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SESQUITERPENE LACTONES FROM *ARTEMISIA LANATA**

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Key Word Index—*Artemisia lanata*; Compositae; Anthemideae, sesquiterpene lactones; germacranolides; 11-epidihydroridentin; ridentin; dihydroridentin; guaianolides; 6α-acetylferulidin; carmenin; andalucin; deacetylmatricarin; anhydrogrossmisin.

Abstract—A reinvestigation of the aerial parts of *Artemisia lanata* afforded a new germacranolide, 11-epidihydroridentin and three new guaianolides, 6α-acetylferulidin, carmenin and andalucin. Furthermore, several known compounds were isolated. The structure of the new compounds were elucidated by spectroscopic methods, and chemical transformations. The structure of andalucin was confirmed by X-ray analysis of its benzoate.

INTRODUCTION

As a part of our continuing phytochemical study of plants of the Compositae family we re-examined *Artemisia lanata* Willd (Anthemideae, subtribe Absinthium). In previous comunications [1, 2] three sesquiterpene lactones and three flavones were reported. A new study of the plant material and careful chromatography of the medium and more polar fractions has now allowed the isolation of eight sesquiterpene lactones: 11-epidihydroridentin (**1**), 6α-acetylferulidin (**2**), carmenin (**3**), andalucin (**4**), ridentin (**5**) [3], 11,13-dihydroridentin (**6**) [3], deacetylmatricarin (**7**) [4] and anhydrogrossmisin (**8**) [5]. The structure elucidation of lactones **1**–**4** is discussed in this paper.

RESULTS AND DISCUSSION

11-Epidihydroridentin (**1**) was very difficult to purify, and it could only be isolated as the acetate (**1a**). Its molecular formula was established as $C_{19}H_{26}O_6$ (*m/z* 350 $[M]^+$, 230.1381 $[M-120]^+$). The IR spectrum showed the presence of a γ-lactone ring, an acetate group and a double bond. The signals of the ^{1}H NMR spectrum (Table 1) closely resembled those of 11,13-dihydroridentin (**6**). The latter could be obtained by stereoselective reduction of **5** [6], also obtained from this plant. Comparison of the ^{1}H NMR spectra of **1a** and **6a** showed two main differences: the paramagnetic shift of the lactonic proton (0.19 ppm) and the smaller coupling constants ($J_{7,11} = 7.5$ Hz) in **1a** with respect to **6a**. These differences can be explained if a β-orientation of the C-11 methyl group is assumed. Therefore, the natural lactone **1** was the 11-epimer of 11,13-dihydroridentin (**6**).

6α-Acetylferulidin (**2**), mp 207–210° (EtOAc) gave a molecular ion at *m/z* 304.1350 (8.6% relative intensity) which had a formula of $C_{17}H_{20}O_5$. Its IR spectrum revealed the presence of a γ-lactone ring, an acetate group, an α,β-unsaturated carbonyl group and double bonds. The UV spectrum showed $\lambda_{\max}^{\mathrm{MeOH}}$ 254 nm. The ^{1}H NMR spectrum of **2** (Table 1) showed a triplet ($J = 10$ Hz) which seemed to be due to the hydrogen geminal to the lactonic oxygen, but it was clearly deshielded. Accordingly, this signal can be better assigned to the hydrogen geminal to the acetate group, and hence, the lactonic ring closure must be located at C-8. The *trans*-relationship between H-5, H-6 and H-7, ($J_{5,6} = J_{6,7} = 10$ Hz) together with the multiplicity of H-8 (*ddd*, 3.94, $J = 9.5$ Hz, $J' = 4.5$ Hz, $J'' = 8.2$ Hz) confirmed the above assumptions. The value of the chemical shift and coupling constants of H-11 (double quartet, δ2.63 $J = 7$ Hz, $J' = 10$ Hz) compared with those obtained by Serkerov [7] for badjisin, ferulin and ferulidin led us to assign an α-orientation for this proton. All these data were consistent with the assigned structure **2**.

Carmenin (**3**) was obtained as a crystalline compound, mp 273–275° ($CHCl_3$–MeOH). The mass spectrum showed a molecular peak, *m/z* 262.1204 (M^+, 7.3% relative intensity) in agreement with the molecular formula $C_{15}H_{18}O_4$. The IR spectrum showed the presence of hydroxyl groups, a saturated γ-lactone ring, an α,β–α′,β′ unsaturated carbonyl group and double bonds. The crossed conjugation of the carbonyl group, similar to that presented by achillin-type compounds [1], was further confirmed by the value of the UV absorption ($\lambda_{\max}$ 254 nm). The ^{1}H NMR spectrum (Table 1) lies in close correspondence with that of 6α-acetylferulidin (**2**) except for the features associated with the chiral centers C-6 and C-11. As the signals of H-5, H-6, H-7, H-8 and H-11 showed shift and/or *J* value differences, most likely these lactones differed only in the stereochemistry of some of these centers. The doublet at δ3.50 ($J = 4.3$ Hz) was assigned to H-5. Assuming an α-orientation for this proton,

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*Part 10 in the series 'Structure and Chemistry of Secondary Metabolites from Compositae'. For Part 9 see Collado, I. G., Macías, F. A., Massanet, G. M. and Luis, F. R. (1987) *J. Chem. Soc. Perkin Trans. I* 1641.

Table 1. ^{1}H NMR spectral data of compounds **1a**, **2**, **3**, **3a**, **3b** and **4a** (200 MHz), **4** (270 MHz) and **4b** (400 MHz) using TMS as internal standard.

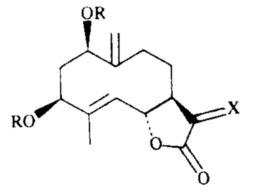
H	$CDCl_3$ **1a**	$CDCl_3$ **2**	$CDCl_3$:MeOD† **3**	$CDCl_3$ **3a**	$CDCl_3$ **3b**	$CDCl_3$ **4**	$CDCl_3$ **4a**	$CDCl_3$ **4b**	C_6D_6 **4b**
1	4.95 *m**	–	–	–	–	–	–	–	–
2	– *	–	–	–	–	4.04 *d*	4.04 *d*	4.10 *d*	4.05–3.95*
3	5.21 *dd*	6.20 *q*	6.14 *q*	6.07 *q*	6.23 *q*	4.04 *d*	4.97 *d*	5.14 *d*	4.28 *d*
5	5.40 *d*	3.47 *dbr*	3.50 *d*	3.47 *d*	3.60 *d*	2.52 *d*	2.60 *d*	2.69 *d*	2.37 *d*
6	4.52 *dd*	5.03 *dd*	4.26 *dd*	5.58 *dd*	5.35 *dd*	4.56 *dd*	4.53 *dd*	4.54 *d*	4.05–3.95*
7	– *	2.30 *dd*	2.02 *ddd*	2.01 *ddd*	2.24 *	2.75 *m*	2.71 *m*	2.71 *m*	1.35 *m*
8	– *	3.94 *ddd*	4.70 *ddd*	4.61 *ddd*	4.66 *ddd*	1.83 *ddd*	1.77 *ddd*	1.72 *ddd*	1.21 *ddd*
8′	– *	–	–	–	–	1.57 *ddd*	1.55 *ddd*	1.57 *ddd*	0.75 *ddd*
9	– *	2.72 *d**	3.30 *dd*	3.24 *dd*	3.30 *dd*	2.20 *dd*	2.20 *dd*	2.10 *dd*	1.81 *dd*
9′	– *	2.72 *d**	2.49 *dd*	2.42 *dd*	2.48 *dd*	2.00 *dd*	2.00 *dd*	1.95 *dd*	1.52 *dd*
11	2.64 *dq*	2.63 *dq*	2.70 *dq*	2.61 *dq*	2.66 *dq*	–	–	–	–
13						6.27 *d*	6.24 *d*	6.22 *d*	6.00 *d*
13′	1.12 *d*	1.27 *d*	1.38 *d*	1.15 *d*	1.47 *d*				
						5.56 *d*	5.53 *d*	5.50 *d*	5.09 *d*
14	5.20 *d*	2.15 *s*	2.30 *s*	2.25 *s*	2.33 *s*	1.39 *s*	1.73 *s*	1.83 *s*	1.75 *s*
14′	4.97 *d*								
15	1.61 *s*	2.45 *d*	2.16 *d*	1.95 *d*	2.19 *brs*	1.77 *s*	1.36 *s*	1.36 *s*	1.09 *s*
–OAc	1.99 *s*	2.17 *s*	–	1.90 *s*	–	–	2.11 *s*	–	–
–OAc	1.93 *s*	–	–	–	–	–	–	–	–
–OMs	–	–	–	–	2.93 *s*	–	–	–	–
–OH	–	–	–	–	–	4.15 *brs*	–	–	–

4b $CDCl_3$: H-2″ = 7.96 *dd*, H-3″ = 7.40 *dd*, H-4″ = 7.55 *ddd*, H-5″ = 7.40 *dd*, H-6″ = 7.96 *dd* C_6D_6: H-2″ = 8.12 *dd*, H-3″ = 7.25–7.05*, H-4″ = 7.25–7.05*, H-5″ = 7.25–7.05*, H-6″ = 8.12 *dd*.

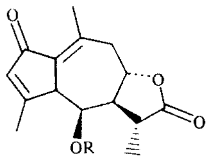
*Obscured by others signals.

†$CDCl_3$–MeOD, (3:1)

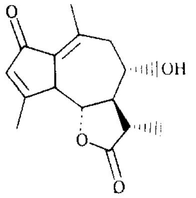
J (Hz): **1a**: 3,2 = 11.0; 3,2′ = 4.0; 14,14′ = 2.0; 11,13 = 7.5; 15,5 = 1.5. **2**: 3,15 = 1.0; 7,8 = 9.5; 8,9 = 4.5; 8,9′ = 8.2; 7,11 = 10. **4b**: 2″,3″ = 5″,6″ = 8.3; 2″,4″ = 4″,6″ = 1.1; 4″,5″ = 3″,4″ = 8.3; 3″,5″ = 1.4. **3**, **3a**, **3b**: 3,15 = 1.4; 5,6 = 4.3; 6,7 = 7.2; 7,8 = 10.8; 7,11 = 11.6; 8,9 = 5.8; 8,9′ = 10.1; 9,9′ = 18.8. **4**, **4a**, **4b**: 2,3 = 3.1; 7,8 = 7,8′ = 10.3; 7,13 = 7,13′ = 3.1; 8,8′ = 15.4; 8′,9 = 8,9′ = 5.1; 9,9′ = 12.8. **2**, **3**, **3a**, **3b**: 11,13 = 7.0. **1a**, **2**, **4**, **4a**, **4b**: 5,6 = 6,7 = 10.0.



1 R = H; X = β-Me
1a R = Ac; X = β-Me
5 R = H; X = CH_2
6 R = H; X = α-Me
6a R = H; X = α-Me



3 R = H
3a R = Ac
3b R = MeS



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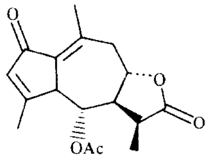

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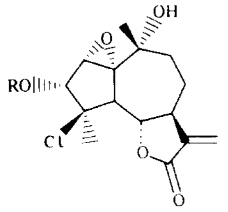
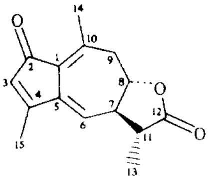


4 R = H
4a R = Ac
4b R = Bz



8

the relatively small value of the coupling constant suggested that the hydroxyl group attached at C-6 is β-oriented. Irradation of H-5 allowed the assignment of the H-6 signal which was a doublet thus indicating the presence of an H-7 proton. The value of the coupling constant $J_{6,7}$ (7.2 Hz) and the paramagnetic shift (1.32 ppm) experienced by H-6 in the spectrum of the acetate (**3a**), corroborate the α-orientation proposed for H-6.

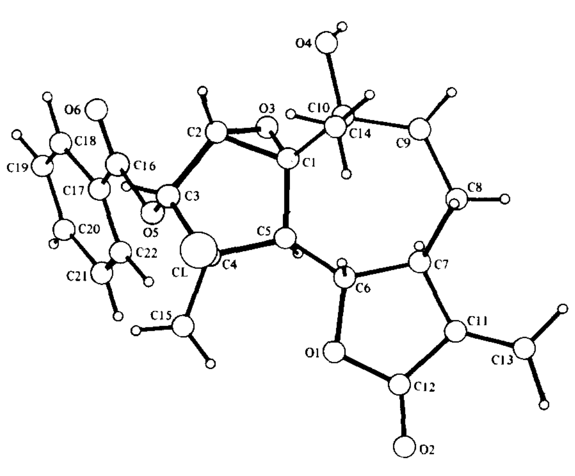
A doublet of quartets at δ2.70 ($J = 11.6$ Hz, $J' = 7.0$ Hz) was assigned to H-11, while the doublet at δ1.38 ($J = 7.0$ Hz) was assigned to the methyl attached at C-11. These data indicated that a C-11 α-methyl group was most likely. A further evidence of these assumptions was obtained by regioselective elimination of the hydroxyl group via the mesilate (**3b**). Physical constants of the trienone obtained in this reaction were identical to that of anhydrogrossmisin (**8**) also obtained from this plant.

Andalucin (**4**) was a colourless gum with the molecular formula $C_{15}H_{19}O_5Cl$ (*m/z* 279 $[M-35]^+$). Its IR spectrum showed hydroxyl groups, an α,β-unsaturated-γ-lactone ring and double bonds. The ^{1}H NMR spectrum (Table 1) confirmed the presence of an α-methylene lactone moiety by exhibiting two one proton doublets at δ6.27 and 5.56. The signals for H-2 and H-3 were observed as two totally superimposed doublets at δ4.04. On the basis of the chemical shift of H-5 (δ2.52) and its multiplicity (doublet, $J_{5,6} = 10$ Hz), as well as the multiplicity of H-6, which appeared as a doublet with large coupling constants ($J_{5,6} = J_{6,7} = 10$ Hz), a guayanolide type skeleton for this sesquiterpene lactone can be proposed. The configurations at C-5, C-6 and C-7 followed from the ^{1}H NMR large coupling constants $J_{5,6}$ and $J_{6,7}$ which clearly indicated the antiperiplanar arrangement of H-5, H-6 and H-7. The assignment of the signals H-5, H-7, H-8', H-8, H-9 and H-9' were deduced from the double irradiation experiments.

Treatment of **4** with acetic anhydride-pyridine gave **4a**. Its ^{1}H NMR spectrum (Table 1) showed that acetylation caused downfield shift for the proton H-3 from δ4.04 to 4.97 The presence of an oxirane ring between C-1, C-2 had to be assumed from the above data and the molecular formula. Singlets at δ1.77 and 1.39 are characteristic of methyl groups attached to a chlorine and a hydroxyl group, respectively [8].

Benzoylation of **4** gave a crystalline solid (**4b**) that decomposes at 200°. Its CIMS (NH_3) spectrum showed peaks *m/z* 438 $[M+2+NH_4]^+$, 436 $[M+NH_4]^+$ and 383 $[M-Cl]^+$ characteristic of presence of a chlorine atom in the molecule. In the ^{1}H NMR spectrum a paramagnetic displacement (1.1 ppm) for the doublet assigned at H-3 took place and new signals at 7.96 *dd* (2H), 7.55 *ddd* (1H) and 7.40 *dd* (2H) were observed.

Taking into account that H-7 is α-oriented in all known lactones from higher plants, and from the above mentioned ^{1}H NMR data of **4**, H-5 must have an α-orientation. The stereochemistry of all chiral centers of **4** followed from NOE difference spectroscopy on **4b**. Only the H-3 and H-14 (3H), recorded an inversion and concomitant enhancement upon irradiation of H-2, thus establishing that these protons are *cis* to each other and are *trans* to H-5. The above assumptions were corroborated by a X-ray analysis of the benzoate (4b).



4b

Fig. 1.

Crystal structure analysis of the benzoate of andalucin (**4b**)

The absolute molecular structure of **4b** is illustrated in Fig. 1. The C–Cl distance is 1.822(2)Å, and the epoxide is slightly asymmetric, with O-3–C-1 1.455(2)Å and O-3–C-2 1.436(2)Å. All other bond lengths are normal except for those involving C-20 of the benzoate group, which are slightly shortened due to the large thermal motion. Conformations of the two five-membered rings are best described as enveloped with C-4 at the flap, and half chair for the lactone, with C-12 on the local twofold axis. The seven-membered ring is in the chair conformation, with C-8 on the pseudo-mirror. Exocyclic torsion angle O-2–C-12–C-11–C-13 has a negative sign, −14.5(5)°.

Molecules in the crystal are linked in chains by hydrogen bonds involving hydroxy group O-4 as donor and lactone carbonyl O-2 as acceptor. The O···O distance is 2.778(3)Å, and the angle at H is 162(4)°.

EXPERIMENTAL

Artemisia lanata Willd was collected in Algora (Guadalajara) during July 1981. A voucher is on deposit at the Herbarium of the Department of Botany (SEVF), Faculty of Pharmacy, Sevilla, Spain.

The air-dried material (10 kg) was extracted with hot EtOH and the resulting extract separated by CC (silica gel). The medium and the more polar fractions were chromatographed on a column of silica gel (Merck, 0.063–0.2 mm) (petrol–EtOAc; increasing polarity) and after repeated prep. TLC (silica gel) or fractionated crystallization afforded: **1a** (6 mg) (prep. TLC, C_6H_6–EtOAc, 7:3), **2** (30 mg), **3** (112 mg), **4** (22 mg) (prep. TLC, $CHCl_3$–*n*-ButOH, 9:1), **5** (20 mg) (prep. TLC, C_6H_6–EtOAc, 1:1), **6** (10 mg) (prep. TLC, C_6H_6–EtOAc 1:1), **7** (30 mg), **8** (30 mg).

11-*Epidihydroridentin* (**1**). Colourless gum, was isolated as acetate **1a**. IR $\nu_{max}^{CHCl_3}$ cm^{-1}: 1770, 1735, 1630. ^{1}H NMR: see Table 1. MS *m/z* (rel. int.): 350 $[M]^+$ (0.9), 291.1624 $[M-59]^+$ (4.5) ($C_{17}H_{23}O_4$, requires 291.1621), 230.1381 $[M-120]^+$ (9.9), etc.

6α-*Acetylferulidin* (**2**). Crystalline compound, mp 207–210° (petrol–EtOAc). IR $\nu_{max}^{CHCl_3}$ cm^{-1}: 1780, 1740, 1690, 1640, 1620. ^{1}H NMR: see Table 1. MS *m/z* (rel. int.) 304.1350 $[M]^+$ (8.6) ($C_{17}H_{20}O_5$, requires 304.1346), 244.1110 $[M-60]^+$ (100). UV λ_{max}^{MeOH} nm: 254.

Carmenin (**3**). Crystalline compounds, mp 273–275°. (petrol–EtOAc). IR ν_{max}^{BrK} cm^{-1}: 3300, 1790, 1690, 1640, 1620. ^{1}H NMR: see Table 1. MS *m/z* (rel. int.): 262.1204 $[M]^+$ ($C_{15}H_{18}O_4$, requires 262.1221), 244 $[M-18]^+$ (8.55, etc. UV λ_{max}^{MeOH} nm: 254.

Monoacetate (**3a**). Was obtained by acetylation of **3** with 1 ml Ac_2O–pyridine (3:1) for 24 hr, room temp. to afford **3a** as a colourless gum. IR $\nu_{max}^{CHCl_3}$ cm^{-1}: 1780, 1740, 1690 1640, 1620. ^{1}H NMR: see Table 1. MS *m/z* (rel. int.): 304 $[M]^+$ (70.9), 262 $[M-42]^+$ (57.8), 244 $[M-60]^+$ (31), 43 (100), etc. UV λ_{max}^{MeOH} nm: 254.

Mesylate **3b**. The lactone **3** was dissolved in a minimum quantity of dry pyridine, and mesyl chloride (1 ml) was added at 0°. The mixture was kept at room temp for 24 hr. The usual work-up and column chromatography (petrol–EtOAc, 7:3) gave the mesylate **3b** as an oil. IR ν_{max}^{film} cm^{-1}: 1790, 1690, 1640, 1620, 1420, 1180. ^{1}H NMR: see Table 1.

The elimination product **8** was prepared by mixing 5 mg of **3b** with 10 ml pyridine and reflux during 1 hr. The physical and spectroscopic data were similar to the natural product anhydrogrossmisin also obtained from this plant.

Andalucin (**4**). A non-crystalline compound. IR $\nu_{max}^{CHCl_3}$ cm^{-1}: 3460, 1785, 1625, 1610, 1020, 980. ^{1}H NMR: see Table 1. MS *m/z* (rel. int.): 279 $[M-Cl]^+$ (2.7), 261.1124 $[M-Cl-H_2O]^+$ (11.4) ($C_{15}H_{17}O_4$ requires 261.1142), 243 $[M-Cl-2H_2O]^+$ (5.32).

Monoacetate **4a**. Prepared as reported for **3a**. Colourless gum. IR ν_{max}^{film} cm^{-1}: 1780, 1750, 1620, 1610, 1220, 1020, 980. ^{1}H NMR see Table 1. MS *m/z* (rel. int.): 356 $[M]^+$ (0.1), 279 $[M-Cl-42]^+$ (18.2).

Table 2. Coordinates for $C_{22}H_{23}O_6Cl$

Atom	x	y	z	B(Å^2)
C-2	0.0937(1)	0.91795(3)	0.33484(4)	6.31(2)
O-1	0.3132(2)	0.81385(7)	0.2533(1)	4.44(4)
O-2	0.4117(2)	0.77241(9)	0.1549(1)	6.00(5)
O-3	0.2459(2)	0.82574(6)	0.52047(8)	3.96(3)
O-4	−0.0141(2)	0.78663(8)	0.53299(9)	5.07(4)
O-5	0.3926(2)	0.91873(7)	0.4835(1)	4.74(4)
O-6	0.3189(2)	0.94786(9)	0.5961(1)	6.29(5)
C-1	0.1608(2)	0.8230(1)	0.4527(1)	3.52(5)
C-2	0.1673(3)	0.8729(1)	0.4985(1)	4.04(5)
C-3	0.2508(3)	0.9159(1)	0.4575(1)	4.33(5)
C-4	0.2576(3)	0.8957(1)	0.3756(1)	4.43(6)
C-5	0.2536(3)	0.8330(1)	0.3835(1)	3.62(5)
C-6	0.2185(3)	0.7990(1)	0.3141(1)	3.86(5)
C-7	0.2378(3)	0.7380(1)	0.3263(1)	4.19(5)
C-8	0.1130(3)	0.7085(1)	0.3596(2)	5.19(6)
C-9	0.0827(3)	0.7237(1)	0.4422(2)	4.80(6)
C-10	0.0391(3)	0.7835(1)	0.4578(1)	4.12(5)
C-11	0.2831(3)	0.7206(1)	0.2484(2)	4.80(6)
C-12	0.3438(3)	0.7690(1)	0.2121(1)	4.69(6)
C-13	0.2713(5)	0.6732(1)	0.2135(2)	7.5(1)
C-14	−0.0831(3)	0.8013(1)	0.4097(2)	5.23(7)
C-15	0.3739(4)	0.9198(1)	0.3290(2)	6.36(8)
C-16	0.4114(3)	0.9359(1)	0.5550(2)	4.77(6)
C-17	0.5625(3)	0.9397(1)	0.5740(2)	5.52(7)
C-18	0.5977(4)	0.9567(2)	0.6463(2)	8.00(9)
C-19	0.7374(4)	0.9622(2)	0.6650(2)	10.3(1)
C-20	0.8357(4)	0.9500(2)	0.6134(3)	12.0(1)
C-21	0.8030(4)	0.9329(2)	0.5424(3)	11.3(1)
C-22	0.6645(4)	0.9270(2)	0.5220(2)	7.52(9)

The equivalent isotropic thermal parameter, for atoms refined anisotropically, is defined by the equation: $\frac{4}{3}[a^2B_{11}+b^2B_{22}+c^2B_{33}+abB_{12}\cos\gamma+acB_{13}\cos\beta+bcB_{23}\cos\alpha]$.

Monobenzoate **4b**. It was prepared by addition of 1 ml $ClCOC_6H_5$–pyridine (3:1) for 24 hr, room temp to afford **4b** as a crystalline compound that decomposes at 200°. IR ν_{max}^{film} cm^{-1} 3500, 1790, 1740, 1620, 1610, 1480, 1420, 1290. ^{1}H NMR see Table 1. CIMS (NH_3) *m/z* (rel. int.): 438 $[M+2+NH_4]^+$ (12.9), 436 $[M+NH_4]^+$ (25.0), 419 $[M+1]^+$ (4.3), 105 $[COC_6H_5]^+$ (100).

X-ray analysis of compound **4b**. A crystal of dimensions 0.04 × 0.40 × 0.40 mm was used for data collection on an Enraf-Nonius CAD4 equipped with CuK_α radiation ($\lambda = 1.54184$ Å) and a graphite monochromator. Crystal data are: $C_{22}H_{23}ClO_6$, $M_r = 418.9$, orthorhombic space group $C222_1$, $a = 9.652$ (2), $b = 24.478$ (5), $c = 17.701$ (4)Å, $Z = 8$, $d = 1.330$ g/cm^3, $\mu(CuK_\alpha = 19.2$ cm^{-1}. Data were collected by ω-2-θ scans at speeds ranging 0.48–4.0 deg/min, subject to a maximum scan time of 120 sec, in order to measure observable data with $I = 50\sigma\ (I)$. One octant of data having $h+k$ even and $4° \leqslant 2\theta \leqslant 150°$ was measured at 23°, yielding 2410 unique data, of which 1986 had $I > 3\sigma\ (I)$ and were used in the refinement. Data reduction included corrections for background, Lorentz, polarization, decay (2.3%), and absorption. The absorption corrections were based upon psi scans, and the minimum relative transmission coefficient was 69.94%.

The structure was solved using direct methods program MULTAN [9], employing Karle recycling [10], and was refined by full-matrix least-squares based on F with weights, $w = \sigma^{-2}(F_0)$, using the Enraf-Nonius SDP programs [11]. Nonhydrogen atoms were refined anisotropically. Hydrogen atoms were located from difference maps; those on C-2, C-13, and the hydroxyl group were refined isotropically, while others were adjusted to calculated positions with C–H distance 0.95Å. Convergence was achieved with $R = 0.034$, $R_w = 0.040$, residual electron density 0.17 eA^{-3}, extinction coefficient $2.46(12) \times 10^{-6}$ 279 variables. This model, which is illustrated in Fig. 1, and for which coordinates are tabulated in Table 2, was demonstrated to be the correct absolute configuration by refinement of the enantiomorph under identical circumstances. That refinement yielded $R = 0.047$ and $R_w = 0.057$.

Compounds **5–8** and their derivatives were identified by comparing the ^{1}H NMR spectra with those of authentic material and by co-TLC.

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REFERENCES

1. González, A. G., Bermejo, J., De la Rosa, A. D. and Massanet G. M. (1976) *Anal. Quím.* **72**, 695.
2. Esteban, Mª. D., González Collado, I., Macías, F. A., Massanet, G. M. and Rodríguez Luis, F. (1986) *Phytochemistry* **25**, 1502.
3. Irwin, M. A., Lee, K. H., Simpson, R. F. and Geissman, T. A. (1969) *Phytochemistry* **8**, 2009.
4. White, E. H., Eguchi, S. and Marx, J. N. (1969) *Tetrahedron* **25**, 2099.

5. Yong-Long, L. and Mabry, T. J. (1981) *J. Nat. Prod.* **44**, 722.
6. Mathur, S. B., Hiremath, S. V., Kulkarni, G. H., Kelkar, G. R., Bhattacharyya S. C., Simonovic, D and Rao, A. S. (1972) *Tetrahedron* **21**, 3556.
7. Serkerov, S. Y. (1980) *Khim. Prir. Soedin.* **5**, 629.
8. Ault A. and Ault M. R. (1980) *A Handy and Systematic Catalog of NMR Spectra.* University Science Books. Mill Valley, California.
9. Main, P., Fiske, S. J., Hull, S. E., Lessinger, L., Germain, G. Declercq, J. P. and Woolfson, M. M., (1982) MULTAN 11/82. *A System of Computer Programs for the Automatic Solution of Crystal Structures from X-Ray Diffraction Data.* University of York, England.
10. Karle, J. (1968) *Acta Cryst.* **B24**, 182.
11. Frenz, B. A. (1985) *Enraf-Nonius Structure Determination Package*, SDP/VAX V3.0, Enraf-Nonius, Delft, Holland.