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STEROIDAL ALKALOID GLYCOSIDES FROM *SOLANUM SUAVEOLENS**†

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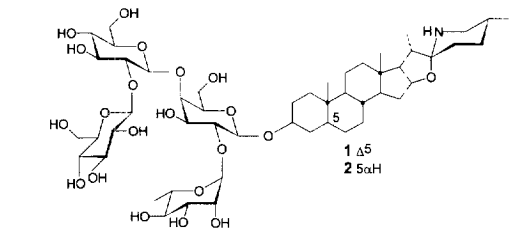
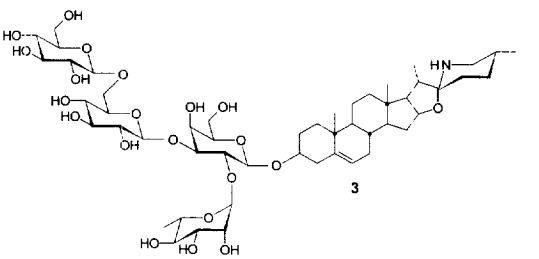
Key Word Index—*Solanum suaveolens*; Solanaceae; steroidal alkaloid glycosides; solasuaveoline; dihydrosolasuaveoline; isosolasuaveoline.

Abstract—In addition to khasianine, solamargine, xylosylsolamargine and solasonine, three steroidal alkaloid glycosides, solasuaveoline, dihydrosolasuaveoline and isosolasuaveoline, have been isolated from aerial parts of *Solanum suaveolens*. The structures have been assigned by NMR investigations as (25*R*)-3β-{*O*-β-D-glucopyranosyl-(1 → 2)-*O*-β-D-glucopyranosyl-(1 → 4)-[*O*-α-L-rhamnopyranosyl-(1 → 2)]-β-D-galactopyranosyloxy}-22α*N*-spirosol-5-ene, (25*R*)-3β-{*O*-β-D-glucopyranosyl-(1 → 2)-*O*-β-D-glucopyranosyl-(1 → 4)-[*O*-α-L-rhamnopyranosyl-(1 → 2)]-β-D-galactopyranosyloxy}-5α,22α*N*-spirosolane and (25*R*)-3β-{*O*-β-D-glucopyranosyl-(1 → 6)-*O*-β-D-glucopyranosyl-(1 → 3)-[*O*-α-L-rhamnopyranosyl-(1 → 2)]-β-D-galactopyranosyloxy}-22α*N*-spirosol-5-ene, respectively. © 1997 Elsevier Science Ltd

INTRODUCTION

Solanum suaveolens, a plant growing in Central America, belongs to the section Tuberarium (Dun.) Bitt. (subsection Basarthrum Bitt.) of the subgenus *Solanum*. The steroidal alkaloids of this species have not yet been studied. From the aerial parts khasianine (yield 0.014%), solamargine (yield 0.28%), xylosylsolamargine (yield 0.08%), solasonine (yield 0.08%), solasuaveoline (yield 0.007%), dihydrosolasuaveoline (yield 0.007%) and isosolasuaveoline (yield 0.014%) have now been isolated. Khasianine was identified by its electrospray ionization mass spectrum (ESI-MS) and its ^{13}C NMR spectrum in pyridine-d_5 [2, 3], solamargine, xylosylsolamargine and solasonine were compared with authentic samples [4, 5]. For solasuaveoline, dihydrosolasuaveoline and isosolasuaveoline the structures (25*R*)-3β-{*O*-β-D-glucopyranosyl-(1 → 2)-*O*-β-D-glucopyranosyl-(1 → 4)-[*O*-α-L-rhamnopyranosyl-(1 → 2)]-β-D-galactopyranosyloxy} - 22α*N* - spirosol - 5 -ene (**1**), (25*R*)-3β-{*O*-β-D-glucopyranosyl-(1 → 2)-*O*-β-D-glucopyranosyl-(1 → 4)-[*O*-α-L-rhamnopyranosyl-(1 → 2)]-β-D-galactopyranosyloxy} - 5α,22α*N* - spirosolane (**2**) and (25*R*)-3β-{*O*-β-D-glucopyranosyl-(1 → 6)-*O*-β-D-glucopyranosyl-(1 → 3)-[*O*-α-L-rhamnopyranosyl-(1 → 2)]-β-D-galactopyranosyloxy}-22α*N*-spirosol-5-ene (**3**), respectively, have been assigned mainly by NMR measurements, as outlined below.





RESULTS AND DISCUSSION

Solasuaveoline (**1**) and its 5α,6-dihydro compound **2** were separated by reverse-phase chromatography. In the electrospray ionization mass spectra, solasuaveoline (**1**), dihydrosolasuaveoline (**2**) and isosolasuaveoline (**3**) gave rise to $[M+H]^+$ peaks.

The ^{13}C NMR spectra of **1** and **3** indicated gly-

* Part 140 in the series '*Solanum* Alkaloids'. For part 139, see ref. [1].

† Dedicated to Professor G. Adam with best wishes on the occasion of his 65th birthday.

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cosides with solasodine as the aglycone (Experimental, cf. ref. [6]), the spectrum of **2** was in agreement with a soladulcidine glycoside [7]. The assignment of the signals was supported by DEPT measurements.

The ^{13}C signals of the oligosaccharide portion of **1** and **2** had the same values (small deviations for C-1 and C-2 of galactose) indicating identical structures. Therefore, only the carbohydrate structure of dihydrosolasuaveoline (**2**) was studied (Table 1). The values of the ^{1}H NMR signals were recognized by the gradient-selected HSQC spectrum. The ^{1}H spin systems of the sugar units were assigned by a ^{1}H-^{1}H 2D DQF COSY NMR spectrum and confirmed by 2D TOCSY measurements. Two spin systems were observed for galactose, because $J_{H\text{-}4,H\text{-}5} = 0.0$ Hz. The relationships of these systems were detected by the ROESY spectrum (correlation of H-1/H-5, H-3/H-5 and H-4/H-5). The corresponding ^{13}C NMR signals were assigned by the gradient-selected HSQC spectrum. The value of C-4 of galactose was δ 80.2 and not 78.2 (signals for H-2 and H-4 δ 4.51), because the gradient-selected HMBC spectrum displayed coupling of C-4 with H-5, H-6a and H-6b. Other couplings recognized in the HMBC spectrum were in agreement with the ^{1}H and ^{13}C NMR assignments (coupling via two or three bonds). Each ^{1}H-^{1}H coupling constant (Table 1) could not be derived from the ^{1}H NMR spectrum because of superimposition. Nevertheless, the sugar moieties were recognized. The coupling constants $J_{H\text{-}1,H\text{-}2}$ of the galactose and glucose units corresponded with β-configurations. While the galactose and glucoses showed cross-peaks in the ROESY spectrum relating H-1 and H-5 in agreement with β-configurations, the absence of such a peak in the rhamnose unit indicated an α-configuration. The ^{13}C NMR signals of rhamnose were in agreement with this configuration [6]. For the galactosyl, glucosyl and rhamnosyl residues the D-, D- and L-configurations, respectively were assumed as these usually occur in glycosides of higher plants.

Finally, the connections of the four sugar components had to be determined. Long-range couplings

Table 1. NMR (δ values, J Hz) for compounds **1**–**3** (oligosaccharide portions)

Sugar	**1**		**2**			**3**	
Position	C	H	J (H,H)	C	H	J (H,H)	C
Galactose							
1	100.3	4.89	7.8 (1,2)	99.9	4.88	7.8 (1,2)	100.4
2	77.9	4.51	8.4 (2,3)	78.2	4.64	9.7 (2,3)	75.1
3	76.1	4.16	3.6 (3,4)	76.1	4.35	3.4 (3,4)	84.8
4	80.2	4.51	0.0 (4,5)	80.2	4.89	0.0 (4,5)	70.2
5	75.1	3.98	7.3 (5,6a)	75.2	4.23	6.0 (5,6a)	76.0
6a	60.4	4.20	8.8 (5,6b)	60.6	4.32	5.9 (5,6b)	62.3
6b		4.64	9.5 (6a,6b)		4.42	11.0 (6a,6b)	
Rhamnose							
1	102.2	6.13	1.5 (1,2)	102.3	6.20	1.5 (1,2)	102.2
2	72.3	4.74	3.4 (2,3)	72.3	4.78	3.4 (2,3)	72.5
3	72.7	4.52	9.3 (3,4)	72.6	4.52	9.4 (3,4)	72.8
4	74.0	4.25	9.4 (4,5)	74.0	4.22	9.6 (4,5)	74.2
5	69.8	4.85	6.1 (5,6)	69.8	4.86	6.1 (5,6)	69.4
6	18.4	1.73		18.4	1.66		18.6
Glucose (inner)							
1	104.5	5.10	7.6 (1,2)	104.5	5.05	7.8 (1,2)	105.7
2	84.1	4.17	8.4 (2,3)	84.2	3.87	8.3 (2,3)	74.8
3	78.8	4.20	8.2 (3,4)	78.8	4.05	9.0 (3,4)	78.35*
4	71.4*	3.90	7.9 (4,5)	71.4*	3.82	9.1 (4,5)	71.9
5	78.8†	3.89	8.0 (5,6a)	78.8†	3.99	8.8 (5,6a)	77.2
6a	63.0	4.09	11.0 (6a,6b)	63.0	4.05	1.7 (5,6b)	70.4
6b		4.54			4.79	9.0 (6a,6b)	
Glucose (terminal)							
1	105.6	5.46	7.8 (1,2)	105.7	4.97	7.8 (1,2)	105.6
2	75.8	4.07	9.0 (2,3)	75.8	4.01	9.1 (2,3)	75.3
3	78.5	4.14	9.0 (3,4)	78.5	4.24	9.2 (3,4)	78.2
4	71.5*	4.26	9.2 (4,5)	71.5*	4.17	9.3 (4,5)	71.6
5	78.4†	3.89		78.4†	3.85	5.2 (5,6a)	78.4*
6a	62.6	4.54		62.5	4.30	8.9 (5,6b)	62.6
6b		4.54			4.44	10.2 (6a,6b)	

*,† May be exchanged.

were detected in the gradient-selected HMBC spectrum between H-1 of galactose and C-3 of the aglycone soladulcidine, H-1 of rhamnose and C-2 of galactose, H-1 of the inner glucose and C-4 of galactose and H-1 of the terminal glucose and C-2 of the inner glucose. Other interglycosidic couplings to be expected could not unambiguously be assigned, because some ^{1}H NMR signals were superimposed. Correlation in the ROESY spectrum between H-3 of the aglycone soladulcidine and H-1 of galactose was in agreement with these results. Again some expected correlations could not be unambiguously assigned.

The structure of the sugar portion of isosolasuaveoline (**3**) was elucidated in a similar manner. Again two ^{1}H spin systems were observed for galactose. The relationships of these systems were detected by ROESY correlations H-1/H-5 and/or H-4/H-5. The anomeric configurations of the sugar moieties were detected, as described for **1** and **2**.

The sequence of the sugar chain and its connection with the aglycone solasodine followed from long-range couplings observed in the gradient-selected HMBC spectrum: H-3 of solasodine/C-1 of galactose, H-1 of galactose/C-3 of solasodine, H-2 of galactose/C-1 of rhamnose, H-1 of rhamnose/C-2 of galactose, H-3 of galactose/C-1 of inner glucose, H-1 of inner glucose/C-3 of galactose and H-1 of terminal glucose/C-6 of inner glucose. These results were corroborated by correlation in the ROESY spectrum between H-3 of solasodine and H-1 of galactose, H-2 of galactose and H-1 of rhamnose and H-3 of galactose and H-1 of the inner glucose.

Structure **3** was already proposed for solashabanine isolated from root bark of *Solanum laciniatum* Ait. on the basis of its ^{13}C NMR spectrum, which was compared with those of solasonine and a β-gentiobiose subunit [8]. This is not a rigorous proof, but the structure was in accordance with the claimed enzymatic transformation into solasonine [8]. Unfortunately, only melting point (decomposition) and the ^{13}C NMR spectrum measured in a mixture of pyridine-d_5 and CD_3OD in an unspecified ratio was published. Therefore, our product cannot be exactly compared with solashabanine, although the ^{13}C NMR data seem to suggest non-identity. Attempts to obtain an authentic sample of solashabanine were not successful.

EXPERIMENTAL

Seeds of *S. suaveolens* Kunth et Bouché were obtained from Hortus Botanicus, Nijmegen. The species was identified by Mr G. M. van der Weerden, Nijmegen, in 1990. Plants were grown in a field in Halle (Saale) and harvested in September 1992. A voucher specimen is retained in the Institute of Plant Biochemistry, Halle.

^{13}C NMR spectra were measured in pyridine-d_5 (126 MHz, TMS), ^{1}H NMR, ^{1}H-^{1}H DQF COSY, 2D TOCSY, gradient-selected HSQC, gradient-selected HMBC and ROESY spectra in pyridine-d_5-CD_3OD (19:1; 500 MHz, TMS). The values for the ^{13}C signals were practically identical in both solvents, however the ^{1}H signals were better resolved in the latter mixt.

Isolation of alkaloids. Aerial parts were dried at 60°, ground and extracted with MeOH at room temp. Evapn of MeOH *in vacuo* gave a residue which was partitioned between H_2O and C_6H_6–Et_2O (1:1). After addition of $KHCO_3$ to the aq. layer, the latter was extracted with $CHCl_3$–EtOH (2:1). Evapn of solvents *in vacuo* gave a mixt. of alkaloids. This was chromatographed over Merck silica gel with $CHCl_3$–MeOH–conc. NH_3 (3:1:1, 12:5:4 and 6:3:2, lower phases) and over Merck LiChroprep RP-8 with 0.4% HOAc–MeOH (1:1). Frs containing alkaloids were basified with conc. NH_3, the MeOH evapd *in vacuo*, the aq. soln extracted with $CHCl_3$–EtOH (2:1) and the solvents evapd again *in vacuo*. TLC: Merck TLC aluminium sheets silica gel 60 WF_{254S}, $CHCl_3$–MeOH–conc. NH_3 (3:3:1), detection by Dragendorff's reagent [R_f: khasianine 0.58, solamargine 0.38, xylosylsolamargine 0.22, solasonine 0.16, solasuaveoline 0.08, dihydrosolasuaveoline 0.08, isosolasuaveoline 0.04] or Merck TLC plates RP-8 F_{254S}, MeOH–buffer soln (3:2; buffer soln: 50 g of NH_4OAc dissolved in 50 ml of H_2O, 560 ml of 1 M HCl and 720 ml of H_2O added; detection by I_2 vapour) [R_f: khasianine 0.23, solamargine 0.30, xylosylsolamargine 0.34, solasonine 0.31, solasuaveoline 0.39, dihydrosolasuaveoline 0.35, isosolasuaveoline 0.39].

Solasuaveoline, (25R)-3β-{O-β-D-*glucopyranosyl*-(1 → 2)-O-β-D-*glucopyranosyl*-(1 → 4)-[O-α-L-*rhamnopyranosyl*-(1 → 2)]-β-D-*galactopyranosyloxy*}-22αN-*spirosol*-5-*ene* (**1**). From MeOH–H_2O crystals. Mp 277–278° (dec.). $[\alpha]_D^{22}$ −64.6° (pyridine, *c* 1.00). ^{13}C NMR: δ 15.7 (C-21), 16.5 (C-18), 19.3 (C-19), 19.7 (C-27), 21.1 (C-11), 30.1 (C-2), 30.9 (C-24), 31.6 (C-8, C-25), 32.3 (C-15), 32.5 (C-7), 34.5 (C-23), 37.1 (C-10), 37.5 (C-1), 38.8 (C-4), 40.0 (C-12), 40.6 (C-13), 41.6 (C-20), 47.9 (C-26), 50.3 (C-9), 56.6 (C-14), 63.4 (C-17), 77.7 (C-3), 79.1 (C-16), 98.4 (C-22), 121.8 (C-6), 140.8 (C-5), oligosaccharide signals: cf. Table 1. ESI-MS (positive ion): 1046 $[M+H]^+$.

Dihydrosolasuaveoline, (25R)-3β-{O-β-D-*glucopyranosyl*-(1 → 2)-O-β-D-*glucopyranosyl*-(1 → 4)-[O-α-L-*rhamnopyranosyl*-(1 → 2)]-β-D-*galactopyranosyloxy*}-5α,22αN-*spirosolane* (**2**). From MeOH–H_2O crystals. Mp 275–277° (dec.). $[\alpha]_D^{24}$ −43.8° (pyridine, *c* 0.54). ^{1}H NMR: δ 0.81 (*d*, *J* = 5.5 Hz, H_3-27), 0.84 (*s*, H_3-19), 0.86 (*s*, H_3-18), 1.10 (*d*, *J* = 6.7 Hz, H_3-21). ^{1}H NMR (derived from the gradient-selected HSQC spectrum): δ 0.80 (H-1), 1.57 (H-1), 1.76 (H-2), 2.07 (H-2), 3.93 (H-3), 1.62 (H-4), 1.89 (H-4), 0.90 (H-5), 1.14 (H-6), 1.14 (H-6), 0.79 (H-7), 1.53 (H-7), 1.43 (H-8), 0.53 (H-9), 1.22 (H-11), 1.42 (H-11), 1.06 (H-12), 1.66 (H-12), 1.05 (H-14), 1.42 (H-15), 2.03 (H-15), 4.46 (H-16), 1.79 (H-17), 0.86 (H-18), 0.84 (H-19), 1.97 (H-20), 1.10 (H-21), 1.70 (H-23), 1.70 (H-23), 1.60 (H-24), 1.60 (H-24), 1.65 (H-25), 2.76 (H-26), 2.76 (H-26), 0.81 (H-27), oligosaccharide signals: cf. Table 1. ^{13}C NMR: δ 12.4 (C-19), 15.6 (C-21), 16.7

(C-18), 19.6 (C-27), 21.2 (C-11), 28.9 (C-6), 29.8 (C-2), 30.8 (C-24), 31.2 (C-25), 32.38* (C-7), 32.43* (C-15), 34.3 (C-4), 34.4 (C-23), 35.2 (C-8), 35.9 (C-10), 37.2 (C-1), 40.2 (C-12), 40.9 (C-13), 41.6 (C-20), 44.6 (C-5), 47.8 (C-26), 54.4 (C-9), 56.4 (C-14), 63.5 (C-17), 76.9 (C-3), 79.3 (C-16), 98.3 (C-22), oligosaccharide signals: cf. Table 1. ESI-MS (positive ion): 1048 $[M+H]^+$.

Isosolasuaveoline, (25R)-3β-{O-β-D-*glucopyranosyl*-(1 → 6)-O-β-D-*glucopyranosyl*-(1 → 3)-[O-α-L-*rhamnopyranosyl*-(1 → 2)]-β-D-*galactopyranosyloxy*}-22αN-*spirosol*-5-*ene* (**3**). From MeOH needles. Mp 277–279° (dec.). $[\alpha]_D^{23}$ −71.4° (pyridine, *c* 1.00). ^{1}H NMR: δ 0.82 (*d*, *J* = 6.2 Hz, H_3-27), 0.88 (*s*, H_3-18), 1.06 (*s*, H_3-19), 1.09 (*d*, *J* = 7.0 Hz, H_3-21), 5.31 (*d*, *J* = 5.2 Hz, H-6). ^{1}H NMR (derived from the gradient-selected HSQC spectrum): δ 0.97 (H-1), 1.74 (H-1), 1.84 (H-2), 2.07 (H-2), 3.89 (H-3), 2.71 (H-4), 2.71 (H-4), 5.31 (H-6), 1.49 (H-7), 2.06 (H-7), 1.57 (H-8), 0.91 (H-9), 1.45 (H-11), 1.45 (H-11), 1.13 (H-12), 1.71 (H-12), 1.09 (H-14), 1.49 (H-15), 1.90 (H-15), 4.44 (H-16), 1.78 (H-17), 0.88 (H-18), 1.06 (H-19), 1.97 (H-20), 1.09 (H-21), 1.70 (H-23), 1.75 (H-23), 1.62 (H-24), 1.62 (H-24), 1.63 (H-25), 2.75 (H-26), 2.75 (H-26), 0.82 (H-27), oligosaccharide signals: cf. Table 1. ^{13}C NMR: δ 15.7 (C-21), 16.5 (C-18), 19.4 (C-19), 19.7 (C-27), 21.1 (C-11), 30.1 (C-2), 30.9 (C-24), 31.4 (C-25), 31.7 (C-8), 32.3 (C-15), 32.5 (C-7), 34.6 (C-23), 37.1 (C-10), 37.5 (C-1), 38.8 (C-4), 40.0 (C-12), 40.6 (C-13), 41.6 (C-20), 47.9 (C-26), 50.3 (C-9), 56.6 (C-14), 63.4 (C-17), 77.4 (C-3), 79.0 (C-16), 98.4 (C-22), 121.7 (C-6), 140.9 (C-5), oligosaccharide signals: cf. Table 1. ESI-MS (positive ion): 1046 $[M+H]^+$.

* May be exchanged.

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