# Labdane Diterpenoids from *Alpinia chinensis*

Lai-King Sy and Geoffrey D. Brown*

*Chemistry Department, The University of Hong Kong, Pokfulam Road, Hong Kong*

*Received May 12, 1997*[⊗]

Nine new labdane diterpenes (**1**, **4**−**11**) and two known diterpenes have been isolated from the aerial parts of the medicinal plant *Alpinia chinensis*. Their structures were determined from 2D NMR spectroscopy. Biogenetic relationships among these terpenoids are discussed.

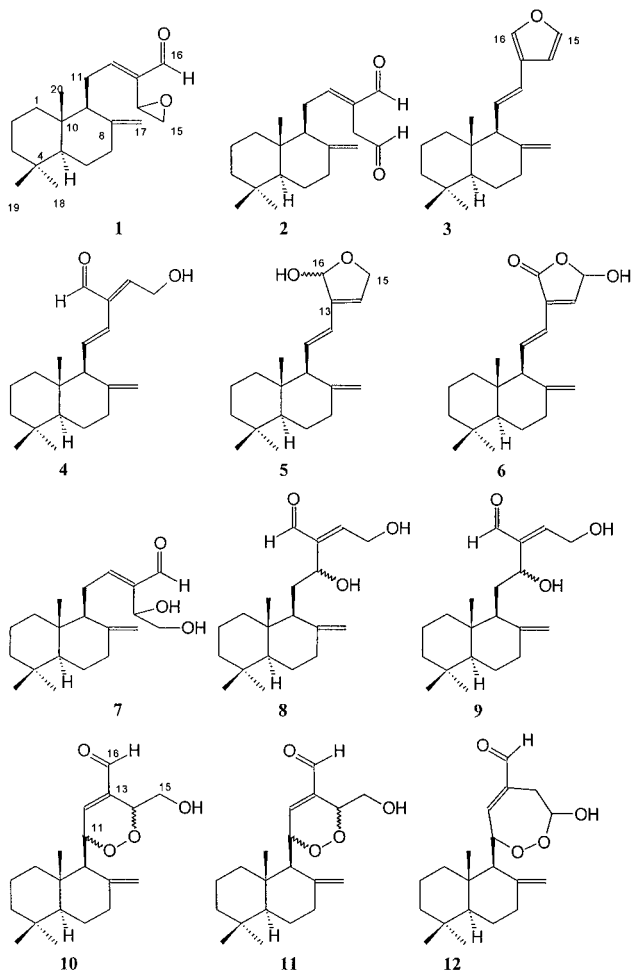
*Alpinia chinensis* Rosc. (Zingiberaceae) is a perennial herb found growing in ravines and shaded woodland in Hong Kong where it is used in traditional medicine as an antiasthmatic and analgesic.[1] A previous gas chromatographic investigation of the flowers of *A. chinensis* reported a number of sesquiterpene hydrocarbons.[2]

## Results and Discussion

Column chromatography of the $CH_2Cl_2$ extract from the aerial parts of *A. chinensis* yielded the novel labdane diterpene **1** (Chart 1) as the principal component (1.2% w/w). High-resolution electron impact mass spectroscopy of **1** demonstrated the molecular formula $C_{20}H_{30}O_2$, and IR showed an unsaturated aldehyde functional group ($\nu_{max}$ 1682 $cm^{-1}$). $^{13}C$/DEPT NMR confirmed the presence of 20 carbons with 30 directly attached protons and indicated an exocylic double bond ($\delta_C$ 107.8 $CH_2$, 148.0 C) in addition to the unsaturated aldehyde ($\delta_C$ 193.2 CH, 137.5 C, 160.6 CH). $^1H$ NMR indicated three protons of a terminal epoxide ($\delta_H$ 3.63, dd, $J$ = 5.5, 2.7 Hz, H-14; 2.99, dd, $J$ = 5.5, 4.5 Hz, H-15a; 2.84, dd, $J$ = 4.5, 2.7 Hz, H-15b). The labdane skeleton of **1** was established by means of the 2D NMR experiments HSQC ($^{13}C$ and $^1H$ assignments given in Tables 1 and 2) and HMBC (two- and three-bond correlations between $^{13}C$ and $^1H$ indicated in Figure 1). Results of $^1H-^1H$ COSY confirmed these NMR assignments. All other labdanes in this study have also been assigned using these 2D NMR techniques.

The relative stereochemistry around the rigid decalin ring system of **1** was established from NOESY experiments (see Figure 2). Free rotation of the branched alicyclic substituent (C11−C16) meant that NOESY results were considered unreliable in determining stereochemistry for the terminal epoxide in this portion of the molecule, however. The absolute stereochemistry for **1** was deduced by isolation of the known compounds **2**[3−11] and **3**[6,12,13] (both compounds have only been reported previously as natural products from the Zingiberaceae) which were minor products in the extract. Erroneous literature assignments for C7/C14[3−6,8,9,11] of compoumd **2** and for C15/C16[6,12] and C11/C12[12] of compound **3** are corrected in Tables 1 and 2 from rigorous analysis of their 2D NMR spectra. Optical rotations for **2** and **3** from *A. chinensis* gave good agreement with literature values and the absolute stereochemistry of **1** has been assigned on the assumption that **2** and **3** are biogenetically related to **1**.

**Chart 1**




A plausible mechanism for conversion of **1** into **3**, involving opening of the epoxide, is shown in Figure 3. Experimental evidence for such a mechanism comes from isolation of both the diene alcohol **4** and the cyclic hemiacetal **5**. Compound **4**, which can be viewed as the initial product of epoxide ring opening, was shown to have (*E*) stereochemistry for the 13,14 double bond from NOESY correlations (H16 gave an enhancement to to H14 and H15 gave an enhancement to H11). Compound **5** (isolated as a 1:1 mixture of diastereoisomers at the 16 position) is expected to result from cyclization of the primary alcohol and the 16-aldehyde group of the (*Z*) isomer of **4**, which can also be formed from epoxide ring opening of **1**. The stereochemistry of the new 11,12 double bond formed by allylic epoxide opening in both 4 and 5 was clearly *trans* ($J$ = 16 Hz from $^1H$ NMR).

We were surprised to note that the largest chemical shift difference between the two epimers in both the $^1H$

* To whom correspondence should be adressed. Tel: 852-2859 7915. Fax: 852-2857 1586. E-mail: GDBROWN@HKUCC.HKU.HK.

[⊗] Abstract published in *Advance ACS Abstracts,* September 1, 1997.

S0163-3864(97)00243-7 CCC: $14.00 

**Table 1.** $^{13}$C-NMR[a] Chemical Shift Values (in ppm) for Diterpenes **1**−**12**

| assignment | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 39.1 | 39.2 | 40.2 | 40.7 | 40.85/40.82[b] | 40.8 | 39.3 | 38.9 | 38.9 | 41.0 | 39.0 | 39.1 |
| 2 | 19.3 | 19.3 | 19.1 | 19.1 | 19.11/19.13[b] | 19.0 | 19.3 | 19.3 | 19.3 | 19.2 | 19.2 | 19.2 |
| 3 | 42.0 | 42.0 | 42.3 | 42.2 | 42.28 | 42.2 | 42.0 | 42.1 | 42.0 | 41.9 | 42.0 | 42.0 |
| 4 | 33.5 | 33.6 | 33.6 | 33.5 | 33.56 | 33.6 | 33.6 | 33.6 | 33.6 | 33.7 | 33.6 | 33.6 |
| 5 | 55.3 | 55.4 | 54.8 | 54.6 | 54.71 | 54.7 | 55.5 | 55.5 | 55.6 | 55.6 | 55.8 | 55.9 |
| 6 | 24.1 | 24.1 | 23.4 | 23.3 | 23.35 | 23.3 | 24.1 | 24.4 | 24.3 | 24.1 | 24.0 | 24.0 |
| 7 | 37.9 | 37.9 | 36.8 | 36.7 | 36.70 | 36.7 | 37.9 | 38.3 | 38.2 | 38.1 | 38.1 | 38.0 |
| 8 | 148.0 | 148.0 | 150.3 | 149.5 | 149.70/149.79[b] | 149.2 | 147.8 | 148.5 | 148.7 | 147.0 | 144.4 | 145.0 |
| 9 | 56.8 | 56.5 | 61.5 | 62.7 | 61.80/61.82[b] | 62.2 | 56.7 | 52.0 | 53.5 | 59.4 | 62.1 | 62.2 |
| 10 | 39.6 | 39.6 | 39.2 | 39.1 | 39.25/39.28[b] | 39.4 | 39.6 | 39.3 | 39.6 | 41.5 | 40.0 | 40.2 |
| 11 | 24.1 | 24.7 | 128.3 | 137.8 | 133.58/133.43[b] | 139.7 | 24.5 | 31.2 | 30.5 | 80.0 | 78.6 | 85.8 |
| 12 | 160.6 | 160.0 | 121.7 | 121.4 | 123.63/123.74[b] | 120.2 | 161.2 | 66.8 | 68.1 | 152.9 | 152.9 | 156.0 |
| 13 | 137.5 | 134.9 | 124.5 | 137.7 | 138.86/138.90[b] | 132.5 | 139.6 | 145.1 | 143.1 | 136.7 | 144.4 | 136.5 |
| 14 | 47.3 | 39.4 | 107.7 | 151.4 | 125.32/125.36[b] | 140.6 | 70.3 | 152.9 | 154.2 | 78.9 | 79.3 | 28.1 |
| 15 | 46.2 | 197.3 | 143.3 | 60.1 | 73.56 | 96.1 | 65.4 | 59.7 | 59.5 | 62.7 | 62.2 | 101.9 |
| 16 | 193.2 | 193.5 | 139.6 | 193.8 | 102.67/102.64[b] | 169.7 | 196.8 | 195.3 | 195.5 | 190.5 | 190.3 | 192.5 |
| 17 | 107.8 | 107.9 | 108.0 | 108.3 | 108.37/108.02[b] | 108.4 | 108.3 | 106.6 | 107.2 | 109.4 | 110.7 | 109.3 |
| 18 | 33.6 | 33.6 | 33.6 | 33.5 | 33.56 | 33.6 | 33.6 | 33.6 | 33.5 | 33.9 | 33.7 | 33.7 |
| 19 | 21.7 | 21.7 | 22.0 | 21.9 | 21.94 | 21.9 | 21.7 | 21.7 | 21.7 | 21.8 | 21.6 | 21.7 |
| 20 | 14.4 | 14.4 | 15.0 | 15.1 | 15.03 | 15.1 | 14.5 | 14.6 | 14.6 | 16.4 | 16.9 | 16.7 |

[a] Spectra recorded at 125 MHz. [b] Doubled signals due to epimer (1:1) at C16.

**Table 2.** $^{1}$H-NMR[a] Chemical Shift Values (in ppm) for Diterpenes **1**−**12**

| atom | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1$\beta$ | 1.75 | 1.69 | 1.40 | 1.45 | 1.43 | 1.42 | 1.71 | 1.72 | 1.65 | 1.81 | 1.92 | 1.88 |
| 1$\alpha$ | 1.10 | 1.07 | 1.00 | 1.02 | 1.00 | 1.00 | 1.08 | 1.09 | 0.76 | 1.12 | 1.22 | 1.21 |
| 2$\beta$ | 1.60 | 1.58 | 1.52 | 1.52 | 1.52 | 1.53 | 1.60 | 1.55 | 1.52 | 1.54 | 1.65 | 1.65 |
| 2$\alpha$ | 1.53 | 1.52 | 1.42 | 1.42 | 1.40 | 1.40 | 1.52 | 1.52 | 1.45 | 1.48 | 1.55 | 1.55 |
| 3$\beta$ | 1.42 | 1.42 | 1.40 | 1.43 | 1.42 | 1.40 | 1.42 | 1.39 | 1.39 | 1.40 | 1.45 | 1.45 |
| 3$\alpha$ | 1.20 | 1.18 | 1.17 | 1.20 | 1.20 | 1.20 | 1.20 | 1.19 | 1.13 | 1.18 | 1.20 | 1.20 |
| 5 | 1.15 | 1.14 | 1.09 | 1.10 | 1.08 | 1.10 | 1.13 | 1.17 | 1.00 | 1.09 | 1.10 | 1.10 |
| 6$\alpha$ | 1.75 | 1.75 | 1.70 | 1.70 | 1.70 | 1.71 | 1.75 | 1.75 | 1.71 | 1.75 | 1.72 | 1.72 |
| 6$\beta$ | 1.35 | 1.35 | 1.35 | 1.40 | 1.37 | 1.40 | 1.35 | 1.32 | 1.30 | 1.35 | 1.39 | 1.40 |
| 7$\beta$ | 2.40 | 2.42 | 2.45 | 2.45 | 2.43 | 2.43 | 2.40 | 2.40 | 2.38 | 2.42 | 2.33 | 2.38 |
| 7$\alpha$ | 2.02 | 2.02 | 2.07 | 2.08 | 2.07 | 2.08 | 2.05 | 2.03 | 1.90 | 2.03 | 2.02 | 2.02 |
| 9 | 1.90 | 1.90 | 2.37 | 2.37 | 2.34 | 2.38 | 1.91 | 2.08 | 1.31 | 2.19 | 2.19 | 2.20 |
| 11 | 2.75 | 2.50 | 5.97 | 6.33 | 6.03 | 6.95 | 2.58 | 1.92 | 1.96 | 5.32 | 5.39 | 5.52 |
| | 2.65 | 2.32 | | | | | 2.50 | 1.50 | 1.25 | | | |
| 12 | 6.61 | 6.77 | 6.19 | 6.01 | 6.10 | 6.10 | 6.57 | 4.62 | 4.58 | 7.24 | 6.94 | 6.45 |
| 14 | 3.63 | 3.38 | 6.55 | 6.45 | 5.92 | 6.86 | 4.67 | 6.55 | 6.63 | 4.74 | 4.74 | 3.30 |
| | | 3.47 | | | | | | | | | | 2.68 |
| 15 | 2.99 | 9.63 | 7.35 | 4.61 | 4.79 | 6.10 | 3.74 | 4.59 | 4.49 | 3.93 | 3.94 | 5.48 |
| | 2.84 | | | 4.61 | 4.57 | | 3.58 | 4.51 | 4.32 | 3.93 | 3.94 | |
| 16 | 9.31 | 9.41 | 7.36 | 9.47 | 6.17/6.15[b] | – | 9.30 | 9.38 | 9.40 | 9.51 | 9.50 | 9.40 |
| 17 | 4.86 | 4.87 | 4.75 | 4.76 | 4.75/4.75[b] | 4.77 | 4.88 | 4.88 | 4.92 | 4.99 | 4.82 | 4.84 |
| | 4.48 | 4.37 | 4.52 | 4.49 | 4.51/4.45[b] | 4.47 | 4.41 | 4.58 | 4.74 | 4.81 | 4.65 | 4.79 |
| 18 | 0.89 | 0.89 | 0.90 | 0.89 | 0.89 | 0.89 | 0.89 | 0.88 | 0.85 | 0.87 | 0.88 | 0.88 |
| 19 | 0.83 | 0.82 | 0.84 | 0.84 | 0.84 | 0.84 | 0.83 | 0.80 | 0.78 | 0.83 | 0.84 | 0.84 |
| 20 | 0.76 | 0.73 | 0.85 | 0.84 | 0.83/0.82[b] | 0.87 | 0.75 | 0.64 | 0.67 | 0.95 | 0.97 | 0.98 |

[a] Spectra recorded at 500 MHz. [b] Doubled signals due to epimer (1:1) at C16.

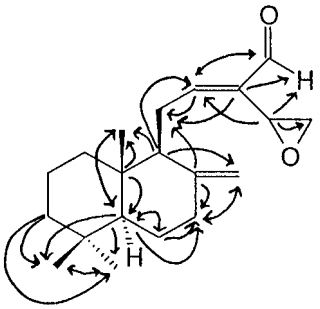



**Figure 1.** HMBC correlations for compound **1**, indicated by arrows from $^{13}$C to $^{1}$H.

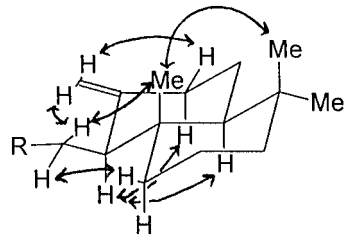



**Figure 2.** Typical critical NOESY correlations observed for decalin nucleus of compounds **1**−**12**, indicated by double-headed arrows.

and $^{13}$C NMR spectra of **5** appeared at C17, which is quite distant from the new chiral centre in the hemiacetal ring. Equally surprisingly, all $^{13}$C signals in the upper portion of the labdane decalin system (C1,2,8,9,10) were clearly distinguished in the two isomers (those in the lower portion were not). A possible explanation is that configurations of the hemiacetal hydroxyl group in these epimers are associated with different preferred solution conformations for the C11−C16 substituent, which is then able to influence the upper portion of the decalin system.

NMR spectra for compound **6** showed some similarities to those of **5**; both had a conjugated diene system directly attached to the decalin nucleus and a hemiac-

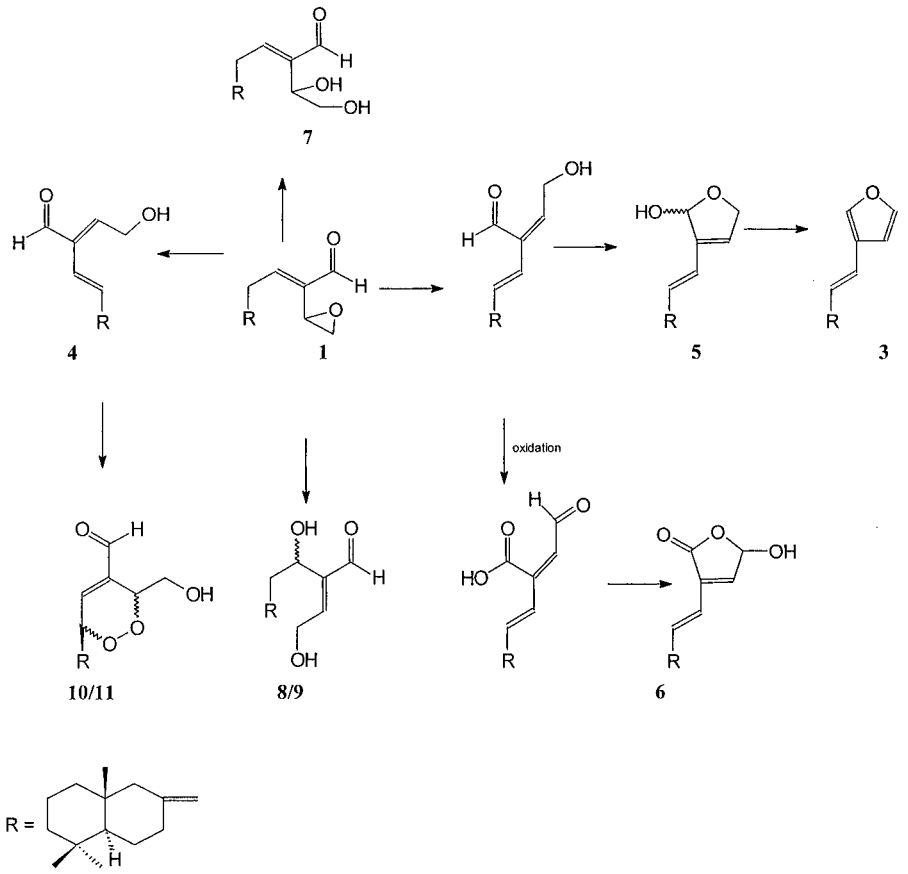



**Figure 3.** Postulated biogenetic relationships among compounds **1**−**11**.

etal group ($\delta_C$ 96.1, $\delta_H$ 6.10 in **6**; $\delta_C$ 102.6, $\delta_H$ 6.17/6.15 in **5**). The principal difference in 1D NMR spectra of compound **6** was that a conjugated lactone signal ($\delta_C$ 169.7) replaced the oxygenated methylene signal in **5** ($\delta_C$ 73.56). 2D NMR conclusively demonstrating that compound **6** is a hemiacetal lactone, which can be formally derived from the (*Z*) isomer of **4** by oxidation of the 15-alcohol group to an aldehyde and of the 16-aldehyde to a carboxylic acid, followed by lactonization (Figure 3). A number of closely related five-membered lactones such as yunnanocoronarin B and zerumin B have been reported previously from the Zingiberaceae. Literature NMR data for these compounds supported the structure of **6**.[5,9,12−14]

The vicinal diol **7** is obviously formed by direct hydrolytic cleavage of the epoxide ring in **1** (Figure 3). Whereas attack by $H_2O$ at the terminal position of the epoxide in **1** to yield **7** is expected to result in only one diastereoisomer for which the stereochemistry at the 14-position is conserved, no diastereoselectivity is required for allylic hydrolytic cleavage of the epoxide. In accordance with this expectation, two diastereoisomeric 1,4-diols **8** and **9**, which can be viewed as products of such allylic cleavage, were present in the extract, and both could be separated from one another by HPLC and characterized individually by NMR. The stereochemistry of the double bond for both compounds **8** and **9** was established by observation of a strong correlation between H14 and H16 in NOESY spectra.

The highest relative mass ion observed in electron impact mass spectra of **10** was at *m*/*z* 316. Application of atmospheric pressure chemical ionization mass spectroscopy (APCI-MS) showed the true molecular ion at *m*/*z* 335 (M + 1), and MS/MS analysis of this ion confirmed a strong tendency to lose $H_2O$ (*m*/*z* 317) in agreement with the results of EIMS. 1D NMR spectra for compound **10** showed that it contained an aldehyde ($\delta_C$ 190.5, $\delta_H$ 9.51) conjugated to a double bond ($\delta_C$ 136.7 C, $\delta_C$ 152.9 CH), an oxygenated methylene carbon ($\delta_C$ 62.7 $CH_2$, $\delta_H$ 3.93 [2H, m]), and two oxygenated methine carbons ($\delta_C$ 78.9 CH, $\delta_C$ 80.0 CH) in addition to the decalin nucleus common to all other natural products described in this paper. Secondary isotope effects observed from a $D_2O$ shake experiment confirmed that the carbon signal at $\delta$ 62.7 was associated with an alcohol group and that the signals at $\delta$ 78.9 and 80.0 were not associated with exchangeable hydrogen (the signal at $\delta$ 62.7 showed an upfield shift of 0.14 ppm when OH was converted to OD while the other two signals were essentially unchanged). Chemical shifts for these carbons were consistent with primary alcohol and endoperoxide functional groups respectively, and the complete structure of **10** was confirmed by correlations observed in $^1H-^1H$ COSY and HMBC spectra. Compound **11**, which gave similar APCI, EI-MS, 1D and 2D NMR spectra to **10**, is a diastereoisomer of compound **10**. Both compounds **10** and **11** may have arisen by direct oxygenation of **4**.

1D NMR analysis of compound **12** showed several familiar resonances in the side chain of the labdane skeleton such as an unsaturated aldehyde ($\delta_C$ 192.5 CH, $\delta_C$ 136.5 C, $\delta_C$ 156.0 CH), an endoperoxide methine group ($\delta_C$ 85.8, $\delta_H$ 5.52), and a doubly oxygenated center ($\delta_C$ 101.9, $\delta_H$ 5.48). Compound **12** is a seven-membered endoperoxide hemiacetal which has been reported previously from the Zingiberaceae family.[5,9]

## Experimental Section

**General Experimental Procedures.** Chemical shifts are expressed in ppm ($\delta$) relative to TMS as int. standard. All NMR experiments were run on a Bruker DRX 500 instrument with $CDCl_3$ as solvent. HSQC and HMBC spectra were normally recorded with 2048 data points in $F_2$ and 128 data points in $F_1$, while high resolution experiments had 8192 data points in $F_2$ and 1024 data points in $F_1$. MS were recorded in EI mode (70 eV) on a Finnigan-MAT 95 MS spectrometer. FTIR spectra were recorded on a Shimadzu FTIR-8201 PC instrument. TLC plates were developed using *p*-anisaldehyde. HPLC separations were performed using a PREP-SIL 20 mm × 25 cm column, flow rate 8 mL/min.

**Plant Material.** The aerial parts of *A. chinensis* were collected from Tai Tam Country Park, Hong Kong Island, in November 1996. A voucher specimen (GDBROWN 97/2) is deposited in the University of Hong Kong Herbarium.

**Extraction and Isolation of Diterpenoids.** The aerial parts of *A. chinensis* (850 g) were ground to a fine powder under liquid $N_2$ and extracted with $CH_2Cl_2$. Drying and rotary evaporation yielded a green gum (24.4 g w/w, 2.9%). The various components of the extracts were isolated by gradient elution silica gel chromatography (starting with 100% hexane, finishing with 100% ethyl acetate), and final purification was by HPLC: **1** (9.9 g), **2** (977 mg), **3** (18.4 mg), **4** (150 mg), **5a/5b** (94 mg), **6** (12 mg), **7** (19.8 mg), **8** (40 mg) **9** (15 mg), **10** (17 mg), **11** (13 mg), **12** (23 mg).

**14ξ,15-Epoxylabda-8(17),12-dien-16-al *[E]* (1)**: gum; $[\alpha]_D$ +11.0° ($c$ = 3.78, $CHCl_3$); IR ($CHCl_3$) $\nu_{max}$ 2990, 2932, 2847, 1682, 1643 $cm^{-1}$; $^1H$ NMR ($CDCl_3$, 500 MHz) $\delta$ 0.76 (3H, s), 0.83 (3H, s), 0.89 (3H, s), 2.02 (1H, ddd, $J$ = 12.9, 12.8, 5.0 Hz), 2.40 (1H, ddd, $J$ = 12.8, 2.3, 2.3 Hz), 2.65 (1H, ddd, $J$ = 16.8, 11.2, 7.5 Hz), 2.75 (1H, ddd, $J$ = 16.8, 6.0, 3.0 Hz), 2.84 (1H, dd, $J$ = 5.5, 2.7 Hz), 2.99 (1H, dd, $J$ = 5.5, 4.5 Hz), 3.63 (1H, dd $J$ = 4.5, 2.7 Hz), 4.48 (1H, s), 4.86 (1H, s), 6.61 (1H, dd, $J$ = 7.5, 6.0 Hz), 9.31 (1H, s); $^{13}C$ NMR, see Table 1; HREIMS $m/z$ [$M^+$, 302.2243 calcd for $C_{20}H_{30}O_2$, 302.2246] (19), 284 (26), 269 (24), 255 (7), 199 (7), 190 (11), 177 (18), 165 (10), 137 (100), 123 (23).

**Labda-8(17),12-diene-15,16-dial *[E]* (2)**: oil; $[\alpha]_D$ +14.1° ($c$ = 3.97, $CHCl_3$); IR ($CHCl_3$) $\nu_{max}$ 2932, 2870, 2845, 1726, 1682, 1641 $cm^{-1}$; $^1H$ NMR ($CDCl_3$, 500 MHz) $\delta$ 0.73 (3H, s), 0.82 (3H, s), 0.89 (3H, s), 3.38 (1H, d, $J$ = 16.9 Hz), 3.47 (1H, d, $J$ = 16.9 Hz), 4.37 (1H, s), 4.87 (1H, s), 6.77 (1H, t, $J$ = 6.8 Hz), 9.41 (1H, s), 9.63 (1H, s); $^{13}C$ NMR, see Table 1; HREIMS $m/z$ [$M^+$, 302.2247 calcd for $C_{20}H_{30}O_2$, 302.2246] (83), 273 (17), 258 (14), 190 (9), 177 (15), 165 (12), 137 (100), 123 (30).

**Coronarin E (3)**: oil; $[\alpha]_D$ +8.0° ($c$ = 2.12, $CHCl_3$); IR ($CHCl_3$) $\nu_{max}$ 2930, 2870, 1643 $cm^{-1}$; $^1H$ NMR ($CDCl_3$, 500 MHz) $\delta$ 0.84 (3H, s), 0.85 (3H, s), 0.90 (3H, s), 4.52 (1H, d, $J$ = 1.9 Hz), 4.75 (1H, d, $J$ = 1.9 Hz), 5.97 (1H, dd, $J$ = 15.8, 9.7 Hz), 6.19 (1H, d, $J$ = 15.8 Hz), 6.55 (1H, s), 7.35 (1H, s), 7.36 (1H, s); $^{13}C$ NMR, see Table 1; HREIMS $m/z$ [$M^+$, 284.2149 calcd for $C_{20}H_{28}O$, 284.2140] (6), 217 (5), 190 (10), 177 (20), 153 (35), 137 (100), 123 (30).

**15-Hydroxylabda-8(17),11,13-trien-16-al *[E,E]* (4)**: oil; $[\alpha]_D$ +7.7° ($c$ = 0.90, $CHCl_3$); IR ($CHCl_3$) $\nu_{max}$ 3412 (br), 2930, 2868, 2847, 1692, 1643 $cm^{-1}$; $^1H$ NMR ($CDCl_3$, 500 MHz) $\delta$ 0.84 (6H, s), 0.89 (3H, s), 2.37 (1H, d, $J$ = 9.9, Hz), 2.45 (1H, ddd, $J$ = 13.4, 4.3, 2.2 Hz), 4.49 (1H, d, $J$ = 1.8 Hz), 4.61 (2H, d, $J$ = 5.6 Hz), 4.76 (1H, d, $J$ = 1.8 Hz), 6.01 (1H, d, $J$ = 16.0 Hz), 6.33 (1H, dd, $J$ = 16.0, 9.9 Hz), 6.45 (1H, t, $J$ = 5.6 Hz), 9.47 (1H, s); $^{13}C$ NMR, see Table 1; HREIMS $m/z$ [$M^+$, 302.2242, calcd for $C_{20}H_{30}O_2$, 302.2246] (56), 284 (8), 177 (12), 137 (100).

**15,16-Epoxylabda-8(17),11,13-trien-16-ol *[E]* (5a/5b)**: oil; $[\alpha]_D$ +17.6° ($c$ = 0.23, $CHCl_3$); IR ($CHCl_3$) $\nu_{max}$ 3620, 3435 (br), 3013, 2930, 2870, 1684, 1642 $cm^{-1}$; $^1H$ NMR ($CDCl_3$, 500 MHz) $\delta$ 0.82 (3H, s)/0.83 (3H, s), 0.84 (3H, s), 0.89 (3H, s), 2.07 (1H, ddd, $J$ = 13.7, 13.7, 5.2 Hz), 2.34 (1H, d, $J$ = 9.4 Hz), 2.43 (1H, d, $J$ = 11.0 Hz), 2.73 (1H, br m, OH), 4.51 (1H, d, $J$ = 1.6 Hz)/4.45 (1H, d, $J$ = 1.6 Hz), 4.57 (1H, d, $J$ = 15.0 Hz), 4.75 (1H, d, $J$ = 1.8 Hz), 4.79 (1H, d, $J$ = 15.0 Hz), 5.92 (1H, s), 6.03 (1H, ddd, $J$ = 16.0, 9.4, 3.0 Hz), 6.10 (1H, d, $J$ = 16.0 Hz), 6.17 (1H, br s)/6.15 (1H, br s); $^{13}C$ NMR, see Table 1; EIMS $m/z$ [$M^+$, 302] (14), 284 (100), 245 (13), 191 (10), 177 (13), 160 (13), 147 (74), 137 (66), 123 (18).

**15-Hydroxylabda-8(17),11,13-trien-16,15-olide *[E]* (6)**: gum; $[\alpha]_D$ +33.7° ($c$ = 0.35, $CHCl_3$); IR ($CHCl_3$) $\nu_{max}$ 3393, 2930, 1769, 1641 $cm^{-1}$; $^1H$ NMR ($CDCl_3$, 500 MHz) $\delta$ 0.84 (3H, s), 0.87 (3H, s), 0.89 (3H, s), 2.38 (1H, d, $J$ = 10.2 Hz), 2.43 (1H, ddd, $J$ = 13.8, 4.3, 2.1 Hz), 4.47 (1H, s), 4.77 (1H, s), 6.10 (1H, s), 6.10 (1H, d, $J$ = 15.9 Hz), 6.86 (1H, s), 6.95 (1H, dd, $J$ = 15.9, 10.2 Hz); $^{13}C$ NMR, see Table 1; EIMS $m/z$ [$M^+$, 316] (22), 298 (11), 272 (13), 243 (16), 215 (4), 180 (7), 162 (13), 153 (17), 137 (100), 123 (20).

**14ξ,15-Dihydroxylabda-8(17),12-dien-16-al *[E]* (7)**: gum; $[\alpha]_D$ +4.9° ($c$ = 0.83, $CHCl_3$); IR ($CHCl_3$) $\nu_{max}$ 3447 (br), 3011, 2932, 1690, 1643 $cm^{-1}$; $^1H$ NMR ($CDCl_3$, 500 MHz) $\delta$ 0.75 (3H, s), 0.83 (3H, s), 0.89 (3H, s), 2.50 (1H, ddd, $J$ = 17.6, 11.0, 6.5 Hz), 2.58 (1H, ddd, $J$ = 17.6, 6.5, 3.7 Hz), 3.57 (1H, dd, $J$ = 11.3, 4.3 Hz), 3.74 (1H, dd, $J$ = 11.3, 6.7 Hz), 4.41 (1H, s), 4.67 (1H, m), 4.88 (1H, s), 6.57 (1H, t, $J$ = 6.5 Hz), 9.30 (1H, d, $J$ = 1.7 Hz); $^{13}C$ NMR, see Table 1; EIMS $m/z$ [M − $H_2O$, 302] (87), 284 (99), 273 (35), 245 (16), 205 (5), 191 (12), 177 (19), 165 (43), 147 (62), 137 (100), 123 (51).

**12ξ,15-Dihydroxylabda-8(17)-13-dien-16-al *[E]* (8)**: oil; $[\alpha]_D$ +23.9° ($c$ = 0.24, $CHCl_3$); IR ($CHCl_3$) $\nu_{max}$ 3420 (br), 2930, 2847, 1680, 1643 $cm^{-1}$; $^1H$ NMR ($CDCl_3$, 500 MHz) $\delta$ 0.64 (3H, s), 0.80 (3H, s), 0.88 (3H, s), 4.51 (1H, dd, $J$ = 16.7, 5.1 Hz), 4.58 (1H, s), 4.59 (1H, dd, $J$ = 16.7, 5.4 Hz), 4.62 (1H, d, $J$ = 10.7 Hz), 4.88 (1H, s), 6.55 (1H, dd, $J$ = 5.4, 5.1 Hz), 9.38 (1H, s); $^{13}C$ NMR, see Table 1; HREIMS $m/z$ [$M^+$, 302.2240 M − $H_2O$, calcd for $C_{20}H_{30}O_2$, 302.2246] (40), 284 (17), 281 (14), 205 (71), 191 (37), 177 (20), 149 (40), 137 (100), 109 (55).

**12ξ,15-Dihydroxylabda-8(17)-13-dien-16-al *[E]* (9)**: oil; $[\alpha]_D$ +23.0° ($c$ = 0.08, $CHCl_3$); IR ($CHCl_3$) $\nu_{max}$ 3412 (br), 2932, 2854, 1676, 1639 $cm^{-1}$; $^1H$ NMR ($CDCl_3$, 500 MHz) $\delta$ 0.67 (3H, s), 0.78 (3H, s), 0.85 (3H, s), 2.38 (1H, m), 4.32 (1H, dd, $J$ = 16.2, 5.2 Hz), 4.49 (1H, dd, $J$ = 16.2, 6.0 Hz), 4.58 (1H, t, $J$ = 6.5, Hz), 4.74 (1H, s), 4.92 (1H, d, $J$ = 1.2 Hz), 6.63 (1H, dd, $J$ = 6.0, 5.2 Hz), 9.40 (1H, d, $J$ = 1.8 Hz); $^{13}C$ NMR, see Table 1; HREIMS $m/z$ [$M^+$, 302.2247 M − $H_2O$, calcd for $C_{20}H_{30}O_2$, 302.2246] (49), 284 (17), 269 (10), 205 (74), 191 (22), 177 (19), 149 (42), 137 (100), 109 (60).

**15-Hydroxy-11ξ,14ξ-peroxylabda-8(17),12-dien-16-al (10)**: gum; $[\alpha]_D$ +2.6° ($c$ = 0.51, $CHCl_3$); IR

($CHCl_3$) $\nu_{max}$ 3620, 3427 (br), 3010, 2921, 1684 $cm^{-1}$; $^1H$ NMR ($CDCl_3$, 500 MHz) $\delta$ 0.83 (3H, s), 0.87 (3H, s), 0.95 (3H, s), 2.42 (1H, ddd, $J$ = 12.7, 4.6, 2.5 Hz), 3.93 (2H, m), 4.74 (1H, dd, $J$ = 5.6, 4.6 Hz), 4.81 (1H, s), 4.99 (1H, s), 5.32 (1H, d, $J$ = 5.5 Hz), 7.24 (1H, t, $J$ = 1.5 Hz), 9.51 (1H, s); $^{13}C$ NMR, see Table 1; EIMS $m/z$ [M − $H_2O$] 316 (20), 302 (100), 219 (5), 191 (23), 177 (7), 137 (52); APCI-MS $m/z$ 335 [M + 1] (45), 317 [M + 1 − $H_2O$] (100), 299 (90). (MS/MS of ion at 335 showed daughter ions at 317 and 299.)

**15-Hydroxy-11ξ,14ξ-peroxylabda-8(17),12-dien-16-al (11)**: gum; $[\alpha]_D$ −2.1° ($c$ = 0.61, $CHCl_3$); IR ($CHCl_3$) $\nu_{max}$ 3612, 3420 (br), 2974, 2930, 1686 $cm^{-1}$; $^1H$ NMR ($CDCl_3$, 500 MHz) $\delta$ 0.84 (3H, s), 0.88 (3H, s), 0.97 (3H, s), 2.33 (1H, ddd, $J$ = 13.2, 4.7, 2.2 Hz), 3.94 (2H, m), 4.65 (1H, s), 4.74 (1H, m), 4.82 (1H, s), 5.39 (1H, t, $J$ = 1.8 Hz), 6.94 (1H, d, $J$ = 1.8 Hz), 9.50 (1H, s); $^{13}C$ NMR, see Table 1; EIMS $m/z$ 316 [M − $H_2O$] (5), 302 (37), 219 (15), 191 (39), 176 (12), 153 (100), 137 (77), 107 (92); APCI-MS $m/z$ 335 [M + 1] (25), 317 [M + 1 − $H_2O$] (100), 299 (60). (MS/MS of ion at 335 showed daughter ions at 317 and 299.)

**Coronarin C (12)**: gum; $[\alpha]_D$ +25.3° ($c$ = 0.07, $CHCl_3$); IR ($CHCl_3$) $\nu_{max}$ 3591, 3398 (br), 2932, 2872, 1686, 1643 $cm^{-1}$; $^1H$ NMR ($CDCl_3$, 500 MHz) $\delta$ 0.84 (3H, s), 0.88 (3H, s), 0.98 (3H, s), 2.20 (1H, s), 2.68 (1H, m), 3.30 (1H, m), 4.79 (1H, d, $J$ = 1.1 Hz), 4.84 (1H, s), 5.48 (1H, s), 5.52 (1H, s), 6.45 (1H, s), 9.40 (1H, s); $^{13}C$ NMR, see Table 1; EIMS $m/z$ 316 [M − $H_2O$] (10), 302 (5), 219 (4), 191 (16), 177 (10), 161 (5), 137 (100), 123 (23).

**Acknowledgment.** We thank the CRCG for funding this research.

## References and Notes

(1) Cheung, S. C. *Chinese Medicinal Herbs of Hong Kong*; The Commercial Press: Hong Kong, 1988; Vol. 5, p 198.
(2) Dung, N. X.; Chinh, T. D.; Rang, D. D.; Leclerq, P. A. *J. Essent. Oil Res.* **1994**, *6*, 637−638.
(3) Kimbu, S. F.; Nagadjui, B.; Sondengam, L. B.; Njimi, T. K.; Connolly, J. D.; Fakunle, C. O. *J. Nat. Prod.* **1987**, 50, 230−231.
(4) Itokawa, H.; Morita, M.; Mihashi, S. *Chem. Pharm. Bull.* **1980**, *28*, 3452−3454.
(5) Nakatani, N.; Kikuzaki, H.; Yamaji, H., Yoshio, K.; Kitora, C.; Okada, K.; Padolina, W. G. *Phytochemistry* **1994**, *37*, 1383−1388.
(6) Sirat, H. M.; Masri, D.; Rahman, A. A. *Phytochemistry* **1994**, *36*, 699−701.
(7) Firman, K.; Konoshita, T.; Itai, A.; Sankawa, U. *Phytochemistry* **1988**, *27*, 3887−3891.
(8) Itokawa, H.; Yoshimoto, S.; Morita, H. *Phytochemistry* **1988**, *27*, 435−438.
(9) Itokawa, H.; Morita, H.; Katou, I.; Takeya, K.; Cavalheiro, A. J.; de Oliveira, R. C. B.; Ishige, M.; Motidome, M. *Planta Medica* **1988**, *54*, 311−315.
(10) Sirat, H. M. *Planta Medica* **1994**, *60*, 497.
(11) Morita, H.; Itokawa, H. *Planta Medica* **1988**, *54*, 117−120.
(12) Zhao, Q.; Hao, X.-J.; Chen, Y.-Z.; Zou, C. *Chem. J. Chin. Univ.* **1995**, *16*, 64−68.
(13) Singh, S.; Gray, A. I.; Skelton, B. W.; Waterman, P. G.; White, A. H. *Aust. J. Chem.* **1991**, *44*, 1789−1793.
(14) Xu, H.-X.; Dong, H.; Sim, K. Y. *Phytochemistry* **1996**, *42*, 149−151.

NP970243D