Phytochemistry, Vol. 20, No. 7, pp. 1591–1595, 1981.
Printed in Great Britain.

0031-9422/81/071591-05 $02.00/0

IRIDOID AND OTHER CONSTITUENTS OF *CANTHIUM SUBCORDATUM**

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(*Received* 19 *July* 1980)

Key Word Index—*Canthium subcordatum*; Rubiaceae; shanzhisin methyl ester gentiobioside; new iridoid; shanzhiside methyl ester; indole; D-mannitol; orcinol monomethyl ether; roseoside; scopoletin.

Abstract—The main constituent of the stem bark of *Canthium subcordatum* was found to be shanzhiside methyl ester, an iridoid recently described for two *Mussaenda* species; it is accompanied by the new iridoid shanzhisin methyl ester gentiobioside. No alkaloids were detected.

INTRODUCTION

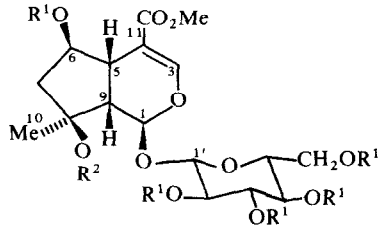
Canthium subcordatum is a tree which grows in central and western Africa and reaches a height of more than 10 m [1]. Its roots, leaves and stem bark are used for medicinal purposes [1]. It has recently been reported that alcoholic extracts of the stem bark have potential antidiabetic properties [2]. Earlier investigators of the chemical constituents of the stem bark of *C. glabriflorum* (syn. *C. subcordatum*) described the isolation of calmatambin, a water-soluble glucoside with empirical formula $C_{19}H_{28}O_{13}\cdot 2H_2O$ [3,4], whose structure was not determined. This paper reports the isolation and structure elucidation of two major and five minor constituents from the stem bark.

RESULTS AND DISCUSSION

Isolation

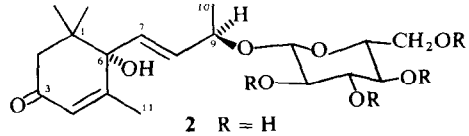
Chromatography of the methanolic extract of the dried stem bark over Sephadex LH-20 gave fractions A1 to A5. A1 mainly contained polymeric materials and was not further investigated. Rechromatography of A2 (main fraction) over silica gel yielded, as the main component, a glycoside, which crystallized to give **1** (7% of total extract), a compound identical with shanzhiside methyl ester, an iridoid glycoside recently found in two *Mussaenda* species [5]. **1** could be isolated more easily and directly by adsorption onto charcoal of the water-soluble fraction of the methanolic extract.

Upon concentration of fractions A2 and A3 another major compound (2%) was identified as D-mannitol on the basis of its physico-chemical properties and by conversion into its diisopropylidene derivative. Fraction A4 contained two compounds (0.6 and 0.8%) with similar R_f values on silica gel but which could be easily separated on aluminium oxide. From the spectral data and by comparison with authentic substances they were identified as orcinol monomethyl ether and scopoletin. Fraction A5 consisted mainly of indole (0.5%).



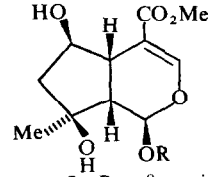
1 $R^1 = R^2 = H$
4 $R^1 = Ac$, $R^2 = H$
5 $R^1 = R^2 = Ac$

The water-soluble constituents of the methanolic extracts of the plant material were adsorbed on charcoal and then eluted with ethanol [6]. This method efficiently separated sugars from glycosides. Subsequent chromatography of the ethanolic solution over silica gel gave, in addition to other fractions, **1** in high purity. The fraction, which was eluted immediately prior to **1** appeared as a single spot in different TLC systems, but ^{1}H NMR measurements indicated a complex mixture. Therefore the whole fraction was acetylated and rechromatographed to yield, as the major product, a tetraacetyl derivative of the glycoside roseoside **2** (0.1%) [7–9].



2 R = H
8 R = Ac

A slower running fraction from the column gave small amounts of the new iridoid **3** (0.05%), which was purified by HPLC. The structure determination and synthesis of this hitherto unknown shanzhisin methyl ester gentiobioside are described elsewhere [10].



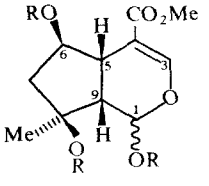
3 R = β-gentiobiosyl

*Part 5 in the series "Constituents of West African Medicinal Plants". For Part 4 see ref. [16].

All attempts to detect alkaloids were unsuccessful. Only trace amounts of basic materials could be separated from the methanolic extracts and the usual alkaloid-indicating colour tests on thin layer chromatograms of this basic fraction did not show any positive reaction.

Structure determinations

1 has mp 116–124°, $[\alpha]_D^{20}$ −115° (MeOH, $c = 0.9$) and molecular formula $C_{17}H_{26}O_{11}$. Treatment with acetic acid anhydride–pyridine converts **1** into the pentaacetate **4**, while under more vigorous conditions the hexaacetate **5** is isolated. Enzymic cleavage of **1** with β-glucosidase gave D-glucose and the ether-soluble aglycone **6** (M^+ 244.2437 = $C_{11}H_{16}O_6$). HPLC and ^{1}H NMR showed that **6** exists in solution as an equilibrium mixture of two tautomeric (anomeric) forms.

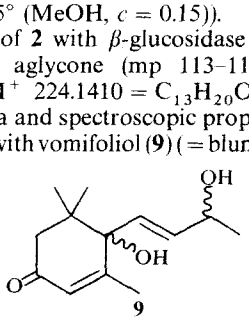


6 R = H
7 R = Ac

Acetylation using standard procedures yielded only one triacetate for which structure **7** is proposed from the spectral data. The facile acetylation of the tertiary hydroxyl in **6** could possibly be due to a transacylating effect of the *peri*- OH group at C-1. All spectral data and, in particular, extensive ^{1}H NMR irradiation studies are in complete agreement with the given structures, as are the ^{13}CNMR data for **1**. Thus the main constituent **1** of *Canthium subcordatum* is shanzhiside methyl ester, whose structure and absolute configuration have recently been deduced by Inouye [5]. Comparison of **4** with authentic shanzhiside methyl ester pentaacetate, kindly supplied by Prof. Dr. H. Inouye, Kyoto, clearly demonstrated the identity of the substances. Since shanzhiside methyl ester and its derivatives exhibit physico-chemical and chemical properties similar to those described earlier for calmatambin and its derivatives [3, 4], we suppose that these substances are identical.

2 came from the column in an intermediate fraction together with several other substances which all showed similar chromatographic behaviour. Therefore, the whole fraction was acetylated prior to further separation and **2** was isolated as its tetraacetate **8**. Deacetylation with MeONa/MeOH led to the recovery of **2** as a colourless oil ($[\alpha]_D^{20}$ +105° (MeOH, $c = 0.15$)).

Cleavage of **2** with β-glucosidase yielded, besides D-glucose, an aglycone (mp 113–115°; $[\alpha]_{578}^{20}$ +218° (MeOH); M^+ 224.1410 = $C_{13}H_{20}O_3$), which, from its physical data and spectroscopic properties, was found to be identical with vomifoliol (**9**) (= blumenol A), [7, 11–15].



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From further structural work, **2** was deduced to be roseoside, a terpenoid glucoside first found in the leaves of *Vinca rosea* [7] and later in the leaves of *Betula alba*, as well as in the fruits of *Cydonia oblonga* [8]. Very recently roseoside was also isolated from the leaves and stems of *Martynia louisiana* [9].

EXPERIMENTAL

General procedures. All mps are uncorr. Unless otherwise stated, ^{1}H NMR were recorded at 250 MHz, ^{13}C NMR at 62.8 MHz; chemical shifts are given in δ values (ppm) with TMS as internal standard and in $CDCl_3$, unless otherwise stated. Mass spectra were run at 70 eV; IR spectra in $CHCl_3$; UV spectra in MeOH. HPLC was carried out with a 30 cm column with Nucleosil 10-C_{18} (Macherey-Nagel) and MeOH–H_2O (1:4) as the eluent; rate of flow 1.5 ml/min; detection by UV at 254 nm. For column chromatography we used Si gel 60 (Macherey-Nagel, < 200 mesh). TLC was performed on plates coated (0.25 mm) with Si gel (Merck), with fluorescent indicator.

Plant material. The bark of *Canthium subcordatum* DC. (syn. *Canthium glabriflorum* Hiern) was collected near Bepong (eastern Ghana, mountainous forest area, altitude > 600 m) on 14 May 1978 and identified by Mr. A. A. Enti, Legon; a bark specimen was reinspected by Prof. Vogellehner, Botanical Institute, University of Freiburg, and is deposited in our collection under No. 7801.

Isolation procedure. Powdered dry stem bark (5.5 kg) (air-dried immediately after collection) was extracted with 15 l. hot MeOH. The soln was evapd yielding *ca* 380 g residue.

Separation via Sephadex LH 20. The residue (10 × 10 g) was separated on a column (φ 6.5 cm) containing 500 g Sephadex LH 20, with MeOH as the eluant, into 90 fractions (15 ml each), which were then combined (TLC control) as follows and evapd: No. 1 to 30 = A1 (11 g); 31 to 42 = A2 (51 g); 43 to 61 = A3 (18 g); 62 to 79 = A4 (10 g); 80 to 90 = A5 (8 g).

D-*Mannitol.* Upon standing the conc. fractions A2 and A3 gave mannitol (*ca* 2.5 g), which after two recrystallizations from MeOH had mp 166/168°; $[\alpha]_D^{20}$ −4.0° (H_2O, $c = 1.0$); isopropylidene derivative, mp 68°; $[\alpha]_D^{20}$ +12° (EtOH, $c = 1.0$), identical with an authentic sample.

A4 (2 × 2.5 g) was chromatographed over 200 g Si gel column (φ 2.5 cm) in $CHCl_3$–MeOH (19:1) into 60 fractions (20 ml each). Fractions 12–28 gave 1.8 g residue upon evapn, of which 1.2 g was rechromatographed over 100 g Al_2O_3 (Woelm, neutral act. III; column φ 1.5 cm) into 50 fractions B (25 ml each) with 500 ml $CHCl_3$–MeOH (4:1), 250 ml MeOH and 500 ml MeOH–H_2O (4:1).

Orcinol monomethyl ether. Upon concn combined fractions B1–B19 gave 270 mg colourless crystals, mp 60–62.5°; M^+ 138.0681 = $C_8H_{10}O_2$, identical with an authentic sample prepared by partial methylation of orcinol.

Scopoletin. Fractions B34–B50 were combined and evapd. Crystallization from MeOH yielded 350 mg pale yellow needles, mp 202–205°; M^+ 192.0424 = $C_{10}H_8O_4$. Comparison with authentic scopoletin and isoscopoletin (Roth, Karlsruhe) identified the compound as scopoletin.

Indole. Rechromatography of 250 mg of A5 upon Si gel (column φ 1.5 cm) using $CHCl_3$–MeOH (4:1) gave 50 fractions (8 ml each). Upon concentration fractions 19–23 yielded 15 mg pale crystals, mp 50–51°; M^+ 117.0576 = C_8H_7N, identical with indole.

Separation via charcoal. The residue (100 g) of the methanolic extract was stirred with 1 l. H_2O for 24 hr. Insoluble material (*ca* 36 g) was removed by filtration and the aq. soln extracted with EtOAc (5 × 200 ml). Charcoal (200 g) was added to the aq. phase and the mixture stirred for 36 hr. The charcoal was separated and eluted with 500 ml EtOH–H_2O (1:1) and then 2 l. EtOH. Evapn of the combined extracts gave 8 g residue (= iridoid fraction).

Shanzhiside methyl ester (**1**). 2.5 g of the iridoid fraction was chromatographed over 250 g Si gel (column φ 2.5 cm) into 350 fractions C (20 ml each) using successively: 1.5 l. $CHCl_3$–MeOH

(4:1), 0.5 l. $CHCl_3$–MeOH (7:3), 1 l. $CHCl_3$–MeOH (3:2) and 1 l. $CHCl_3$–MeOH (1:1). Concn of combined fractions C69–C110 gave 1.9 g colourless, TLC-pure material, mp 116–124° (after drying in high vacuum); $[\alpha]_D^{20}$ −115° (MeOH, c = 0.9); $C_{17}H_{26}O_{12}$ (406.4) (Found: C, 50.09; H, 6.48. Calc. C, 50.25; H, 6.40%); MS (Varian-MAT 312, FD-technique): m/z 406 (M^+); UV λ_{max}^{EtOH} nm (log ε): 234 (3.95); IR ν_{max}^{KBr} cm^{-1}: 3400, 1691, 1638; ^1H NMR: see Table 1; ^{13}C NMR; δ 169.80 (*s*, C-11), 152.89 (*d*, C-3), 111.40 (*s*, C-4), 99.86 (*d*, C-1′)*, 94.94 (*d*, C-1),* 79.09 (*s*, C-8), 78.28 (*d*, C-3′), 77.96 (*d*), 77.50 (*d*, C-6, C-5′), 74.63 (*d*, C-2′), 71.64 (*d*, C-4′), 62.86 (*t*, C-6′), 51.90 (*t*, C-7)*, 51.74 (*t*, C-9), 49.22 (*q*, C-12), 41.48 (*d*, C-5),* 24.66 (*q*, C-10) (*: assignment by single-off-resonance).

Pentaacetylshanzhiside methyl ester (**4**) was prepared by acetylation with Ac_2O/pyridine at room temp. for 12 hr: colourless crystals, mp 181°; $[\alpha]_D^{20}$ −110° ($CHCl_3$, c = 1.1); $C_{27}H_{36}O_{16}$ (616.6) (Found: C, 52.49; H, 5.79. Calc. C, 52.60; H, 5.89%); UV λ_{max}^{EtOH} nm (log ε): 236 (4.03); IR ν_{max} cm^{-1}: 3600, 1758, 1640, 1602; ^1H NMR: see Table 1; MS: highest observable ion at m/z 331 (oxonium ion of tetraacetylhexose).

Hexaacetylshanzhiside methyl ester (**5**) was prepared by acetylation with Ac_2O in BF_3–Et_2O: colourless crystals, mp 182/184°; $[\alpha]_D^{20}$ −139° ($CHCl_3$, c = 0.9): UV λ_{max}^{EtOH} nm (log ε): 236 (4.01); IR ν_{max} cm^{-1}: 1758, 1639, 1603; ^1H NMR: see Table 1; MS: highest observable ion at m/z 331 (oxonium ion of tetraacetylhexose).

Cleavage of **1**. With dil HCl: 40 mg **1** was dissolved in 2 ml 2 N HCl and stirred at room temp. After 6 hr the reaction mixture was evapd and chromatographed using TLC with $CHCl_3$–MeOH (3:2). From the zone having R_f 0.4 the main product was eluted with H_2O–MeOH as 8 mg colourless, amorphous D-glucose: melting beginning at 143°; final value of optical rotation $[\alpha]_D^{20}$ +52° (H_2O, c = 0.8). The identity of the isolated substance was determined by conversion into its peracetyl derivative, mp 111°; $[\alpha]_D^{20}$ +101° ($CHCl_3$, c = 0.5); this was shown to be identical with authentic pentaacetyl-α-D-glucopyranose.

With β-glucosidase-aglycone **6**: 20 mg β-glucosidase were added to a soln of 40 mg **1** in 2 ml water. After standing for 2 days at room temp. the mixture was extracted for 24 hr with Et_2O using a liquid/liquid extractor. The aq. layer was worked-up as described above: the ethereal extract after drying and evapn yielded 12 mg **6** as colourless crystals, mp 138–142°; $[\alpha]_D^{20}$ −46° (EtOH, c = 1.2); UV λ_{max}^{EtOH} nm (log ε): 242 (3.81); IR ν_{max} cm^{-1}: 3600, 1690, 1636; ^1H NMR: see Table 1; MS (Varian MAT 312): m/z (int. > 10%) = 244.2437 $C_{11}H_{16}O_6$ (5, M^+) 226 (24), 208 (11), 198 (11), 182 (15), 179 (13), 176 (14), 168 (14), 165 (18), 158 (20), 153 (16), 151 (16), 148 (31), 141 (11), 140 (59), 139 (76), 137 (16), 126 (27), 125 (53), 124 (12), 123 (16), 109 (18), 108 (16), 102 (15), 98 (15), 97 (38), 96 (11), 95 (17), 91 (10), 87 (34), 81 (18), 73 (34), 71 (14), 70 (11), 69 (18), 68 (10), 61 (10), 60 (23), 57 (12), 55 (18), 53 (11), 43 (100), 41 (34). The acetate **7** melted at 79–82°, $[\alpha]_D^{20}$ −14° ($CHCl_3$, c = 0.7); UV λ_{max}^{MeOH} nm (log ε): 240 (3.80); IR ν_{max} cm^{-1}: 1758, 1640, 1607; ^1H NMR: see Table 1; MS: highest observable ion at m/z 339 (M − OMe).

Shanzhisin methyl ester gentiobioside (**3**). Combined fractions C125–C152 were evapd to dryness (50 mg), redissolved in 2 ml MeOH and separated into five fractions (t_R: 1–3, 6, 10, 23, 30) with the HPLC system by repeated injections (25 μl each) using MeOH–water (1:4). Upon evapn the fraction with t_R 23 gave 5 mg **3** as colourless needles, dec. > 150° (after drying in vacuo); $[\alpha]_D^{20}$ −56° (MeOH, c = 0.24); MS (Varian MAT 312, FD technique): m/z 591 $[M + Na]^+$; UV λ_{max}^{MeOH} nm (log ε): 232 (3.94); IR ν_{max}^{KBr} cm^{-1} 3400, 1692, 1635; ^1H NMR (in CD_3OD); δ 7.41 (1 H, *d*, J ≈ 1 Hz, H-3), 5.54 (1 H, *d*, J = 3 Hz, H-1), 4.8–4.93 (solvent), 4.64 (1 H, *d*, J = 8 Hz, H-1′), 4.38 (1 H, *d*, J = 8 Hz, H-1″), 4.18 (1 H, *dd*, J_1 = 12, J_2 = 2 Hz, H-6′), 4.05 (1 H, *ddd*, $J_1 \approx J_2 \approx 6$, $J_3 \sim 4$ Hz, H-6), 3.88 (1 H, *d br*, J = 12 Hz, H-6″), 3.73 (3 H, *s*, OMe), 3.66 (1 H, *m*), 3.50 (1 H, *dd*, $J_1 \approx J_2 \approx 8$ Hz), 3.44–3.12 (signals, partly hidden by solvent), 3.02 (1 H, *dd*, J_1 = 9.5, $J_2 \sim 4$ Hz, H-5), 2.58 (1 H, *dd*, J_1 = 9.5, J_2 = 3 Hz), 2.04 (1 H, *dd*, J_1 = 13.5, J_2 = 6 Hz, H-7′), 1.82 (1 H, *dd*, J_1 = 13.5, J_2 = 6 Hz, H-7″), 1.28 (3 H, *s*, C-Me); ^{13}C NMR (in CD_3OD, noise-decoupled): δ 170.05 (C=O), 153.15 (C-3), 111.8 (C-4), 105.35 (C-1″), 100.22 (C-1′), 95.47 (C-1), 79.43 (C-8), 77.57 or 77.79 (C-6), 78.13, 77.79 or 77.57, 76.18, 75.35, 74.82, 71.88, 70.30 (C from sugar), 62.97 (C-6″), 52.06 and 51.59 (C-9 and C-7), 41.96 (C-5), 25.03 (C-10); signals of two more C (from sugar part) and OMe may be hidden in noise or by solvent.

Nonaacetylshanzhisin methyl ester gentiobioside **5**, colourless needles from MeOH, mp 163–166°; $[\alpha]_D^{20}$ −54° ($CHCl_3$, c = 0.1); UV λ_{max}^{MeOH} (log ε): 228 (3.91); ^1H NMR: δ 7.42 (1 H, *d*, $J \approx 2$ Hz, H-3), 6.21 (1 H, *s br*., H-1), 5.60 (1 H, *dd*, $J_1 \approx J_2 \approx 9$ Hz), 5.37 (1 H, *d br*, $J \sim 4$ Hz, H-6), 5.23 (1 H, *d*, J = 8 Hz, H-1″), 5.21 (1 H, *dd*, $J_1 \approx J_2 \approx 9$ Hz), 5.02 (1 H, *dd*, $J_1 \sim J_2 \sim 9$ Hz), 5.00 (1 H, *dd*, $J_1 \sim J_2 \sim 9$ Hz), 4.96 (1 H, *dd*, $J_1 \sim J_2 \sim 9$ Hz), 4.82 (1 H, *d*, J = 8 Hz, H-1′), 4.81 (1 H, *dd*, $J_1 \sim J_2 \sim 9$ Hz), 4.22 (1 H, *dd*, J_1 = 12, $J_2 \approx 5$ Hz), 4.11 (1 H, *dd*, J_1 = 12, $J_2 \sim 2$ Hz), 4.07 (1 H, *m*), 3.88 (1 H, *dd*, J_1 = 13, J_2 = 8 Hz), 3.76–3.6 (1–2 H, *m*), 3.69 (3 H, *s*), 3.21 (1 H, *d br*, J = 9 Hz, H-5 or H-9), 3.11 (1 H, *d br*, J = 9 Hz, H-9 or H-5), 2.33 (1 H, *d br*, $J \approx 16$ Hz, H-7[1] or H-7[2]), 2.08 (3 H, *s*), 2.05 (3 H, *s*), 2.01 (6 H, *s*), 1.99 (3 H, *s*), 1.97 (3 H, *s*), 1.95 (3 H, *s*), 1.92 (3 H, *s*), 1.83 (3 H, *s*) (9 × O—CO—Me); 1.50 (3 H, *s*, C—Me); MS: highest observable ion at m/z 619, base peak at m/z 331.

Cleavage of **3**. With dilute HCl: 2 mg **3** was dissolved in 1 ml 2 N HCl and worked-up as described for the cleavage of **1**. The only product of hydrolysis was acetylated and identified as pentaacetyl-D-glucopyranose. With β-glucosidase: 2 mg **3** was hydrolysed with 2 mg β-glucosidase and worked-up as described for the cleavage of **1**. The ether-soluble product was found to be identical with **6**.

Tetraacetylroseoside (**8**). Combined fractions C54–C69 (total = 42 mg from chromatography of three times 2.5 g iridoid fraction), which did not show any OCOMe signals in the ^1H NMR spectrum, were acetylated using the standard procedure and after evapn rechromatographed over 10 g Si gel (column-ϕ 1 cm) with $CHCl_3$–MeOH (9:1) into 50 fractions D (5 ml each). Upon evapn fractions D15–D26 gave 15 mg **8** as a viscous non-crystallizable oil: $[\alpha]_D^{20}$ +70° ($CHCl_3$, c = 1.4), UV λ_{max}^{MeOH} nm (log ε): 234 (4.1); IR ν_{max}^{KBr} cm^{-1}: 3395 (OH), 1755 (C=O), 1645 (C=O); ^1H NMR: see Table 2; ^{13}C NMR: δ 197.55 (*s*, C-3), 170.74 (*s*), 170.41 (*s*), 169.53 (*s*), 169.40 (*s*) (4 × C=O of acetyl), 162.19 (*s*, C-1), 132.61 (*d*), 131.92 (*d*), 127.26 (*d*) (C-2, C-7, C-8), 98.54 (*d*, C-1′), 79.17 (*s*, C-6), 74.84 (*d*), 73.09 (*d*), 72.87 (*d*), 71.76 (*d*), 69.73 (*d*) (C-2′ to C-5′, C-9), 62.22 (*t*, C-6′), 49.76 (*t*, C-4), 41.16 (*s*, C-5), 24.25 (*q*), 22.92 (*q*), 21.99 (*q*), 20.68 (*q*), 20.59 (*q*), 18.78 (*q*) (at least 6 Me); MS: highest observable ion at m/z 331.

Roseoside **2**. One drop of NaOMe–MeOH was added to a soln of 15 mg **8** in 1 ml MeOH. After 2 hr at room temp. the mixture was evapd *in vacuo* and chromatographed over 10 g Si gel with $CHCl_3$–MeOH (17:3) to yield 7 mg **2** as a pure, viscous oil, $[\alpha]_D^{20}$ +105° (MeOH, c = 0.15); UV λ_{max}^{MeOH} nm (log ε): 235 (4.1); IR ν_{max}^{KBr} cm^{-1}: 3390, 1647; ^1H NMR (in CD_3OD): see Table 2.

Cleavage of **2** *with β-glucosidase.* β-Glucosidase (10 mg) was added to a soln of 5 mg **2** in 2 ml water. After 16 hr at room temp. the reaction mixture was evapd to dryness, the residue dissolved in MeOH and chromatographed upon Si gel plates with $CHCl_3$–MeOH (9:1). A product (ca 2 mg) extracted from the zone R_f 0.05 was identical with pentaacetyl-α-D-glucopyranose after acetylation using the standard procedure. The zone with R_f 0.3 yielded 1.2 mg of colourless, amorphous **9**, mp 113–115° (lit. [11]: mp 115°); $[\alpha]_{578}^{20}$ +218° (MeOH, c = 0.12) (lit. [11]: $[\alpha]_{578}$ +233° ($CHCl_3$, c = 1)); UV λ_{max}^{MeOH} nm (log ε): 236 (4.03); IR ν_{max} cm^{-1}: 3370 (OH), 1668 (C=O); ^1H NMR (in CD_3OD):

Table 1. ^{1}H NMR data of iridoid derivatives (250 MHz)

Proton	**1** (CD_3OD)	**4**	**5**	**6** (CD_3OD)* (mixture of anomers I and II)		**7**
				I	II	
H-1	5.57 (*d*, $J = 3$)	5.45 (*d*, $J = 3$)	5.89 (*d*, $J = 2$)	5.45 (*d*, $J_{1-9} = 2$)	5.20 (*d*, $J_{1-9} = 3$)	6.68 (*d*, $J = 2$)
H-3	7.41 (*d*, $J = 1$)	7.39 (*d*, $J = 1$)	7.39 (*d*, $J = 1.5$)	7.44 (*s br*)	7.44 (*s br*)	7.41 (*d*, $J = 1.5$)
H-5	2.99 (*m*)*, $J_{5-3} = 1$, $J_{5-6} = 3.5$, $J_{5-9} = 10$	3.20 (*m*)	3.10 (*m*)	3.13–3.0 (*m*)	3.13–3.0 (*m*)	3.21 (*m*)
H-6	4.03 (*m*)* $J_{6-5} = 3.5$, $J_{6-7^1} = 6$, $J_{6-7^2} = 6.5$	5.21 (*m*)	5.29 (*m*)	4.24 (*ddd*, $J_{6-5} \approx J_{6-7^1} \approx 2$, $J_{6-7^2} = 6$	4.00 (*ddd*, $J_{6-5} \sim 3$, $J_{6-7^1} \sim J_{6-7^2} \sim 4.5$	5.32 (*m*)
H-7^1	1.83 (*dd*, $J = 13$, $J = 6$)	†	†	1.67 (*ddd*, $J_{gem} = 9$ Hz, $J_{7^1-6} = 2$, $J_{7^1-9} = 1$	1.80 (*dd*, *bd*, $J_{gem} = 9$, $J_{7^1-6} = 4$	2.04 (*dd*, $J_1 = 15$, $J_2 = 5$)
H-7^2	2.01 (*dd*, $J_1 = 13$, $J_2 = 6.5$)	†	2.31 (*d br*) ($J_1 = 15.5$)	2.30 (*dd*, $J_{gem} = 9$, $J_{7^2-6} = 6$)	2.03 (*dd*, $J_{gem} = 9$, $J_{7^2-6} = 4.5$)	2.32 (*d br*, $J_1 = 15$)
H-9	2.61 (*dd*, $J_1 = 10$, $J_2 = 3$)	2.71 (*dd*, $J_1 = 10$, $J_2 = 3$)	3.04 (*dd*, $J_1 = 10$, $J_2 = 2$)	2.15 (*ddd*, $J_{9-1} = 2$, $J_{9-5} = 5.5$, $J_{9-7^1} = 1$)	2.39 (*dd bd*, $J_{9-1} = 3$, $J_{9-5} = 6$)	2.97 (*dd*, $J_1 = 9$, $J_2 = 2$)
C–Me	1.26 (3 H, *s*)	1.34 (3 H, *s*)	1.48 (3 H, *s*)	1.27 or 1.37 (*s*)	1.37 or 1.27 (*s*)	1.51 (3 H, *s*)
O–Me	3.72 (3 H, *s*)	3.72 (3 H, *s*)	3.68 (3 H, *s*)	3.73 or 3.75 (*s*)	3.75 or 3.73 (*s*)	3.72 (3 H, *s*)
H-1′	4.61 (*d*, $J = 8$)	4.84 (*d*, $J = 8$)	4.84 (*d*, $J = 8$)			
H-2′	†	4.96 (*dd*, $J_1 \approx J_2 \approx 9$)	4.97 (*dd*, $J_1 \approx J_2 \approx 9.5$)			
H-3′	†	5.20 (*dd*, $J_1 \approx J_2 \approx 9$)	5.21 (*dd*, $J_1 \approx J_2 \approx 9.5$)			
H-4′	†	5.08 (*dd*, $J_1 \approx J_2 \approx 9$)	5.09 (*dd*, $J_1 \approx J_2 \approx 9$)			
H-5′	†	3.72 (*m*)	3.75 (*m*)			
H-6$^{1'}$	3.64 (*dd*, $J_1 = 12$, $J_2 = 6$)	4.72 (*dd*, $J_1 = 12.5$, $J_2 = 4$)	4.30 (*dd*, $J_1 = 12.5$, $J_2 = 5$)			
H-6$^{2'}$	3.91 (*dd*, $J_1 = 12$, $J_2 = 2$)	4.13 (*dd*, $J_1 = 12.5$, $J_2 = 2$)	4.12 (*dd*, $J_1 = 12.5$, $J_2 = 2.5$)			
O–CO–Me	—	1.89–2.09	1.89–2.09			1.98–2.06
		5 × (3 H, *s*)	6 × (3 H, *s*)			3 × (3 H, *s*)

*Correlated by irradiation experiments.
†Hidden under signals of solvents or acetyl groups.
Coupling constants in hertz.

Table 2. ^{1}H NMR data of **2** (in CD_3OD) and **8** (in $CDCl_3$)

2	**8**	Assignment
5.98 (1 H, *d br*, $J = 15$)	5.72 (1 H, *d*, $J = 15$)	H-7
5.87 (1 H, *s br*)	5.91 (1 H, *s br*)	H-4
5.73 (1 H, *dd*, $J_1 = 15$, $J_2 = 7$)	5.63 (1 H, *dd*, $J_1 = 15$, $J_2 = 6$)	H-8
4.87 (solvent)		
4.53 (1 H, *qd*, $J_1 \approx J_2 \approx 6.5$)	4.35 (1 H, *qd*, $J_1 \approx J_2 \approx 6$)	H-9
4.28 (1 H, *d*, $J = 7.5$)	4.48 (1 H, *d*, $J = 8$)	H-1′
3.84 (1 H, *dd*, $J_1 = 12$, $J_2 = 2.5$)	4.11 (1 H, *dd*, $J_1 = 12$, $J_2 = 3$)	H-6′
3.63 (1 H, *dd*, $J_1 = 12$, $J_2 = 6$)	4.23 (1 H, *dd*, $J_1 = 12$, $J_2 = 5$)	H-6′
3.3 (solvent)		
3.3–3.1 (4–5 H, *m*)	5.14 (1 H, *dd*, $J_1 \approx J_2 \approx 8.5$)	H-2′
	5.05 (1 H, *dd*, $J_1 \approx J_2 \approx 9$)	H-3′
	4.96 (1 H, *dd*, $J_1 \approx J_2 \approx 8.5$)	H-4′
	3.59 (1 H, *ddd*, $J_1 \sim 9$, $J_2 = 5$, $J_3 = 3$)	H-5′
2.62 (1 H, *d*, *br*, $J = 17$)	2.42 (1 H, *d br*, $J = 17$)	H-2^1
2.17 (1 H, *d br*, $J = 17$)	2.25 (1 H, *d br*, $J = 17$)	H-2^2
1.95 (3 H, *d*, $J \sim 1$)	1.91 (3 H, *d*, $J \sim 1$)	Me-11
1.29 (3 H, *d*, $J = 6.5$)	1.28 (3 H, *d*, $J = 6$)	Me-10
1.04 (3 H, *s*)	1.07 (3 H, *s*)	
1.01 (3 H, *s*)	0.98 (3 H, *s*)	
	2.05–1.99 4 × (3 H, *s*)	4 × OCO–Me

Coupling constants in hertz.

δ 5.89 (1 H, *m*), 5.79–5.78 (2 H, *m*), 4.86 (solvent), 4.33 (1 H, *qdd*, $J_1 = 6.5$, $J_2 = 3$, $J_3 = 1$ Hz), 3.30 (solvent), 2.52 (1 H, *d*, $J = 16$ Hz), 2.16 (1 H, *dd*, $J_1 = 16.5$, $J_2 \sim 1$ Hz), 1.93 (3 H, *d*, $J \sim 1$ Hz), 1.24 (3 H, *d*, $J = 6.5$ Hz), 1.04 (3 H, *s*), 1.01 (3 H, *s*). MS: *m/z* (int. > 5%, except M^+): 224.1410 $C_{13}H_{20}O_3$ (1, M^+), 206.1307 $C_{13}H_{18}O_2$ (9), 168.0797 $C_9H_{12}O_3$ (14), 151 (5), 150 (7), 135 (6), 125 (12), 124.0524 $C_7H_8O_2$ (100), 123 (6), 121 (8), 111 (8), 107 (6), 79 (6), 69 (6), 55 (6), 45 (8), 43 (19), 41 (8).

Acknowledgements—This work was financially supported by the Deutsche Forschungsgemeinschaft, the Gesellschaft für technische Zusammenarbeit (GTZ) and the Fonds der Chemischen Industrie. Furthermore we are grateful to Professor Dr. Hiroyuki Inouye, Faculty of Pharmaceutical Sciences, Kyoto University, Kyoto, Japan, for an authentic sample of shanzhiside methyl ester pentaacetate. Our thanks are also due to Mr. A. A. Enti of the Forestry Enterprises Ltd., Accra, Ghana, for collection of plant material.

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