethane (DME) were distilled from sodium/benzophenone immediately prior to use. Benzene, toluene, and dimethylsulfoxide were distilled from calcium hydride. Merck precoated silica gel plates (Art. 5554) with fluorescent indicator were used for analytical TLC. Flash column chromatography was performed using silica gel 9385-9 (Merck). Melting points were determined in capillary tubes on a Haake Buchler apparatus and are uncorrected. Proton nuclear magnetic resonance ($^1$H NMR) spectra were recorded on a GE Model QE-300 (300 MHz) and a Varian XL-300 (300 MHz) spectrometer, using TMS as intenal standard (0.0 ppm). Carbon nuclear magnetic resonance ($^{13}$C NMR) spectra were recorded on a GE Model QE-300 (75 MHz) spectrometer, and chemical shifts are reported, using $CDCl_3$ as internal standard at 77.0 ppm. IR spectra were recorded on a Bomem MB-100 Series FTIR spectrophotometer. Low-resolution EI mass spectra were performed on a Hewlett Packard 5988A spectrometer. High-resolution mass spectra (HRMS) were obtained on JEOL J MS-SX 102A spectrometer.

**4,5,6,7-Tetrahydrobenzofuran-4-one (11).**[29] To a solution of rhodium acetate (192 mg, 0.434 mmol) in vinyl acetate (10.0 mL, 108 mmol) in PhF (50 mL) was added a solution of 2-diazo cyclohexane-1,3-dione (3.0 g, 22 mmol) in PhF (5 mL) at room temperature. The reaction mixture was stirred for 10 h. Evaporation and purification by silica gel chromatography with 50% ethyl acetate in hexane as eluent afforded the acetate adduct (3.622 g, 85%) as an oil.

To a stirred solution of the acetate (2.0 g, 10 mmol) in dry toluene (50 mL) was added 100 mg of *p*-toluenesulfonic acid. The mixture was stirred at reflux for 1 h and then cooled to room temperature and added to saturated sodium bicarbonate solution (30 mL). The organic layer was separated, the aqueous layer was extracted with ether and the combined organic extracts were washed with brine and dried over anhydrous magnesium sulfate. Evaporation of solvent gave an oil which was purified by silica gel chromatography with 50% ether in pentane to yield 1.125 g (81%) of tetrahydrobenzofuran **11** as a colorless oil: $^1$H NMR (300 MHz, $CDCl_3$) $\delta$ 7.32 (d, J = 2.0 Hz, 1H, OC<u>H</u>=CH), 6.67 (d, J = 2.0 Hz, 1H, OCH=C<u>H</u>), 2.89 (m, 2H), 2.50 (m, 2H), 2.18 (m, 2H); $^{13}$C NMR (75 MHz, $CDCl_3$) $\delta$ 193.9 (<u>C</u>=O), 166.7, 142.2 (O<u>C</u>H=CH), 120.6, 105.9, 37.2, 22.8, 22.2; IR (neat) 3131, 2948, 1677 (C=O), 1595 (C=C), 1516, 1447, 1414, 1294, 1242, 1184, 1119, 1026 cm$^{-1}$; MS (EI) 136 ($M^+$), 121, 108, 94, 80, 77, 63, 55, 52.

**2-Methyl-4,5,6,7-tetrahydrobenzofuran-4-one (12).** To a solution of rhodium acetate (26 mg, 0.06 mmol) in isopropenyl acetate (2.899 g, 28.99 mmol) in PhF (10 mL) was added a solution of 2-diazo cyclohexane-1,3-dione (0.40 g, 2.9 mmol) in PhF (5 mL) at room temperature. The reaction mixture was stirred for 10 h. Evaporation and purification by silica gel chromatography with 50% ethyl acetate in hexane as eluent afforded the acetate adduct (0.398 g, 65%) as an oil.

To a stirred solution of the acetate (0.30 g, 1.4 mmol) in dry toluene (25 mL) was added 100 mg of *p*-toluenesulfonic acid. The mixture was stirred at reflux for 1 h and then cooled to room temperature and added to saturated sodium bicarbonate solution (20 mL). The organic layer was separated, the aqueous layer was extracted with ether and the combined organic extracts were washed with brine and dried over anhydrous magnesium sulfate. Evaporation of solvent gave an oil which was purified by silica gel chromatography with 50% ether in pentane to yield 0.204 g (95%) of tetrahydrobenzofuran **12** as a colorless oil: $^1$H NMR (300 MHz, $CDCl_3$) δ 6.22 (s, 1H, OC=C<u>H</u>), 2.81 (t, J = 6.3 Hz, 2H), 2.43 (dd, J = 7.0, 6.0 Hz, 2H), 2.27 (s, 3H, C<u>H</u>$_3$), 2.14 (m, 2H); $^{13}$C NMR (75 MHz, $CDCl_3$) δ 194.4 (<u>C</u>=O), 165.8, 152.2 (O<u>C</u>($CH_3$)), 121.6, 101.5, 37.2, 22.9, 22.3, 13.0; IR (neat) 2945, 1672 (C=O), 1582, 1427, 1358, 1237, 1124, 1011 cm$^{-1}$; HRMS m/z ($M^+$) calcd for $C_9H_{10}O_2$: 150.0681. Found: 150.0683

**6-Methyl-4,5,6,7-tetrahydrobenzofuran-4-one (13).**[30] To a solution of rhodium acetate (23 mg, 0.05mmol) in vinyl acetate (2.263 g, 26.29 mmol) in PhF (20 mL) was added a solution of 2-diazo 5-methylcyclohexane-1,3-dione (0.40 g, 2.6 mmol) in PhF (5 mL) at room temperature. The reaction mixture was stirred for 10 h. Evaporation and purification by silica gel chromatography with 50% ethyl acetate in hexane as eluent afforded the acetate adduct (0.381 g, 69%) as an oil.

To a stirred solution of the acetate (0.280 g, 1.33 mmol) in dry toluene (25 mL) was added 100 mg of *p*-toluenesulfonic acid. The mixture was stirred at reflux for 1 h and then cooled to room temperature and added to saturated sodium bicarbonate solution (20 mL). The organic layer was separated, the aqueous layer was extracted with ether and the combined organic extracts were washed with brine and dried over anhydrous magnesium sulfate. Evaporation of solvent gave an oil which was purified by silica gel chromatography with 50% ether in pentane to yield 0.171 g (85%) of tetrahydrobenzofuran **13** as a colorless oil: $^1$H NMR (300 MHz, $CDCl_3$) δ 7.32 (d, J = 1.9 Hz, 1H, OC<u>H</u>=CH), 6.66 (d, J = 1.9 Hz, 1H, OCH=C<u>H</u>), 3.00-2.25 (m, 5H), 1.18 (d, J = 6.3 Hz, 3H, C<u>H</u>$_3$); $^{13}$C NMR (75 MHz, $CDCl_3$) δ 194.6 (<u>C</u>=O), 167.1, 142.8, 121.0, 106.3, 46.1, 31.4, 30.8, 21.0; IR (neat) 2953, 1678 (C=O), 1594 (C=C), 1448, 1413, 1285, 1219, 1119, 1039 cm$^{-1}$.

**Evodone (14).**[23] To a solution of rhodium acetate (18 mg, 0.04 mmol) in 1-propenyl acetate (2.0 g, 20 mmol) in PhF (15 mL) was added a solution of 2-diazo 5-methylcyclohexane-1,3-dione (0.304 g, 2.00 mmol) in PhF (5 mL) at room temperature. The reaction mixture was stirred for 10 h. Evaporation and purification by silica gel chromatography with 50% ethyl acetate in hexane as eluent afforded the acetate adduct (0.260 g, 58%) as an oil.

To a stirred solution of the acetate (0.10 g, 0.45 mmol) in dry toluene (15 mL) was added 70 mg of *p*-toluenesulfonic acid. The mixture was stirred at reflux for 1 h and then cooled to room temperature and added to saturated sodium bicarbonate solution (20 mL). The organic layer was separated, the aqueous layer was extracted with ether and the combined organic extracts were washed with brine and dried over anhydrous magnesium sulfate. Evaporation of solvent gave an oil which was purified by silica gel chromatography with 50% ether in pentane to yield 52 mg (71%) of tetrahydrobenzofuran **14** as a solid: mp 70 °C (lit.[7] mp 66.5-67 °C, lit.[10] mp 70-71 °C); $^1$H NMR (300 MHz, $CDCl_3$) δ 7.06 (s, 1H, OC<u>H</u>=C$CH_3$), 2.92-2.21 (m, 5H), 2.18 (s, 3H, OCH=CC<u>H</u>$_3$)), 1.14 (d, J = 6.3 Hz, 3H, CHC<u>H</u>$_3$); $^{13}$C NMR (75 MHz, $CDCl_3$) δ 197.1 (<u>C</u>=O), 170.6, 151.0,

131.6, 104.9, 49.9, 43.0, 26.8, 20.8, 9.6; IR (KBr) 3000, 2966, 1662 (C=O), 1603, 1560, 1456, 1440, 1430, 1410, 1390, 1324, 1242, 1139, 1080, 1045, 1001 $cm^{-1}$.

**6, 6-Dimethyl-4,5,6,7-tetrahydrobenzofuran-4-one (15).** To a solution of rhodium acetate (18 mg, 0.04 mmol) in vinyl acetate (1.72 g, 2.00 mmol) in PhF (15 mL) was added a solution of 2-diazo 5, 5-dimethylcyclohexane-1,3-dione (0.328 g, 2.00 mmol) in PhF (5 mL) at room temperature. The reaction mixture was stirred for 10 h. Evaporation and purification by silica gel chromatography with 50% ethyl acetate in hexane as eluent afforded the acetate adduct (0.358 g, 80%) as an oil.

To a stirred solution of the acetate (0.310 g, 0.140 mmol) in dry toluene (20 mL) was added 100 mg of p-toluenesulfonic acid. The mixture was stirred at reflux for 1 h and then cooled to room temperature and added to saturated sodium bicarbonate solution (20 mL). The organic layer was separated, the aqueous layer was extracted with ether and the combined organic extracts were washed with brine and dried over anhydrous magnesium sulfate. Evaporation of solvent gave an oil which was purified by silica gel chromatography with 50% ether in pentane to yield 0.202 g (89%) of tetrahydrobenzofuran **15** as a colorless oil: $^1H$ NMR (300 MHz, $CDCl_3$) $\delta$ 7.33 (d, J = 1.9 Hz, 1H, OC<u>H</u>=CH), 6.67 (d, J = 1.9 Hz, 1H, OCH=C<u>H</u>), 2.76 (s, 2H), 2.39 (s, 2H), 1.15 (s, 6H, C(C<u>H</u>$_3$)$_2$); $^{13}C$ NMR (75 MHz, $CDCl_3$) $\delta$ 194.0 (<u>C</u>=O), 166.2, 142.7, 119.5, 106.0, 51.7, 37.1, 35.1, 28.3, 28.3; IR (neat) 3132, 2952, 2878, 1678 (C=O), 1596, 1514, 1445, 1370, 1281, 1228, 1174, 1118, 1042 $cm^{-1}$; HRMS m/z ($M^+$) calcd for $C_{10}H_{12}O_2$: 164.0837. Found: 164.0840

**2, 6, 6-Trimethyl-4,5,6,7-tetrahydrobenzofuran-4-one (16).** To a solution of rhodium acetate (22 mg, 0.05 mmol) in isopropenyl acetate (2.440 g, 24.37 mmol) in PhF (20 mL) was added a solution of 2-diazo 5, 5-dimethylcyclohexane-1,3-dione (0.40 g, 2.4 mmol) in PhF (5 mL) at room temperature. The reaction mixture was stirred for 10 h. Evaporation and purification by silica gel chromatography with 50% ethyl acetate in hexane as eluent afforded the acetate adduct (0.412 g, 71%) as an oil.

To a stirred solution of the acetate (0.30 g, 1.3 mmol) in dry toluene (20 mL) was added 100 mg of p-toluenesulfonic acid. The mixture was stirred at reflux for 1 h and then cooled to room temperature and added to saturated sodium bicarbonate solution (20 mL). The organic layer was separated, the aqueous layer was extracted with ether and the combined organic extracts were washed with brine and dried over anhydrous magnesium sulfate. Evaporation of solvent gave an oil which was purified by silica gel chromatography with 50% ether in pentane to yield 0.202 g (90%) of tetrahydrobenzofuran **16** as a colorless oil: $^1H$ NMR (300 MHz, $CDCl_3$) $\delta$ 6.22 (s, 1H, OC(CH$_3$)=C<u>H</u>), 2.68 (s, 2H), 2.33 (s, 2H), 2.28 (s, 3H, OC(C<u>H</u>$_3$)=CH), 1.12 (s, 6H, C(C<u>H</u>$_3$)$_2$); $^{13}C$ NMR (75 MHz, $CDCl_3$) $\delta$ 193.6 (<u>C</u>=O), 164.8, 152.5, 120.3, 101.4, 51.5, 36.9, 34.9, 28.2, 28.1, 13.0; IR (neat) 2955, 2361, 1676 (C=O), 1584, 1433, 1226, 1115, 1035 $cm^{-1}$; HRMS m/z ($M^+$) calcd for $C_{11}H_{14}O_2$: 178.0944. Found: 178.0992

**Methyl-4-oxo-4,5,6,7-tetrahydrobenzofuran-5-carboxylate (17).** To a stirred suspension of sodium hydride (1.396 g, 34.89 mmol, 60% dispersion in mineral oil) and potassium hydride (0.050 g, 35 wt % dispersion in mineral oil) in dry DME (50 mL) under a $N_2$ atmosphere was added a solution of tetrahydrobenzofuran **11** (0.950 g, 6.98 mmol) in dry DME (5 mL) at 0 °C. The mixture was stirred for 30 min and dimethyl carbonate (0.629 g, 34.9 mmol) was added slowly over 10 min. The ice bath was removed and the

reaction mixture was heated slowly to reflux over 30 min and maintained at reflux for a further 30 min. After the mixture had cooled, water (10 mL) and saturated $NH_4Cl$ solution (30 mL) were added carefully dropwise and the aqueous layer was extracted with ethyl acetate (3 x 50 mL). The combined organic layers were washed with brine, dried over $MgSO_4$, and evaporated under reduced pressure. The resulting oil was purified by flash column chromatography on silica gel (elution with 30% ethyl acetate in hexane) to give **17** (1.274 g, 94%): $^1$H NMR (300 MHz, $CDCl_3$) δ 7.34 (d, J=1.9 Hz, 1H, OC<u>H</u>=CH), 6.69 (d, J=2.0 Hz, 1H, OCH=C<u>H</u>), 3.76 (s, 3H, $CO_2C\underline{H}_3$), 3.52 (dd, J=4.8, 4.8 Hz, 1H), 3.05 (m, 1H), 2.91 (m, 1H), 2.56 (m, 1H), 2.38 (m, 1H); $^{13}$C NMR (75 MHz, $CDCl_3$) δ 188.5 (<u>C</u>=O), 170.1 ($\underline{C}O_2CH_3$), 166.5, 140.0, 120.2, 106.6, 53.0, 52.3, 25.6, 21.7; IR (neat) 3144, 3113, 2955, 1733 (C=O of ester), 1675 (C=O), 1582 (C=C), 1454, 1433, 1276, 1208, 1164, 1122, 1025, 983, 903, 861 cm$^{-1}$; MS (EI) 194 ($M^+$), 163, 162, 141, 134, 108, 94, 80, 77, 55, 52; HRMS m/z ($M^+$) calcd for $C_{10}H_{10}O_4$: 194.0579. Found: 194.0575.

**Methyl-4- hydroxybenzofuran -5-carboxylate (18).** A mixture of **12** (0.950 g, 4.89 mmol) and DDQ (1.333 g, 5.870 mmol) in dry dioxane (30 mL) was heated under reflux for 3 h. The resulting mixture was cooled in an ice bath and solids were removed by filtration through Celite. The filtrate was evaporated under reduced pressure and purified by flash column chromatography on silica gel (elution with 15% ethyl acetate in hexane) to give **18** (0.780 g, 83%) as a colorless solid: mp 105 °C; $^1$H NMR (300 MHz, $CDCl_3$) δ 7.78 (d, J=8.9 Hz, 1H, Ar<u>H</u>), 7.57 (d, J=2.1 Hz, 1H, OC<u>H</u>=CH), 7.03 (d, J=8.9 Hz, 1H, Ar<u>H</u>), 6.98 (d, J=2.1 Hz, 1H, OCH=C<u>H</u>), 3.97 (s, 3H, $CO_2C\underline{H}_3$); $^{13}$C NMR (75 MHz, $CDCl_3$) δ 171.2 (<u>C</u>=O of ester), 159.5, 157.4, 144.3, 125.9, 117.1, 104.9, 104.7, 103.8, 52.2; IR (KBr) 3500 (OH), 3071, 2950, 1677 (C=O of ester), 1629 (C=C), 1471, 1446, 1358, 1288, 1234, 1195, 1169, 1134, 1052 cm$^{-1}$; MS (EI) 192 ($M^+$), 162, 160, 132, 104, 96, 74, 51; HRMS m/z ($M^+$) calcd for $C_{10}H_8O_4$: 192.0422. Found: 192.0426

**4-Hydroxy-5-methylsulfinylacetyl benzofuran (19).** A mixture of dry DMSO (2.6 mL) and sodium hydride (0.460 g, 18.2 mmol, 95 %) in dry benzene (30 mL) was heated under $N_2$ for 2 h at 80 °C. The solution was cooled to 35 °C and treated dropwise with **13** (0.70 g, 3.6 mmol) in dry benzene (4 mL). The reaction mixture was then stirred for 1 h, diluted with ether (50 mL), and quenched with a saturated solution of $NH_4Cl$ (30 mL). The organic and aqueous layers were separated and the aqueous layer was further extracted with ether (3 x 30 mL). The combined organic layers were washed with brine, dried over $MgSO_4$, filtered, and evaporated under reduced pressure. The resulting residue was purified by flash column chromatography on silica gel (elution with ethyl acetate) to give **19** (0.720 g, 83%) as a solid: mp 113 °C; $^1$H NMR (300 MHz, $CDCl_3$) δ 7.65 (d, J = 9.0 Hz, 1H, Ar<u>H</u>), 7.60 (d, J = 2.2 Hz, 1H, OC<u>H</u>=CH), 7.12 (d, J = 9.0 Hz, 1H, Ar<u>H</u>), 7.00 (d, J = 2.2 Hz, 1H, OCH=C<u>H</u>), 4.40 (q, 2H, $SOC\underline{H}_2$), 2.79 (s, 3H, $SO\underline{C}H_3$); $^{13}$C NMR ($CDCl_3$) δ 196.2 (<u>C</u>=O), 160.5, 159.7, 145.0, 127.3, 117.7, 114.2, 105.1, 104.9, 62.0, 39.5; IR (KBr) 3435 (OH), 3115, 2993, 2905, 1632 (C=O), 1614 (C=C), 1474, 1435, 1335, 1298, 1214, 1135, 1092, 1045, 1027 cm$^{-1}$; MS (EI) 238 ($M^+$), 209, 174, 161, 119, 91, 51; HRMS m/z ($M^+$) calcd for $C_{11}H_{10}O_4S$: 238.0301. Found: 238.0308

**Lanceolatin (1).** Benzaldehyde **20** (0.445 g, 4.20 mmol) in 3 mL of dry toluene was slowly added to a warm solution (40 °C) of **19** (0.10 g, 0.42 mmol) in dry toluene (20 mL) containing a catalytic amount of piperidine (4 drops) and the resulting mixture was allowed to reflux for 3 h. After distillation of the solvent, the

residue was purified by flash column chromatography on silica gel (elution with 15% ethyl acetate in hexane) to give **1** (87 mg, 79%) as a white solid: mp 126-127 °C (lit 127 °C,[10] 135-136 °C[6b]); $^1$H NMR (300 MHz, $CDCl_3$) $\delta$ 8.17 (d, J=8.8 Hz, 1H), 7.97 (m, 2H), 7.78 (d, J=2.1 Hz, 1H, OC<u>H</u>=CH), 7.56 (m, 4H), 7.24 (d, J=2.1 Hz, 1H, OCH=C<u>H</u>), 6.90 (s, 1H, COC<u>H</u>=CPh); $^{13}$C NMR ($CDCl_3$) $\delta$ 178.2 (<u>C</u>=O), 162.6, 158.3, 150.8, 145.8, 131.6, 129.0, 126.1, 121.8, 121.6, 119.3, 117.1, 110.1, 108.1, 107.9, 104.2, 104.1; IR (KBr) 3113, 1647 (C=O), 1604 (C=C), 1493, 1455, 1404, 1361, 1253, 1140, 1070, 1035, 851 cm$^{-1}$; MS (EI) 262 (M$^+$), 234, 205, 161, 160, 132, 117, 104, 102, 76, 50.

**Pongaglabrone (2).** Reaction of **19** (105 mg, 0.440 mmol) with the aldehyde **21** (1.0 g, 6.7 mmol) afforded **2** (111 mg, 82 %) as a solid: mp 233-234 °C (lit 228-130 °C,[8] 228-229 °C,[11] 231 °C[13] ); $^1$H NMR (300 MHz, $CDCl_3$) $\delta$ 8.17 (d, J=9.0 Hz, 1H), 7.78 (d, J=1.1 Hz, 1H), 7.56 (m, 2H), 7.41 (d, J=1.8 Hz, 1H), 7.21 (d, J=1.8 Hz, 1H), 6.97 (d, J=8.1 Hz, 1H), 6.85 (s, 1H, COC<u>H</u>=CPh), 6.11 (s, 2H, O<u>CH$_2$</u>O); $^{13}$C NMR ($CDCl_3$) $\delta$ 178.1 (<u>C</u>=O), 162.6, 158.4, 150.7, 148.6, 145.9, 125.6, 121.7, 121.5, 119.3, 119.0, 117.1, 110.3, 108.9, 106.8, 106.3, 104.1, 102.0, 77.2; IR (KBr) 1639 (C=O), 1502, 1447, 1403, 1255, 1144, 1068, 1037, 931, 912, 849, 809 cm$^{-1}$; MS (EI) 306 (M$^+$), 278, 243, 199, 160, 146, 88, 76.

**Isopongaglabol (3).** Reaction of **19** (100 mg, 0.420 mmol) with the aldehyde **22** (103 mg, 0.840 mmol) afforded **3** (93 mg, 79%) as a solid: mp 333-335 °C; $^1$H NMR (300 MHz, DMSO-$d_6$) $\delta$ 10.30 (s, 1H), 8.25 (d, J=2.1 Hz, 1H), 8.07 (d, J=8.7 Hz, 2H), 7.95 (d, J=8.7 Hz, 1H), 7.73 (d, J=8.7 Hz, 1H), 7.60 (d, J=1.8 Hz, 1H), 6.95 (d, J=8.7 Hz, 2H), 6.94 (s, 1H, COC<u>H</u>=CPh); $^{13}$C NMR (DMSO-$d_6$) $\delta$ 176.7 (<u>C</u>=O), 162.4, 160.9, 157.5, 149.9, 147.4, 128.4, 121.5, 120.9, 118.8, 117.0, 116.0, 110.0, 105.0, 104.5; IR (KBr) 2843, 1633 (C=O), 1572, 1453, 1407,1366, 1298, 1255, 1173, 1140, 1071, 813 cm$^{-1}$; MS (EI) 278 (M$^+$), 250, 221, 193, 160, 125, 76, 44.

**Isopongaglabol methyl ether (4).** Reaction of **19** (101 mg, 0.420 mmol) with the aldehyde **23** (115 mg, 0.850 mmol) afforded **4** (111 mg, 90%) as a solid: mp 217-218 °C (lit 218-219 °C[11] ); $^1$H NMR (300 MHz, $CD_2Cl_2$) $\delta$ 8.06 (d, J=8.7 Hz, 1H), 7.94 (d, J=6.9 Hz, 2H), 7.81 (d, J=2.1 Hz, 1H), 7.54 (d, J=8.7 Hz, 1H), 7.24 (d, J=1.8 Hz, 1H), 7.06 (d, J=7.2 Hz, 2H), 6.74 (s, 1H, COC<u>H</u>=CPh), 3.89 (s, 3H, O<u>CH$_3$</u>); $^{13}$C NMR ($CD_2Cl_2$) $\delta$ 178.1 (<u>C</u>=O), 162.8, 162.4, 158.3, 150.7, 145.7, 127.9, 123.9, 119.2, 117.1, 114.5, 110.0, 106.4, 104.1, 55.5; IR (KBr) 1653 (C=O), 1601 (C=C), 1514, 1403, 1459, 1424, 1400, 1360, 1267, 1188, 1140, 1069, 1021, 813 cm$^{-1}$; MS (EI) 292 (M$^+$), 249, 221, 192, 160, 132, 89, 76.

**Pongol (5).** Reaction of **19** (101 mg, 0.420 mmol) with the aldehyde **24** (103 mg, 0.840 mmol) afforded **5** (93 mg, 79%) as a solid: mp 245-247 °C (lit 246-248 °C[14] ); $^1$H NMR (300 MHz, $CDCl_3$/DMSO-$d_6$) $\delta$ 8.06 (d, J=9.0 Hz, 1H), 7.90 (d, J=3.0 Hz, 1H), 7.57 (d, J=9.0 Hz, 1H), 7.45 (s, 1H), 7.44 (d, J=9.0 Hz, 1H), 7.35 (t, J=9.0 Hz, 1H), 7.26 (d, J=3.0 Hz, 1H), 7.03 (m, 1H), 6.79 (s, 1H, COC<u>H</u>=CPh); $^{13}$C NMR ($CDCl_3$/DMSO-$d_6$) $\delta$ 177.3 (<u>C</u>=O), 162.1, 160.9, 157.9, 157.3, 149.9, 145.4, 131.9, 129.4, 120.6, 118.5 118.3, 116.5, 116.4, 112.4, 109.3, 106.9, 103.5; IR (KBr) 3143, 1617 (C=O), 1580 (C=C), 1493, 1407,1460, 1408, 1359, 1298, 1253, 1199, 1143, 1072, 1037, 873, 848, 819 cm$^{-1}$; MS (EI) 278 (M$^+$), 257, 223, 184, 141, 111, 83, 43.

**Methyl-4-methoxy benzofuran-5-carboxylate (25).** A mixture of phenol **18** (0.20 g, 1.0 mmol), potassium bicarbonate (0.719 g, 5.20 mmol), methyl iodide (0.65 ml, 10 mmol) and acetone (10 mL) was refluxed for 3 h. The reaction mixture was cooled to room temperature and the precipitated inorganic material was removed by filtration. The filtrate was concentrated and the residue was diluted with ether (30 mL) to precipitate the remaining inorganic impurities, which were removed by a second filtration. The filtrate thus obtained was concentrated and purified by flash column chromatography on silica gel (elution with 30% ethyl acetate in hexane) to give **25** (204 mg, 95%): $^1$H NMR ($CDCl_3$) δ 7.77 (d, J = 8.9 Hz, 1H, ArH), 7.59 (d, J = 2.0 Hz, 1H, OCH=CH), 7.22 (d, J = 8.9 Hz, 1H, ArH), 6.97 (d, J = 2.0 Hz, 1H, OCH=CH) 4.10 (s, 3H, $OCH_3$), 3.90 (s, 3H, $CO_2CH_3$); $^{13}$C NMR ($CDCl_3$) δ 166.8 (C=O of ester), 158.7, 154.9, 144.8, 127.7, 120.2, 116.8, 106.6, 105.2, 61.5, 52.1; IR (neat) 3135, 2950, 1717 (C=O of ester), 1597 (C=C), 1476, 1432, 1358, 1332, 1275, 1192, 1186, 1087, 1003 cm$^{-1}$; MS (EI) 206 ($M^+$), 175, 160, 145, 117, 89, 76, 63, 53, 50; HRMS m/z ($M^+$) calcd for $C_{11}H_{10}O_4$: 206.0579. Found: 206.0580

**Pongamol (6).** To a solution of acetophenone **26** (0.291 g, 2.42 mmol) and sodium amide (95 mg, 2.4 mmol) in ether (10 mL) was added **25** (0.10 g, 0.48 mmol) in ether (2 mL) at room temperature. The reaction mixture was refluxed for 3 h. After the mixture had cooled, water (10 mL) and saturated $NH_4Cl$ solution (30 mL) were added carefully dropwise and the aqueous layer was extracted with ethyl acetate (3 x 50 mL). The combined organic layers were washed with brine, dried over $MgSO_4$, evaporated under reduced pressure. The resulting residue was purified by flash column chromatography on silica gel (elution with 20% ethyl acetate in hexane) to give **6** (114 mg, 80%) as a solid: mp 130 °C (lit 127-129 °C,[12] 130 °C,[15] 128-129 °C[17]); $^1$H NMR (300 MHz, $CDCl_3$) δ 16.92 (s, 1H, OH), 7.97 (m, 2H), 7.87 (d, J=8.7 Hz, 1H), 7.63 (d, J=2.2 Hz, 1H, OCH=CH), 7.48 (m, 3H), 7.31 (d, J=8.7 Hz, 1H), 7.17 (s, 1H, COCH=COH), 7.00 (d, J=2.2 Hz, 1H, OCH=CH), 4.15 (s, 3H, $OCH_3$); $^{13}$C NMR ($CDCl_3$) δ 186.1, 184.2, 158.7, 153.8, 144.8, 135.6, 132.2, 128.6, 127.1, 126.5, 122.2, 120.0, 107.1, 105.4, 105.2, 98.0, 97.8, 61.2; IR (KBr) 3400 (OH), 3151, 1656 (C=O), 1582 (C=C), 1472, 1357, 1286, 1225, 1196, 1064, 999, 975, 804 cm$^{-1}$; MS (EI) 294 ($M^+$), 263, 214, 175, 160, 133, 105, 89, 77, 69, 63.

**Ovalitenone (7).** Reaction of **25** (110 mg, 0.530 mmol) with the acetophenone **27** (435 mg, 2.65 mmol) afforded **7** (130 mg, 72%) as a solid: mp 117-118 °C (lit 117-120 °C,[18] 120-123 °C[8]); $^1$H NMR (300 MHz, $CDCl_3$) δ 7.85 (m, 2H), 7.59 (m, 3H), 7.45 (d, J=1.9 Hz, 1H, OCH=CH), 7.30 (d, J=8.8 Hz, 1H), 7.05 (s, 1H, COCH=COH), 6.98 (d, J=2.1 Hz, 1H, OCH=CH), 6.89 (d, J=8.8 Hz, 1H), 6.05 (s, 2H, $OCH_2O$), 4.00 (s, 3H, $OCH_3$); $^{13}$C NMR ($CDCl_3$) δ 184.9, 183.8, 158.5, 153.5. 151.1, 148.1, 144.8, 130.2, 126.3, 122.8, 121.8, 119.6, 108.2, 107.1, 107.1, 105.2, 101.8, 97.2, 61.1; IR (KBr) 3460 (OH), 3130, 1654 (C=O), 1596 (C=C), 1540, 1462, 1354, 1291, 1253, 1239, 1122, 1073, 1038, 980, 931, 793, 748 cm$^{-1}$; MS (EI) 338 ($M^+$), 308, 307, 248, 201, 175, 160, 149, 91, 69, 65, 63.

**5-Acetyl-4-oxo-4,5,6,7-tetrahydrobenzofuran (28).** To a stirred suspension of sodium hydride (0.445 g, 17.6 mmol, 95%) and potassium hydride (0.050 g, 35 wt % dispersion in mineral oil) in dry DME (35 mL) under a $N_2$ atmosphere was added a solution of tetrahydrobenzofuran **18** (0.480 g, 3.52 mmol) in dry DME (3 mL) at 0 °C. The mixture was stirred for 30 min and ethyl acetate (0.930 g, 10.56 mmol) was added slowly over

10 min. The ice bath was removed and the reaction mixture was heated slowly to reflux over 30 min and maintained at reflux for a further 30 min. After the mixture had cooled, water (10 mL) and saturated $NH_4Cl$ solution (30 mL) were added carefully dropwise and the aqueous layer was extracted with ethyl acetate (3 x 50 mL). The combined organic layers were washed with brine, dried over $MgSO_4$, evaporated under reduced pressure. The resulting oil was purified by flash column chromatography on silica gel (elution with 15% ethyl acetate in hexane) to give **28** (0.528 g, 84%): $^1$H NMR (300 MHz, $CDCl_3$) enol form δ 7.32 (d, J=2.0 Hz, 1H, OCH=CH), 6.66 (d, J=2.0 Hz, 1H, OCH=CH), 2.85 (m, 2H), 2.29 (s, 3H, $CH_3$), 2.24 (m, 2H). keto form δ 7.32 (d, J=2.0 Hz, 1H, OCH=CH), 6.70 (d, J=1.9 Hz, 1H, OCH=CH), 3.19 (m, 1H, COCHCO), 3.11 (m, 1H), 2.75 (m, 1H), 2.53 (m, 1H), 2.20 (m, 1H), 2.09 (s, 3H, $CH_3$); IR (KBr) 3436 (OH), 3126, 2937, 1715 (C=O), 1673 (C=O of enone), 1610 (C=C), 1516, 1450, 1389, 1358, 1349, 1182, 1120, 1055, 1028, 1004, 987, 916, 873, 801 cm$^{-1}$; MS (EI) 178 ($M^+$), 145, 135, 107, 94, 80, 52; HRMS m/z ($M^+$) calcd for $C_{10}H_{10}O_3$: 178.0630. Found: 178.0632

**5-Acetyl-4-hydroxybenzofuran (29).** A mixture of **28** (0.40 g, 2.2 mmol) and DDQ (0.612 g, 2.69 mmol) in dry dioxane (20 mL) was heated under reflux for 3 h. The resulting mixture was cooled in an ice bath and solids were removed by filtration through Celite. The filtrate was evaporated under reduced pressure and purified by flash column chromatography on silica gel (elution with 10% ethyl acetate in hexane) to give **29** (0.301 g, 76%) as a colorless solid: mp 92-93 °C; $^1$H NMR (300 MHz, $CDCl_3$) δ 7.65 (d, J=8.9Hz, 1H, ArH), 7.56 (d, J=2.2 Hz, 1H, OCH=CH), 7.04 (d, J=8.8 Hz, 1H, ArH), 6.99 (d, J=2.1 Hz, 1H, OCH=CH), 2.66 (s, 3H, $CH_3$); $^{13}$C NMR (75 MHz, $CDCl_3$) δ 204.2 (C=O), 159.7, 158.8, 144.5, 127.0, 117.5, 114.2, 105.0, 103.7, 27.0; IR (neat) 3463, 3145, 3126, 1627 (C=O), 1474, 1429, 1393, 1372, 1328, 1292, 1224, 1134, 1056, 1018, 914, 841 cm$^{-1}$; MS (EI) 176 ($M^+$), 161, 133, 129, 105, 80, 77, 51; HRMS m/z ($M^+$) calcd for $C_{10}H_8O_3$: 176.0473. Found: 176.0475

**5–Acetyl-4-methoxybenzofuran (30).** A mixture of phenol **29** (0.280 g, 1.47 mmol), potassium bicarbonate (1.014 g, 7.330 mmol), methyl iodide (0.46 ml, 7.3 mmol) and acetone (10 mL) was refluxed for 3 h. The reaction mixture was cooled to room temperature and the precipitated inorganic material was removed by filtration. The filtrate was concentrated and the residue was diluted with ether (30 mL) to precipitate the remaining inorganic impurities, which were removed by a second filtration. The filtrate thus obtained was concentrated and purified by flash column chromatography on silica gel (elution with 20% ethyl acetate in hexane) to give **30** (0.288 g, 95%): mp 54-55 °C; $^1$H NMR (300 MHz, $CDCl_3$) δ 7.72 (d, J=8.7 Hz, 1H, ArH), 7.59 (d, J=2.3 Hz, 1H, OCH=CH), 7.20 (d, J=8.7 Hz, 1H, ArH), 6.98 (d, J=2.3 Hz, 1H, OCH=CH), 4.15 (s, 3H, $OCH_3$), 2.64 (s, 3H, $CH_3$); $^{13}$C NMR (75 MHz, $CDCl_3$) δ 199.3 (C=O), 159.1, 154.4, 144.6, 126.8, 124.7, 118.3, 106.4, 105.6, 60.4, 31.6; IR (KBr) 3117, 1654 (C=O), 1578, 1543, 1470, 1418, 1363, 1332, 1278, 1158, 978 cm$^{-1}$; MS (EI) 190 ($M^+$), 175, 160, 132, 117, 104, 89, 76, 63, 53, 50; HRMS m/z ($M^+$) calcd for $C_{11}H_{10}O_3$: 190.0630. Found: 190.0635

**Ovalitenin A (8).** To a solution of **30** (65 mg, 0.34 mmol) in methanol (10 mL) and potassium hydroxide (95 mg, 1.7 mmol) was added benzaldehyde **31** (108 mg, 1.02 mmol) at room temperature. The reaction mixture was stirred for 6 h at room temperature. Evaporation of methanol and extraction with ethyl

acetate (3x 50 mL), washing with saturated $NH_4Cl$ solution and brine, drying over $MgSO_4$ and removal of the solvent followed by flash column chromatography on silica gel (elution with 15% ethyl acetate in hexane) gave **8** (69 mg, 73%): mp 95-97 °C (lit 99-100 °C[19]); $^1H$ NMR (300 MHz, $CDCl_3$) $\delta$ 7.67 (d, J=16.0 Hz, 1H, COCH=CH), 7.64-7.59 (m, 4H), 7.47 (d, J=15.9 Hz, 1H, COCH=CH), 7.39 (m, 3H), 7.28 (d, J=8.6 Hz, 1H), 7.00 (d, J=2.0 Hz, 1H, OCH=CH), 4.09 (s, 3H, $OCH_3$); $^{13}C$ NMR (75 MHz, $CDCl_3$) $\delta$ 192.5 (C=O), 158.0, 153.0, 144.8, 143.1, 135.1, 130.3, 129.0, 128.9, 128.8, 128.5, 128.2, 126.9, 126.7, 106.8, 105.3, 61.3; IR (KBr) 3116, 1641 (C=O), 1598, 1498, 1471, 1448, 1420, 1362, 1336, 1315, 1256, 1219, 1156, 1073, 967, 812 $cm^{-1}$; MS (EI) 278 ($M^+$), 263, 261, 250, 207, 187, 175, 161, 160, 132, 130, 103, 77, 63, 51.

**Ovalitenin C (9).** Reaction of **30** (55 mg, 0.29 mmol) with the aldehyde **32** (131 mg, 0.870 mmol) afforded **9** (67 mg, 72%) as a solid: mp 126-128 °C (lit 119-120 °C,[19] 126 °C[20]); $^1H$ NMR (300 MHz, $CDCl_3$) $\delta$ 7.62 (d, J =2.0 Hz, 1H), 7.61 (d, J=2.0 Hz, 1H), 7.57 (d, J=8.7 Hz, 1H), 7.30 (d, J=12.4 Hz, 1H), 7.20 (d, J=2.0 Hz), 7.13 (s, 1H), 7.06 (d, J=12.4 Hz, 1H), 6.99 (d, J=2.0 Hz, 1H), 6.81 (d, J=8.7 Hz, 1H), 6.01 (s, 2H, $OCH_2O$), 4.08 (s, 3H, $OCH_3$); $^{13}C$ NMR (75 MHz, $CDCl_3$) $\delta$ 192.4 (C=O), 158.0, 153.4, 149.6, 148.3, 145.0, 144.7, 143.1, 129.6, 126.8, 126.6, 125.9, 125.1, 119.1, 108.6, 106.7, 105.3, 101.5, 61.3; IR (KBr) 1651 (C=O), 1587, 1499, 1471, 1420, 1359, 1324, 1256, 1241, 1155, 1078, 1038, 983, 927, 808 $cm^{-1}$; MS (EI) 322 ($M^+$), 263, 251, 221, 175, 161, 145, 135, 117, 91, 89, 76, 63, 62.

**Purpuritenin (10).** Reaction of **30** (55 mg, 0.29 mmol) with the aldehyde **33** (105 mg, 0.870 mmol) afforded **10** (67 mg, 79%) as a solid: mp 134-136 °C (lit 134-135 °C[6b]); $^1H$ NMR (300 MHz, $CDCl_3$) $\delta$ 7.66–7.51 (m, 5H), 7.50 (d, J=8.0 Hz, 1H), 7.42 (d, J=15.8 Hz, 1H, COCH=CH), 7.27 (d, J=8.8 Hz, 1H), 7.20 (d, J=7.8 Hz, 1H), 6.99 (d, J=2.2 Hz, 1H), 4.08 (s, 3H, $OCH_3$), 2.38 (s, 3H, $ArCH_3$); $^{13}C$ NMR (75 MHz, $CDCl_3$) $\delta$ 192.6 (C=O), 158.5, 153.4, 144.9, 144.6, 143.3, 140.7, 137.5, 132.3, 129.6, 128.4, 127.7, 126.7, 126.0, 119.1, 106.6, 105.2, 61.3, 21.4; IR (KBr) 3124, 1653 (C=O), 1594, 1511, 1469, 1421, 1356, 1324, 1287, 1256, 1156, 1140, 1072, 1048, 977, 947, 804 $cm^{-1}$; MS (EI) 292 ($M^+$), 275, 264, 221, 187, 175, 160, 145, 132, 131, 117, 115, 105, 102, 91, 89, 76, 65, 63.

**Acknowledgment.** We thank the KOSEF (Korea) for financial support in the form of a fellowship (YRL), Duke University for the C. R. Hauser Fellowship (ATM), Professor M.C. Pirrung for his guidance, and for providing laboratory space and supplies.

## References & Notes

1. Postdoctoral fellow of the Korea Science and Engineering Foundation.
2. (a) Wagner, H.; Farkas, L.; In *The Flavonoids*; Harborne, J. B., Mabry, T.J., Mabry, H., Eds., Academic Press: New York, 1975; p 127. (b) Gripenberg, J. In *The Chemistry of Flavonoids Compounds*; Geissman, T. A., Ed.; MacMillan: New York, 1962; p 409.
3. (a) Welton, A. F.; Tobias, L. D.; Fiedler-Nagy, C.; Anderson, W.; Hope, W.; Meyers, K.; Coffey, J.W. In *Plant Flavnoids in Biology and Medicine*; Cody, V., Middleton, E., Jr., Harbone, J. B., Eds.; Alan R.

Liss Inc.; New York, 1986; p 231. (b) Selway, J. W. T. In *Plant Flavonoids in Biology and Medicine*; Cody, V., Middleton, E., Jr., Harbone, J. B., Eds.; Alan R. Liss Inc.; New York, 1986; p 521. (c) Hagiwara, M,; Inoue, S.; Tanaka, T.; Nunoki, K.; Ito, M.; Hidaka, H. *Biochem. Pharmacol.* **1988**, *37*, 2987. (d) Chopra, R. N., Nayyer, S. L.; Chopra, I. C. *Glossary of Indian Medicinal Plants*; C. S. I. R., New Delhi, 1956; p 241. (e) Saxena, B. N.; Dubey, D. N.; Nair, A. L. *Def. Sci. J.* **1974,** *24*, 43.

4. Parmar, B. S.; Sahrawat, K. K.; Mukerjee, S. K. *J. Sci. India Res.* **1976**, *35*, 608.
5. Tanaka, T.; Iinuma, M.; Yuki, K.; Fujii, Y.; Mizuno, M. *Phytochemistry* **1992**, *31*, 993.
6. (a) Pelter, A.; Ward, R. S.; Rao, E. V.; Raju, N. R. *J. Chem. Soc., Perkin Trans.* 1, **1981**, 2491. (b) Sinha, B.; Natu, A. A.; Nanavati, D. D. *Phytochemistry* **1982**, *21*, 1468.
7. (a) Talapatra, S. K.; Mallik, A. K.; Talapatra, B. *Phytochemistry* **1980**, *19*, 1199. (b) Talapatra, S. K..; Mallik, A. K.; Talapatra, B. *Phytochemistry* **1982**, *21*, 761.
8. Garcez, F. R.; Scramin, S.; Nascimento, M.C. D.; Mors, W. *Phytochemistry* **1988**, *27*, 1079.
9. Sultana, S.; Ilyas, M. *Indian J. Chem.* **1986**, *25*B, 416.
10. Rangaswami, S.; Sastry, B. V. *Curr Sci., India*, **1955**, *24*, 13.
11. Lyra, E. A.; De Mello, J. F. *Gazztta Chimica Italiana* **1979**, *109*, 93.
12. Narayanaswami, S.; Rangaswami, s.; Seshadri, T. R. *J. Chem. Soc.* **1954**, 1871.
13. Subrahmanyam, K.S.; Rao, J. M.; Rao, K. V. *Indian J. Chem.* **1977**, *15*B, 12.
14. Roy, D.; Khanna, R. N. *Indian J. Chem.* **1979**, *18*B, 525.
15. Rajani, P.; Sarma, P. N. *Phytochemistry* **1988**, *27*, 648.
16. Parmar, V. S.; Rathore, J.; Jain, R.; Henderson, D. A.; Malone, J. F. *Phytochemistry* **1988**, *27*, 1079.
17. Mukerjee, S. K.; Seshadri, T. R. *J. Chem. Soc.* C **1955**, 2048.
18. Sharma, P.; Parthasarthy, M. R. *Indian J. Chem.* **1977**, *15*B, 866.
19. Gupta, R. K.; Krishnamurti, M. *Phytochemistry* **1977**, *16*, 1104.
20. Islam, A.; Kumar, G.; Krishnamurti, M. *Phytochemistry* **1980**, *19*, 1558.
21. Khanna, R. N.; Seshadri, T. R. *Tetrahedron* **1963**, *19*, 219.
22. Pirrung, M. C.; Lee, Y. R. *Tetrahedron Lett.* **1994**, *35*, 6231.
23. Birch, A. J.; Richards, R. W. *Aust. J. Chem.* **1956**, *9*, 241.
24. Allan, J.; Robinson, R. *J. Chem. Soc.* **1924**, 2192.
25. (a) Baker, W.; *J. Chem. Soc.* **1933,** 1381. (b) Mahal, H. S.; Venkataraman, K. *J. Chem. Soc.* **1934**, 1767.
26. (a) Iinuma, M.; Iwashima, K.; Matsuura, S. *Chem. Pharm. Bull.* **1984**, *32*, 4935. (b) Hoshino, Y.; Oohinata, T.; Takeno, N. *Bull. Chem. Soc. Jpn.* **1986**, *59*, 2351.
27. (a) Hercouet, A.; LeCorre, M.; LeFloc'h, Y. *Synthesis* **1982**, 597. (b) LeFloc'h, Y.; LeFeuvre, M. *Tetrahedron Lett.* **1986**, 5503.
28. von Strandtmann, M.; Klutchko, S.; Cohen, M.P.; Shavel, J. *J. Heterocyclic Chem.* **1972**, *9*, 171.
29. Zambias, R. A.; Caldwell, C. G.; Kopka, I. E.; Hammond, M. L. *J. Org. Chem.* **1988**, *53*, 4135.
30. Kraus, G. A.; Ridgeway, J. *J. Org. Chem.* **1994**, *59*, 4735.

(*Received in USA* 4 *October* 1994; *accepted* 21 *February* 1995)