LIGNANS FROM WOOD OF *CALOCEDRUS FORMOSANA*

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Abstract—Hinokinin, savinin, calocedrin, matairesinol and three new lignans, 7-oxohinokinin, 4',5-dihydroxy-3,3',4-trimethoxylign-7-en-9,9'-olide and 4,4'-dihydroxy-3,3',5-trimethoxylign-7-en-9,9'-olide, were isolated from an acetone extract of the wood of *Calocedrus formosana*. The structures of new lignans were determined by spectral methods.

INTRODUCTION

The constituents of the heartwood of *Calocedrus formosana*, a member of Cupressaceae indigenous to Taiwan [1], have been extensively investigated in our laboratory [2–7]. In addition to a large quantity of terpenoid acids, such as shonanic, thujic and chaminic acids, the wood also contains tropolones, monoterpenes, naphthalene-type sesquiterpenes, diterpenoid phenols and lignans, viz. (–)-hinokinin (**1**), (–)-savinin (hibalactone, **2**), and (+)-calocedrin (**3**). On continuing a study of the chemical constituents, we have now isolated (–)-matairesinol (**4**) [8, 9] and three new lignans **5–7** from an acetone extract of the wood of *C. formosana*.

RESULTS AND DISCUSSION

Compound **5**, $[M]^+$ m/z 368, showed resonances of 20 carbons in its ^{13}C NMR spectrum. The resonances of $\delta 172.7$ (s) and 190.9 (s) are ascribed to two carbonyl carbons. The IR absorptions at 1765 and 1660 cm^{-1} indicate the presence of γ -butyrolactone and conjugated ketone moieties. By comparison of the ^1H and ^{13}C NMR data with those of hinokinin [3, 10], the structure of compound **5** is determined to be 7-oxohinokinin. The H-8 resonance appears at $\delta 4.19$ as a doublet ($J = 5.7\text{ Hz}$). On treatment with a strong base ($t\text{-BuOK}$, $t\text{-BuOH}$, THF) at room temperature for 34 hr, no epimerization took place. Thus, this lignan is considered to have the thermodynamically stable 8,8'-*trans*-configuration. The absolute configuration (8*S*,8'*R*) of (–)-7-oxohinokinin is tentatively assigned by analogy to (–)-hinokinin and other lignan constituents found in the same plant.

Compounds **6** and **7**, both of them showing $[M]^+$ at m/z 386, must be isomeric compounds because they have similar IR and UV spectra. The presence of a cinnamic acid γ -lactone moiety is inferred from IR absorptions at 1740 and 1640 cm^{-1} as well as from UV absorption at 320 nm . In the ^1H NMR spectrum, **6** displayed five aromatic protons, two phenolic hydroxyl protons and resonances at $\delta 3.86$, 3.87 and 3.95 attributable to three anisole methyl groups. The positions of hydroxyl and methoxy groups are readily deduced by comparison with the literature [10]. Thus, the structure of **6** is assigned as

(7*E*)-4',5-dihydroxy-3,3',4-trimethoxylign-7-en-9,9'-olide. On the other hand, the ^1H and ^{13}C NMR spectra of **7** ($\text{C}_{21}\text{H}_{22}\text{O}_7$) revealed that it has symmetry on a phenyl ring; there were only 18 peaks visible in the ^{13}C NMR spectrum. The three methoxy groups appeared at two positions, $\delta 55.8$ and 56.3 (two superimposed carbons). The corresponding proton signals occurred at $\delta 3.80$ (3H) and 3.85 (6H) in the ^1H NMR spectrum. The aromatic protons H-2 and H-6 had the same chemical shift of $\delta 6.77$ (s). The structure of **7** is thus (7*E*)-4,4'-dihydroxy-3,3',5-trimethoxylign-7-en-9,9'-olide.

EXPERIMENTAL

Plant material. *Calocedrus formosana* (Florin) Florin was collected in the campus of the National Taiwan University. A

voucher specimen is deposited in the herbarium of the Department of Botany. The skinned and air-dried wood (600 g) from branches 6–8 cm diam. was selected for study. After extraction $\times 3$ with Me_2CO , the combined extracts were concd *in vacuo* to give 20 g of residue. Components were sepd by CC on silica gel (230 g) and elution with hexane–EtOAc gradients. Compound 1 was eluted first, followed by 6, 7, 2, 5, 4 and 3.

7-Oxohinokinin (5). $\text{C}_{20}\text{H}_{16}\text{O}_7$, needle-like crystals (from CHCl_3 –MeOH), mp 109.5–111°, $[\alpha]_D^{25} + 10^\circ$ (CHCl_3 ; c 0.82). $\lambda_{\text{max}}^{\text{CHCl}_3}$ nm (ϵ): 313 (7 570), 281 (8 620), 240 (8 250). IR $\nu_{\text{max}}^{\text{neat}}$ cm^{-1} : 1765, 1660. EIMS m/z (rel. int.): 368 $[\text{M}]^+$ (13), 260 (5), 242 (6), 233 (9), 227 (5), 201 (9), 178 (10), 160 (100), 149 (68), 135 (33), 131 (69), 121 (40). $^1\text{H NMR}$ (CDCl_3 , 300 MHz): δ 2.75 (1H, *dd*, $J = 13.6, 8.2$ Hz, H-7'), 2.79 (1H, *dd*, $J = 13.6, 7.8$ Hz, H-7'), 3.31 (1H, *m*), 4.12 (1H, *dd*, $J = 9.0, 7.0$ Hz, H-9'), 4.19 (1H, *d*, $J = 5.7$ Hz, H-8), 4.51 (1H, *dd*, $J = 9.0, 5.3$ Hz, H-9'), 5.93 (2H, *s*), 6.05 (2H, *s*), 6.61 (1H, *dd*, $J = 7.8$ Hz, 1.2 Hz, H-6'), 6.63 (1H, *d*, $J = 1.2$ Hz, H-2'), 6.72 (1H, *d*, $J = 7.8$ Hz, H-5'), 6.82 (1H, *d*, $J = 8.1$ Hz, H-5'), 7.30 (1H, *d*, $J = 1.7$ Hz, H-2), 7.42 (1H, *dd*, $J = 8.1, 1.7$ Hz, H-6). $^{13}\text{C NMR}$ (CDCl_3 , 75 MHz, DEPT): δ 38.1 (*t*, C-7'), 41.4 (*d*, C-8'), 53.6 (*d*, C-8), 71.9 (*t*, C-9'), 101.1 (*t*, OCH_2O), 102.1 (*t*, OCH_2O), 107.9 (*d*, C-2), 108.5 (*d*, C-2'), 108.6 (*d*, C-5), 109.1 (*d*, C-5'), 122.0 (*d*, C-6), 126.2 (*d*, C-6'), 130.1 (*s*, C-1), 131.1 (*s*, C-1'), 146.6 (*s*, C-4'), 148.1 (*s*, C-3'), 148.3 (*s*, C-3), 152.6 (*s*, C-4), 172.7 (*s*, C-9), 190.9 (*s*, C-7).

(7E)-4',5-Dihydroxy-3,3',5-trimethoxylign-7-en-9,9'-olide (6). $\text{C}_{21}\text{H}_{22}\text{O}_7$, needle-like crystals (obtained by HPLC), mp 130–131°, $[\alpha]_D^{25} - 94^\circ$ (CHCl_3 ; c 0.15). UV λ_{max} nm (ϵ): 322 (21 620), 299 (17 300), 280 (21 700), 238 (27 410). IR ν_{max} cm^{-1} : 3440, 1735, 1640, 1600, 1510. MS m/z (rel. int.): 386 $[\text{M}]^+$ (8), 249 (23), 205 (3), 193 (7), 189 (7), 161 (12), 137 (100), 122 (23), 105 (6). $^1\text{H NMR}$ (CDCl_3): δ 2.57 (1H, *dd*, $J = 14.1, 10.2$ Hz, H-7'), 3.02 (1H, *dd*, $J = 14.1, 3.9$ Hz, H-7'), 3.82 (1H, *m*, H-8'), 3.86 (3H, *s*, OMe), 3.87 (3H, *s*, OMe), 3.95 (3H, *s*, OMe), 4.25 (2H, *m*, H-9'), 5.50 (1H, *s*, OH), 5.86 (1H, *s*, OH), 6.61 (1H, *d*, $J = 1.8$ Hz, H-6), 6.69 (1H, *br d*, $J = 8.4$ Hz, H-6'), 6.70 (1H, *br s*, H-2'), 6.83 (1H, *d*, $J = 8.4$ Hz, H-5'), 6.95 (1H, *d*, $J = 1.8$ Hz, H-2), 7.45 (1H, *d*, $J = 1.8$ Hz, H-7). $^{13}\text{C NMR}$ (CDCl_3 , DEPT) δ 37.6 (*t*, C-7'), 40.1 (*d*, C-8'), 55.9 (*q*, OMe), 56.0 (*q*, OMe), 61.1 (*q*, OMe), 70.0 (*t*, C-9'), 107.6 (*d*, C-2), 108.7 (*d*, C-6), 111.4 (*d*, C-2'), 114.5 (*d*, C-5'), 121.5

(*d*, C-6'), 127.7 (*s*, C-1), 129.8 (*s*, C-1' and C-8), 137.0 (*s*, C-4), 137.1 (*d*, C-7), 144.6 (*s*, C-4'), 146.7 (*s*, C-3'), 149.5 (*s*, C-5), 152.3 (*s*, C-3), 172.5 (*s*, C-9).

(7E)-4,4'-Dihydroxy-3,3',5-trimethoxylign-7-en-9,9'-olide (7). $\text{C}_{21}\text{H}_{22}\text{O}_7$, needle-like crystals (obtained by HPLC), mp 112–113°, $[\alpha]_D^{25} - 16.3^\circ$ (CHCl_3 ; c 0.3). UV λ_{max} nm (ϵ): 320 (17 000), 299 (16 090), 278 (11 550), 238 (11 300). IR ν_{max} cm^{-1} : 3400, 1740, 1640, 1580, 1500. MS m/z (rel. int.): 386 $[\text{M}]^+$ (7), 249 (75), 221 (5), 205 (3), 193 (20), 189 (25), 161 (12), 137 (100), 122 (23), 105 (11). $^1\text{H NMR}$ (CDCl_3): δ 2.58 (1H, *dd*, $J = 14.4, 10.2$ Hz, H-7'), 3.03 (1H, *dd*, $J = 14.4, 4.2$ Hz, H-7'), 3.80 (3H, *s*, OMe), 3.82 (1H, *m*, H-8), 3.85 (6H, *s*, two OMe), 4.22 (2H, *m*, H-9'), 5.75 (1H, *br s*, OH), 6.06 (1H, *br s*, OH), 6.58 (1H, *d*, $J = 0.9$ Hz, H-2'), 6.62 (1H, *dd*, $J = 8.1, 0.9$ Hz, H-6'), 6.77 (2H, *s*, H-2 and H-6), 6.78 (1H, *d*, $J = 8.1$ Hz, H-5'), 7.40 (1H, *d*, $J = 1.8$ Hz, H-7). $^{13}\text{C NMR}$ (CDCl_3 , DEPT): δ 37.2 (*t*, C-7'), 39.3 (*d*, C-8'), 55.8 (*q*, OMe), 56.3 (*q*, two OMe), 69.7 (*t*, C-9'), 107.4 (*d*, C-2 and C-6), 111.5 (*d*, C-2'), 114.5 (*d*, C-5'), 121.0 (*d*, C-6'), 125.2 (*s*, C-8), 125.6 (*s*, C-1), 129.4 (*s*, C-1'), 137.0 (*s*, C-4), 137.7 (*d*, C-7), 144.5 (*s*, C-4'), 146.6 (*s*, C-3'), 147.2 (*s*, C-3 and C-5), 172.7 (*s*, C-9).

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