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ISOMERIC HYDROPEROXYEUDESMANOLIDES FROM *ARTEMISIA UMBELLIFORMIS**

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Key Word Index—*Artemisia umbelliformis*; Compositae, sesquiterpene lactones; hydroperoxides; *cis*-decalin derivatives; 5-desoxy-5-hydroperoxytelekin; 5-desoxy-5-hydroperoxy-5-epitelekin.

Abstract—Investigation of the aerial parts of *Artemisia umbelliformis* afforded the new eudesmanolides 5-desoxy-5-hydroperoxytelekin and 5-desoxy-5-hydroperoxy-5-epitelekin. A conformational study of the latter and some transformation products showed that these *cis*-decalin-type eudesmanolides exist in solution at room temperature as single preferred rotamers whose conformation depends on the substituent at C-5.

INTRODUCTION

The cultivation of alpine plants of high commercial value could be a profitable exploitation for the agriculture of mountain regions. Because of this, experimental cultivation of *A. genipi* Weber in Stechm. and *A. umbelliformis* Lam. (= *A. mutellina* Vill.), rare alpine Compositae used for the production of the known liqueur 'genepì', has been successfully attempted [1].

Commercial evaluation of these plants calls for the identification of metabolites characteristic of these species in order to permit assessment of their actual presence in liqueurs. With this aim, chemical studies on alpine plants belonging to the section 'genepì' of genus *Artemisia* [2] have been undertaken [3, 4].

In previous work on the bitter principles of *A. genipi* [3], we pointed out that this species and *A. umbelliformis*, although very similar and often confused, contain different sesquiterpene lactones. We describe here the isolation and structural elucidation of the main sesquiterpene lactones from *A. umbelliformis*.

RESULTS AND DISCUSSION

The aerial parts of *A. umbelliformis* gave a complex mixture of sesquiterpene lactones, whose major constituents were the hydroperoxides **1** and **5**. Repeated chromatography of the plant extract afforded a *ca* 4:1 mixture (^{1}H NMR analysis) of these compounds in the form of a thick brown oil, which behaved as a single substance when analysed by TLC or HPLC, and gave strong positive tests for the presence of hydroperoxides (liberation of iodine from ethanolic potassium iodide, blood-red colour with ferrous thiocyanate). Crystallization from *n*-hexane–ether removed quantitatively from the mixture the minor constituent **5**, which could thus be obtained in pure form. Compound **1**, the major constituent of the mixture, could not be obtained completely pure. However, methylation of the mother liquors after removal of **5** gave a crystalline methyl derivative (**2**). The electron-impact mass spectra of **1** and **5** showed the peak of highest mass number at *m/z* 232, the result of the loss of a molecule of oxygen from hydroperoxy starting compounds having MW 264 and formula $C_{15}H_{20}O_4$. In keeping with this, the chemical-ionization spectra, using ammonia as a reacting gas, displayed a parent ion at *m/z* 282 $[M+NH_4]^+$ (10%).

Compounds **1** and **5** were α,β'-unsaturated-γ-lactones, as shown by their IR, UV, ^{1}H NMR ^{13}C NMR spectra which revealed the usual features of this group of compounds [5]. Spin-decoupling experiments starting with the doublets of the H-13 protons allowed the location of H-7 at δ 3.27 in **1** and 3.20 in **5**, and then H-8 and H-9a,b on one side, and H-6a,b on the other, in both compounds. The protons at C-6 and C-9 showed only one vicinal coupling (Table 1), thus establishing that they were adjacent to one tetrasubstituted carbon. Furthermore, the ^{1}H NMR spectra of **1** and **5** showed characteristic signals of an angular methyl (δ 0.91 in **1** and 1.07 in **5**) and one unconjugated exomethylene (broad singlets with incompletely resolved fine structure at δ 4.97 and 4.66 in **1** and δ 5.23 and 5.11 in **5**). The ^{13}C NMR spectra of **1** and **5** (Table 2) showed the presence of three additional methylenes whose protons formed a strongly coupled spin system not analysable by first-order rules at 200 MHz. From the reported data, it was concluded that **1** and **5** had a common 5-hydroperoxy-$\Delta^{4(15),11(13)}$-eudesmen-7,8-olide structure. As the coupling constants of all the signals were practically the same in both compounds, **1** and **5**

*Dedicated to the memory of Silvio Stefenelli, deceased on Jan 23, 1983.

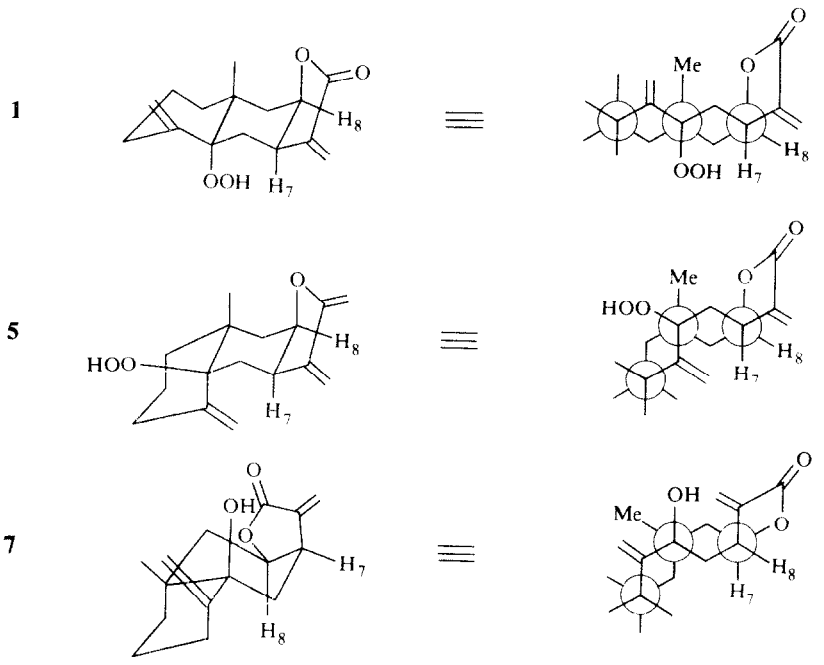


Fig. 1. Conformation of compounds **1**, **5** and **7**.

differed only in the stereochemistry at the tetrasubstituted ring-junction centre(s).

The exomethylene-γ-lactone group of both **1** and **5** belonged to an extreme pseudorotational A-type ($J_{7,13}$ < 1 Hz in **1** and *ca* 1.3 Hz in **5**) [6]. This is quite characteristic of *cis*-eudesmanolides [6, 7], and showed that **1** and **5** were *cis*-lactones, with the B-ring assuming in both compounds the same chair conformation with the C-7, C-11 bond equatorial, the C-8, oxygen bond axial and φ (H_B,C_D) ($\not< H_7$-C_7-C_{11}-C_{13}) [6] near 0° [6]. As **1** and **5** had the same ring B conformation, the different chemical shift of H-7 in these compounds ($\Delta\delta_{(1/5)}$ = 0.07 ppm) was attributed to a different relationship between this proton and the hydroperoxyl group at C-5: *cis* in **1** (δ H-7 = 3.27) and *trans* in **5** (δH-7 = 3.20). On the assumption that **1** and **5** had a β-oriented C-7 side chain [8], the hydroperoxyl group was therefore α in **1** and β in **5**. In a similar way, the lower field position of H-14 in **5** compared to **1** ($\Delta\delta_{(5/1)}$ = 0.16 ppm) showed that in the former compound the angular methyl group and the hydroperoxyl group were *cis*, while a *trans*-relationship between these groups existed in **1**. The most abundant isomer was therefore represented by the *trans*-decalin stereostructure **1**, and the minor one of the *cis*-decalin stereostructure **5**. On the basis of the presence of negative maxima at 260 nm in the CD curves of **5** and **2** (the methyl derivative of **1**) (θ_{260} = −2000° and −1700°, respectively), it is likely that these formulae also represent the absolute configuration of the compounds [9, 10]. *Cis*-decalin-type eudesmanolides are uncommon in nature: to this steric series belong the *ent*-derivative (+)-*cis*-β-cyclocostunolide [11], most probably inucrithmolide [12] and possibly graveolide [13].

Reduction of **1** gave telekin (**3**), a compound of known relative and absolute configuration [14]. Compounds **1** and **3** had very similar ^{1}H NMR spectra, except for the presence in **1** of the low-field signal of the hydroperoxyl proton (δ8.68, *br s*). The ^{1}H NMR spectrum of the alcohol **7**, obtained from the reduction of **5**, showed instead marked differences with the spectrum of the starting hydroperoxide. Furthermore, the CD curve of **7** did not show any appreciable maximum in the zone of the n–π^* transition of the conjugated lactone carbonyl.

The high values of $J_{7,13}$ (3.6 and 3.2 Hz, respectively) showed that **7** had an exomethylene-γ-lactone group belonging to the pseudorotational S-type. In the case of *cis*-lactones bound to a six-membered ring, the change from the A-type to the S-type requires the conformational inversion of the homocycle [6] and the presence of an axial C_7–C_{11} bond [6]. The changes in coupling constants observed for protons in segment C-7 to C-9 when going from **5** to **7** (Table 1) were also explainable in terms of the conformational inversion of ring B.† The reduction of the hydroperoxyl group was therefore accompanied by the passage of the *cis*-decalin system from a steroid-like to a non-steroid conformation (Fig. 1) [16].

The analysis of the ^{1}H NMR spectrum of the methyl peroxide **6** showed that this compound existed in solution at room temperature as a steroid-like rotamer; this conformation was also adopted by the ester **8**, obtained upon '*in situ*' addition of trichloroacetylisocyanate (TAI) [17] to a $CDCl_3$ solution of the alcohol **7**, which instead adopts a non-steroid conformation. Conformational changes in the course of the acylation of a tertiary hydroxyl group had already been observed in the case of the guaianolide arctolide [18].

The ^{1}H NMR spectra of compounds **5**–**8** displayed

†The value of $J_{7,8}$ (7.8 Hz) in **7** is considerably higher than the one expected for an axial–equatorial interaction, thus requiring a certain degree of deviation from the ideal chair form of ring B with a dihedral angle between H-7 and H-8 lower than 60°. The same situation has been encountered in the $C_{(8)}$ cadinanolide cycloepitulipinolide, which also has a *cis*-exomethylene-γ-lactone group of the S-type, and displays a value of 7.2 Hz for $J_{7,8}$ [15].

Table 1. ^{1}H NMR spectral data for compounds **1**–**4** and **5**–**8** (200 MHz, TMS as internal standard)

	1	**2**	**3**		**4**		**5**	**6**	**7**		**8**	
	($CDCl_3$)	($CDCl_3$)	($CDCl_3$)	(C_6D_6)	(C_6D_6)	Δ TAI	($CDCl_3$)	($CDCl_3$)	($CDCl_3$)	(C_6D_6)	(C_6D_6)	Δ TAI
H-1α/β	*	*	*	*	*	*	*	*	*	*	*	*
H-2α/β	*	*	*	*	*	*	*	*	*	*	*	*
H-3α	*	*	2.00 *dq*	1.94 *br dq*	*	*	*	*	*	*	*	*
H-3β	*	*	*	*	*	*	*	*	*	*	*	*
H-6α	1.80 *dd*	*	*	1.22 *dd*	1.60 *dd*	+0.38	1.93 *dd*	1.90 *dd*	1.96 *dd*	1.56 *dd*	*	*
H-6β	2.06 *dd*	*	*	1.51 *dd*	1.69 *dd*	+0.18	2.55 *dd*	2.50 *dd*	2.48 *dd*	1.82 *dd*	*	*
H-7	3.27 *m*	3.24 *m*	3.33 *m*	2.75 *m*	2.68 *m*	−0.07	3.20 *m*	3.17 *m*	3.24 *m*	2.59 *m*	2.85 *m*	+0.26
H-8	4.48 *td*	4.55 *td*	4.54 *td*	4.03 *td*	4.01 *td*	−0.02	4.55 *dq*	4.53 *dq*	4.31 *dq*	4.29 *dq*	3.96	−0.33
H-9α	*	*	1.86 *dd*	1.65 *dd*	1.79 *dd*	+0.14	1.70 *dd*	1.65 *dd*	1.78 *dd*	1.38 *dd*	*	*
H-9β	2.06 *dd*	*	2.01 *dd*	1.79 *dd*	2.18 *dd*	+0.39	2.01 *dd*	1.96 *dd*	*	1.51 *dd*	*	*
H-13a	6.07 *d*	6.13 *d*	6.12 *d*	6.06 *br s*	6.00 *br s*	−0.06	6.19 *d*	6.17 *d*	6.31 *d*	6.27 *d*	6.11 *d*	−0.16
H-13b	5.57 *d*	5.62 *d*	5.57 *d*	5.04 *br s*	5.00 *br s*	−0.04	5.63 *d*	5.62 *d*	5.65 *d*	5.14 *d*	5.16 *d*	+0.02
H-14	0.91 *s*	0.96 *s*	0.94 *s*	0.87 *s*	0.85 *s*	−0.02	1.07 *s*	1.02 *s*	0.84 *s*	0.57 *s*	1.09 *s*	+0.52
H-15a	4.97 *br s*	5.00 *br s*	4.84 *t*	4.64 *t*	4.87 *t*	+0.23	5.23 *br s*	5.15 *br s*	5.04 *t*	5.01 *t*	5.01 *t*	0.00
H-15b	4.66 *br s*	4.68 *br s*	4.67 *br s*	4.35 *br s*	4.69 *br s*	+0.34	5.11 *br s*	5.02 *br s*	4.92 *br s*	4.77 *br s*	4.76 *br s*	−0.01
–OOH	8.68 *br s*	—	—	—	—		7.10 *s*	—	—	—	—	
–OH	—	—	*	0.60 *br s*	—		—	—	*	0.65 *br s*	—	
$-OOCH_3$	—	3.81 *s*	—	—	—		—	3.69 *s*	—	—	—	
–NH–	—	—	—	—	8.57 *br s*		—	—	—	—	8.26 *br s*	

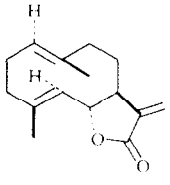
Most coupling constants were virtually the same for compounds **1**, **2**, **3**, **4** and for compounds **5**, **6** and **8**. Those for **3** and **5** are given as representative. For **3** (C_6D_6): $J_{3\alpha,3\beta}$ = 14.4 Hz; $J_{3\alpha,15a}$ = 1.9 Hz; $J_{6\alpha,6\beta}$ = 14.0 Hz; $J_{6\alpha,7}$ = 7.2 Hz; $J_{6\beta/7}$ = 11.5 Hz; $J_{7,13a}$ = < 1 Hz; $J_{7,13b}$ = < 1 Hz; $J_{7,8}$ = 5.2 Hz; $J_{8,9\alpha}$ = 2.1 Hz; $J_{8,9\beta}$ = 5.2 Hz; $J_{9\alpha,9\beta}$ = 14.0 Hz. For **5** ($CDCl_3$): $J_{6\alpha,6\beta}$ = 15 Hz; $J_{6,7}$ = 7.8 Hz; $J_{6,7}$ = 11.5 Hz; $J_{7,8}$ = 4.8 Hz; $J_{7,13a}$ = 1.4 Hz; $J_{7,13b}$ = 1.2 Hz; $J_{8,9\alpha}$ = 3.2 Hz; $J_{8,9\beta}$ = 5.2 Hz; $J_{9\alpha,9\beta}$ = 15.5 Hz. For compound **7** (C_6D_6): $J_{3\alpha,15a}$ = 1.9 Hz; $J_{6\alpha,6\beta}$ = 16 Hz; $J_{6\alpha,7}$ = 2.5; $J_{6\beta,7}$ = 7.5 Hz; $J_{7,8}$ = 7.8 Hz; $J_{7,13a}$ = 3.6 Hz; $J_{7,13b}$ = 3.2 Hz; $J_{8,9\alpha}$ = 6.4 Hz; $J_{8,9\beta}$ = 9.9 Hz; $J_{9\alpha,9\beta}$ = 14.0 Hz.

*Could not be observed because of overlapping.

Table 2. ^{13}C NMR spectral data for compounds **1**–**3** and **5**–**7** (25.18 MHz, $CDCl_3$, TMS as internal standard)

	1	2	3	5	6	7
C-1	35.79 *t**	37.75 *t**	35.60 *t**	22.59 *t**	35.75 *t**	38.52 *t**
C-2	35.16 *t**	37.30 *t**	35.37 *t**	35.72 *t**	35.55 *t**	34.49 *t**
C-3	31.96 *t**	32.21 *t**	33.79 *t**	35.89 *t**	32.57 *t**	32.91 *t**
C-4	147.2 *s*	148.0 *s*	150.1 *s*	144.9 *s*	146.0 *s*	151.1 *s*
C-5	84.90 *s*	84.23 *s*	74.19 *s*	85.46 *s*	84.30 *s*	75.84 *s*
C-6	21.84 *t**	21.96 *t**	21.71 *s**	22.03 *t**	22.20 *t**	21.88 *t**
C-7	37.38 *d*	37.75 *d*	37.58 *d*	38.61 *d*	38.67 *d*	37.82 *d*
C-8	77.12 *d*	76.87 *d*	76.95 *d*	76.04 *d*	76.08 *d*	75.45 *d*
C-9	27.88 *t**	28.42 *t**	31.81 *t**	29.46 *t**	30.09 *t**	32.36 *t**
C-10	37.08 *s*	37.30 *s*	36.47 *s*	37.86 *t*	37.72 *s*	39.71 *s*
C-11	142.0 *s*	141.90 *s*	142.1 *s*	141.1 *s*	141.0 *s*	138.5 *s*
C-12	170.87 *s*	170.6 *s*	170.6 *s*	170.0 *s*	170.1 *s*	170.4 *s*
C-13	120.4 *s*	120.5 *t*	120.2 *t*	120.9 *s*	121.0 *t*	120.9 *s*
C-14	22.86 *q*	22.67 *q*	21.71 *q*	23.33 *q*	23.49 *q*	21.80 *q*
C-15	111.8 *t*	110.9 *t*	108.8 *t*	114.3 *t*	112.7 *t*	109.1 *t*
$-OOCH_3$	—	62.62 *q*	—	—	62.61 *q*	—

*Assignments with the same sign in the same column are interchangeable.



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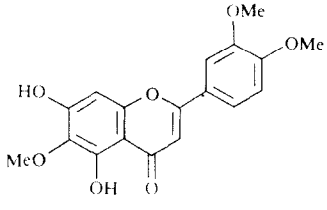

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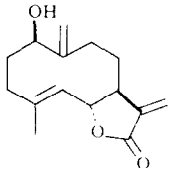

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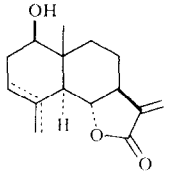
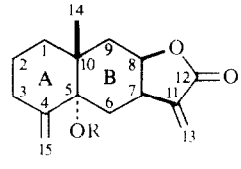


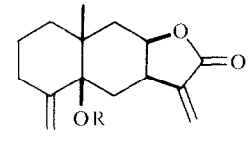
12 $\Delta^{3,4}$

13 $\Delta^{4,15}$



R

1 OH
2 OMe
3 H
4 TAC



R

5 OH
6 OMe
7 H
8 TAC

TAC = CCl_3-CO-NH-CO-

sharp signals at room temperature. Furthermore, the values of $J_{7,13}$ in these compounds were characteristic of extreme pseudorotational types of exomethylene-γ-lactones [6]. It seems therefore that at room temperature the equilibrium between steroid and non-steroid conformation is frozen for all these compounds, as a rapid interconversion between the rotamers would lead to time-mediated intermediate values of $J_{7,13}$.

This simple conformational analysis does not explain the predominance of a particular rotamer at room temperature. However, it is useful in explaining some features of the ^{13}C NMR spectra of these compounds. As can be seen from Table 2, the reduction of the hydroperoxyl group was accompanied by a much larger β-downfield and γ-upfield shift for **5** than **1** ($\Delta\delta$ C-$4_{(OOH/OH)}$ = −6.2 for **5** and −2.9 for **1**; $\Delta\delta$ C-$15_{(OOH/OH)}$ = +5.2 for **5** and +3.0 for **1**). The β-upfield and γ-downfield shifts observed in the ^{13}C NMR spectra of the allylic hydroperoxides relative to the corresponding alcohols have been attributed to the presence in the former of a stronger n–π^* conjugation between the n π-type orbital of the oxygen and the π^* orbital of the double bond [19]. This interaction requires an anticlinal orientation of the oxygen atom and the double bond [20], and in the case of the *cis*-decalin derivatives **5** **8** it is only possible in the

steroid-like conformation, and not in the nonsteroid conformation, which has the oxygen atom and the exocyclic methylene almost synclinal (Fig. 1).

The reduction of the hydroperoxyl group of **5** was accompanied by the passage from a steroid to a nonsteroid conformation, and therefore involved the complete loss of n–π^* conjugation. On the other hand, in the case of **1**, the rigid *trans*-decalin skeleton kept the oxygenated function at C-5 and the C-4 methylene in an optimal anticlinal orientation for this interaction to manifest both in the hydroperoxide and in its corresponding alcohol. The latter therefore had δ C-4 (C_β) and δ C-15 (C_γ) more similar to those of the starting hydroperoxide.

Previous data on allylic tertiary hydroperoxides have shown that the carbon bearing the –OOH group is strongly deshielded in these compounds, and resonates at fields as low as 97.5 ppm [21]. However, in **1** and **5** the resonance of this carbon was found at higher fields (δ 84.90 in **1** and 85.46 in **5**). These differences reflect the wide range of chemical shift values that have been reported for the corresponding carbon in the tertiary allylic alcohols; for example, compare artabsin [22] and matricin [23]. Therefore, it seems that a deshielding of this carbon by more than 8–10 ppm in tertiary allylic hydroperoxides compared to the corresponding alcohols is more characteristic than changes in the chemical shift values for the α-carbons of these compounds.

Besides the hydroperoxides **1** and **5** and the flavone eupatilin (**9**), some known C-6 *trans*-lactones were also found in some of the 16 samples of *A. umbelliformis* analysed. Costunolide (**10**), artemorin (**11**), santamarine (**12**) and reynosin (**13**) occurred in one sample collected near Valgrisanche (Aosta, Italy), and artemorin (**11**) was present in one sample obtained from experimental cultivations to the south of Piedmont.

The co-occurrence in these samples of C-8 *cis*- and C-6 *trans*-lactones might be connected with the ease with which *A. umbelliformis* hybridizes with other species of *Artemisia*, particularly with those belonging to the section 'genepi' [2, 24]. In this connection it is noteworthy that all the C-6 *trans*-lactones found in these samples of *A. umbelliformis* had previously been isolated from *A. genipi* [3].

EXPERIMENTAL

Mps are uncorr. Silica gel 60 (70–230 mesh) was used for CC. Silica gel pre-coated plates were used for prep. TLC (thickness: 2 mm). Trichloroacetylisocyanate (TAI) was added to solns of **3** and **7** as described in ref. [17]. Qualitative and quantitative analyses of sesquiterpene lactones in plant material were accomplished according to ref. [3].

Plant material. Naturally occurring samples of *A. umbelliformis* (*ca* 10 g of dried aerial parts) were collected in various places of the Valle d'Aosta. Cultivated samples came from experimental cultivations at the Centro Sperimentale Coltura Fiori, Erbe Alpine 'Regina delle Alpi' (Pietraporzio, CN, Italy) and the Giardino Botanico Alpino 'Paradisia' (Cogne, AO, Italy). Voucher specimens of all the plants analysed have been deposited at the herbarium of the Giardino Botanico Alpino 'Paradisia'. Owing to the rarity of the plant, whose collection is strictly regulated in many Italian regions, the isolation of plant constituents was accomplished on cultivated plants.

Isolation of sesquiterpene lactones. Dried aerial parts (leaves, stems and flowers, 1 kg) were ground and then extracted with $CHCl_3$ (4 × 8 l.) at room temp. The tarry residue (124 g) remaining after removal of the solvent at red. pres. was purified as described in ref. [3], affording a thick black syrup (35 g) which was chromatographed on a silica gel column (400 g) eluted with $CHCl_3$; 200 ml eluates were collected. Fractions 17–18 gave 1.8 g of an impure mixture of **1** and **5**. These fractions were rechromatographed (silica gel, 100 g, $CHCl_3$ as eluant) to remove some odoriferous and less polar impurities. The brown gum obtained in this way (1.48 g) was dissolved in *n*-hexane–Et_2O (1:1) and allowed to stand in the refrigerator overnight. Colourless small cubes of **5** were obtained (250 mg, 0.025% on dried plant material). The mother liquors when analysed by ^{1}H NMR did not show any trace of uncrystallized **5**. In the case of plants coming from experimental cultivation near Pietraporzio (CN, Italy), besides **1** and **5** artemorin (0.08% on dried plant material) was also isolated.

5-Desoxy-5-hydroperoxytelekin (**1**). Brownish gum, $[\alpha]_D^{25}$ +138° ($CHCl_3$; *c* 1.1); IR $\nu_{max}^{CHCl_3}$ cm^{-1}: 3500, 1750, 1660; UV λ_{max}^{EtOH} nm (log ε): 210 (4); EIMS 70 eV, *m/z* (rel. int.): 232 $[M-O_2]^+$ (30); CIMS (NH_3): 282 $[M+NH_4]^+$ (10), 266 $[282-O_2]^+$ (45), 249 (20).

5-Desoxy-5-hydroperoxy-5-epitelekin. Colourless small cubes without mp; $[\alpha]_D^{25}$ −21° ($CHCl_3$; *c* 0.7); IR ν_{max}^{KBr} cm^{-1}: 3420, 3090, 1745, 1660, 1640; UV λ_{max}^{EtOH} nm (log ε): 212 (4.3); EIMS 70 eV, *m/z* (rel. int.): 232 $[M-O_2]^+$ (25); CIMS (NH_3): 282 $[M+NH_4]^+$, 266 $[282-O_2]^+$ (55).

Methylation of **1**. The hydroperoxide **1** (1.3 g) was dissolved in 15 ml CH_2Cl_2, and the soln was stirred with 6.5 ml MeI and 3 g Ag_2O for 1 hr at room temp. After filtering, the reaction mixture was evapd, giving a solid residue. Trituration with Et_2O gave 800 mg **2** as a white powder. Recrystallization from C_6H_6 afforded shining needles of mp 168–170°; $[\alpha]_D^{25}$ +231° ($CHCl_3$; *c* 0.50); IR ν_{max}^{KBr} cm^{-1}: no hydroxyl band, 1765, 1665, 1650; UV λ_{max}^{EtOH} nm (log ε): 210 (4); EIMS 70 eV, *m/z* (rel. int.): 278 $[M]^+$ (1.5).

Methylation of **5**. Compound **5** (50 mg) was methylated as described for **1**, to give 43 mg of a colourless oil. $[\alpha]_D^{25}$ +8°; IR $\nu_{max}^{CHCl_3}$ cm^{-1}: no hydroxyl band, 1760, 1660, 1650; UV λ_{max}^{EtOH} nm (log ε): 210 (4.2); EIMS 70 eV, *m/z* (rel. int.): 278 $[M]^+$ (< 1).

Reduction of **1**. A soln of **1** (500 mg) in MeOH (10 ml) was treated with triphenylphosphine (400 mg) for 2 hr at room temp. The solvent was evapd to dryness and the residue chromatographed on a silica gel column (80 g, $CHCl_3$ as eluant) to give 120 mg telekin (**3**), $[\alpha]_D^{25}$ +220° ($CHCl_3$; *c* 0.75). The mp, ^{1}H NMR, IR and mass spectra were identical with those of natural telekin.

Reduction of **5**. Compound **5** 40 mg, (0.15 mmol) was dissolved in 8 ml MeOH and treated with 60 mg triphenylphosphine (0.22 mmol, 1.5 equiv.). After stirring for 2 hr at room temp., the soln was evapd to dryness and the residue purified by prep. TLC ($CHCl_3$–Me_2CO, 3:1) to yield 34 mg **7** as a white powder. Mp 145°; $[\alpha]_D^{25}$ +76° ($CHCl_3$; *c* 0.50); IR ν_{max}^{KBr} cm^{-1}: 3540, 3090, 1745, 1670, 1645; UV λ_{max}^{EtOH} nm (log ε): 215 (3.9); EIMS 70 eV, *m/z* (rel. int.): 248 $[M]^+$ (29.5).

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NOTE ADDED IN PROOF

The stereochemistry assigned to inuchritmolide in ref. [12] is most probably incorrect: an alternative *trans*-decalin structure has been suggested [Bohlmann, F., Jakupovic, J. and Schuster, A. (1983) *Phytochemistry* **22**, 1637].

Further investigation of *A. umbelliformis* has led to the isolation of one 4,5-*seco*-eudesmanolide related to hydroperoxides **1** and **5**. This compound was present, in small amounts, in all the samples analysed [Appendino, G., Gariboldi, P., Calleri, M., Chiari, G. and Viterbo, D. (1983) *J. Chem. Soc. Perkin Trans.* 1 (in press)].