Three New Illudalane Sequiterpenoids from *Pteris semipinnata*

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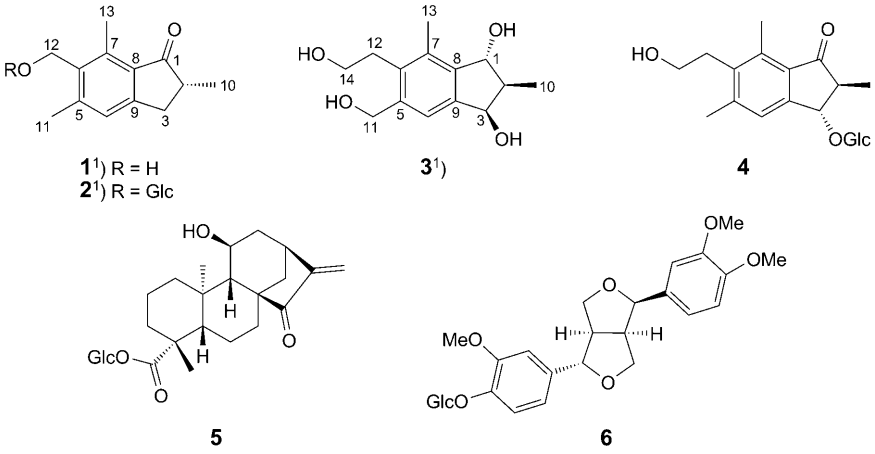
The chemical investigation of the aerial parts of *Pteris semipinnata* resulted in the isolation of three illudalane sesquiterpenoids, namely (2*R*)-norpterosin B (**1**), (2*R*)-12-*O*-*β*-D-glucopyranosylnorpterosin B (**2**), and semipterosin A (**3**), along with three known compounds. The structures of **1**–**3** were established by spectroscopic methods, including extensive 2D-NMR and CD analyses.

Introduction. – The C_{14} and C_{15} illudalane sesquiterpenoids, known as pterosins, and *ent*-kaurane diterpenoids represent the chemotaxonomical constituents of the genus *Pteris* [1–5]. *Pteris semipinnata* L. (Pteridaceae) is a plant widely distributed in China, and the whole plant has been used in traditional Chinese medicine (TCM) to treat toothache, diarrhea, jaundice, and viper bites [6]. A series of *ent*-kaurane diterpenoids and pterosins with antitumor bioactivity from this plant has been reported [7–12]. In the continuing search for biologically active compounds from Chinese medicinal plants, the three illudalane sesquiterpenoids **1**–**3**[1]) were isolated from the aerial parts of *Pteris semipinnata* as well as three known compounds, *i.e.*, pterosin C 3-*O*-*β*-D-glucoside (= 3-*O*-*β*-D-glucopyranosylpterosine C; **4**), paniculoside III (**5**), and phillyrin (**6**). Their structures were established by mass-spectrometric and spectroscopic analyses, especially through 2D-NMR techniques (HMQC, HMBC, and NOESY).

Results and Discussion. – (2*R*)-Norpterosin B (**1**), with the molecular formula $C_{13}H_{16}O_2$ determined by HR-EI-MS, was obtained as amorphous powder. C=O and OH Groups (1701 and 3205 cm^{-1}, resp.) were indicated in the IR spectrum. Thirteen C-atom signals in the ^{13}C-NMR spectrum (*Table*) were assigned by a DEPT experiment to three Me, two CH_2, and two CH groups, and six sp^2 quaternary C-atoms. The ^{1}H-NMR spectrum (*Table*) displayed three Me signals at δ(H) 2.70 (*s*), 2.50 (*s*), and 1.23 (*d*, *J* = 7.3 Hz), and an O-atom-bearing CH_2 at δ(H) 4.72 (*s*). A typical signal at δ(H) 7.16 (*s*) was also observed in the ^{1}H-NMR spectrum, which was assignable to the H-atom of a pentasubstituted phenyl ring. The above-mentioned evidence and the six degrees of unsaturation suggested that compound **1** is a dinorsesquiterpenoid with an indan-1-one skeleton [4]. Comparison of the ^{1}H- and ^{13}C-NMR spectroscopic data (*Table*) of **1** with those of pterosin B (=(2*R*)-2,3-dihydro-6-(2-hydroxyethyl)-2,5,7-trimethyl-1*H*-inden-1-one) showed that the only structural difference was one less CH_2 group in **1** than in

[1]) Trivial atom numbering; for systematic names, see *Exper. Part.*



1[1]) R = H
2[1]) R = Glc

3[1])

4

5

6

pterosin B [13], and this was supported by its molecular composition. Thus, the structure of **1** was identified as norpterosin B, which was confirmed by the interpretation of 2D-NMR data. In the NOESY plot, the signal at δ(H) 4.72 (CH_2(12)) showed correlations with Me(11) and Me(13), which was indicative of the presence of a CH_2OH group at C(6). The absolute configuration of **1** was determined from its CD spectrum which showed a positive *Cotton* effect at 315 nm in MeOH, indicating that the absolute configuration at C(2) is (*R*). Accordingly, compound **1** was assigned as (2*R*)-norpterosin B.

Compound **2** showed the molecular formula $C_{19}H_{26}O_7$ as deduced by the HR-ESI-MS (*m*/*z* 389.1565 ($[M+Na]^+$)). The presence of a β-D-glucopyranosyl moiety was inferred from the ^{1}H- and ^{13}C-NMR data (*Table*). Except for the sugar part, the NMR data of the aglycone **2** were very similar to those of **1**. The downfield C-atom signal for C(12) (δ(C) 64.9) compared with that of **1** showed that the sugar moiety was linked to C(12), which was confirmed by the correlation between the H-atom signal at δ(H) 4.30 and C(12) in the HMBC spectrum. From these results and 2D-NMR experiments (HMQC, HMBC, and NOESY), the structure of **2** was elucidated as 12-*O*-β-D-glucopyranosylnorpterosin B, and the absolute configuration at C(2) was also (*R*) as deduced from its CD spectrum.

Semipterosin A (**3**) was obtained as amorphous powder. The molecular formula of **3** was determined as $C_{14}H_{20}O_4$ by HR-ESI-MS, which provided a quasi-molecular-ion peak at *m*/*z* 253.1434 ($[M+H]^+$), in conjunction with its ^{13}C-NMR spectrum displaying 14 resonances. The IR spectrum showed absorption bands of OH (3312 cm^{-1}) and phenyl (1607 cm^{-1}) functionalities. The ^{1}H-NMR data (*Table*) indicated the presence of two Me signals at δ(H) 2.42 (*s*) and 0.96 (*d*, $J = 7.2$ Hz), two O-atom-bearing CH_2 groups at δ(H) 4.66 (*s*) and 3.67 (*t*, $J = 7.5$ Hz), and two O–CH units at δ(H) 5.22 (*d*, $J = 6.2$ Hz) and 4.90 (*d*, $J = 3.7$ Hz). A diagnostic H-atom at δ(H) 7.27 (*s*) attributed to an isolated phenyl H-atom was also observed in the ^{1}H-NMR spectrum. A DEPT NMR experiment permitted the differentiation of the 14 resonances into two Me, three CH_2, and four CH groups, and five quaternary C-atoms. The data mentioned above were

Table. *^{1}H- and ^{13}C-NMR Data* (CD_3OD, 500 and 125 MHz, resp.) *of* **1**–**3**. δ in ppm, J in Hz.

	1		**2**		**3**	
	δ(H)	δ(C)	δ(H)	δ(C)	δ(H)	δ(C)
C(1) or CH(1)	–	212.5	–	212.4	4.90 (*d*, *J* = 3.7)	79.6
H–C(2)	2.61–2.63 (*m*)	43.8	2.62–2.63 (*m*)	43.8	2.37–2.39 (*m*)	49.1
CH_2(3) or CH(3)	3.26–3.28 (*m*), 2.57–2.58 (*m*)	34.8	3.32–3.34 (*m*), 2.57–2.59 (*m*)	34.8	5.22 (*d*, *J* = 6.2)	74.6
CH(4)	7.16 (*s*)	126.9	7.17 (*s*)	126.8	7.27 (*s*)	122.5
C(5)	–	144.9	–	147.9	–	134.6
C(6)	–	139.6	–	135.0	–	140.3
C(7)	–	138.1	–	140.8	–	135.2
C(8)	–	132.8	–	132.7	–	141.4
C(9)	–	155.8	–	156.3	–	142.5
Me(10)	1.23 (*d*, *J* = 7.3)	16.8	1.24 (*d*, *J* = 7.5)	16.8	0.96 (*d*, *J* = 7.2)	10.9
Me(11) or CH_2(11)	2.50 (*s*)	20.7	2.53 (*s*)	20.7	4.66 (*s*)	62.6
CH_2(12)	4.72 (*s*)	57.9	5.06 (*d*, *J* = 11.5), 4.80 (*d*, *J* = 11.5)	64.9	3.02 (*t*, *J* = 7.5)	31.5
Me(13)	2.70 (*s*)	13.5	2.73 (*s*)	13.5	2.42 (*s*)	13.6
CH_2(14)					3.67 (*t*, *J* = 7.5)	60.9
Glc:						
CH(1)			4.30 (*d*, *J* = 7.5)	103.2		
CH(2)			3.19 (*t*, *J* = 8.0)	75.0		
CH(3)			3.32–3.34 (*m*)	78.0		
CH(4)			3.31–3.32 (*m*)	71.6		
CH(5)			3.32–3.34 (*m*)	78.0		
CH_2(6)			3.93 (*dd*, *J* = 12.5, 2.0), 3.73 (*dd*, *J* = 12.5, 5.5)	62.8		

similar to those of pterosin T (=(2*S*,3*S*)-2,3-dihydro-3-hydroxy-6-(2-hydroxyethyl)-5-(hydroxymethyl)-2,7-dimethyl-1*H*-inden-1-one) [13]. The difference in the 1D-NMR spectra of **3** was that the C(1)=O group of pterosin T was replaced by an O-atom-bearing CH group, which was confirmed by the interpretation of the 2D-NMR spectra (*Fig.*). In the HMBC spectrum, the correlation CH_2(11)/C(5) and CH_2(11)/C(4) established the presence of a CH_2OH group at C(5), which was confirmed by the key NOESY correlation CH_2(11)/H–C(4). The relative configuration of **3** was deduced from the NOESY plot. The correlation H–C(1)/Me(10) showed that H–C(1) and Me(10) are on the same side of the molecule. As a consequence, H–C(2) is on the

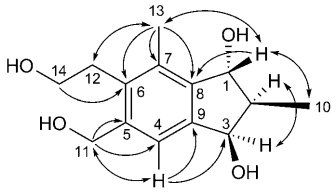


Figure. *Key HMBC* (H → C) *and NOESY* (H ↔ H) *correlations of* **3**

other side. The cross-peak H–C(2)/H–C(3) suggested that the OH at C(3) was on the β-face. Based on these data, the structure of **3** was identified, with the absolute configuration not being determined, and named semipterosin A.

The structures of three known compounds also isolated from the title plant were identified as pterosin C 3-*O*-β-D-glucoside (**4**) [14], paniculoside III (**5**) [15], and phillyrin (**6**) [16] by comparison of their spectroscopic data with literature values.

Experimental Part

General. All solvents used were of anal. grade (*Shanghai Chemical Plant*). Thin-layer chromatography (TLC): precoated silica gel GF_{254} plates (SiO_2; *Qingdao Haiyang Chemical Plant*). Column chromatography (CC): SiO_2 (230–400 mesh), SiO_2 *H-60*, C_{18} reversed-phase SiO_2 (150–200 mesh, *Merck*), and *MCI-CHP-20P* gel (75–150 μm; *Mitsubishi Chemical Industries Ltd.*). Optical rotations: *Perkin-Elmer-341* polarimeter. UV Spectra: *Shimadzu-UV-2450* spectrometer; λ_{max} (log ε) in nm. CD Spectra: *Jasco J-815*; λ ([θ]) in nm. IR Spectra: *Thermo-Nicolet-6700* spectrophotometer; $\tilde{\nu}$ in cm^{-1}. NMR Spectra: *Bruker-AM-500* apparatus; δ in ppm rel. to Me_4Si as internal standard, J in Hz. MS: *Agilent-6210* Lc/Tof mass spectrometer; in m/z (rel. %).

Plant Material. The plant material used for this study was collected from the Guiling area in Guangxi Province of P. R. China and identified by Prof. *Hai-Bo Bai* of the College of City, Zhejiang University, P. R. China. A voucher specimen (No. ZJUT 08550P) was deposited with the Zhejiang University of Technology.

Extraction and Isolation. The air-dried and powdered aerial parts of *P. semipinnata* (6.8 kg) were extracted with 95% EtOH at r.t. After evaporation of the solvent *in vacuo*, the residue was dissolved in H_2O (3 l) and then extracted successively with AcOEt (5 × 500 ml) and BuOH (5 × 500 ml). The BuOH extract (88.0 g) was subjected to CC (*MCI-CHP-20P* gel, MeOH/H_2O 0:10 → 5:5) *Fractions 1–3*. *Fr. 1* (13.5 g) was applied to CC (*RP-18* SiO_2, MeOH/H_2O 3:7 → 5:5): **3** (35 mg), **5** (12 mg), and **6** (37 mg). *Fr. 2* (8.1 g) was subjected to CC (SiO_2, $CHCl_3$/MeOH 15:1): **2** (160 mg) and **4** (45 mg). *Fr. 3* (4.0 g) was separated by CC (C_{18} column, MeOH/H_2O 4:6 → 5:5): **1** (39 mg).

*(2*R*)-Norpterosin B* (=*(2*R*)-2,3-Dihydro-6-(hydroxymethyl)-2,5,7-trimethyl-1*H*-inden-1-one*; **1**): White amorphous powder. $[\alpha]_D^{20} = -16.0$ ($c = 0.4$, MeOH). UV (MeOH): 219 (4.52), 258 (4.15), 297 (3.33). CD (MeOH): 315.0 ($+1.74 \cdot 10^3$). IR (KBr): 3205 (OH), 1701 (C=O), 1601, 1511, 1384, 1246, 1123, 1083, 1036. ^{1}H- and ^{13}C-NMR: *Table.* EI-MS: 204 (81), 189 (100, $[M - CH_3]^+$), 186 (90, $[M - H_2O]^+$), 171 (43, $[M - H_2O - CH_3]^+$), 157 (10), 143 (28), 128 (32), 115 (29), 105 (13), 91 (15), 77 (12). HR-EI-MS: 204.1148 (M^+, $C_{13}H_{16}O_2^+$; calc. 204.1150).

*(2*R*)-12-*O*-β-*D*-Glucopyranosylnorpterosin B* (=*(2*R*)-6-[(β-*D*-Glucopyranosyloxy)methyl]-2,3-dihydro-2,5,7-trimethyl-1*H*-inden-1-one*; **2**): White amorphous powder. $[\alpha]_D^{20} = +16.0$ ($c = 0.2$, MeOH). UV (MeOH): 218 (4.32), 258 (3.90), 302 (3.06). CD (MeOH): 307.0 ($+1.35 \cdot 10^3$). IR (KBr) 3432, 2924, 2874, 1702, 1600, 1441, 1422, 1381, 1078, 1025, 887, 636, 517. ^{1}H- and ^{13}C-NMR: *Table.* ESI-MS (pos.): 389 ($[M + Na]^+$). HR-ESI-MS: 389.1565 ($[M + Na]^+$, $C_{19}H_{26}NaO_7^+$; calc. 389.1576).

Semipterosin A (= rel-*(1*R*,2*S*,3*R*)-2,3-Dihydro-5-(2-hydroxymethyl)-6-(hydroxymethyl)-2,4-dimethyl-1*H*-indene-1,3-diol*; **3**): White amorphous powder. $[\alpha]_D^{20} = -142.0$ ($c = 0.1$, MeOH). UV (MeOH): 244 (2.48). IR (KBr): 3312, 2883, 1607, 1413, 1015, 879. ^{1}H- and ^{13}C-NMR: *Table.* ESI-MS (pos.): 253 ($[M + H]^+$). HR-ESI-MS: 253.1434 ($[M + H]^+$, $C_{14}H_{21}O_4^+$; calc. 253.1440).

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