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THREE PRENYLATED ISOFLAVANS FROM *MAACKIA TENUIFOLIA*

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Key Word Index—*Maackia tenuifolia*; Leguminosae; isolation; isoflavans; manuifolin G, H, and K.

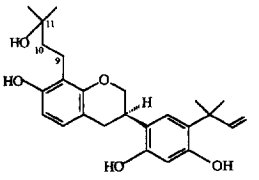
Abstract—Three new isoflavans, manuifolin G, H and K were isolated from roots of *Maackia tenuifolia*. Their structures were established as (3*R*)-5′-(1,1-dimethyl-2-propenyl)-8-(3-hydroxy-3-methylbutyl)-7-2′,4′-trihydroxyisoflavan, (3*R*)-6-(3-methyl-2-butenyl)-7,2′,4′-trihydroxyisoflavan and (3*R*)-5′-(1,1-dimethyl-2-propenyl)-7,2′,4′-trihydroxyisoflavan by spectroscopic methods.

INTRODUCTION

Previously, we reported the isolation of five isoflavans [1, 2] from *Maackia tenuifolia* which has been used as anti-tumour drug and fungicide in Chinese folk medicine. In a continuing study of this plant, we isolated three new isoflavans, manuifolin G(**1**), H(**2**) and K(**3**). In this paper, we report the isolation and identification of three new compounds.

RESULTS AND DISCUSSION

Compound **1** was obtained as white semisolid. HR mass spectrometry of **1** indicated its molecular formula to be $C_{25}H_{32}O_5$. The absorption bands, 208(4.90), 286(3.94) in the UV spectrum and signals at δ 2.91 (1H, *br dd*), 3.02(1H, *dd*), 3.46(1H, *m*), 4.05(1H, *t*), 4.37(1H, *br d*) in ^{1}H NMR spectrum are consistent with those of an isoflavan [3]. In ^{1}H NMR spectrum a singlet at δ 1.26 of six protons of gem-dimethyl groups and two triplets for methylene protons centered at δ 1.75 and 2.73 respectively were attributable to a 3-hydroxy-3-methylbutyl group, which was supported by the ion peak *m/z* 394 in the EI mass spectrum derived from the elimination of a H_2O molecule from parent ion *m/z* 412. The corresponding ^{1}H and ^{13}C NMR data of this group were in accord with that reported in the literature [4]. ^{1}H NMR spectrum revealed the presence of a 1,1-dimethyl-2-propenyl group and two *ortho*-coupled doublets and two singlets corresponding to four aromatic protons were also observed. In EI mass spectrometry, the characteristic fragment ions *m/z* 191 and 204 formed by the following RDA cleavage were also shown, which combining the chemical shifts of aromatic protons suggested that two C_5 units should be located on C-8 and C-5′ or C-6 and C-3′, respectively. The unambiguous assignments of the positions of substituents were made by HMBC experiments. The correlations between C-8 and H-9, C-7′ and H-6′ clearly indicated the 3-hydroxy-3-methylbutyl group should be attached to C-8 and the 1,1-dimethyl-2-propenyl group be at C-5′. Hence, **1** must be 5′-(1,1-dimethyl-2-propenyl)-8-(3-hydroxy-3-methylbutyl)-7,2′,4′-trihydroxyisoflavan.



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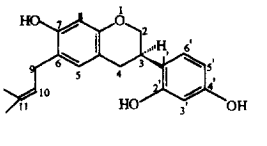

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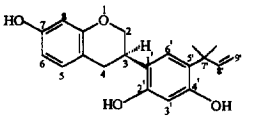

3

Compound **2** was assigned a molecular formula of $C_{20}H_{22}O_4$ from HR mass spectrometry. The UV and ^{1}H NMR spectrum showed **2** was an isoflavan. The ^{1}H NMR spectrum showed signals at δ 1.75, 1.76 (each 3H, *s*), 3.26 (2H, *d*), 5.28 (1H, *br t*) which were assignable to a 3-methyl-2-butenyl group. In aromatic region, two singlets at δ 6.33, 6.77 and signals for three protons at δ 6.29 (1H, *d*, J = 2.4 Hz), 6.37 (1H, *dd*, J = 8.2, 2.4 Hz) and 6.93 (1H, *d*, J = 8.2 Hz)

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constituting an ABX system were observed. In mass spectrum the fragment ions at *m/z* 191 and 136 clearly revealed the attachment of the 3-methyl-2-butenyl unit to ring A. In the ^1H and ^{13}C NMR spectrum of **2**, the chemical shifts of aromatic protons and downfield carbons [5] suggested that C-7, C-2′ and C-4′ should be oxygenated. The substitution mode was further demonstrated by HMBC experiments (see Table 1), e.g. assignment of C_5 unit at C-6 was based on a correlation between C-7 and H-9. Thus, **2** was characterized to be 6-(3-methyl-2-butenyl)-7,2′,4′-trihydroxyisoflavan.

Compound **3** was obtained as a powder which possessed the molecular formula $C_{20}H_{22}O_4$ by HR mass spectrometry. The UV and ^1H NMR spectra showed its isoflavan nature. The ^1H NMR spectrum of **3** was very similar with that of **1** except for the presence of three ABX type aromatic protons instead of two *ortho*-coupled protons and lacking a 3-hydroxy-3-methylbutyl group. In the EI mass spectrum, the characteristic fragment ions *m/z* 204 and 123 indicated the location of 1,1-dimethyl-2-propenyl group on B ring. Chemical shifts of aromatic protons and downfield carbons as well as biogenetic considerations suggested that C-7, C-2′ and C-4′ should be oxygenated. Careful comparison of ^1H and ^{13}C NMR data with that of **1** revealed that the C_5 unit was attached to C-5′ for chemical shifts of both hydrogen and carbon atoms of B ring of **3** were very similar to those of relevant atoms of **1**. In HMBC spectrum of **3**, the cross-peak between C-7′ and H-6′ further confirmed above result. Hence, **3** was determined to be 5′-(1,1-dimethyl-2-propenyl)-7,2′,4′-trihydroxyisoflavan.

The stereochemistry at C-3 of compounds **1–3** was determined on the basis of positive Cotton effects in the region 275–300 nm in their CD spectra as observed in (3*R*)-isoflavans [6, 7] and coexistence of biogenetically relevant pterocarpans [2]. So, they all possess the *R* configuration at C-3.

EXPERIMENTAL

General. Mps uncorr. ^1H NMR (at 400 MHz), ^{13}C NMR (at 100 MHz). Chemical shifts were given in δ (ppm) and the solvent signal was used as ref. ($CDCl_3$, δ 7.24 ppm for ^1H and CD_3COCD_3, δ 29.50 ppm for ^{13}C, respectively). EIMS and HRMS were performed on a MAT-95 mass spectrometer. CD were obtained with a JASCO DIP-181 DIGITAL Polarimeter. CC and TLC were carried out using silica gel obtained from Qingdao Ocean Chemical Co.

Isolation of compounds. The extraction and fractionation of the plant material are described in ref. [1]. The frs 128–135 eluted with $CHCl_3$–MeOH (30:1) were further purified by CC with petrol-Me_2CO (8:5) and Sephadex LH-20 to give **2** and **3**. Frs 145–148 eluted with $CHCl_3$–MeOH (10:1) were further purified by CC with CH_2Cl_2–Me_2CO (4:1) to give **1**.

3R(−)-*Manufolin G* (**1**). $C_{25}H_{32}O_5$, colourless gum. $[\alpha]_D^{23}$ −13.55° (MeOH: *c* 0.1173). UV λ_{max}^{MeOH} nm (log ε):

Table 1. ^{13}C NMR and HMBC(C → H) data for compounds **1**, **2** and **3** (in CD_3COCD_3)

C	C(**1**)	HMBC(**1**)	C(**2**)	HMBC(**2**)	C(**3**)	HMBC(**3**)
2	70.43*t*	3H, 4H	70.18*t*	3H	70.27*t*	3H, 4H
3	32.51*d*	6′H	32.33*d*	4H, 6′H	32.67*d*	2H, 4H, 6′H
4	31.33*t*	5H	30.78*t*	2H, 5H	30.79*t*	2H, 3H, 5H
4a	114.03*s*	4H, 6H	113.56*s*	4H, 8H	113.94*s*	3H, 4H, 6H, 8H
5	127.23*d*	4H	130.45*d*	4H	130.57*d*	4H
6	108.15*d*	7-OH	120.53*s*	8H, 7-OH, 9H	108.30*d*	5H, 8H
7	154.44*s*[a]	5H, 6H, 9H, 7-OH	154.20*s*	5H, 7-OH, 9H	157.11*s*	5H, 6H, 8H
8	117.11*s*	9H, 10H, 6H, 7-OH	102.94*d*	7-OH	103.20*d*	6H, 5H
8a	153.37*s*	4H, 5H, 9H	153.51*s*	2H, 8H	155.71*s*	2H, 4H, 5H
9	18.46*t*	10H	28.02*t*			
10	43.26*t*	9H, 11-2 × CH_3	124.16*d*	9H, 11-2 × CH_3		
11	70.43*s*	9H, 11-2 × CH_3	131.14*s*	9H, 11-2 × CH3		
CH_3	29.12*q*	10H	17.41*q*	10H		
CH_3	29.12*q*	10H	25.51*q*	10H		
1′	118.62*s*	3H, 3′H, 4H, 2′-OH	119.16*s*	5′H, 2′-OH	118.20*s*	2H, 3H, 4H, 3′H, 6′H
2′	154.35*s*[a]	3H, 6′H, 2′-OH	156.34s	3H, 6′H, 2′-OH	154.43*s*	3H, 3′H, 6′H
3′	104.41*d*	2′-OH, 4′-OH	103.05*d*	5′H, 2′-OH	104.30*d*	6′H
4′	155.08*s*	3′H, 6′H, 4′-OH	157.45*s*	6′H, 4′-OH	155.18*s*	3′H, 6′H
5′	125.53*s*	3′H, 7′-2 × CH_3, 4′-OH	107.08*d*	3′H, 4′-OH	125.42*s*	3′H, 6′H, 7′-2 × CH_3, 8′H
6′	126.41*d*	3′H	128.13*d*	3H	126.32*d*	3H
7′	40.35*s*	6′H, 8′H, 9′H, 7′-2 × CH_3			40.33*s*	6′H, 7′-2 × CH_3, 8′H, 9′H
CH_3	27.11*q*	9′H			27.12*q*	8′H, 9′H
CH_3	27.16*q*	9′H			27.12*q*	8′H, 9′H
8′	148.90*d*	9′H, 7′-2 × CH_3			148.94*d*	7′-2 × CH_3, 9′H
9′	109.89*t*				109.77*t*	7′-2 × CH_3

[a] Assignments may be interchanged.

208(4.90), 286(3.94), EIMS, *m/z*: 394 $[M-H_2O]^+$ (40), 204(36), 191(100), 135(35), 91(25). HRMS, *m/z* 412,2248 $[M]^+$ (calcd for $C_{25}H_{32}O_5$ *m/z*: 412.2250). ^1H NMR (400 MHz, $CDCl_3$) δ 1.26 (6H, *s*, Me_2-11), 1.34, 1.35 (each 3H, *s*, Me_2-7′), 1.75 (2H, *t*, $J = 7.1$ Hz, H-10), 2.73 (2H, *t*, $J = 7.1$ Hz, H-9), 2.91 (1H, *br*, *dd*, $J = 15.6$, 5.2 Hz, H-4_{eq}), 3.02 (1H, *dd*, $J = 15.6$, 10.7 Hz, H-4_{ax}), 3.46 (1H, *m*, *H*-3), 4.05 (1H, *t*, $J = 10.1$ Hz, H-2_{ax}), 4.37 (1H, *br d*, $J = 10.1$ Hz, H-2_{eq}), 5.27 (1H, *d*, $J = 10.9$ Hz, H_a-9′), 5.33 (1H, *d*, $J = 17.7$ Hz, H_b-9′), 6.14 (1H, *dd*, $J = 17.7$, 10.9 Hz, H-8′), 6.28 (1H, *s*, H-3′), 6.42 (1H, *d*, $J = 8.1$ Hz, H-6), 6.81 (1H, *d*, $J = 8.1$ Hz, H-5), 6.94 (1H, *s*, H-6′). ^{13}C NMR (100 MHz, CD_3COCD_3): see Table 1. CD (MeOH; *c* 0.0055), $[\theta]_{200}-9240$, $[\theta]_{202}0$, $[\theta]_{208}+17160$, $[\theta]_{235}+3960$, $[\theta]_{251}+7920$, $[\theta]_{272}+5280$, $[\theta]_{275}+5610$, $[\theta]_{308}0$.

3R(−)-*manuifolin H* (**2**). $C_{20}H_{22}O_4$, light brown crystal. mp 177–178°. $[\alpha]_D^{24.5}-15.03°$ (MeOH; *c* 0.1717). UV λ_{max}^{MeOH} nm (log ε): 208(4.90), 286(3.94). EIMS, *m/z*: 326 $[M]^+$ (50), 191(66), 136(38), 85(100). HRMS, *m/z* 326.1517 $[M]^+$ (calcd for $C_{20}H_{22}O_4$ *m/z*: 326.1518). ^1H NMR (400 MHz, $CDCl_3$) δ 1.75, 1.76 (each 3H, *s*, Me_2-11), 2.85 (1H, *br dd*, $J = 15.6$, 5.2 Hz, H-4_{eq}), 2.96 (1H, *dd*, $J = 15.6$, 10.4 Hz, H-4_{ax}), 3.26 (2H, *d*, $J = 7.1$ Hz, H-9), 3.46 (1H, *m*, H-3), 3.98 (1H, *t*, $J = 10.2$ Hz, H-2_{ax}), 4.28 (1H, *br*, *d*, $J = 10.2$ Hz, H-2_{eq}), 5.28 (1H, *br t*, $J = 7.1$ Hz, H-10), 6.29 (1H, *d*, $J = 2.4$ Hz, H-3′), 6.33 (1H, *s*, H-8), 6.37 (1H, *dd*, $J = 8.2$, 2.4 Hz, H-5′), 6.77 (1H, *s*, H-5), 6.93 (1H, *d*, $J = 8.2$ Hz, H-6′). ^{13}C NMR (100 MHz, CD_3COCD_3): see Table 1. CD (MeOH; *c* 0.009), $[\theta]_{207}+19470$, $[\theta]_{214}0$, $[\theta]_{223}-1980$, $[\theta]_{235}0$, $[\theta]_{252}+4125$, $[\theta]_{275}+1485$, $[\theta]_{287}+3300$, $[\theta]_{300}0$.

3R(−)-*manuifolin K* (**3**). $C_{20}H_{22}O_4$, white powder, mp 186–187°. $[\alpha]_D^{20}-22.71°$ (MeOH; *c* 0.1453). UV λ_{max}^{MeOH} nm (log ε): 205(4.98), 284(4.14), 288(4.10). EIMS, *m/z*: 326 $[M]^+$ (76), 324(70), 204(52), 191(63), 189(100), 161(50), 137(66), 123(52), 59(75). HRMS, *m/z* 326.1507 $[M]^+$ (calcd for $C_{20}H_{22}O_4$ *m/z*: 326.1518). ^1H NMR (400 MHz, $CDCl_3$) δ 1.34, 1.35 (each 3H, *s*, Me_2-7′), 2.88 (1H, *br dd*, $J = 15.6$, 5.2 Hz, H-4_{eq}), 3.01 (1H, *dd*, $J = 15.6$, 10.7 Hz, H-4_{ax}), 3.48 (1H, *m*, H-3), 4.06 (1H, *t*, $J = 10.1$ Hz, H-2_{ax}), 4.32 (1H, *br d*, $J = 10.1$ Hz, H-2_{eq}), 5.27 (1H, *d*, $J = 10.6$ Hz, H_a-9′), 5.32 (1H, *d*, $J = 17.7$ Hz, H_b-9′), 6.14 (1H, *dd*, $J = 17.7$, 10.6 Hz, H-8′), 6.29 (1H, *s*, H-3′), 6.34 (1H, *d*, $J = 2.4$ Hz, H-8), 6.37 (1H, *dd*, $J = 8.1$, 2.4 Hz, H-6), 6.92 (1H, *d*, $J = 8.1$ Hz, H-5), 6.93 (1H, *s*, H-6′). ^{13}C NMR (100 Hz, CD_3COCD3): see Table 1. CD (MeOH; *c* 0.00475), $[\theta]_{207}+22440$, $[\theta]_{224}0$, $[\theta]_{231}-3630$, $[\theta]_{238}0$, $[\theta]_{255}+6270$, $[\theta]_{272}+4950$, $[\theta]_{284}+5940$, $[\theta]_{308}0$.

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