Coumarins from the Fruits of *Cnidium monnieri*

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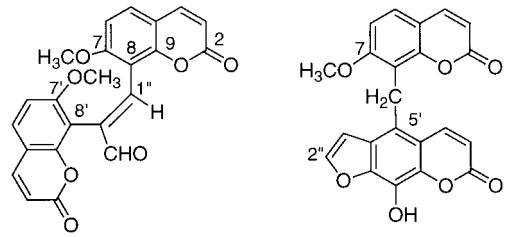
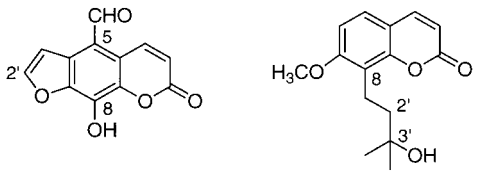
Two novel biscoumarins, cnidimonal (**1**) and cnidimarin (**2**), and two new coumarin derivatives, 5-formylxanthotoxol (**3**) and 2′-deoxymeranzin hydrate (**4**), were isolated from a traditional Chinese crude drug, the fruits of *Cnidium monnieri*, together with 15 known compounds. Among the known compounds, five of the minor compounds were isolated for the first time from this plant. The structures of **1**−**4** were determined with the use of spectroscopic methods.

Cnidium monnieri (L.) Cusson (Umbelliferae) is an important crude drug "Fructus Cnidii" (Chinese name *Shechaungzi* and Japanese name *Jashoshi*) used in traditional Chinese medicine for the treatment of impotence and frigidity.[1] This drug has also been used traditionally for skin-related diseases.[2] Recent pharmacological studies have revealed antiallergic,[3,4] antidermatophytic,[5] antiosteoporotic,[6−8] and antibacterial and antifungal[9] activities of the crude extracts or isolated constituents from this drug. Coumarin derivatives such as osthol,[10,11] xanthotoxin,[12,13] isopimpinellin,[12,14] bergapten,[15,16] and imperatorin,[17,18] have been reported as the main constituents[19] from *C. monnieri*.

The main problem connected with this drug on the market is a distinctive variation in its chemical constituents, due to the collection of this plant from different locations. Therefore, a proper quality evaluation based on the profile of its chemical constituents is necessary. In this regard, we have performed a comparative study on the constituents of 25 cultivated and wild samples of *C. monnieri* by a capillary GC method[20] and 50 samples by GC-MS and HPLC methods (manuscript in preparation). For this purpose, a detailed chemical analysis was carried out on a wild sample of *C. monnieri*, and we have isolated four new (**1**−**4**) and 15 known compounds. This paper deals with the structure determination of two novel biscoumarins (**1** and **2**) and two new coumarin derivatives (**3** and **4**), together with the provision of spectral information of several known compounds that were not previously reported in detail.



1 **2**



3 **4**

Results and Discussion

Compound **1** was obtained as a white crystalline solid with mp 242−244 °C. The molecular composition ($C_{23}H_{16}O_7$) of compound **1** was established by HREIMS. It exhibited a UV spectrum with λ_{max} 206 and 307 nm, similar to that of coumarin.[21,22] The IR spectrum of **1** showed the presence of carbonyl groups (1735 and 1720 cm^{-1}). The ^1H NMR spectrum of **1** showed signals for two pairs of coumarin protons (δ_H 7.43, 2H, d, J = 9.4 Hz, H-4 and H-4′ and δ_H 5.97, 1H, d, J = 9.4 Hz, H-3; 5.99, 1H, d, J = 9.4 Hz, H-3′), suggesting the presence of two coumaryl moieties. The ^1H NMR spectrum of **1** also exhibited two pairs of AB-type aromatic proton signals (δ_H 7.28, 1H, d, J = 8.4 Hz, H-5 and 6.79, 1H, d, J = 8.4 Hz, H-6; δ_H 7.30, 1H, d, J = 7.7 Hz, H-5′ and 6.81, 1H, d, J = 7.7 Hz, H-6′), and it is interesting to note that, although the coupling constants of these protons remained fairly distinct, the relative chemical shifts were very close to one another. In addition, signals for two methoxyl groups (δ_H 3.90 and 3.86, each 3H, s), an aldehyde proton (δ_H 9.89, 1H, s), and one sp^2 proton (δ_H 7.88, 1H, s) were also observed in the ^1H NMR spectrum of **1**. The ^{13}C NMR showed 23 carbon signals, and DEPT spectrum analysis showed 11 signals as singlets, 10 signals as doublets, and two signals as quartets. Two methoxyl groups were assigned to positions of C-7 and C-7′, as expected from the biogenetic pathways,[23] and it was confirmed by a NOESY experiment. Based on the above information, the partial structures for **1** could be proposed as shown in Figure 1A. The long-range coupling in the HMBC spectrum of **1** suggested that two 7-methoxycoumarin units were linked with a two-carbon chain and an aldehyde group substituted at one carbon of the chain (Figure 2). The cross-peak observed between the aldehyde proton (δ_H 9.89, 1H, s) and the singlet peak of the sp^2 proton (δ_H 7.88, 1H, s) in the NOESY spectrum suggested that the two coumarin groups were *cis*-substituted (Figure 2). Complete assignments of the NMR signals of **1** were confirmed by HMQC and HMBC spectral analysis (Tables 1 and 2). Selected cross-peaks observed in the HMBC and NOESY spectra are shown in Figure 2. Therefore, the structure for **1** is assigned as shown, and this compound has been named cnidimonal. There are only a few reports of biscoumarins in which two coumarin moieties are linked by a two-carbon chain;[23−25] however, there are several examples of biscoumarins with a direct linkage or an ether

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Table 1. ^{1}H NMR Data for Compounds **1**−**4**[a]

position	**1**[b]	**2**[c]	**3**[c]	**4**[b]
3	5.97 d (9.4)	6.28 d (9.4)	6.60 d (10.2)	6.23 d (9.4)
4	7.43 d (9.4)	7.66 d (9.4)	9.16 d (10.2)	7.62 d (9.4)
5	7.28 d (8.4)	7.38 d (8.4)		7.29 d (8.5)
6	6.79 d (8.4)	6.86 d (8.4)		6.83 d (8.5)
1′				2.93 dd (13.2, 8.2)
2′			8.09 d (5.4)	1.72 dd (13.2, 8.2)
3′	5.99 d (9.4)	6.53 d (10.0)	7.65 d (5.4)	
4′	7.43 d (9.4)	8.71 d (10.0)		
5′	7.30 d (7.7)			
6′	6.81 d (7.7)			
1″	7.88 s			
2″		7.87 d (2.4)		
3″		7.25 d (2.4)		
CH_3	3.90 s CH_3O-7′	3.72 s CH_3O-7		3.93 s CH_3O-7
CH_3	3.86 s CH_3O-7			1.32 s $-CH_3 \times 2$
CHO	9.89 s		10.73 s	
CH_2		4.59 s		

[a] 400 MHz. *J* are given in Hz in parentheses. [b] Recorded in $CDCl_3$. [c] Recorded in pyridine-d_5.

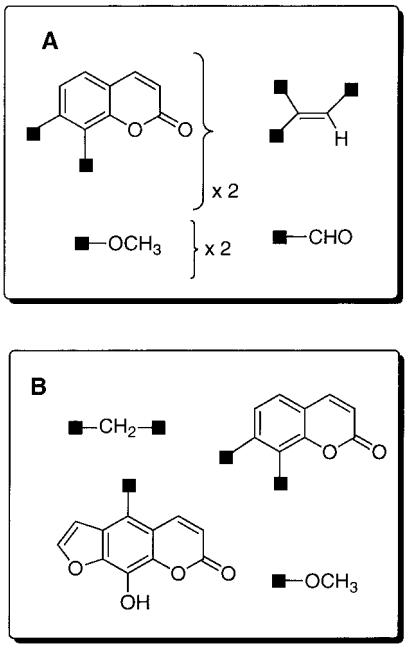

Figure 1. Partial structures of **1** (A) and **2** (B) determined from their ^{1}H NMR, ^{1}H−^{1}H COSY, and HMQC spectra.

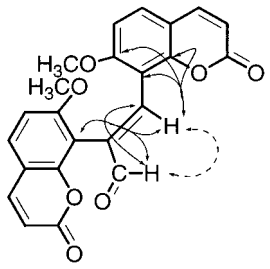

Figure 2. Significant long-range correlations observed in the HMBC (↔) and NOESY (←−−→) NMR spectra of **1**.

linkage.[23−25] Further studies are needed to clarify the biogenetic origin of **1**.

Compound **2** was isolated as the pale yellow crystalline solid with mp 226 °C. It gave the molecular ion peak $[M]^+$, *m*/*z* 390, and the molecular formula is identified as $C_{22}H_{14}O_7$ by HREIMS. The ^{1}H NMR spectrum of **2** and the analysis of its ^{1}H−^{1}H COSY NMR spectrum showed a set of 7-methoxycoumarin signals, δ_H 7.66 (1H, d, J = 9.4 Hz, H-4), 6.28 (1H, d, J = 9.4 Hz, H-3), 7.38 (1H, d, J = 8.4 Hz, H-5), and 6.86 (1H, d, J = 8.4 Hz, H-6), and another set of 5-substituted furanocoumarin signals, δ_H 8.71 (1H, d, J = 10.0 Hz, H-4′), 6.53 (1H, d, J = 10.0 Hz, H-3′), 7.87 (1H, d, J = 2.4 Hz, H-2″), and 7.25 (1H, d, J = 2.4 Hz, H-3″). In addition, methylene (δ_H 4.59, 2H, s) and methoxyl (δ_H 3.72, 3H, s) NMR signals were also observed. Similarly, analogous 7-methoxycoumarin and 5-substituted furanocoumarin signals were observed together with the methylene and methoxy carbon signals in the ^{13}C NMR spectrum of **2**. The partial structure proposed for **2** is presented in Figure 1B. It was assumed that the two coumarin units are connected by the methylene group between the C-8 and C-5′ positions. This connectivity was supported by the cross-peaks observed between the proton signal δ_H 4.59 (2H, s) and five carbon signals δ_C 160.7 (C-7), 116.2 (C-8), 153.3 (C-9), 119.9 (C-5′), and 126.5 (C-6′) in the HMBC spectrum. Complete assignments of the NMR signals of **2** were obtained from its HMQC and HMBC spectra (Tables 1 and 2). This compound was assigned with structure **2** and accorded the trivial name cnidimarin.

Table 2. ^{13}C NMR Data of Compounds **1**−**4**[a]

position	**1**[b]	**2**[c]	**3**[c]	**4**[b]
2	159.9 s	160.4 s	159.7 s	161.4 s
3	112.9 d	113.2 d	117.1 d	112.9 d
4	143.1 d	144.3 d	141.0 d	143.8 d
5	129.5 d	128.2 d	112.5 s	126.2 d
6	107.6 d	108.2 d	129.5 s	107.3 d
7	160.5 s	160.7 s	145.8 s	160.2 s
8	116.7 s	116.2 s	139.2 s	118.7 s
9	151.7 s	153.3 s	141.5 s	152.9 s
10	112.4 s	113.5 s	117.6 s	112.9 s
1′				17.6 t
2′	159.3 s	160.9 s	149.5 d	42.5 t
3′	112.6 d	113.3 d	106.3 d	71.0 s
4′	143.0 d	143.3 d		29.0 q
5′	128.7 d	119.9 s		29.0 q
6′	107.2 d	126.5 s		
7′	160.1 s	146.3 s		
8′	113.0 s	131.0 s		
9′	151.2 s	141.5 s		
10′	112.3 s	115.5 s		
1″	142.7 d			
2″	137.7 s	146.3 d		
3″		107.1 d		
CH_3O-7	56.1 q	56.0 q		56.1 q
CH_3O-7′	56.1 q			
CHO	191.2 d		188.0 d	
CH_2		22.5 t		

[a] The multiplicities of carbon signals were determined by means of the DEPT methods, and indicated as s, d, t, and q for singlet, doublet, triplet, and quartet, respectively. [b] Recorded in $CDCl_3$. [c] Recorded in pyridine-d_5.

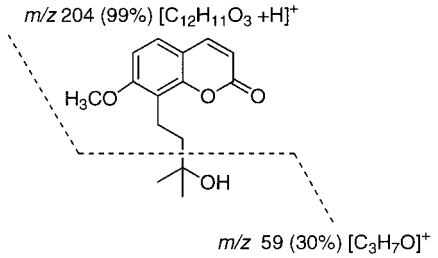

Figure 3. Mass spectral fragmentation of **4**.

Compound **3**, obtained as yellow needles, decomposed at 270 °C. It showed a molecular ion peak $[M]^+$, *m/z* 230, and its molecular formula was established as $C_{12}H_6O_5$ by HREIMS. It showed NMR signals for five protons and 12 carbons. The ^1H and ^{13}C NMR signal patterns were similar to that of xanthotoxol.[13,26] In contrast to xanthotoxol, a formyl group (δ_H 10.73 and δ_C 188.0) was found instead of an aromatic proton. As a result, the structure of **3** could be proposed as a xanthotoxol moiety with a formyl substituent. The position of the formyl group was assigned as C-5 by detailed analysis of the HMBC spectrum because a cross-peak was observed between the aldehyde proton signal (δ_H 10.73, s) and three carbon signals at δ_C 112.5 (C-5), 129.5 (C-6), and 117.6 (C-10). The complete assignments of all NMR signals were determined by the detailed analysis of the DEPT, $^1H-^1H$ COSY, HMQC, and HMBC spectra of **3**. It is the first time that a formyl-substituted furanocoumarin has been isolated, and it was named 5-formylxanthotoxol.

Compound **4** was isolated as a yellowish crystalline solid with mp 60−62 °C. It gave a molecular ion peak at *m/z* 262, and the molecular formula was established as $C_{15}H_{18}O_4$ by HREIMS. The ^1H and ^{13}C NMR signals for **4** were very similar to that of osthol[10,11] except at the C-8 position. In contrast to osthol, **4** showed a hydrated isoprenyl group with a pair of methylene groups (δ_C 42.5 and 17.6; δ_H 2.93, dd, J = 13.2, 8.2 Hz and 1.72, dd, J = 13.2, 8.2 Hz), a pair of methyl groups (δ_C 29.0, 2C; δ_H 1.32, s, 6H), and a hydroxy-substituted quaternary carbon (δ_C 71.0). The position of the hydroxyl group was further supported by the mass fragmentation pattern at *m/z* 204 (99%) and 59 (30%) (Figure 3). In addition, it showed no optical rotation when measured in $CHCl_3$ or MeOH, suggesting that the hydroxyl group is at a position without a chiral center. The complete assignments of all NMR signals for **4** were made from the detailed analysis of the DEPT, $^1H-^1H$ COSY, HMQC, and HMBC spectra. Compound **4** was found to be a new natural product and has been named 2′-deoxymeranzin hydrate.

Among 15 known compounds—osthol,[10,11] imperatorin,[17,18] isopimpinellin,[12,14] bergapten,[15,16] xanthotoxin,[12,13,26] xanthotoxol,[13,26] 5-hydroxyxanthotoxol (**5**),[27] auraptenol (**6**),[28,29] murrayacarpin A (**7**),[21] diosmetin (**8**),[30] 7-methoxy-8-formylcoumarin (**9**),[10,29] meranzin hydrate (**10**),[10,22,29,31] cnidimol B (**11**),[28,32] alloimperatorin (**12**),[19] and cnidimoside A (**13**)[33]—isolated from *C. monnieri*, compounds **5**, **7**, **9**, **10**, and **13** were isolated for the first time from this species.

Experimental Section

General Experimental Procedures. Melting points were determined on a Yanagimoto micromelting point apparatus and are uncorrected. Optical rotations were measured on a JASCO DIP-360 digital polarimeter at 25 °C. IR spectra were recorded on a Hitachi 260−01 spectrometer in KBr disks. UV spectra were taken on a Shimadzu UV-2200 UV−vis spectrophotometer. EIMS and HREIMS (ionization voltage, 70 eV) were measured with a JEOL JMS DX-300 spectrometer. ^1H and ^{13}C NMR spectra were obtained on a JEOL JNM-GX 400 spectrometer with TMS as an internal standard. 2D NMR spectra ($^1H-^1H$ COSY, NOESY, HMQC, and HMBC) were measured by the use of JEOL standard pulse sequences.

Plant Material. The fruits of *C. monnieri* were collected from Shandong Province, People's Republic of China, and the plant was identified by Prof. Luo-Shan Xu. A voucher specimen is deposited in the Museum of Materia Medica, Toyama Medical and Pharmaceutical University, Toyama, Japan (TMPW no. 19080, CJN:1001) and the Herbarium of China Pharmaceutical University, Nanjing, People's Republic of China (ref. no. C-2103).

Extraction and Isolation. Dried fruits (11.5 kg) of *C. monnieri* were pulverized and extracted three times with 90% EtOH at room temperature. The combined extracts were filtered and evaporated on a rotatory evaporator under reduced pressure to obtain a viscous alcoholic extract. This whole material was suspended in H_2O and then partitioned with petroleum ether (3 L × 3) and EtOAc (3 L × 3) to give a petroleum ether-soluble fraction (575 g), an EtOAc-soluble fraction (60.5 g), and an aqueous fraction (21.5 g).

The petroleum ether-soluble layer gave a crude crystalline solid (50 g) before evaporation, from which osthol (30 g), xanthotoxol (15.5 mg), **12** (31.0 mg), **6** (22.2 mg), **4** (15.0 mg), and **9** (6.5 mg) were isolated by repeated Si gel column chromatography, crystallization, and preparative TLC. The mother liquor and petroleum ether-soluble fraction were combined, applied to Si gel column chromatography, and eluted with petroleum ether, with the polarity increased with additional amount of EtOAc, and a final wash with MeOH. Four fractions were obtained as Fr-A (10% EtOAc−ether), Fr-B (30% EtOAc−ether), Fr-C (40% EtOAc−ether), and Fr-D (MeOH). Fraction A afforded osthol (68.0 g), imperatorin (20.0 g), isopimpinellin (1.2 g), bergapten (500 mg), xanthotoxin (50 mg), and xanthotoxol (120 mg) after repeated column chromatography and crystallization. By a similar method of purification, Fr-B gave 8.6 mg of **8** and 11.0 mg of **9**, while Fr-C gave 8.4 mg of **1**, 2.0 mg of **2**, 6.0 mg of **7**, 15.0 mg of **10**, and 12.5 mg of **11**.

A part of the EtOAc-soluble fraction (20 g) was subjected to column chromatography on Si gel (Wakogel C 200, Wako Pure Chemicals, Osaka, Japan). The column was eluted with petroleum ether−EtOAc (8:2, 7:3, and 6:4), and three fractions were collected. Fraction 1 was rechromatographed by Si gel column chromatography. Initial elution with *n*-hexane and then with *n*-hexane−EtOAc gradient yielded osthol, imperatorin, isopimpinellin, bergapten, xanthotoxin, and xanthotoxol. Fraction 2 was subjected to recrystallization with EtOH to give the new compound **3** (6.5 mg), and the mother liquor was chromatographed by Si gel column chromatography eluting with petroleum ether and acetone to obtain 10 mg of **6**. Fraction 3 was rechromatographed by Si gel column chromatography eluting with *n*-hexane−EtOAc (1:9) and finally purified by crystallization with MeOH to give 15 mg of **11** and 25 mg of **13**.

Cnidimonal (1): white crystalline solid; mp 242−244 °C; UV ($CHCl_3$) λ_{max} (log ϵ) 206 (4.20), 307 (2.51) nm; IR (KBr) ν_{max} 2950, 1735, 1720, 1685, 1602, 1560, 1290, 1255, 1145, 1120, 1090 cm^{-1}; ^1H and ^{13}C NMR, Tables 1 and 2; EIMS *m/z* 404 $[M]^+$ (100), 373 (55), 361 (12), 218 (12), 189 (57), 131 (31); HREIMS *m/z* 404.0860 (calcd for $C_{23}H_{16}O_7$, 404.0896).

Cnidimarin (2): yellowish solid; mp 226 °C; UV ($CHCl_3$) λ_{max} (log ϵ) 205 (4.05), 217 (3.11), 315 (2.25) nm; IR (KBr) ν_{max} 2920, 2850, 1715, 1710, 1610, 1560, 1170, 1090, 1040, 830 cm^{-1}; ^1H and ^{13}C NMR, Tables 1 and 2; EIMS *m/z* 390 $[M]^+$ (23), 368 (100), 247 (37), 149 (55), 105 (60), 84 (100), 56 (100); HREIMS *m/z* 390.1260 (calcd for $C_{22}H_{14}O_7$, 390.1269).

5-Formylxanthotoxol (3): yellow needles; mp 270 °C (dec); UV (MeOH) λ_{max} (log ϵ) 201 (3.57), 240 (3.12), 267 (2.93), 325 (1.52) nm; IR (KBr) ν_{max} 2920, 2840, 1732, 1720, 1685, 1602, 1560, 1255, 1145, 1120 cm^{-1}; ^1H and ^{13}C NMR, Tables 1 and 2; EIMS *m/z* 230 $[M]^+$ (70), 202 (40), 182 (19), 174 (36), 149 (100), 137 (80), 81 (65); HREIMS *m/z* 230.0219 (calcd for $C_{12}H_6O_5$, 230.0215).

2′-Deoxymeranzin hydrate (4): yellowish crystalline solid; mp 60−62 °C; $[\alpha]^{25}_D$ °C (*c* 0.024, $CHCl_3$; 0.03, MeOH); UV ($CHCl_3$) λ_{max} (log ϵ) 207 (4.02), 322 (2.72) nm; IR (KBr) ν_{max} 3460, 2975, 2925, 1718, 1602, 1497, 1270, 1255, 1155, 1130, 1085, 850 cm^{-1}; ^1H and ^{13}C NMR, Tables 1 and 2; EIMS *m/z* 262 $[M]^+$ (88), 244 (100), 229 (87), 213 (35), 204 (99), 189 (100), 175 (60), 131 (58), 59 (30); HREIMS *m/z* 262.0860 (calcd for $C_{15}H_{18}O_4$, 262.0896).

Auraptenol (6):[28,29] white solid; mp 56−58 °C; $[\alpha]_D$ +9.8° (*c* 0.02, $CHCl_3$); ^{13}C NMR ($CDCl_3$, 100 MHz) δ 161.1 (s, C-2), 160.7 (s, C-7), 153.5 (s, C-9), 147.2 (s, C-3′), 143.8 (d, C-4), 127.0 (d, C-5), 115.1 (s, C-8), 113.1 (s, C-10), 113.0 (d, C-3), 110.5 (t, C-4′), 107.3 (d, C-6), 75.2 (d, C-2′), 56.2 (q, OCH_3), 29.4 (t, C-1′) 18.1 (q, C-5′); EIMS *m/z* 260 $[M]^+$ (10), 243 (11), 219 (7), 191 (96), 190 (100), 189 (100), 175 (92), 161 (63), 131 (96), 103 (18), 77 (14).

Murrayacarpin A (7):[21] white crystals; mp 163−165 °C; ^1H NMR ($CDCl_3$, 400 MHz) δ 7.64 (1H, d, *J* = 9.4 Hz, H-4), 7.40 (1H, d, *J* = 8.4 Hz, H-5), 6.88 (1H, d, *J* = 8.4 Hz, H-6), 6.25 (1H, d, *J* = 9.4 Hz, H-3), 4.96 (2H, s, CH_2OH), 3.93 (3H, s, OCH_3); ^{13}C NMR ($CDCl_3$, 100 MHz) δ 160.7 (s, C-2), 160.7 (s, C-7), 153.1 (s, C-9), 143.6 (d, C-4), 128.0 (d, C-5), 116.6 (s, C-8), 113.3 (d, C-3), 113.0 (s, C-10), 107.5 (d, C-6), 56.2 (q, OCH_3), 53.5 (t, CH_2OH); EIMS *m/z* 206 $[M]^+$ (100), 205 (69), 177 (98), 174 (82), 163 (24), 146 (19), 131 (26), 89 (19), 77 (14).

Diosmetin (8):[30] yellow solid; mp 270−272 °C; ^1H NMR (pyridine-d_5, 400 MHz) δ 13.68 (1H, s, HO-5), 7.86 (1H, d, *J* = 2.1 Hz, H-2′), 7.56 (1H, dd, *J* = 8.4, 2.1 Hz, H-6′), 7.04 (1H, d, *J* = 8.4 Hz, H-5′), 6.96 (1H, s, H-3), 6.74 (1H, d, *J* = 2.1 Hz, H-8), 6.71 (1H, d, *J* = 2.1 Hz, H-6), 3.79 (3H, s, OCH_3-4′); ^{13}C NMR (pyridine-d_5, 100 MHz) δ 182.8 (s, C-4), 165.9 (s, C-7), 164.4 (s, C-2), 163.2 (s, C-5), 158.6 (s, C-9), 151.9 (s, C-4′), 148.6 (d, C-3′), 124.7 (s, C-1′), 118.8 (d, C-6′), 114.5 (d, C-2′), 112.1 (d, C-5′), 105.1 (s, C-10), 104.7 (d, C-3), 100.0 (d, C-6), 94.9 (d, C-8), 55.9 (q, OCH_3); EIMS *m/z* 300 $[M]^+$ (100), 257 (32), 229 (20), 189 (10), 177 (12), 153 (11), 131 (11).

7-Methoxy-8-formylcoumarin (9):[10,29] yellow solid; mp 216−218 °C; ^{13}C NMR (acetone-d_6, 100 MHz) δ 186.8 (s, CHO), 164.5 (s, C-7), 159.8 (s, C-2), 155.9 (s, C-9), 144.5 (d, C-4), 135.5 (d, C-5), 114.4 (d, C-3), 113.7 (s, C-8), 113.6 (s, C-10), 109.3 (d, C-6), 57.2 (q, OCH_3); EIMS *m/z* 204 $[M]^+$ (100), 176 (40), 147 (18), 118 (41).

Meranzin hydrate (10):[10,22,29,31] white crystals; mp 80−82 °C; $[\alpha]_D$ −4.4° (*c* 0.50, $CHCl_3$); ^{13}C NMR ($CDCl_3$, 100 MHz) δ 161.1 (s, C-2), 160.5 (s, C-7), 153.4 (s, C-9), 143.8 (d, C-4), 126.9 (d, C-5), 115.7 (s, C-8), 113.1 (s, C-10), 113.1 (d, C-3), 107.4 (d, C-6), 78.3 (d, C-2′), 72.3 (s, C-3′), 56.2 (q, OCH_3), 26.0 (q, C-4′), 25.5 (t, C-1′), 24.0 (q, C-5′); EIMS *m/z* 278 $[M]^+$ (4), 263 (4), 245 (3), 220 (39), 190 (22), 189 (24), 177 (100), 131 (15).

Cnidimol B (11):[28,32] white needles; mp 214−215 °C; $[\alpha]_D$ −112.8° (*c* 0.238, MeOH); ^1H NMR (pyridine-d_5, 400 MHz) δ 13.64 (1H, s, HO-5), 6.42 (1H, s, H-8), 6.09 (1H, s, H-3), 5.43 (1H, dd, *J* = 9.4, 8.4 Hz, H-2′), 4.31 (1H, d, *J* = 10.4 Hz, Ha-3″), 4.08 (1H, d, *J* = 10.4 Hz, Hb-3″), 3.68 (1H, dd, *J* = 15.5, 8.4 Hz, Ha-3′), 3.32 (1H, dd, *J* = 15.5, 9.4 Hz, Hb-3′), 2.06 (3H, s, 2-CH_3), 1.54 (3H, s, 2″-H); ^{13}C NMR (pyridine-d_5, 100 MHz) δ 182.8 (s, C-4), 167.1 (s, C-2), 167.0 (s, C-7), 158.6 (s, C-5), 157.2 (s, C-9), 110.0 (s, C-6), 108.7 (d, C-3), 105.5 (s, C-10), 89.6 (d, C-8), 89.0 (d, C-2′), 74.1 (s, C-1″), 67.7 (t, C-3″), 26.6 (t, C-3′), 21.3 (q, C-2-CH_3), 19.9 (q, C-2″); EIMS *m/z* 292 $[M^+]$ (44), 261 (14), 243 (26), 218 (44), 217 (100), 189 (36).

Alloimperatorin (12):[19] yellow crystals; mp 224−225 °C; ^1H NMR (DMSO-d_6, 400 MHz) δ 8.20 (1H, d, *J* = 9.9 Hz, H-4), 7.97 (1H, d, *J* = 2.1 Hz, H-2′), 7.03 (1H, d, *J* = 2.1 Hz, H-3′), 6.41 (1H, d, *J* = 9.9 Hz, H-3), 5.11 (1H, t, *J* = 6.7 Hz, H-2″), 3.70 (2H, d, *J* = 6.7 Hz, H-1″), 1.81 (3H, s, H-5″), 1.64 (3H, s, H-4″); ^{13}C NMR (DMSO-d_6, 100 MHz) δ 161.3 (s, C-2), 147.8 (d, C-2′), 145.7 (s, C-7), 143.2 (d, C-4), 141.1 (s, C-9), 132.7 (s, C-3″), 128.9 (s, C-8), 125.6 (s, C-6), 123.3 (d, C-2″), 123.0 (s, C-5), 114.3 (s, C-10), 113.7 (d, C-3), 106.7 (d, C-3′), 27.8 (t, C-1″), 25.3 (q, C-5″), 17.7 (q, C-4″); EIMS *m/z* 270 $[M]^+$ (100), 255 (32), 227 (19), 202 (31), 199 (16), 171 (8), 87 (9), 69 (10).

Cnidimoside A (13):[33] white solid; mp 139−140 °C; ^1H NMR (methanol-d_4, 400 MHz) δ 12.73 (1H, s, HO-5), 6.35 (1H, s, H-8), 6.04 (1H, s, H-3), 5.47 (1H, t, *J* = 7.4 Hz, H-2′), 4.66 (1H, d, *J* = 11.8 Hz, Ha-4′), 4.32 (1H, d, *J* = 11.8 Hz, Hb-4′), 4.31 (1H, d, *J* = 8.7 Hz, H-1″), 3.89 (1H, dd, *J* = 11.8, 2.4 Hz, Ha-6″), 3.73 (1H, dd, *J* = 11.8, 5.0 Hz, Hb-6″), 3.34−3.38 (5H, m, H-3″, H-4″, H-5″, CH_2-1′), 3.18 (1H, dd, *J* = 7.9, 4.8 Hz, H-2″), 2.35 (3H, s, 2-CH_3), 1.76 (3H, s, 3′-CH_3); ^{13}C NMR (methanol-d_4, 100 MHz) δ 184.0 (s, C-4), 168.8 (s, C-2), 163.5 (s, C-7), 159.9 (s, C-5), 157.8 (s, C-9), 132.6 (s, C-3′), 128.7 (d, C-2′), 112.2 (s, C-6), 108.8 (d, C-3), 104.9 (s, C-10), 102.5 (d, C-1″), 94.1 (d, C-8), 78.1 (d, C-3″), 77.7 (d, C-5″), 75.1 (d, C-2″), 71.6 (d, C-4″), 68.2 (t, C-4′), 62.7 (t, C-6″), 21.9 (t, C-1′), 21.8 (q, CH_3-3′), 20.3 (q, CH_3-2); EIMS *m/z* 438 $[M]^+$ (8), 276 (30), 259 (90), 243 (100), 205 (85).

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