# Phragmalin Limonoids from the Stem Barks of *Chukrasia tabularis* var. *velutina*

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**Key words**
- *Chukrasia tabularis*
- Meliaceae
- phragmalin
- limonoid
- chukvelutilide I
- *Artemia sinica*

## Abstract

Seven new phragmalin limonoids, chukvelutilides I–O (**1**–**7**), were isolated from the stem barks of *Chukrasia tabularis* var. *velutina*. Their structures were elucidated by extensive spectroscopic analysis. Among them, compound **1** showed moderate lethal activity against brine shrimp larvae, with an $LC_{50}$ value of 84.1 µM.

**Supporting information** available online at http://www.thieme-connect.de/products

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## Introduction

Phragmalin limonoids possess characteristic rings of A and B tricyclo[$3.3.1^{2,10}.1^{1,4}$]decane or tricyclo [$4.2.1^{10,30}.1^{1,4}$]decane, some of which also bear an orthoester group at positions 1, 8, 9; 8, 9, 11; 8, 9, 14; or 8, 9, 30 [1]. Bioassays on these structurally diverse molecules have shown them to have a broad range of activities [1–3]. *Chukrasia tabularis* var. *velutina,* a timber tree, grows mainly in tropical areas of Asia, and its stem bark has been traditionally used as astringent, antidiarrheal, and anti-influenza agent in China. As part of our continuing search for novel limonoids from the Meliaceae family with bioactivity [4–8], seven new phragmalin derivatives, chukvelutilides I–O (**1**–**7**), were isolated from the air-dried stem barks of *C. tabularis* from Yuxi, in the Yunnan Province of China. Among them, compounds **1**–**5** were 15-acyl phragmalins with an 1,8,9-orthoacetate group and a C-16/30 $\delta$-lactone ring, while compounds **6** and **7** featured an 8,9,30-orthoacetate group and a C-16/17 $\delta$-lactone ring (**Fig. 1**). Moreover, a brine shrimp (*Artemia sinica*) lethality test was performed to assay the biological activity [9]. Herein, the isolation, structural elucidation, and bioassay results of these compounds are presented.

## Results and Discussion

The MeOH extract from the dried stem barks of *C. tabularis* was suspended in water and partitioned successively with petroleum ether and EtOAc. The EtOAc-soluble extract was subjected to column chromatography followed by RP-HPLC to yield seven new limonoids. The structures of the new compounds were identified by spectroscopic analysis.

Chukvelutilide I (**1**), a white amorphous powder, had the molecular formula of $C_{43}H_{52}O_{20}$, as determined by HRESIMS at *m/z* 911.2964 $[M + Na]^+$ (calcd. 911.2949), with 18 degrees of unsaturation. The $^1H$ and $^{13}C$ NMR data of **1** (**Table 1** and **2**) indicated the presence of five acetyl groups, one $\beta$-furanyl, one $\beta$-dicarbonyl, one orthoacetate group, one ester carbonyl, one methoxyl, two tertiary methyls, three methylenes (one oxygenated), seven methines (five oxygenated), and seven quaternary carbons (four oxygenated). Ten degrees of unsaturation were occupied by seven carbonyl ester groups and three carbon-carbon double bonds, and the remaining eight degrees were accounted for by the octacyclic core.

Extensive analysis of the 2D NMR spectra of compound **1**, especially HMBC (**Fig. 2**), suggested that this compound was a 15-acyl phragmalin limonoid with a 1,8,9-orthoacetate and a C-16/30 $\delta$-lactone ring [10]. The five acetoxyl groups were located at C-2, C-3, C-12, C-17, and C-19 by the HMBC correlations of OAc-2 ($\delta_H$ 2.16, s)/C-2 ($\delta_C$ 79.1), H-3 ($\delta_H$ 5.34, s)/OAc-3 ($\delta_C$ 168.4), H-12 ($\delta_H$ 4.33, br s)/OAc-12 ($\delta_C$ 168.8), H-17 ($\delta_H$ 5.70, s)/

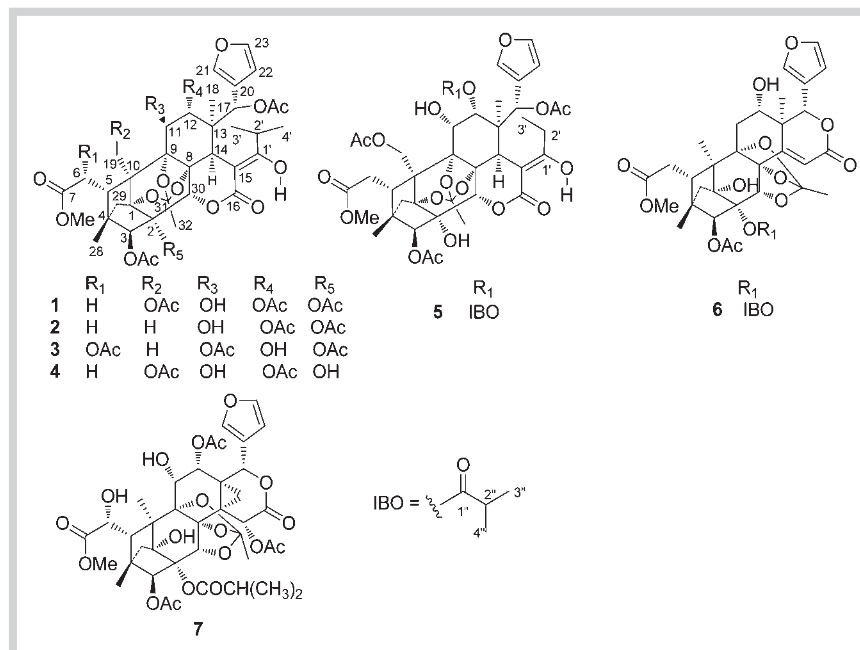


**Fig. 1** Chemical structures of compounds **1**–**7**.

OAc-17 ($\delta_C$ 168.5), and Ha-19 ($\delta_H$ 4.68, d, $J$ = 11.4 Hz)/OAc-19 ($\delta_C$ 169.8). Therefore, the planar structure of compound **1** was established as shown, and the relative configuration of **1** was determined to be the same as that of chukvelutilide C by the ROESY spectrum and 3D computer modelling (**Fig. 2**) [10].

The structures of **2**–**4** were determined to be polyoxygenated phragmalins [10–13]. They all exhibited the same skeleton as **1** but with different substitution patterns, as determined by spectroscopic data analysis and comparison of their NMR data with those of **1**.

The $^1$H and $^{13}$C NMR data of **2** were similar to those of **1**, except for the presence of an additional methyl group [$CH_3$-19 ($\delta_H$ 1.16, s)] and the absence of the *O*-bearing $CH_2$ and $CH_3CO$ groups in **1**, thus indicating that **2** was a 19-deacetoxy analogue of **1** (**Table 1** and **2**). This conclusion was further confirmed by HRESIMS and 2D NMR data.

The molecular formula of chukvelutilide K (**3**) was determined to be $C_{43}H_{52}O_{20}$ at $m/z$ 887.2981 [M – H]$^-$ by HRESIMS. The $^1$H and $^{13}$C NMR spectroscopic data suggested that **3** possessed the same skeleton as **1** but with different substitution patterns (**Table 1** and **2**). The 2D NMR data, especially the HMBC correlations, indicated that OAc-6, OAc-11, and OH-12 of **3** replaced H-6, OH-11, and OAc-12 of **1**. The relative configuration of compound **3** was elucidated to be same as that of **1** by the ROESY spectrum (see Supporting Information).

Chukvelutilide L (**4**) gave the molecular formula $C_{41}H_{50}O_{19}$ from HRESIMS, indicating that it possessed one acetyl group less than **1**. The large chemical shift discrepancy at C-2 (ca. Δ–2.9) and at C-3 (ca. Δ+3.4) between **4** and **1** along with the aforementioned information implied that **4** was the 2-deacetyl analogue of **1** (**Table 1** and **2**). The remaining planar and relative configurations of **4** were identical to those of **1**, as determined by the HMBC and ROESY data.

Chukvelutilide M (**5**) had a molecular formula $C_{42}H_{51}O_{19}$, as determined by the negative HRESIMS ion at $m/z$ 859.3029 [M – H]$^-$ (calcd. 859.3024). The $^1$H and $^{13}$C NMR data of **5** resembled closely those of **4** (**Table 1** and **2**) except that an isobutyryloxyl and an ethyl group in **5** replaced an acetoxyl group at C-12 and an isopropyl group at C-1′ in **4**. The HMBC correlations from H-12 ($\delta_H$ 4.43, br s), Me-3″, and Me-2″ to the carbonyl group ($\delta_C$ 174.3), along with the $^1$H–$^1$H COSY cross-peaks of Me-3″/H-2″ and Me-4″/H-2″, placed the isobutyryloxyl group at C-12. In addition, the HMBC correlations of Me-3′ with C-1′ ($\delta_C$ 178.6), and $H_2$-2′ with C-1′ ($\delta_C$ 178.6) and C-15 ($\delta_C$ 93.1), as well as the $^1$H–$^1$H COSY correlations of Me-3′/$H_2$-2′ indicated that the ethyl was linked to C-1′. Thus, the planar structure of **5** was established as shown. The relative configurations at the chiral centres of **5** were the same as those of **2** on the basis of $^{13}$C NMR shifts and ROESY data (see Supporting Information).

Chukvelutilide N (**6**), a white solid, had a molecular formula of $C_{35}H_{42}O_{14}$, as determined by HRESIMS at $m/z$ 709.2484 [M + Na]$^+$ (calcd. 709.2472). Analysis of its $^1$H and $^{13}$C NMR data (**Table 1** and **2**) indicated that compound **6** is a congener of tabulalin, which possessed a phragmalin skeleton with a 8,9,30-orthoacetate [11]. In the HMBC spectrum of **6**, the observed correlations of one OH ($\delta_H$ 3.62, s) to C-1 ($\delta_C$ 83.6), the other OH ($\delta_H$ 5.11, d, $J$ = 4.9 Hz) to C-12 ($\delta_C$ 64.4), and H-3 ($\delta_H$ 5.00, s) to an ester carbonyl ($\delta_C$ 168.7 s) indicated that the two hydroxyl groups were located at C-1 and C-12, respectively, and that the acetoxyl group was placed at C-3. The location of the isobutyryloxyl moiety at C-2 was supported by the HMBC correlations of H-3 ($\delta_H$ 5.00, s), H-30 ($\delta_H$ 5.18, s), and Me-3″ ($\delta_H$ 1.01, d, $J$ = 7.4 Hz) to the ester carbonyl at C-1″ ($\delta_C$ 174.3). The structure of **6** was established as shown.

Analysis of the NMR data of chukvelutilide O (**7**) (**Table 1** and **2**) showed that it was a derivative of tabularisin C [12]. The only difference was that the OH group at C-6 of **7** replaced the acetoxyl group at the same position of the latter. This conclusion was confirmed by HRESIMS and 2D NMR data (**Table 1** and **2**). The structure of **7** was thus established as shown.

Compounds **1**–**7** were evaluated for their lethal activities against brine shrimp larvae (**Table 3**). Among them, compound **1** was the most lethal to brine shrimp, with an $LC_{50}$ value of 84.1 µM.

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**Table 1** $^1$H NMR data of **1–7** (*J* in Hz).[a, b]

| Position | 1[c] | 2[d] | 3[d] | 4[a] | 5[c] | 6[c] | 7[c] |
|---|---|---|---|---|---|---|---|
| 3 | 5.34 s | 5.51 s | 5.43 s | 4.67 s | 4.67 s | 5.00 s | 5.02 s |
| 5 | 2.90 t (10.5) | 3.03 t (10.5) | 3.36 br. s | 2.98 t (9.2) | 3.01 overlap | 2.05 overlap | 2.46 br. s |
| 6a | 2.87 overlap | 2.67 d (17.4) | 6.17 br. s | 2.92 d (17.2) | 2.95 br. d (17.7) | 2.52 m | 4.79 d (5.8) |
| 6b | 2.70 dd (17.9, 10.5) | 2.42 dd (17.4, 10.5) | | 2.69 dd (17.2, 10.9) | 2.70 dd (17.7, 10.8) | | |
| 11a | 4.86 d (4.1) | 4.38 d (1.6) | 4.48 overlap | 4.89 br. s | 4.87 br. s | 2.05 m | 4.06 d (4.7) |
| 11b | | | | | | 1.79 t (13.7) | |
| 12 | 4.33 br. s | 4.54 d (1.6) | 4.50 overlap | 4.35 br. s | 4.43 br. s | 3.55 overlap | 5.00 overlap |
| 14 | 3.55 s | 3.47 s | 3.47 s | 3.54 s | 3.56 s | | |
| 15 | | | | | | 6.37 s | 6.75 s |
| 17 | 5.70 s | 5.89 s | 5.87 s | 5.68 s | 5.73 s | 5.70 s | 6.33 s |
| 18a | 1.46 s | 1.56 s | 1.56 s | 0.86 s | 1.47 s | 1.27 s | 2.84 dd (6.5, 2.1) |
| 18b | | | | | | | 1.35 overlap |
| 19a | 4.68 d (11.4) | 1.16 s | 1.25 s | 4.67 d (11.5) | 4.65 d (11.4) | 1.20 s | |
| 19b | 4.13 (d 11.4) | | | 4.14 d (11.5) | 4.16 d (11.4) | | |
| 21 | 7.53 s | 7.60 s | 7.64 s | 7.55 s | 7.56 s | 7.49 s | 7.55 s |
| 22 | 6.45 br. s | 6.41 br. s | 6.43 br. s | 6.46 br. s | 6.46 br. s | 6.46 br. s | 6.63 br. s |
| 23 | 7.57 br. s | 7.27 br. s | 7.27 br. s | 7.56 br. s | 7.56 br. s | 7.60 br. s | 7.68 br. s |
| 28 | 0.87 s | 1.00 s | 1.16 s | 0.86 s | 0.90 s | 0.59 s | 0.78 s |
| 29a | 1.90 d (12.4) | 2.02 d (11.2) | 2.14 d (11.2) | 1.85 d (11.3) | 1.88 overlap | 1.97 d (11.8) | 2.25 d (10.7) |
| 29b | 1.86 d (12.4) | 1.86 d (11.2) | 1.87 d (11.2) | 1.69 d (11.3) | 1.72 d (11.2) | 1.51 d (11.8) | 1.47 overlap |
| 30 | 5.55 s | 5.73 s | 5.60 s | 5.27 s | 5.32 s | 5.18 s | 4.83 s |
| 32 | 1.54 s | 1.65 s | 1.64 s | 1.57 s | 1.47 s | 1.62 s | 1.62 s |
| 2′ | 2.97 m | 3.01 m | 3.00 m | 2.96 m | 2.54 overlap | | |
| 3′ | 1.20 d (6.8) | 1.31 d (6.5) | 1.28 d (6.6) | 1.21 d (6.7) | 1.13 m | | |
| 4′ | 1.06 d (6.5) | 1.65 br. d | 1.16 d (6.6) | 1.05 d (6.7) | | | |
| 1-OH | | | | | | 2.06 s | 3.62 s |
| 2-OH | | | | 4.73 s | 4.72 s | | |
| 6-OH | | | | | | | 6.15 d (5.7) |
| 11-OH | 5.56 d (4.4) | 2.63 s | | 5.50 d (4.3) | 5.47 d (4.1) | | 5.11 d (4.9) |
| 12-OH | | | 2.51 s | | | 4.32 d (5.25) | |
| 1′-OH | 13.78 s | 13.96 s | 13.90 s | 13.73 s | 13.51 s | | |
| 7-OMe | 3.61 s | 3.74 s | 3.77 s | 3.63 s | 3.64 s | 3.66 s | |
| 2-OAc | 2.16 s | 1.92 s | 2.17 s | | | | |
| 3-OAc | 1.94 s | 2.15, s | 2.17, s | 2.19, s | 2.19, s | 1.92, s | 1.50, s |
| 6-OAc | | | 2.11, s | | | | |
| 11-OAc | | | 1.66, s | | | | |
| 12-OAc | 1.55, s | 2.40, s | | 1.56, s | | | 2.14, s |
| 15-OAc | | | | | | | 2.05, s |
| 17-OAc | 1.84, s | 1.15, s | 1.93, s | 1.85, s | 1.88, s | | |
| 19-OAc | 1.98, s | | | 1.97, s | 1.97, s | | |
| 2″ | | | | | 2.08, m | 2.60, m | 2.53, m |
| 3″ | | | | | 0.86, d (7.1) | 1.01, t (7.4) | 1.07, d (7.0) |
| 4″ | | | | | 0.80, d (7.1) | 1.01, t (7.4) | 1.05, d (7.0) |

[a] Signals were assigned on the basis of 1H-1H COSY, HSQC, HMBC, and ROESY experiments; [b] spectra were measured at 500 MHz; [c] data measured in DMSO-$d_6$; [d] data measured in $CDCl_3$

## Materials and Methods

### General experimental procedures

NMR spectra were measured in a $CDCl_3$ or DMSO-$d_6$ solution and recorded on a Bruker DRX-400 or DRX-500 instrument using TMS as an internal standard. The optical rotations were recorded on a Perkin-Elmer model 241 polarimeter or a Horiba SEPA-300 polarimeter. IR spectra were measured in a Bio-Rad FTS-135 spectrometer as KBr pellets. MS was performed on a VG Auto Spec-3000 or a Finnigan MAT 90 instrument. UV data were measured on a UV 210A spectrometer. Column chromatography was performed on an MCI gel CHP20P (75–150 µm, Mitsubishi Chemical Corporation), a $C_{18}$ reversed-phase silica gel (40–75 µm, Fuji Silysia Chemical Ltd.), and a Si-gel (300–400 mesh) from Qingdao Marine Chemical Factory. Semi-preparative HPLC was performed on an Agilent 1100 apparatus with a chromolith RP-18e (Merck, 100 × 10 mm) column.

### Material

The stem barks of *C. tabularis* var. *velutina* were collected in Yuxi, Yunnan Province, China, in August 2008 and identified by En-De Liu (Biogeography and Ecology, Kunming Institute of Botany). A voucher specimen (KIB HXJ08003) was deposited at the Key Laboratory of Phytochemistry and Plant Resources in West China, Kunming Institute of Botany, Chinese Academy of Sciences.

### Extraction and isolation

The air-dried and crashed stem barks (13 kg) of *C. tabularis* var. *velutina* were extracted with MeOH (20 L × 3) at room temperature and concentrated to give a residue (320 g) *in vacuo* at 60 °C.



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**Table 2** $^{13}$C NMR data of **1–7** (ppm).[a]

| Position | 1[b] | 2[c] | 3[c] | 4[b] | 5[b] | 6[b] | 7[b] |
|---|---|---|---|---|---|---|---|
| 1 | 84.1 | 84.7 | 84.6 | 84.1 | 84.0 | 83.6 | 84.1 |
| 2 | 79.1 | 78.7 | 83.2 | 76.2 | 76.2 | 83.1 | 83.5 |
| 3 | 79.9 | 80.1 | 80.5 | 83.3 | 83.3 | 85.0 | 85.9 |
| 4 | 45.8 | 46.3 | 46.5 | 45.3 | 45.3 | 47.4 | 43.7 |
| 5 | 35.0 | 35.6 | 40.0 | 36.0 | 35.9 | 39.8 | 43.3 |
| 6 | 32.1 | 33.0 | 71.4 | 32.2 | 32.1 | 32.6 | 69.4 |
| 7 | 173.1 | 172.6 | 170.0 | 173.1 | 173.3 | 173.8 | 176.4 |
| 8 | 82.6 | 83.2 | 78.9 | 79.4 | 79.4 | 83.4 | 86.0 |
| 9 | 83.0 | 83.3 | 83.2 | 83.6 | 83.6 | 85.5 | 84.8, s |
| 10 | 47.5 | 46.4 | 47.2 | 46.8 | 46.8 | 47.4 | 48.7 |
| 11 | 68.9 | 68.9 | 68.7 | 68.9 | 68.8 | 36.8 | 66.3 |
| 12 | 71.7 | 72.1 | 72.0 | 71.7 | 71.1 | 64.4 | 68.3 |
| 13 | 43.6 | 44.8 | 46.5 | 43.8 | 44.3 | 43.7 | 29.3 |
| 14 | 41.7 | 42.9 | 42.8 | 41.8 | 42.1 | 153.0 | 24.5 |
| 15 | 91.5 | 90.9 | 91.0 | 91.9 | 93.1 | 122.5 | 70.5 |
| 16 | 170.4 | 170.3 | 170.3 | 170.8 | 170.5 | 163.4 | 165.6 |
| 17 | 69.9 | 69.9 | 70.1 | 70.0 | 70.3 | 79.8 | 71.7 |
| 18 | 17.4 | 17.9 | 18.0 | 17.3 | 17.6 | 13.2 | 16.5 |
| 19 | 65.6 | 16.4 | 13.8 | 65.8 | 65.9 | 15.0 | 84.8 |
| 20 | 122.5 | 122.0 | 121.9 | 122.6 | 122.7 | 121.8 | 122.8 |
| 21 | 140.2 | 141.4 | 141.4 | 140.3 | 140.1 | 141.3 | 141.0 |
| 22 | 109.8 | 109.9 | 109.9 | 109.9 | 110.0 | 110.7 | 110.0, d |
| 23 | 143.4 | 142.6 | 142.6 | 143.3 | 143.0 | 142.9 | 144.0 |
| 28 | 14.0 | 14.5 | 15.9 | 13.7 | 13.8 | 14.3 | 15.3 |
| 29 | 38.8 | 40.3 | 40.6 | 38.6 | 38.6 | 39.6 | 40.1 |
| 30 | 73.4 | 73.5 | 73.5 | 73.9 | 74.0 | 73.5 | 74.9 |
| 31 | 118.9 | 119.0 | 119.0 | 119.2 | 119.3 | 119.3 | 115.6 |
| 32 | 20.2 | 20.1 | 20.6 | 20.6 | 20.6 | 16.1 | 15.3 |
| 1′ | 182.5 | 183.5 | 183.6 | 181.6 | 178.6 | | |
| 2′ | 29.5 | 30.0 | 30.0 | 29.6 | 25.0 | | |
| 3′ | 18.2 | 18.5 | 18.5 | 18.2 | 11.2 | | |
| 4′ | 20.0 | 20.5 | 20.5 | 20.5 | | | |
| 7-OMe | 51.5 | 51.9 | 53.2 | 51.6 | 51.5 | 52.0 | |
| 2-OAc | 168.4 | 169.3 | 169.5 | | | | |
| | 20.8 | 20.9 | 20.9 | | | | |
| 3-OAc | 168.4 | 170.1 | 169.6 | 169.3 | 169.3 | 168.3 | 168.7 |
| | 21.8 | 21.8 | 21.2 | 20.7 | 20.7 | 21.1 | 19.7 |
| 6-OAc | | | 169.9 | | | | |
| | | | 21.8 | | | | |
| 11-OAc | | | 169.4 | | | | |
| | | | 20.0 | | | | |
| 12-OAc | 168.8 | 169.4 | | 168.8 | | | 170.2 |
| | 20.4 | 21.0 | | 20.3 | | | 20.5 |
| 15-OAc | | | | | | | 167.9 |
| | | | | | | | 20.4 |
| 17-OAc | 168.5 | 168.8 | 168.8 | 168.6 | 168.6 | | |
| | 20.6 | 20.6 | 20.8 | 20.6 | 20.6 | | |
| 19-OAc | 169.8 | | | 169.9 | 169.7 | | |
| | 21.0 | | | 21.0 | 20.9 | | |
| 1′′ | | | | | 174.3 | 175.8 | 175.2 |
| 2′′ | | | | | 33.1 | 33.7 | 33.7 |
| 3′′ | | | | | 18.6 | 18.6 | 18.6 |
| 4′′ | | | | | 17.9 | 18.6 | 18.6 |

[a] Spectra were measured at 100 MHz; [b] data measured in DMSO-$d_6$; [c] data measured in $CDCl_3$

The residue was dispersed in water (4.0 L) and extracted with petroleum ether and then EtOAc to give the EtOAc-soluble fraction (E-Fraction, 190 g). The E-Fraction was processed with a silica gel column (0.2 m × 1.0 m, 100 to 200 mesh, 1.0 kg) and eluted with $CHCl_3$-MeOH (1% MeOH, 3% MeOH, and 10% MeOH, each 5 L). The 3% MeOH eluent (120 g) was subjected to an MCI gel column (5.5 cm × 48 cm, 0.5 kg) eluted with MeOH-$H_2O$ (60% MeOH, 80% MeOH, 90% MeOH, each 2 L) to give three fractions, termed Fr. A −C. Fr. B (89 g) was subjected to a column of $C_{18}$ reversed-phase silica gel (4 cm × 48 cm) eluted with MeOH-$H_2O$ (40% MeOH, 50% MeOH, 60% MeOH, 70% MeOH, 80% MeOH, 90% MeOH, each 2 L) to yield five fractions, termed Fr. B1–B5. Fr. B1 was purified by a silica gel column (2.5 cm × 18 cm, 300 to 400 mesh, 50 g) and eluted with $CHCl_3$-MeOH (75 : 1) to yield compounds **1** (10 mg)

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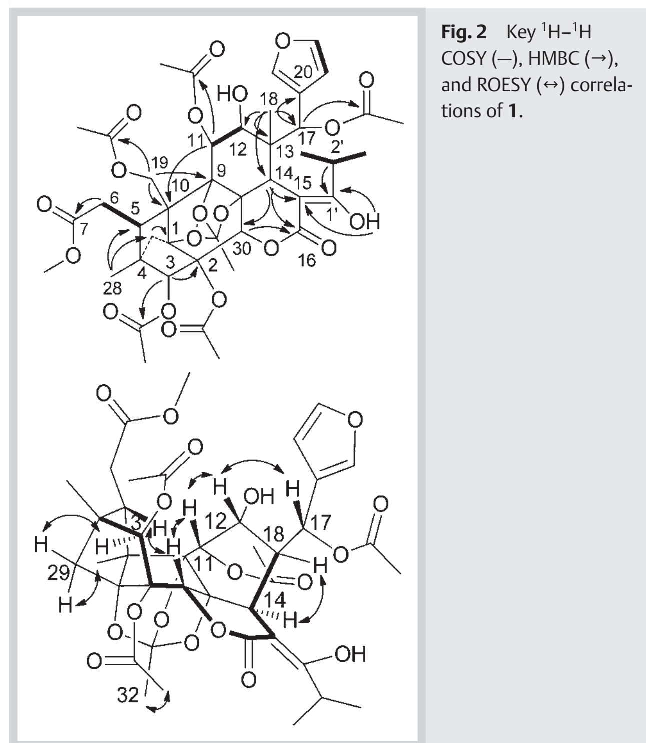

**Fig. 2** Key $^1H$–$^1H$ COSY (–), HMBC (→), and ROESY (↔) correlations of **1**.

**Table 3** $LC_{50}$ values of compounds **1–7** against *Artemia sinica*.

| Compounds | $LC_{50}$ ± SD (µM) |
|---|---|
| 1 | 84.1 ± 4.0 |
| 2 | 203.2 ± 10.0 |
| 3 | 172.3 ± 9.0 |
| 4 | 227.9 ± 11.0 |
| 5 | 143.3 ± 8.0 |
| 6 | 229.1 ± 10.9 |
| 7 | 193.2 ± 10.2 |
| Deltamethrin[a] | 72.0 ± 2.9 |

[a] Positive control

and **3** (7 mg). Fr. B2 was separated with a silica gel column (2.5 × 18 cm, 300 to 400 mesh, 50 g), eluted with $CHCl_3$-MeOH (100 : 1), and further purified by semi-preparative HPLC (45% MeOH) to give compounds **2** (6 mg), **4** (7 mg), and **7** (13 mg). Fr. B5 was separated with a silica column (2.5 × 18 cm, 300 to 400 mesh, 50 g), eluted with $CHCl_3$-MeOH (200 : 1), and then purified with semipreparative HPLC (50% MeOH) to yield compounds **5** (7 mg) and **6** (7 mg). The purities of compounds **1–7** were 95%, as determined by TLC and HPLC-ELSD.

## Isolates

*Chukvelutilide I*: white amorphous powder; $C_{43}H_{52}O_{20}$; $[\alpha]_D^{27}$ − 92.7 (*c* 0.10, MeOH); IR (KBr) $\nu_{max}$: 3441, 2936, 1747, 1631, 1370, 1225 $cm^{-1}$; UV (MeOH) $\lambda_{max}$ (log $\varepsilon$) 210 (3.96), 272 (3.91) nm; positive ion FABMS *m/z* 889 [M + H]$^+$; positive ion HRESIMS *m/z* 911.2964 [M + Na]$^+$ (calcd. for $C_{43}H_{52}O_{20}$Na: 911.2949); $^1H$ (DMSO-*d6*, 500 MHz) and $^{13}C$ (DMSO-*d6*, 100 MHz) NMR data: see **Table 1** and **2**.

*Chukvelutilide J*: white amorphous powder; $C_{41}H_{50}O_{18}$; $[\alpha]_D^{21}$ − 30.8 (*c* 0.41, MeOH); IR (KBr) $\nu_{max}$: 3450, 2936, 1744, 1639, 1402, 1373, 1238 $cm^{-1}$; UV (MeOH) $\lambda_{max}$ (log $\varepsilon$) 202 (3.69), 270 (3.67) nm; positive ion FABMS *m/z* 831 [M + H]$^+$; negative ion HRESIMS *m/z* 829.2918 [M – H]$^-$ (calcd. for $C_{41}H_{49}O_{18}$: 829.2918); $^1H$ ($CD_3OD$, 500 MHz) and $^{13}C$ ($CD_3OD$, 100 MHz) NMR data: **Table 1** and **2**.

*Chukvelutilide K*: white amorphous powder; $C_{43}H_{52}O_{20}$; $[\alpha]_D^{26}$ − 38.8 (*c* 0.28, MeOH); UV (MeOH) $\lambda_{max}$ (log $\varepsilon$) 211 (3.77), 275 (3.81) nm; IR (KBr) $\nu_{max}$: 3460, 2968, 1751, 1641, 1605, 1437, 1373, 1227 $cm^{-1}$; FABMS *m/z* 887 [M – H]$^-$; HRESIMS *m/z* 887.2981 [M – H]$^-$ (calcd. for $C_{43}H_{51}O_{20}$: 887.2973); $^1H$ NMR ($CD_3OD$, 500 MHz) and $^{13}C$ ($CD_3OD$, 100 MHz) data: see **Table 1** and **2**.

*Chukvelutilide L*: white amorphous powder; $C_{41}H_{50}O_{19}$; $[\alpha]_D^{26}$ − 47.6 (*c* 0.14, MeOH); UV (MeOH) $\lambda_{max}$ (log $\varepsilon$) 211 (3.64), 272 (3.64) nm; IR (KBr) $\nu_{max}$: 3442, 2920, 1744, 1630, 1402, 1371, 1233 $cm^{-1}$; positive ion ESIMS *m/z* 847 [M + H]$^+$; positive ion HRESIMS *m/z* 869.2848 [M + Na]$^+$ (calcd. for $C_{41}H_{50}O_{19}$Na: 869.2841); $^1H$ (DMSO-*d6*, 500 MHz) and $^{13}C$ (DMSO-*d6*, 100 MHz) NMR data: see **Table 1** and **2**.

*Chukvelutilide M*: white amorphous powder; $C_{42}H_{52}O_{19}$; $[\alpha]_D^{25}$ − 27.6 (*c* 0.26, MeOH); UV (MeOH) $\lambda_{max}$ (log $\varepsilon$) 213 (3.48), 273 (3.33) nm; IR (KBr) $\nu_{max}$: 3442, 2957, 2919, 2850, 1738, 1640, 1452, 1252 $cm^{-1}$; negative ion FABMS *m/z* 859 [M – H]$^-$; negative ion HRESIMS *m/z* 859.3029 [M – H]$^-$ (calcd. for $C_{42}H_{51}O_{19}$: 859.3024); $^1H$ (DMSO-*d6*, 500 MHz) and $^{13}C$ (DMSO-*d6*, 100 MHz) NMR data: see **Table 1** and **2**.

*Chukvelutilide N*: white amorphous powder; $C_{35}H_{42}O_{14}$; $[\alpha]_D^{26}$ + 47.8 (*c* 0.07, MeOH); UV (MeOH) $\lambda_{max}$ (log $\varepsilon$) 212 (4.27) nm; IR (KBr) $\nu_{max}$: 3439, 2934, 1732, 1630, 1382, 1234 $cm^{-1}$; negative ion FABMS *m/z* 685 [M – H]$^-$; positive ion HRESIMS *m/z* 709.2484 [M + Na]$^+$ (calcd. for $C_{35}H_{42}O_{14}$Na: 709.2472); $^1H$ (DMSO-*d6*, 500 MHz) and $^{13}C$ (DMSO-*d6*, 100 MHz) NMR data: see **Table 1** and **2**.

*Chukvelutilide O*: white amorphous powder; $C_{39}H_{46}O_{19}$; $[\alpha]_D^{26}$ + 10.2 (*c* 0.24, MeOH); UV (MeOH) $\lambda_{max}$ (log $\varepsilon$) 211 (3.73) nm; IR (KBr) $\nu_{max}$: 3440, 2919, 1764, 1737, 1630, 1375, 1211 $cm^{-1}$; negative ion FABMS: *m/z* 817 [M – H]$^-$; negative ion HRESIMS *m/z* 817.2552 [M – H]$^-$ (calcd. for $C_{39}H_{45}O_{19}$: 817.2555); $^1H$ (DMSO-*d6*, 500 MHz) and $^{13}C$ (DMSO-*d6*, 100 MHz) NMR data: see **Table 1** and **2**.

## Brine shrimp toxicity assay

Compounds **1–7** were evaluated for their lethal activity against brine shrimp larvae based on an established 96-well plate protocol [9]. In this test, a drop of DMSO was added to the test and control vials to enhance the solubility of the compounds. Deltamethrin (Sigma, purity ≥ 98%) was used as a positive control.

## Supporting information

The MS, IR, 1D, and 2D NMR spectra of compounds **1–7** are available as Supporting Information.

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## Conflict of Interest

Prof. Xiao-Jiang Hao and Prof. Ying-Tong Di initiated the project. Ms. Jun-Lin Yin, Ms. Chun-Mao Yuan, Ms. Shi-Fei Li, Dr. Yu Zhang, Dr. Hong-Ping He, Dr. Shun-Lin Li performed the extraction, isolation, and structural identification of the compounds. Dr. Xin Fang performed the brine shrimp toxicity assay experiment. Dr. En-De Liu collected and identified the plant material. All authors approved the final version of the manuscript. We declare that all authors have read the manuscript conscientiously, and all agree with its publication. The authors have no conflict of interest to report.

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