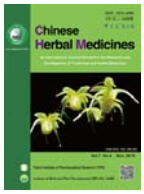

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Letter

Chemical Constituents from *Hypericum beanii*

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ABSTRACT

Objective To study the chemical constituents from the aerial parts of *Hypericum beanii*. **Methods** Various chromatographic techniques were used to separate the constituents and their structures were elucidated on the basis of extensive spectroscopic interpretation. **Results** Fifteen compounds were isolated from the aerial parts of *H. beanii*. Their structures were identified as hyperbeanol E (**1**), (*E*)-linalool-1-oic acid (**2**), (4*S*,5*R*)-5-(4′-methyl-3′-pentenyl)-4-hydroxy-5-methyl-dihydrofuran-2-one (**3**), benzoic acid (**4**), 4-(3-*O*-3″)-3″-methylbutenyl-6-phenyl-pyran-2-one (**5**), 4-hydroxy-4a,7-dimethoxy-4,4a-dihydrodibenzo-*p*-dioxin-2(3*H*)-one (**6**), isoimperatorin (**7**), 2,3-dimethoxyxanthone (**8**), 3,4-dihydroxy-2-methoxyxanthone (**9**), osajaxanthone (**10**), nigrolineaxanthone F (**11**), hypercohone G (**12**), betulinic acid (**13**), oleanolic acid 3β-caffeate (**14**), and isoastilbin (**15**). **Conclusion** Compound **1** is a new menthane monoterpene derivative which owns an extra lactone ring. Compounds **2**–**7** and **10**–**15** are isolated from genus *Hypericum* Linn. for the first time and the other compounds are first obtained from the plants in *H. beanii*.

Key words

hyperbeanol E; *Hypericum* Linn.; *Hypericum beanii*; menthane monoterpene; spirocyclic acylphloroglucinol; xanthone

1. Introduction

The genus *Hypericum* Linn. (Guttiferae) includes about 450 species, is mainly distributed in temperate regions throughout the world, and some of which have been used as traditional medicine in many countries (Zhao et al, 2015). Plants in this genus are well known for their chemical diversity of polyprenylated polycyclic phloroglucinols, which are a group of structurally fascinating and synthetically challenging natural products possessing highly oxygenated phloroglucinol-derived cores densely decorated with prenyl substituents. Besides, a number of naphtodianthrones, flavonoids,

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xanthones, terpenes, and benzophenones were also isolated and those reported secondary metabolite showed a wide variety of bioactivities such as antitumor, antimicrobial, HIV preventive, anti-depressant, and anti-oxidant activities (Zhao et al, 2015; Yan et al, 2014). In traditional Chinese medicine (TCM) theory, the aerial parts of *Hypericum beanii* N. Robson have been used for the treatment of hepatitis. Previous phytochemical investigations on this plant showed that it contained acylphloroglucinols, flavonoids, xanthones, and sesquiterpenes which exhibited cytotoxicity or antistaphylococcal activity (Shiu and Gibbons, 2006; Chen et al, 2011). As part of our program (Yang et al, 2013a; 2013b; 2015a; 2015b) to clarify the effective constituents of folk medicine in Yunnan province, a phytochemical investigation on *H. beanii* led to the isolation and characterization of one new menthane monoterpene derivative (**1**) and 14 known compounds (**2**–**15**) (Figure 1). Compound **1** is a unique menthane monoterpene derivative with an extra lactone ring. Herein, the isolation and structure elucidation of the compounds are reported.

2. Materials and methods

2.1 General

Optical rotations were measured on a Jasco P−1020 Digital Polarimeter. CD spectra were obtained on an Automated Circular Dichroism Spectrometer (Applied Photophysics). UV spectra were obtained using a Shimadzu UV−2401A Spectrophotometer. IR spectra were obtained on a Bruker Tenor 27 Spectrometer with KBr pellets. 1D and 2D NMR spectra were recorded on Bruker AM−400, DRX−500 or AV Ⅲ−600 Spectrometers with TMS as internal standard. ESI-MS was recorded using a Finnigan MAT 90 Instrument; HR-EI-MS was recorded on a Waters AutoSpec Premier P776 Instrument. Column chromatography (CC) was performed on Sephadex LH-20 (Amersham Biosciences, USA), silica gel (200–300 mesh, Qingdao Marine Chemical Ltd., China), RP-18 gel (LiChroprep, 40–63 μm, Merck, Germany), and MCI gel CHP20P (75–150 μm, Mitsubishi Chemical Corporation, Japan). Semi-preparative HPLC was performed on an Agilent 1200 (column: Zorbax SB-C_{18}, 250 mm × 9.4 mm; DAD Detector). Fractions were monitored by TLC, visualized by heating silica gel plates sprayed with 15% H_2SO_4 in EtOH.

2.2 Plant materials

The aerial parts of *Hypericum beanii* N. Robson were collected from Chengjiang county, Yunnan province, China, in November 2011. A voucher specimen (Yangyp-20111104) was deposited in the Herbarium of Kunming Institute of Botany, Chinese Academy of Sciences, which was identified by Prof. Yong-ping Yang.

2.3 Extraction and isolation

The air-dried and powdered aerial parts of *H. beanii* (8.7 kg) were extracted with 90% EtOH (3 × 20 L) for 24 h at room temperature and filtrated. The filtrate was concentrated and partitioned between H_2O and EtOAc and then the EtOAc fraction was decolorized on MCI gel eluted with 95% EtOH. The residue (560 g) was chromatographed on silica gel ($CHCl_3$-acetone 1:0 to 3:2) to afford five fractions (Frs. A–E). Fr. A was repeatedly subjected to Sephadex LH-20 CC ($CHCl_3$-MeOH 1:1) and silica gel CC (petroleum ether-EtOAc 10:1 to 3:1) to afford compounds **1** (8.9 mg), **2** (14.1 mg), and **3** (18.7 mg). Fr. B was purified over a Sephadex LH-20

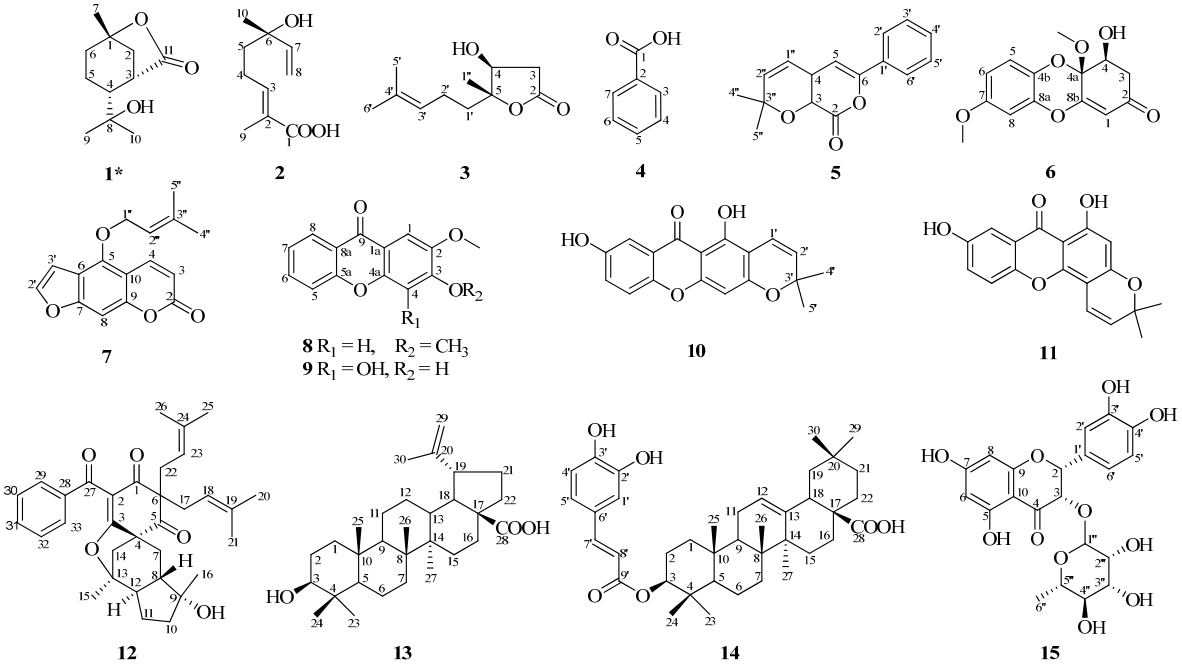

Figure 1 Structures of compounds 1−15

CC ($CHCl_3$-MeOH 1:1), and then subjected to silica gel CC ($CHCl_3$-EtOAc, 10:1 to 4:1) to afford compounds **13** (9.3 mg) and **14** (5.4 mg), and the other part was further purified by semi-preparative HPLC (MeOH-H_2O 75:25) to afford compound **12** (2.5 mg). Fr. C was purified over a Sephadex LH-20 CC ($CHCl_3$-MeOH 1:1) and then fractionated by RP-18 gel (MeOH-H_2O 3:7 to 10:0) to provide three subfractions (Fr. C1–C3). Fr. C2 was repeatedly subjected to silica gel CC ($CHCl_3$-acetone 4:1) and further purified by Sephadex LH-20 CC ($CHCl_3$-MeOH 1:1) to afford compounds **4** (7.4 mg), **9** (6.9 mg), **10** (3.7 mg), and **11** (4.1 mg). Fr. C3 was subjected to silica gel CC eluting with $CHCl_3$-EtOAc (3:1) to afford compounds **5** (6.6 mg) and **7** (3.5 mg), and the other part was further purified by semi-preparative HPLC (MeOH-H_2O 65:35) to obtain compounds **6** (12.3 mg) and **8** (7.8 mg). Fr. E was repeatedly chromatographed on silica gel ($CHCl_3$-MeOH 4:1) and Sephadex LH-20 CC ($CHCl_3$-MeOH 1:1) to obtain compound **15** (9.2 mg).

3. Results and discussion

Compound **1:** colorless oil; $[\alpha]_D^{18}$ +32.9 (*c* 0.13, MeOH); CD (*c* 0.06, MeOH) λ_{max} $\Delta\varepsilon_{208}$ +1.74; UV (MeOH) λ_{max} (log ε) 207 (2.63) nm; IR (KBr) ν_{max} 3387, 2969, 2935, 1733, 1710, 1448, 1415, 1384, 1302, 1230, 1170, 1082, 966, 907, 880, 840, 654, 488 cm^{-1}; ^{1}H-NMR (500 MHz, $CDCl_3$) δ: 2.64 (2H, dd, *J* = 7.3, 2.9 Hz, H-2), 2.14 (1H, m, H-4), 2.08 (1H, t, *J* = 7.3 Hz, H-3), 1.79 (1H, dt, *J* = 13.6, 5.9 Hz, H-5α), 1.62 (1H, d, *J* = 3.1 Hz, H-6β), 1.60 (1H, d, *J* = 5.9 Hz, H-6α), 1.50 (1H, ddd, *J* = 13.6, 6.3, 3.1 Hz, H-5β), 1.22 (3H, s, H-9), 1.20 (3H, s, H-10), 1.19 (3H, s, H-7); ^{13}C-NMR (125 MHz, $CDCl_3$) δ: 85.4 (s, C-1), 32.2 (t, C-2), 49.5 (d, C-3), 49.9 (d, C-4), 24.9 (t, C-5), 35.1 (t, C-6), 17.5 (q, C-7), 79.2 (s, C-8), 28.4 (q, C-9), 29.1 (q, C-10), 178.8 (s, C-11); negative ESI-MS *m/z* 197 $[M-H]^-$, 395 $[2M-H]^-$; HR-EI-MS *m/z* 198.1252 (calcd. for $C_{11}H_{18}O_3$ $[M]^+$, 198.1256).

Compound **1** showed a molecular ion peak in the HR-EI-MS at *m/z* 198.1252 $[M]^+$, analyzing for $C_{11}H_{18}O_3$ with three degrees of unsaturation. The IR spectrum showed absorption bands attributable to hydroxy (3387 cm^{-1}) and carbonyl (1733 cm^{-1}) groups. The ^{13}C-NMR spectrum displayed 11 carbon signals for an ester carbonyl (δ_C 178.8), two oxygenated sp^3 quaternary carbon (δ_C 79.2, 85.4), three methylenes, two methines, and three tertiary methyls (δ_H 1.19, 1.20, 1.22, each 3H, s). Beyond one degree of unsaturation occupied by carboxyl carbon, compound **1** was required to possess a bicyclic system. Preliminary analyses of COSY and HMBC correlations (Figure 2) suggested that compound **1** was a menthane monoterpene which own an extra lactone ring closely related to (*cis*-3H,4H,7Me)-1-hydroxy-3-*p*-menthylformic lactone (Wenkert et al, 1970) and the differences could be rationalized by an OH attached at C-8, which was supported by the downfield shift of C-8 to δ_C 79.2 × 10^{-5} in compound **1** (Lou et al, 2013) and the HMBC correlation of H-3, H-4, H-5, Me-9, Me-10 with C-8 (Figure 2). The HMBC correlations of Me-9, Me-10/C-4; H-2, H-3/C-11, and COSY correlation of H-3/H-4 demonstrated that extra carbonyl moiety was located at C-3. Generally speaking, the chemical shift of oxygenated quaternary carbon which formed a lactonic ring was 85 × 10^{-5} (Rico et al, 1998; Snider et al, 2000), and the HMBC correlations of Me-7/δ_C 85.4 × 10^{-5} indicated that the lactonic bond of compound **1** was formed with 1-OH rather than 8-OH. The observed ROESY correlations (Figure 2) of H-5β/H-3, H-4; H-5α/H-6α; H-6β/H-3, Me-7 suggested that compound **1** shared the same relative configuration with the reported literature (Wenkert et al, 1970). As a result, the structure of compound **1** was determined as shown in Figure 1 and was given a trivial name hyperbeanol E.

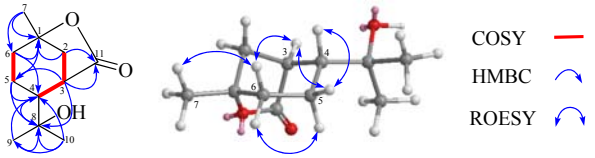

Figure 2 Selected 2D NMR correlations of compound 1

Compound **2**: colorless oil, ESI-MS *m/z*: 207 $[M+Na]^+$, 391 $[2M+Na]^+$; ^{1}H-NMR (400 MHz, $CDCl_3$) δ: 6.86 (1H, t, *J* = 7.1 Hz, H-3), 5.88 (1H, dd, *J* = 17.4, 10.7 Hz, H-7), 5.22 (1H, d, *J* = 17.4 Hz, H-8a), 5.07 (1H, d, *J* = 10.7 Hz, H-8b), 2.21 (2H, m, H-4), 1.80 (3H, s, H-9), 1.66 (2H, m, H-5), 1.30 (3H, s, H-10); ^{13}C-NMR (100 MHz, $CDCl_3$) δ: 173.1 (C-1), 127.1 (C-2), 144.6 (C-3), 23.6 (C-4), 40.3 (C-5), 73.2 (C-6), 144.2 (C-7), 112.3 (C-8), 11.9 (C-9), 27.8 (C-10). These spectrum data were in accordance with the literature value of (*E*)-linalool-1-oic acid (Zou et al, 2014).

Compound **3**: colorless oil, ESI-MS *m/z*: 221 $[M+Na]^+$, 419 $[2M+Na]^+$; ^{1}H-NMR (400 MHz, $CDCl_3$) δ: 5.05 (1H, t, *J* = 5.9 Hz, H-3′), 4.24 (1H, dd, *J* = 7.0, 4.8 Hz, H-4), 2.91 (1H, m, H-3b), 2.52 (1H, m, H-3a), 2.09 (2H, m, H-2′), 1.68 (3H, s, H-6′), 1.66 (2H, m, H-1′), 1.61 (3H, s, H-5′), 1.39 (3H, s, H-1″); ^{13}C-NMR (100 MHz, $CDCl_3$) δ: 175.6 (C-2), 38.4 (C-3), 73.4 (C-4), 90.0 (C-5), 39.2 (C-1′), 22.4 (C-2′), 123.3 (C-3′), 132.9 (C-4′), 17.7 (C-5′), 25.6 (C-6′), 18.4 (C-1″). These spectrum data were in accordance with the literature value of (4*S*,5*R*)-5-(4′-methyl-3′-pentenyl)-4-hydroxy-5-methyldihydrofuran-2-one (Viturro et al, 2001).

Compound **4**: white amorphous powder, ^{1}H-NMR (400 MHz, acetone-d_6) δ: 12.54 (1H, s, COOH), 8.00 (2H, d, *J* = 7.2 Hz, H-3, 7), 7.47 (1H, t, *J* = 7.2 Hz, H-5), 7.33 (2H, t, *J* = 7.2 Hz, H-4, 6). These spectrum data were in accordance with the literature value of benzoic acid (Liu et al, 2006).

Compound **5**: yellow oil, ^{1}H-NMR (500 MHz, $CDCl_3$) δ: 7.80 (2H, m, H-2′, 6′), 7.44 (2H, m, H-3′, 5′), 7.43 (1H, m, H-4′), 6.46 (1H, d, *J* = 10.0 Hz, H-1″), 6.44 (1H, s, H-5), 5.43 (1H, d, *J* = 10.0 Hz, H-2″), 1.49 (6H, s, H-4″, 5″); ^{13}C-NMR (125 MHz, $CDCl_3$) δ: 161.8 (C-2), 164.0 (C-3), 99.4 (C-4), 97.8 (C-5), 160.3 (C-6), 131.2 (C-1′), 125.8 (C-2′, 6′), 128.9 (C-3′, 5′), 130.9 (C-4′), 116.4 (C-1″), 125.5 (C-2″), 80.2 (C-3″), 28.5 (C-4″, 5″). These spectrum data were in accordance with the literature value of 4-(3-*O*-3″)-3″-methylbutenyl-6-phenyl-pyran-2-one (Shiu and Gibbons, 2009).

Compound **6**: colorless amorphous powder, ESI-MS *m/z*: 301 $[M + Na]^+$, 579 $[2M + Na]^+$; ^{1}H-NMR (400 MHz, $CDCl_3$) δ: 7.02 (1H, d, J = 8.7 Hz, H-5), 6.66 (1H, d, J = 2.4 Hz, H-8), 6.63 (1H, dd, J = 8.7, 2.4 Hz, H-6), 5.77 (1H, s, H-1), 4.42 (1H, m, H-4), 3.77 (3H, s, 7-OCH_3), 3.53 (3H, s, 4a-OCH_3), 2.82 (2H, m, H-3); ^{13}C-NMR (100 MHz, $CDCl_3$) δ: 108.5 (C-1), 195.0 (C-2), 42.7 (C-3), 72.3 (C-4), 93.5 (C-4a), 133.6 (C-4b), 117.9 (C-5), 110.4 (C-6), 155.6 (C-7), 102.2 (C-8), 140.9 (C-8a), 162.1 (C-8b), 53.6 (4a-OCH_3), 55.8 (7-OCH_3). These spectrum data were in accordance with the literature value of 4-hydroxy-4a,7-dimethoxy-4,4a-dihydrodibenzo-*p*-dioxin-2(3*H*)-one (Sun et al, 2009).

Compound **7**: white amorphous powder, ^{1}H-NMR (600 MHz, $CDCl_3$) δ: 8.17 (1H, d, J = 9.8 Hz, H-4), 7.60 (1H, d, J = 2.2 Hz, H-2′), 7.16 (1H, s, H-8), 6.96 (1H, d, J = 2.2 Hz, H-3′), 6.28 (1H, d, J = 9.8 Hz, H-3), 5.54 (1H, t, J = 6.9 Hz, H-2″), 4.92 (2H, d, J = 6.9 Hz, H-1″), 1.80 (3H, s, H-4″), 1.70 (3H, s, H-5″); ^{13}C-NMR (150 MHz, $CDCl_3$) δ: 161.6 (C-2), 112.7 (C-3), 139.9 (C-4), 149.1 (C-5), 114.4 (C-6), 158.3 (C-7), 94.4 (C-8), 152.8 (C-9), 107.7 (C-10), 145.1 (C-2′), 105.3 (C-3′), 69.9 (C-1″), 119.2 (C-2″), 140.1 (C-3″), 26.1 (C-4″), 18.5 (C-5″). These spectrum data were in accordance with the literature value of isoimperatorin (Bergendorff et al, 1997).

Compound **8**: white amorphous powder, ^{1}H-NMR (400 MHz, acetone-d_6) δ: 8.22 (1H, d, J = 7.9 Hz, H-8), 7.79 (1H, m, H-6), 7.55 (1H, s, H-1), 7.54 (1H, m, H-5), 7.43 (1H, t, J = 7.9 Hz, H-7), 7.10 (1H, s, H-4), 4.02 (3H, s, 3-OCH_3), 3.93 (3H, s, 2-OCH_3); ^{13}C-NMR (100 MHz, acetone-d_6) δ: 105.7 (C-1), 115.3 (C-1a), 148.0 (C-2), 153.1 (C-3), 100.8 (C-4), 156.0 (C-4a), 118.6 (C-5), 156.8 (C-5a), 135.0 (C-6), 124.7 (C-7), 126.8 (C-8), 122.2 (C-8a), 175.6 (C-9), 56.7 (2-OCH_3), 56.3 (3-OCH_3). These spectrum data were in accordance with the literature value of 2,3-dimethoxyxanthone (Ali et al, 2014).

Compound **9**: yellow amorphous powder, ^{1}H-NMR (400 MHz, DMSO-d_6) δ: 8.15 (1H, d, J = 8.4 Hz, H-8), 7.80 (1H, t, J = 8.4 Hz, H-6), 7.62 (1H, d, J = 8.4 Hz, H-5), 7.42 (1H, t, J = 8.4 Hz, H-7), 7.12 (1H, s, H-1), 3.88 (3H, s, 2-OCH_3); ^{13}C-NMR (100 MHz, DMSO-d_6) δ: 95.8 (C-1), 112.9 (C-1a), 146.0 (C-2), 142.4 (C-3), 141.8 (C-4), 133.5 (C-4a), 118.1 (C-5), 155.4 (C-5a), 134.5 (C-6), 123.9 (C-7), 125.8 (C-8), 120.7 (C-8a), 175.0 (C-9), 55.9 (2-OCH_3). These spectrum data were in accordance with the literature value of 3,4-dihydroxy-2-methoxyxanthone (Ali et al, 2014).

Compound **10**: yellow amorphous powder, ^{1}H-NMR (500 MHz, DMSO-d_6) δ: 13.25 (1H, s, 1-OH), 10.10 (1H, s, 7-OH), 7.46 (1H, d, J = 9.0 Hz, H-5), 7.38 (1H, d, J = 3.0 Hz, H-8), 7.27 (1H, dd, J = 9.0, 3.0 Hz, H-6), 6.59 (1H, d, J = 10.0 Hz, H-1′), 6.40 (1H, s, H-4), 5.76 (1H, d, J = 10.0 Hz, H-2′), 1.41 (6H, s, H-4′, 5′); ^{13}C-NMR (125 MHz, DMSO-d_6) δ: 160.1 (C-1), 102.9 (C-1a), 103.6 (C-2), 156.6 (C-3), 94.5 (C-4), 156.3 (C-4a), 119.0 (C-5), 149.0 (C-5a), 124.7 (C-6), 154.0 (C-7), 107.9 (C-8), 120.3 (C-8a), 180.1 (C-9), 114.4 (C-1′), 128.4 (C-2′), 78.3 (C-3′), 27.9 (C-4′, 5′). These spectrum data were in accordance with the literature value of osajaxanthone (Na and Xu, 2009).

Compound **11**: yellow amorphous powder, ^{1}H-NMR (500 MHz, DMSO-d_6) δ: 13.00 (1H, s, 1-OH), 10.46 (1H, s, 7-OH), 7.55 (1H, d, J = 7.8 Hz, H-5), 7.33 (1H, d, J = 1.4 Hz, H-8), 7.28 (1H, dd, J = 7.8, 1.4 Hz, H-6), 6.97 (1H, d, J = 10.0 Hz, H-1′), 6.23 (1H, s, H-2), 5.79 (1H, d, J = 10.0 Hz, H-2′), 1.43 (6H, s, H-4′, 5′); ^{13}C-NMR (125 MHz, DMSO-d_6) δ: 162.4 (C-1), 103.0 (C-1a), 98.5 (C-2), 160.2 (C-3), 100.9 (C-4), 146.2 (C-4a), 121.2 (C-5), 144.8 (C-5a), 124.4 (C-6), 151.1 (C-7), 114.6 (C-8), 120.8 (C-8a), 180.6 (C-9), 114.7 (C-1′), 127.6 (C-2′), 78.4 (C-3′), 27.8 (C-4′, 5′). These spectrum data were in accordance with the literature value of nigrolineaxanthone F (Rukachaisirikul et al, 2003).

Compound **12**: yellow amorphous powder, ESI-MS *m/z*: 515 $[M - H]^-$, 551 $[M + Cl]^-$; ^{1}H-NMR (600 MHz, $CDCl_3$) δ: 7.80 (2H, d, J = 7.5 Hz, H-29, 33), 7.53 (1H, t, J = 7.5 Hz, H-31), 7.40 (2H, t, J = 7.5 Hz, H-30, 32), 5.03 (1H, m, H-23), 5.02 (1H, m, H-18), 2.69 (1H, dd, J = 13.4, 8.9 Hz, H-17a), 2.64 (1H, dd, J = 13.1, 7.1 Hz, H-22a), 2.61 (1H, dd, J = 13.1, 9.6 Hz, H-22b), 2.40 (1H, dd, J = 13.4, 7.2 Hz, H-17b), 2.08 (1H, d, J = 11.7 Hz, H-14β), 2.02 (1H, dd, J = 12.3, 4.8 Hz, H-7β), 1.97 (1H, td, J = 12.5, 6.0 Hz, H-12), 1.85 (1H, dd, J = 11.7, 1.6 Hz, H-14*α*), 1.79 (1H, m, H-10a), 1.68 (3H, s, H-20), 1.66 (3H, s, H-25), 1.64 (1H, m, H-10b), 1.63 (1H, m, H-11a), 1.59 (1H, m, H-7*α*), 1.56 (3H, s, H-26), 1.51 (3H, s, H-21), 1.38 (3H, s, H-15), 1.29 (3H, s, H-16), 1.20 (1H, dd, J = 12.5, 4.8 Hz, H-8), 1.14 (1H, m, H-11b); ^{13}C-NMR (150 MHz, $CDCl_3$) δ: 196.8 (C-1), 113.4 (C-2), 177.3 (C-3), 58.6 (C-4), 208.7 (C-5), 64.1 (C-6), 32.5 (C-7), 49.0 (C-8), 76.9 (C-9), 40.0 (C-10), 22.3 (C-11), 47.6 (C-12), 91.5 (C-13), 44.1 (C-14), 21.8 (C-15), 26.7 (C-16), 39.7 (C-17), 118.7 (C-18), 135.8 (C-19), 26.1 (C-20), 17.7 (C-21), 35.4 (C-22), 120.1 (C-23), 135.2 (C-24), 26.0 (C-25), 18.0 (C-26), 192.0 (C-27), 137.7 (C-28), 129.2 (C-29, 33), 128.3 (C-30, 32), 133.1 (C-31). These spectrum data were in accordance with the literature value of hypercohone G (Zhang et al, 2014).

Compound **13**: white amorphous powder, ^{1}H-NMR (400 MHz, DMSO-d_6) δ: 4.67 (1H, s, H-29a), 4.54 (1H, s, H-29b), 3.31 (1H, m, H-3), 2.95 (1H, m, H-19), 1.63 (3H, s, H-30), 0.91 (3H, s, H-27), 0.85 (6H, s, H-23, 26), 0.75 (3H, s, H-25), 0.63 (3H, s, H-24); ^{13}C-NMR (100 MHz, DMSO-d_6) δ: 38.6 (C-1), 27.4 (C-2), 76.8 (C-3), 38.5 (C-4), 54.9 (C-5), 18.1 (C-6), 34.3 (C-7), 40.1 (C-8), 49.9 (C-9), 36.7 (C-10), 20.6 (C-11), 25.3 (C-12), 37.6 (C-13), 42.0 (C-14), 29.4 (C-15), 31.9 (C-16), 55.4 (C-17), 49.1 (C-18), 46.6 (C-19), 150.3 (C-20), 30.4 (C-21), 37.0 (C-22), 28.1 (C-23), 15.7 (C-24), 15.8 (C-25), 16.0 (C-26), 14.4 (C-27), 177.3 (C-28), 109.7 (C-29), 19.0 (C-30). These spectrum data were in accordance with the literature value of betulinic acid (Wei et al, 2014).

Compound **14**: white amorphous powder, ESI-MS *m/z*: 617 $[M - H]^-$; ^{1}H-NMR (400 MHz, DMSO-d_6) δ: 7.42 (1H, d, J = 15.8 Hz, H-7′), 7.02 (1H, s, H-1′), 6.97 (1H, d, J = 8.1 Hz, H-5′), 6.73 (1H, d, J = 8.1 Hz, H-4′), 6.22 (1H, d, J = 15.8 Hz, H-8′), 5.14 (1H, m, H-12), 4.48 (1H, dd, J = 11.0, 4.0 Hz, H-3), 1.12 (3H, s, H-27), 1.02 (3H, s, H-25), 0.89 (3H, s, H-26), 0.87 (3H, s, H-30), 0.85 (3H, s, H-29), 0.81 (3H, s, H-23), 0.71 (3H, s, H-24); ^{13}C-NMR (100 MHz, DMSO-d_6) δ: 37.5 (C-1), 23.0 (C-2), 79.8 (C-3), 38.8 (C-4), 54.6 (C-5), 18.3 (C-6), 33.6 (C-7), 39.8 (C-8), 46.9 (C-9), 36.6 (C-10),

22.9 (C-11), 121.4 (C-12), 143.9 (C-13), 41.0 (C-14), 27.5 (C-15), 22.7 (C-16), 45.7 (C-17), 41.4 (C-18), 45.5 (C-19), 30.4 (C-20), 32.3 (C-21), 32.1 (C-22), 27.8 (C-23), 16.7 (C-24), 15.1 (C-25), 16.8 (C-26), 25.6 (C-27), 178.7 (C-28), 32.8 (C-29), 23.4 (C-30), 114.4 (C-1′), 145.6 (C-2′), 148.4 (C-3′), 115.8 (C-4′), 121.4 (C-5′), 125.5 (C-6′), 144.9 (C-7′), 114.7 (C-8′), 166.4 (C-9′). These spectrum data were in accordance with the literature value of oleanolic acid 3β-caffeate (Pan et al, 1994).

Compound **15**: colorless amorphous powder, ^{1}H-NMR (400 MHz, DMSO-d_6) δ: 11.74 (1H, s, 5-OH), 10.93 (1H, s, 7-OH), 8.87 (2H, s, 3′,4′-OH), 6.83 (1H, s, H-2′), 6.70 (1H, d, J = 8.2 Hz, H-6′), 6.67 (1H, d, J = 8.2 Hz, H-5′), 5.93 (1H, d, J = 1.6 Hz, H-6), 5.90 (1H, d, J = 1.6 Hz, H-8), 5.53 (1H, d, J = 2.2 Hz, H-2), 4.76 (1H, d, J = 8.4 Hz, H-1″), 4.20 (1H, d, J = 2.2 Hz, H-3), 3.45 (1H, m, H-2″), 3.16 (1H, t, J = 9.5 Hz, H-3″), 3.03 (1H, dd, J = 9.5, 5.2 Hz, H-4″), 2.49 (1H, m, H-5″), 0.82 (3H, d, J = 6.0 Hz, H-6″); ^{13}C-NMR (100 MHz, DMSO-d_6) δ: 80.0 (C-2), 73.4 (C-3), 193.1 (C-4), 164.0 (C-5), 96.2 (C-6), 167.1 (C-7), 95.2 (C-8), 162.5 (C-9), 100.3 (C-10), 126.4 (C-1′), 114.0 (C-2′), 145.0 (C-3′), 145.2 (C-4′), 115.1 (C-5′), 117.6 (C-6′), 98.8 (C-1″), 70.2 (C-2″), 70.3 (C-3″), 71.2 (C-4″), 69.0 (C-5″), 17.7 (C-6″). These spectrum data were in accordance with the literature value of isoastilbin (Yuan et al, 2004).

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