

Two New Sesquiterpenes from *Celastrus angulatus*

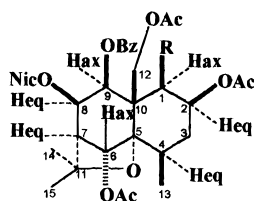
Yanhong Wang,[†] Li Yang,[†] Yongqiang Tu,[†] Kun Zhang,[†] and Yaozu Chen^{*,†,‡}

State Key Laboratory of Applied Organic Chemistry, Lanzhou University, Lanzhou, 730000, People's Republic of China, and Department of Chemistry, Zhejiang University, Hangzhou, 310027, People's Republic of China

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Two new β -dihydroagarofurans, sesquiterpene polyol esters **1** and **2**, were isolated from the leaves of *Celastrus angulatus*. Their structures were established on the basis of spectral analysis.

The Chinese bittersweet, *Celastrus angulatus* Max. (Celastraceae), is widely distributed in the People's Republic of China and has been used as a traditional insecticidal plant to protect other plants from insect damage.¹ In previous studies, an extract of this plant exhibited antifeedant, narcotic, and insecticidal activity against several insect species.^{2,3} Continued study on this plant has resulted in the isolation of two new sesquiterpene polyol esters (**1** and **2**) with a β -dihydroagarofuran skeleton, and their structure elucidation is the subject of this paper.



- 1.** R = OBz
2. R = OH

Compound **1**, colorless needles, analyzed for $C_{41}H_{43}NO_{13}$ by HRMS. Its IR spectrum revealed absorptions for ester groups at 1728 cm^{-1} and a phenyl group at 1589 , 1477 , and 1453 cm^{-1} . The EIMS showed the presence of acetate ester substitution at m/z 715 [$M + H - Ac$]⁺ and 43 [Ac] and benzoate ester substitution at m/z 593 [$M - Ac - C_6H_5COOH$]⁺ and 105 [C_6H_5CO]. Moreover, the NMR spectra indicated the presence of three acetate esters [δ_H 2.11 (3H, s), and 2.03 (6H, s); δ_C 21.1, 21.3 (3 \times Me), 169.4, 169.6, and 170.7 (3 \times $-CO_2-$)], two benzoate esters [δ_H 6.85–7.53 (10H, m); δ_C 132.7 and 132.6 (each CH), 129.5, 129.2, 128.0, and 127.7 (each 2 \times CH), 129.5 and 128.9 (each quaternary carbon), 165.0 and 164.8 (2 \times $-CO_2-$)], and one β -nicotinate ester [δ_H 9.18 (1H, s), 8.72 (1H, dd), 8.24 (1H, dt), and 7.36 (1H, m); δ_C 153.6, 151.0, 137.1, and 123.2 (each CH), 126.1 (quaternary carbon), and 164.8 ($-CO_2-$)]. In addition, the ^{13}C -NMR and DEPT spectra indicated that **1** contained a skeleton based on 15 carbons: three methyl carbons (δ 16.6, 24.6, and 30.3), two methylene carbons (δ 31.3 and 61.1), seven methine carbons (δ 32.9, 53.4, 69.3, 71.6, 72.5, 74.7, and 77.4), and three quaternary carbons (δ 51.7, 81.2, and 90.3). These data were suggestive of a 1,2,6,8,9,12-hexasubstituted β -dihydroagarofuran skeleton.⁴

In the 1H -NMR and NOESY spectra of **1**, a doublet signal at δ 5.85 (1H, d, $J = 3.9$ Hz) was assigned to

Hax-1 because in this class of compound H-1 generally has axial stereochemistry.⁵ The sole upfield doublet at δ 1.17 (3H, d, $J = 7.7$ Hz) was assigned to Me-13, and this doublet was caused by the methine hydrogen at C-4. The singlet at δ 6.83 (1H, s) was assigned to Hax-6 because of the weak coupling between Hax-6 and Heq-7 occurring in all compounds of this class⁵ and the NOE cross-signal between the axial Me-13 and H-6 that was observed in the NOESY spectrum of **1**. Moreover, Hax-9 (δ 5.81), Heq-8 (δ 5.77), Me-14 (δ 1.62), Heq-7 (δ 2.66), Me-15 (δ 1.46), Heq-2 (δ 5.51), Heq-4 (δ 2.25), and Ha-12 (δ 5.54) were also assigned according to the NOE cross-signals between the Hax-1 peak and those at δ 5.81 (1H, d, $J = 6.0$ Hz, H-9), δ 5.77 (1H, dd, $J = 3.9$, 6.0 Hz, H-8), and δ 1.62 (3H, s, Me-14); δ 2.66 (1H, d, $J = 3.9$ Hz, H-7) and δ 1.46 (3H, s, Me-15); δ 5.51 (1H, m, H-2) and δ 2.25 (1H, m, H-4); and Me-13 and δ 5.54 (1H, d, $J = 13.4$ Hz, Ha-12), respectively. Other signals such as those between Hax-9 and Heq-8, Me-13 and Heq-4, Me-14 and Me-15, Hax-9 and Me-14, Heq-8 and Heq-7, and Hax-6 and Heq-7 could be found in the NOESY spectrum, which were in good agreement with the stereochemical elucidation and the chemical shift assignments made for **1**.

The locations of the ester functions were determined on the basis of a 1H - ^{13}C long-range correlation spectrum,⁶ which indicated that a β -nicotinate ester unit occurred at C-8, two benzoate esters were at C-1 and C-9, and three acetate esters were affixed to C-2, C-6, and C-12. On the basis of the above evidence, compound **1** was elucidated as 1 β ,9 β -bis(benzoyloxy)-2 β ,6 α ,12-triacetoxy-8 β -(β -nicotinoyloxy)- β -dihydroagarofuran.

Compound **2**, colorless needles, possessed a molecular formula of $C_{34}H_{39}NO_{12}$ as determined by HRMS. Its characteristic IR absorptions at 3386, 1734, and 1720 cm^{-1} suggested the presence of free hydroxy and ester functions. The NMR spectral data suggested the presence of three acetate esters [δ_H 2.07, 1.98, and 1.91 (each 3H, s); δ_C 21.2 (3 \times Me), 170.5, 169.8, and 169.6 (3 \times $-CO_2-$)], a benzoate ester [δ_H 7.35–7.80 (5H, m); δ_C 129.5, 128.3 (each 2 \times CH), 133.1 (CH), 129.9 (quaternary carbon), and 165.2 ($-CO_2-$)], and a β -nicotinate ester [δ_H 9.19 (1H, s), 8.77 (1H, dd), 8.33 (1H, dt), and 7.41 (1H, m); δ_C 153.7, 151.1, 137.1, and 123.3 (each CH), 125.9 (quaternary carbon), and 164.6 ($-CO_2-$)]. On comparison of the NMR data of **2** with those of compound **1**, it was concluded that both compounds possessed a 1,2,6,8,9,12-substituted β -dihydroagarofuran skeleton.

The molecular formula, the presence of a hydroxy group (IR spectrum), and the absence of a benzoate ester

[†] Lanzhou University.

[‡] Zhejiang University.

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(NMR spectrum) suggested that compound **2** was a debenzoylated analogue of compound **1**, which was supported by the following $^1\text{H-NMR}$ spectral evidence. In the $^1\text{H-NMR}$ spectrum, the signals of **2** corresponded well to those of **1** except for (i) a change in the location and multiplicity of the signal due to H-1; H-1 appeared at δ 5.85 (1H, d, $J = 3.9$ Hz) in **1** and at δ 4.42 (1H, dd, $J = 4.1, 13.2$ Hz) in **2**; and (ii) a new signal due to a hydroxyl proton (OH-1) at δ 3.06 (1H, d, $J = 13.2$ Hz) was observed in **2**. These findings indicated that compound **2** is the C-1 debenzoylated analogue of **1**. The location and configuration of the esters in **2** were assigned from its $^1\text{H-}^{13}\text{C}$ long-range correlation and NOESY spectra. Compound **2** was therefore elucidated as 1 β -hydroxy-2 β ,6 α ,12-triacetoxy-8 β -(β -nicotinoyloxy)-9 β -(benzoyloxy)- β -dihydroagarofuran.

Experimental Section

General Experimental Procedures. Melting points were determined on a Kofler apparatus. $^1\text{H-NMR}$, $^{13}\text{C-NMR}$, DEPT, NOESY, and COLOC spectra were recorded on a Bruker AM-400 NMR spectrometer with TMS as internal standard and CDCl_3 as solvent. UV spectra in MeOH were obtained on a UV-240 spectrophotometer. IR spectra with KBr plates were determined on a FT-170SX spectrometer. EIMS were obtained on VG ZAB-HS mass spectrometer, operating at 70 eV ionizing energy, with a direct insert system. HPLC was carried out on a Merck RP-8 short column.

Plant Material. The leaves of *C. angulatus* were obtained from Zunyi City, Guizhou Province, People's Republic of China, in October 1991. Voucher specimens are deposited at the Department of Biology, Lanzhou University.

Extraction and Isolation. The air-dried leaves (2 kg) of *C. angulatus* were extracted with Me_2CO at room temperature three times (once a week). Removal of the solvent under reduced pressure afforded a black mixture that was partitioned between CHCl_3 -MeOH- H_2O (10:1:9). The organic solvent was then chromatographed on Al_2O_3 (300 g) and eluted with CHCl_3 , and evaporation of the solution yielded 12 g of a residue. The last residue was chromatographed on a Si gel (150 g) column using petroleum ether- Me_2CO (9:1-6:4) as eluent to give 14 fractions. The fractions of medium polarity were combined and purified on a RP-8 short column using MeOH- H_2O (8:2) as eluent to afford compounds **1** (34 mg) and **2** (30 mg).

Compound 1: colorless needles (Me_2CO); mp 206–208 °C; $[\alpha]_{\text{D}} -51.3^\circ$ (c 0.54, MeOH); UV (MeOH) λ max (log ϵ) 201 (3.29), 226 (3.26), 263 (2.53) nm; IR (KBr) ν max 1728, 1589, 1477, 1453, 1293, 1225, 1095, 1022 cm^{-1} ; $^1\text{H NMR}$ (400 MHz, CDCl_3) δ 5.85 (1H, d, $J_{1,2} = 3.9$ Hz, H-1), 5.51 (1H, m, H-2), 1.84 (1H, m, Hax-3), 2.39 (1H, m, Heq-3), 2.25 (1H, m, H-4), 6.83 (1H, s, H-6), 2.66 (1H, d, $J_{7,8} = 3.9$ Hz, H-7), 5.77 (1H, dd, $J_{8,7} = 3.9, J_{8,9} = 6.0$ Hz, H-8), 5.81 (1H, d, $J_{9,8} = 6.0$ Hz, H-9), 5.54, 4.79 (each 1H, d, $J_{12a,12b} = 13.4$ Hz, H-12a, H-12b), 1.17 (3H, d, $J_{13,4} = 7.7$ Hz, Me-13), 1.62 (3H, s, Me-14), 1.46

(3H, s, Me-15), 3 \times OAc [2.21 (3H, s.), 2.03 (6H, s)], 2 \times OBz [6.85–7.53 (10H, m)], ONic [9.18 (1H, s), 8.72 (1H, dd, $J = 1.4$ Hz), 8.24 (1H, dt, $J = 2.0$ Hz), 7.36 (1H, m)]; $^{13}\text{C NMR}$ (100 MHz, CDCl_3) δ 77.4 (d, C-1), 69.3 (d, C-2), 31.3 (t, C-3), 32.9 (t, C-4), 90.3 (s, C-5), 74.7 (d, C-6), 53.4 (d, C-7), 72.5 (d, C-8), 71.6 (d, C-9), 51.7 (s, C-10), 81.2 (s, C-11), 61.1 (t, C-12), 16.6 (q, C-13), 24.6 (q, C-14), 30.3 (q, C-15), OAc [21.1, 21.3 (3 \times Me)]; 169.4, 169.6, 170.7 (3 \times $-\text{CO}_2-$), OBz [132.7, 132.6 (each CH), 129.5, 129.2, 128.0, 127.7 (each 2 \times CH), 129.5, 128.9 (2 \times C), 165.0, 164.8 (2 \times $-\text{CO}_2-$)], ONic [153.6, 151.0, 137.1, 123.2 (each CH), 126.1 (C), 164.8 ($-\text{CO}_2-$)]; EIMS m/z 757 ($[\text{M}]^+$, 41), 715 (49), 653 (27), 593 (11), 520 (10), 305 (14), 228 (26), 105 (100); HREIMS m/z 757.2429 $[\text{M}]^+$ (calcd for $\text{C}_{41}\text{H}_{43}\text{NO}_{13}$, 757.2392).

Compound 2: colorless needles (Me_2CO); mp 200–202 °C; $[\alpha]_{\text{D}} -43.1^\circ$ (c 0.51, MeOH); UV (MeOH) λ max (log ϵ) 201 (3.16), 219 (3.14), 263 (2.49) nm; IR (KBr) ν max 3386, 1734, 1589, 1421, 1227, 1103, 1041 cm^{-1} ; $^1\text{H NMR}$ (400 MHz, CDCl_3) δ 4.42 (1H, dd, $J_{1,2} = 4.1$ Hz, $J_{1,1-\text{OH}} = 13.2$ Hz, H-1), 5.18 (1H, m, H-2), 1.88 (1H, m, Hax-3), 2.20 (1H, m, Heq-3), 2.31 (overlap), 6.23 (1H, s, H-6), 2.67 (1H, d, $J_{7,8} = 4.4$ Hz, H-7), 5.82 (1H, dd, $J_{8,7} = 4.4, J_{8,9} = 5.6$ Hz, H-8), 5.91 (1H, d, $J_{9,8} = 5.6$ Hz, H-9), 5.21, 4.90 (each 1H, d, $J_{12a,12b} = 12.0$ Hz, H-12a, H-12b), 1.21 (3H, d, $J_{13,4} = 9.3$ z, Me-13), 1.60 (3H, s, Me-14), 1.43 (3H, s, Me-15), 3 \times OAc [2.07, 1.98, 1.91 (3H each s)], OBz [7.35–7.80 (5H, m)], ONic [9.19 (1H, s), 8.77 (1H, dd, $J = 1.5$ Hz), 8.33 (1H, dt, $J = 2.0$ Hz), 7.41 (1H, m)], OH (3.06, d, $J_{\text{OH},1} = 13.2$ Hz); $^{13}\text{C NMR}$ (100 MHz, CDCl_3) δ 77.0 (d, C-1), 72.2 (d, C-2), 31.2 (t, C-3), 33.2 (t, C-4), 89.9 (s, C-5), 74.7 (d, C-6), 53.3 (d, C-7), 73.7 (d, C-8), 73.5 (d, C-9), 51.0 (s, C-10), 81.3 (s, C-11), 63.7 (t, C-12), 17.8 (q, C-13), 24.4 (q, C-14), 30.3 (q, C-15), OAc [21.2 (3 \times Me), 170.5, 169.8, 169.6 (3 \times $-\text{CO}_2-$)], OBz [129.5, 128.3 (each 2 \times CH), 133.1 (CH), 129.9 (C), 165.2 ($-\text{CO}_2-$)], ONic [153.7, 151.1, 137.1, 123.3 (each CH), 125.9 (C), 164.6 ($-\text{CO}_2-$)]; EIMS m/z 653 ($[\text{M}]^+$, 43), 593 (17), 547 (11), 520 (16), 305 (22), 228 (38), 105 (100); HREIMS m/z 653.2167 $[\text{M}]^+$ (calcd for $\text{C}_{34}\text{H}_{39}\text{NO}_{12}$, 653.2130).

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