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DITERPENOID, SESQUITERPENOID AND SECOIRIDOID GLUCOSIDES FROM *ASTER AURICULATUS*

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Key Word Index—*Aster auriculatus*; Compositae; roots; diterpenoid glucosides; sesquiterpenoid glucosides; secoiridoid glucoside; auriculatosides A, B and C; gentiopicroside; pimarene; guaiene; 2D NMR.

Abstract—Two new diterpenoid glucosides, auriculatosides A and B, one new sesquiterpenoid glucoside, auriculatoside C, as well as two known compounds, 3β-hydroxy-4(15), 10(14),11(13)-guaiatrien-12,6-olide-8α-*O*-β-D-glucopyranoside and gentiopicroside were isolated from roots of *Aster auriculatus*. On the basis of spectral evidence, auriculatosides A, B and C were identified as pimar-15(16)-β-ene-8β,11β,20-triol-7β-*O*-β-D-glucopyranoside, pimar-15(16)-β-ene-8β,11α-diol-20-(3-hydroxy-3-methyl)-butanoyl-7β-*O*-β-D-glucopyranoside and 3β-hydroxy-4(15), 10(14), 11(13)-guaiatrien-12,6-olide-8α-*O*-β-D-(6′-*O*-formyl)-glucopyranoside, respectively.

INTRODUCTION

Aster auriculatus Franch [1] is used as a Chinese herbal remedy which has anti-inflammatory, insecticidal and antitumour activities [2]. In the course of our studies on its chemical constituents, we have isolated and characterized two new diterpenoid glucosides, auriculatosides A (**1**) and B (**2**), one new sesquiterpenoid glucoside, auriculatoside C (**4**), as well as the known 3β-hydroxy-4(15), 10(14), 11(13)-guaiatrien-12,6-olide-8α-*O*-β-D-glucopyranoside (**3**) and gentiopicroside (**5**) from the roots of *A. auriculatus*.

RESULTS AND DISCUSSION

Gentiopicroside (**5**) was identified by comparison of its spectral data (FAB-MS, ^{1}H and ^{13}C NMR) with those reported in the literature [3].

Auriculatoside A (**1**) gave a positive Molish test. Its IR spectrum showed the presence of hydroxyl groups (3407 cm^{-1}), a double bond (1632 cm^{-1}), a —CMe_2 group (1385 cm^{-1}) and a C—O—C bond (1075 and 1043 cm^{-1}). The molecular formula, $C_{26}H_{44}O_9$, was obtained from its FAB-MS, ^{1}H NMR, ^{13}C NMR and DEPT data (Table 1). Acid hydrolysis of **1** afforded D-glucose. The ^{1}H NMR spectrum of **1** clearly indicated singlets for three methyl groups at δ 0.97, 1.01 and 1.04 (each 3H, *s*), an ABX pattern for olefinic protons at δ 6.47 (1H, *dd*, J = 11.0, 17.7 Hz), 5.14 and 4.90 (each 1H, *dd*, J = 1.2, 17.7 Hz, J = 1.2, 11.0 Hz, respectively), and an anomeric proton of β-glucose at δ 4.42 (1H, *d*, J = 7.8 Hz). The ^{13}C–^{1}H COSY showed the corresponding carbon signals at δ 22.5, 32.6, 34.6 (3 × Me), 149.8 (CH), 109.6 (CH_2) and 106.0 (CH). From these characteristic spectral data, compound **1** was deduced to be a pimarene-type diterpenoid glucoside [4]. Except for the glucose signals, the ^{13}C NMR spectrum of **1** also showed three carbon signals at δ 77.9 (CH), 64.3 (CH_2) and 77.0 (C), each of which was attached to a hydroxy group and one carbon signal at δ 80.6 (CH) linked to the glucose moiety. The NMR data and molecular formula suggested the overall structure **1**. The assignments for each signal based on 2D ^{1}H–^{1}H COSY, ^{13}C–^{1}H COSY and HMBC spectra are shown in Table 1. The cross peaks C,H-1′/H,C-7; C-10/H-5,9,20; C-8/H-7,9; C,H-9/H,C-11 showed that the glucosyl linkage was at C-7 and two hydroxyl groups at C-8 and C-11. Assuming the usual *trans* stereochemistry of the three rings in pimarene-type diterpenes, C-20 and OH-8 were both β and H-5 and H-9 both α [4–8]. The coupling constants of H_7/H_{6a} (11.8 Hz), H_7/H_{6e} (2.3 Hz) showed H-7 was α, while $J_{11,12e}$ = 2.8 Hz, $J_{11,12a}$ = 4.3 Hz, $J_{11,9a}$ = 7.4 Hz showed H-11 was also α. The relatively low field signal of CH_3-17 (δ 32.1) showed this group was equatorial, i.e. α [9, 10]. Taken together, this led to the stereochemistry shown in formula **1**. Thus, auriculatoside A (**1**) was pimar-15(16)-β-ene-8β,11β,20-triol-7β-*O*-β-D-glucopyranoside.

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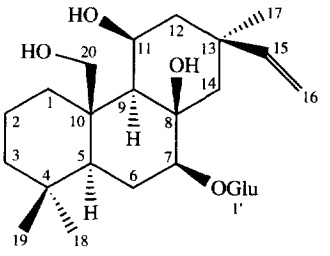

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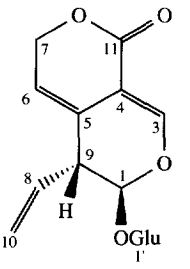

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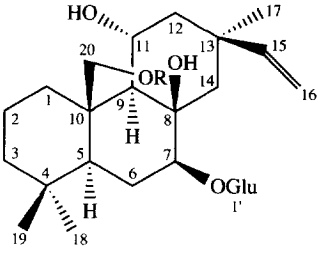
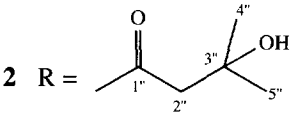
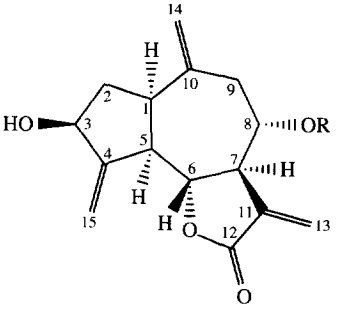




2 R =



3 R = Glu

4 R = 6'-O-formyl-Glu

Auriculatoside B (**2**), $C_{31}H_{52}O_{11}$, gave rise to NMR data very similar to those of **1**, except for the presence of five additional signals at δ 173.7 (C), 70.2 (C), 49.1 (CH_2), 30.1 (CH_3) and 29.2 (CH_3) and δ 2.46, 2.40 (each 1H, *d*, J = 14.0 Hz), 1.195 and 1.204 (each 3H, *s*) consistent with a 3-hydroxy-3-methyl-butanoyl moiety. The HMBC spectrum of **2** (Table 3) showed that this was attached at C-20. Shifts caused by the ester group substitution were shown by the signals of H-20 (+0.7 ppm) and C-20 (+1.5 ppm) compared with the corresponding signals in **1**. The signals of H-7 [δ 3.51 (1H, *dd*, $J_{7a,6a}$ = 10.9 Hz, $J_{7a,6e}$ = 4.0 Hz)] and H-11 [δ 4.42 (1H, *dddd*, $J_{11a,12c}$ = 3.4 Hz, $J_{11a,12a} = J_{11a,9a}$ = 10.7 Hz)] showed that in compound **2**, H-7 was α and H-11 β while in compound **1**, H-11 was α. This was also shown by the difference in the chemical shift of C-11 [δ 77.9 (**1**); 68.7 (**2**)]. Thus, auriculatoside B (**2**) was pimar-15(16)-β-ene-8β,11α-diol-20-(3-hydroxy-3-methyl)-butanoyl-7β-*O*-β-D-glucopyranoside.

Compound **3** was determined as 3β-hydroxy-4(15), 10(14), 11(13)-guaiatrien-12,6-olide-8α-*O*-β-D-glucopyranoside [11] according to its FAB-mass spectrum, ^{1}H and ^{13}C NMR spectra. Comparing the ^{1}H and ^{13}C NMR spectra as well as FAB-mass spectrum of **4** with those of **3** showed that there was a formyl group in **4** [δ_H 8.04 (1H, *s*); δ_C 162.9 (CH)] and this group was esterified to C-6 of the glucose moiety [C-6′ (+1.5), H-6′ (+0.6) and C-5′ (−2.7)] [12]. Thus, auriculatoside C (**4**) was 3β-hydroxy-4(15),10(14),11(13)-guaia-trien-12,6-olide-8α-*O*-β-D-(6′-*O*-formyl)-glucopyranoside.

EXPERIMENTAL

General. ^{1}H and ^{13}C NMR: 500 and 125 MHz, respectively, in FT mode.

Plant material. The roots of *Aster auriculatus* Franch were collected in Sichuan province, P. R. China. It was identified by Professor Song Wan-zhi, Institute of Materia Medica, Chinese Academy of Medical Sciences, and a voucher specimen (880801) is deposited in the herbarium of the authors' Institute.

Extraction and purification. Air dried roots of plants

Table 1. The NMR data of compounds **1** and **2** (500 MHz, δppm, CD_3OD, TMS)

C	1	2	DEPT	H	1	2
1	39.1	37.5	CH_2	1	2.84 *br d* (14.3)	2.80 *br d* (14.0)
2	20.5	19.5	CH_2		0.94 *m*	0.83 *m*
3	42.8	42.5	CH_2	2	1.70–1.40 *m*	1.44 *m* (12.8, 3.7)
4	34.5	34.5	C			1.35 *m*
5	53.7	53.1	CH	3	1.70–1.40 *m*	1.16 *m* (17.0, 3.8)
6	28.0	22.6	CH_2			1.38 *m*
7	80.6	82.6	CH	5	1.07 *dd* (12.1, 4.3)	0.97 *br d* (12.1)
8	77.0	77.7	C	6	1.93 *ddd* (12.1, 11.8, 4.3)	1.81 *dd* (11.0, 12.1, 4.2)
9	62.0	61.8	CH		1.37 *m*	1.39 *m*
10	44.3	43.5	C	7	3.90 *dd* (11.8, 2.3)	3.51 *dd* (10.9, 4.0)
11	77.9	68.7	CH	9	1.08 *d* (7.5)	0.95 *d* (10.5)
12	46.8	49.2	CH_2	11	4.45 *ddd* (2.8, 4.3, 7.5)	4.42 *dddd* (3.4, 10.7, 10.7)
13	37.5	37.4	C	12	2.77 *dd* (2.8, 12.1)	2.01 *dd* (3.4, 12.7)
14	49.5	50.4	CH_2		1.27 *dd* (4.3, 12.1)	1.23 *dd* (10.7, 12.7)
				14	2.23, 1.22 *d* (14.1)	2.16, 1.10 *d* (14.5)
15	149.8	149.5	CH	15	6.14 *dd* (11.0, 17.7)	6.10 *dd* (7.5, 11.0)
16	109.8	109.4	CH_2	16	5.14 *dd* (1.2, 17.7)	4.88 *dd* (17.5, 1.0)
17	32.6	32.1	CH_3		4.90 *dd* (1.2, 11.0)	4.75 *dd* (11.0, 1.0)
18	34.6	34.7	CH_3	17–19	0.97, 1.01, 1.04	0.88, 0.87, 0.86
19	22.5	22.9	CH_3		(each 3H, *s*)	(each 3H, *s*)
20	64.3	65.8	CH_2	20	4.16, 3.95 *d* (12.1)	4.86, 4.67 *d* (11.0)
Glu. 1′	106.0	100.0	CH	1′	4.42 *d* (7.8)	4.34 *d* (7.7)
2′	75.5	75.1	CH	2′		3.12 *dd* (7.7, 9.2)
3′	78.9	78.1	CH	3′		3.16 *m*
4′	71.5	71.8	CH	4′		3.18 *t* (8.5)
5′	78.7	77.8	CH	5′		3.31 *t* (8.5)
6′	62.7	62.9	CH_2	6′	3.93 *br d* (11.9)	3.77 *dd* (11.8, 1.7)
					3.75 *dd* (11.9, 5.1)	3.58 *dd* (11.8, 5.6)
1″		173.7	C			
2″		49.1	CH_2	2″		2.46, 2.40 *d* (14.0)
3″		70.2	C			
4″, 5″		30.1, 29.2	CH_3	4″, 5″		1.195, 1.204 *s*

(2.5 kg) were extracted with Me_2CO (3 × 5 l) at room temp. The combined extracts were evapd to give a crude syrup, which was chromatographed over a silica gel column eluting with petrol–Me_2CO (15:1) followed by increasing concns of Me_2CO; six frs were collected. Fr. 5 (petrol–Me_2CO 2:1) on repeated chromatographic purification over silica gel eluting with $CHCl_3$–MeOH (6:1) gave compounds **1** (30 mg) and **2** (50 mg). Fr. 6 (petrol–Me_2CO; 1:1) was chromatographed repeatedly over silica gel eluting with $CHCl_3$–MeOH–H_2O (4:1:0.1) to give compounds **4** (30 mg), **5** (15 mg) and **3** (80 mg).

Auriculatoside A (**1**). Amorphous powder, mp 129–131°; $[\alpha]_D^{27}$: −17.6° (MeOH, *c* 0.051); IR ν_{max}^{KBr} (cm^{-1}): 3407, 2926, 1632, 1605, 1454, 1385, 1075, 1043; ^1H NMR: Table 1; ^{13}C NMR: Table 1; FAB-MS (S-Gly) *m/z* 501 $[M+H]^+$, 338 $[M-Glu]^+$.

Auriculatoside B (**2**). Amorphous powder, mp 123–125°; $[\alpha]_D^{27}$: −15.1° (MeOH, *c* 0.112); IR ν_{max}^{KBr} (cm^{-1}): 3438, 2925, 1710 (ester group), 1634, 1458, 1371, 1209, 1074, 1042; ^1H NMR: Table 1; ^{13}C NMR: Table 1; FAB-MS (S-Gly) *m/z* 601 $[M+H]^+$ 438 $[M-Glu]^+$, 338 $[M-Glu-100]^+$.

Auriculatoside C (**4**). Amorphous powder, mp 132–134°; $[\alpha]_D^{27}$: −2.6° (MeOH, *c* 0.038); IR ν_{max}^{KBr} (cm^{-1}): 3424, 2925, 1750, 1722, 1672, 1635, 1605, 1077, 940-910; ^1H NMR: Table 2; ^{13}C NMR: Table 2; FAB-MS (S-Gly) *m/z* 453 $[M+H]^+$, 262 [M-6′-*O*-formyl-Glu]$^+$.

Gentiopicroside (**5**). Amorphous powder, ^1H NMR (CD_3OD, TMS) δ: 4.67 (1H, *d*, *J* = 8.0 Hz, H-1′), 5.03, 5.10 (2H, *m*, H-7), 5.25 (1H, *ddd*, 10.5, 1.5, 1.5 Hz, H-10a), 5.28 (1H, *ddd*, *J* = 17.5, 10.5, 5.0 Hz, H-10b), 5.66 (1H, *m*, H-6), 5.70 (1H, *d*, *J* = 3.0 Hz, H-1), 5.80 (1H, *dddd*, *J* = 17.5, 10.5, 7.0 Hz, H-8), 7.49 (1H, *d*, *J* = 1.5 Hz, H-3); ^{13}C NMR (CD_3OD, TMS) δ 98.5 (C-1), 150.6 (C-3), 104.9 (C-4), 126.9 (C-5), 117.2 (C-6), 70.9 (C-7), 134.9 (C-8), 46.5 (C-9), 118.5 (C-10), 166.3 (C-11), 100.1 (C-1′), 74.5 (C-2′), 78.3 (C-

Table 2. Cross peaks in 2D ^{13}C–^{1}H COSY, ^{1}H–^{1}H COSY and HMBC of compound **2**

^{13}C–^{1}H COSY		^{1}H–^{1}H COSY		HMBC	
C-1	H-1	H-1	H-2	C-4	H-5
C-2	H-2	H-2	H-1, 3	C-5	H-6
C-3	H-3	H-3	H-2	C-6	H-5
C-5	H-5	H-5	H-6	C-7	H-1′, 6, 5
C-6	H-6	H-6	H-5, 7	C-8	H-14, 7, 6, 9
C-7	H-7	H-7	H-6	C-9	H-20, 14, 11
C-9	H-9	H-9	H-11	C-10	H-20, 5, 9, 6
C-11	H-11	H-11	H-9, 12	C-11	H-9
C-12	H-12	H-12	H-11	C-12	H-14
C-14	H-14	H-15	H-16	C-13	H-15, 16, 14
C-15	H-15	H-16	H-15	C-15	H-16, 14
C-16	H-16			C-20	H-5, 9
C-17	H-17			C-1′	H-7, 2′
C-18	H-18			C-1″	H-20, 2″
C-19	H-19			C-3″	H-2″, 4″, 5″
C-20	H-20			C-4″, 5″	H-2″
C-1′	H-1′	H-1′	H-2′		
C-2′	H-2′	H-2′	H-3′, 1′		
C-3′	H-3′	H-3′	H-2′, 4′		
C-4′	H-4′	H-4′	H-5′, 3′		
C-5′	H-5′	H-5′	H-4′, 6′		
C-6′	H-6′	H-6′	H-5′		
C-2″	H-2″				
C-4″	H-4″				
C-5″	H-5″				

Table 3. The NMR data of compounds **3** and **4** (500 MHz, δppm, CD_3OD, TMS)

C	**3**	**4**	DEPT	H	**3**	**4**	*J* (Hz)
1	46.3	46.3	CH	1	2.88 *q*	2.87 *q*	8.5, 8.6, 8.6
2	42.9	43.2	CH_2	2β	1.86 *dddd*	1.86 *dddd*	13.8, 7.9, 5.9
3	67.0	67.0	CH	2α	2.24 *ddd*	2.21 *ddd*	14.1, 8.1, 5.9
4	150.9	150.9	C	3	4.53 *dd*	4.45 *dd*	1.9, 6.0
5	52.1	52.0	CH	5	2.65 *dd*	2.66 *dd*	10.1, 8.7
6	79.7	79.8	CH	6	4.49 *dd*	4.47 *dd*	10.5, 8.7
7	50.6	50.5	CH	7	2.96 *dd*	2.97 *dd*	8.6, 3.2
8	81.4	81.9	CH	8	4.23 *dt*	4.23 *dt*	3.2, 5.9, 5.9
9	38.8	38.9	CH_2	9β	2.29 *dd*	2.29 *dd*	13.6, 5.9
10	145.3	145.3	C	9α	2.47 *dd*	2.47 *dd*	13.3, 6.0
11	137.6	137.7	C	13a	6.18 *d*	6.18 *d*	3.5
12	172.2	172.2	C	13b	5.56 *d*	5.56 *d*	3.5
13	122.5	122.4	CH_2	14a	4.98 *d*	4.97 *d*	1.6
14	117.0	117.0	CH_2	14b	4.83 *d*	4.83 *d*	1.6
15	113.3	113.3	CH_2	15a	5.34 *d*	5.33 *d*	1.3
Glu.				15b	5.26 *d*	5.28 *d*	1.3
1′	104.9	103.7	CH	1′	4.36 *d*	4.36 *d*	7.4
2′	75.2	75.2	CH		—	—	
3′	77.9	78.1	CH	2′–5′	3.1–3.6	3.1–3.6	
4′	71.6	71.6	CH				
5′	77.8	75.1	CH				
6′	62.7	64.2	CH_2	6′a	3.56 *dd*	4.19 *dd*	11.9, 6.3
				6′b	3.77 *dd*	4.43 *dd*	11.9, 1.9
1″		162.9	CH	1″		8.04 *s*	

3′), 71.5 (C-4′), 78.0 (C-5′), 62.8 (C-6′); FAB-MS (S-Gly) *m/z* 357 $[M+H]^+$, 194 $[M\text{-}Glu]^+$. Spectral data were identical to those reported in the lit. [3].

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