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CHENOPODIACEAE COMPONENTS: POLYOXIGENATED SESQUITERPENES FROM *CHENOPODIUM BOTRYS*

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Abstract—Several new sesquiterpenes of eudesmane and guaiane types were isolated from the aereal parts of *Chenopodium botrys*. The structures were assigned by spectroscopic methods and confirmed by partial synthesis.

Chenopodium botrys, L. (*Salsolaceae*) is a medicinal plant, widely distributed in sandy soils, all over Southern Europe.

Although the components of this plant have been investigated by a number of workers,[1] most previous papers, deal mainly with the ascaridole contents and pay little attention to the other components.

In two previous papers,[2,3] we reported the isolation of several sesquiterpenes of elemane and eudesmane type, from the hexane and benzene extracts of the aereal parts of *Ch.botrys*, collected at the end of October near by Villaquejida (León) on the NW of Spain, but we were unable to detect any ascaridole as a component of the extracts.

Now, we report the isolation of twelve sesquiterpenes from the MeOH extract of *Ch.botrys*, which have been identified as: 6α-acetoxyselin-4(15)-en-11-ol, **1** [β-chenopodiol(6)-monoacetate], 11-acetoxy-*cis*-guai-lo(14)-en-4α-ol, **2**, 6α-acetoxyselin-3-en-11-ol-2-one, **3** [α-chenopodiol-2-one(6)monoacetate], 4α-acetoxyselinane-6α,11-diol, **4** [pygmol(4)monoacetate], selin-4(15)-en-3β, 11-diol, **5**, selin-3,5-dien-11-ol-2-one, **6** [chenopodienolone], *cis*-guai-lo-en-4α,11-diol, **7**, selin-4(15)-en-3α,6α,11-triol, **8** (chenopotriol), selin-4(15)-en-3β,6α,11-triol, **9** (3-epichenopotriol), selin-4-en-3α,6α,11-triol, **10** (isochenopotriol), selinane-3α,4α,6α,11-tetraol, **11** (chenopotetraol) and selinane-3β,4α,6α,11-tetraol, **12** (3-epichenopotetraol).

The identification of **1** (mp 68°, $[\alpha]_D = -38°$, *c*: 1.1, MeOH), **3** (mp 59°, $[\alpha]_D = +77.1°$, *c*: 0.9, $CHCl_3$) and **4** (mp 84°, $[\alpha]_D = +6.3°$, *c*: 0.9, MeOH), has been easy, because **1** and **4**, give β-chenopodiol, **13** (mp 168°, $[\alpha]_D = +115°$) and pygmol, **15** (mp 153°, $[\alpha]_D = -13.5°$) respectively, by treatment with LAH, both already isolated from *Ch.botrys*.[2] Saponification of **3**, gives α-chenopodiol-2-one, **14** (mp 104°, $[\alpha]_D = -130°$) also isolated from *Ch.botrys*.[3]

The CD curve of **3**, recorded in MeOH, shows dichroic absorptions at 328 nm ($\Delta\varepsilon = -1.7$) due to a $n-\pi^*$ transition, 241 nm ($\Delta\varepsilon = +12.4$) due to a $\pi-\pi^*$ transition and 205 nm ($\Delta\varepsilon = -3.7$). The application of the reverse octante rule, proposed by Snatzke for transoid enones,[4] the helicity rules[5,6] and the data collected by Snatzke,[7] so as the fact that the acetoxyl group on C-6 is equatorial, allow us to allow the configuration (5R, 6R, 7R, 10S)6-acetoxyselin-3-en-11-ol-2-one. The preferred conformation must be the one shown:

The mass spectrum of **2** (oil, $[\alpha]_D = +20°$, *c*: 0.9, $CHCl_3$) with a molecular ion M^+280 ($C_{17}H_{28}O_3$) shows that it is the monoacetate of a bicyclic sesquiterpenic diol. IR absorptions are indicative of unsaturations (3080, 1630, 880 cm^{-1}), OH (3380, 1120 cm^{-1}) and acetoxyl (1715, 1250 cm^{-1}) groups. This funtionality is confirmed by the ^{1}H-NMR spectrum, with signals at δ (ppm) 4.68 (s, 2H, $C{=}CH_2$) and 1.93 (s, 3H, AcO). The spectrum shows also another two singletes at 1.41 (6H, Me_2C—OAc) and 1.18 (3H, MeC—OH).

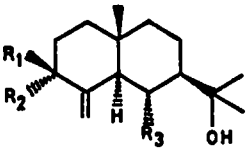
Reduction of **2** with LAH, yields the diol **7** (mp 117°, $[\alpha]_D = -35°$, *c*: 1.2, MeOH) whose ^{1}H-NMR spectrum shows now the group Me_2C—OH at 1.18 ppm.

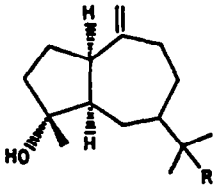
The absence in both **2** and **7** of the angular Me group, shows that they are sesquiterpenes of a different type than the other ones isolated from *Ch.botrys*, and suggests the *cis*-guaiane skeleton, which is biogenetically related with elemanes and eudesmanes.[8] Additional evidence for the guaiane skeleton is afforded by the dehydrogenation (Pd/C) of **7** to S-guaiazulene.[9]

The spectral data of **7** are very alike those exhibited by a *trans*-guaianediol isolated from *Pleocarphus revolutus* (Compositae),[10] except for the ^{1}H-NMR signal due to the olefinic protons, which in our case is shown as a singlet at 4.70 ppm, as in another guaianes with the same stereochemistry on C–1.[11]

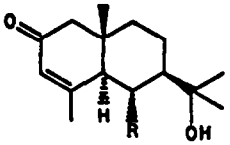
Substance **5** (mp 107–8°, $[\alpha]_D = -5.5°$, *c*: 0.6, $CHCl_3$) is also a diol $C_{15}H_{26}O_2$. The mass spectrum

R	1	5	8	9	13	16	17	18
R_1	H	OH	H	OH	H	OAc	H	OAc
R_2	H	H	OH	H	H	H	OAc	H
R_3	OAc	H	OH	OH	OH	H	OH	OH

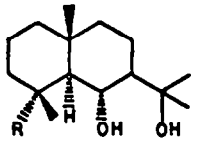




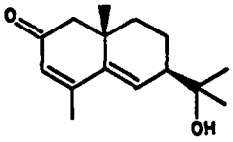
2 - R = OAc
7 - R = OH



3 - R = OAc
14 - R = OH



4 - R = OAc
15 - R = OH



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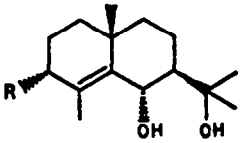
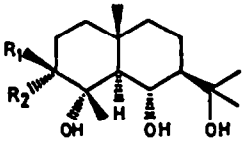
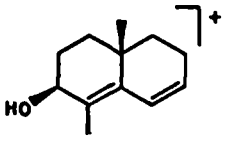


10 - R = OH
19 - R = OAc

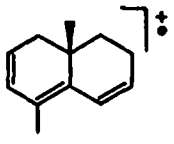


11 - R_1 = H R_2 = OH
12 - R_1 = OH R_2 = H
20 - R_1 = H R_2 = OAc
21 - R_1 = OAc R_2 = H

shows fragments which clearly suggest a diol with an eudesmane skeleton:



163



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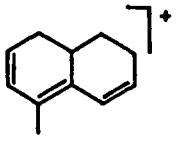


145

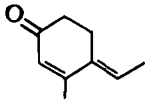
105

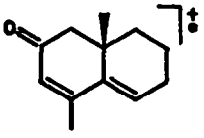
$Me_2C=\overset{+}{O}H$

59

The IR absorptions show the presence of secondary and tertiary OH groups (3280, 1150, 1060 cm^{-1}), which are confirmed by the ^{1}H-NMR signals at δ (ppm) 4.87 and 4.63 (2s, 2H, C=CH_2), 4.10 (m, $W_{\frac{1}{2}}$ = 17 Hz, 1H, axial *H*C—OH),[12] 1.18 (s, 6H, Me_2C—OH), 0.74 (s, 3H, Me—C), which is very similar to that exhibited by β-eudesmol,[2] but for the signal due to the geminal OH-proton, that show the presence of an extra secondary-OH group; **5** is readily acetylated to an oily allylic monoacetate, **16**, $[\alpha]_D = +14°$, whose spectral data are in agreement with the proposed structure.

The position and stereochemistry of the secondary-OH group on C-3, was readily adduced from the deshielding effect on the olefinic protons and from the chemical shift and coupling constant for the geminal-OH proton.[12]

Chenopodienolone, **6** (oil, $[\alpha]_D = -13.6°$, *c*: 1.1, MeOH) has been identified as a double bond extended conjugated ketone, for the UV absorption at $\lambda_{max}^{EtOH} = 293$ nm ($\varepsilon = 12.500$) (calc. for the chromophore  298 nm).[13] The deshielded angular Me group in the ^{1}H-NMR spectrum, at $\delta = 1.10$ ppm (s, 3H), is evidence for the double bond on C-5.[14] The fragmentation pattern suggests an eudesmane skeleton and agrees with the proposed structure:



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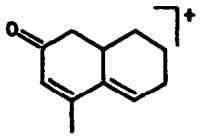

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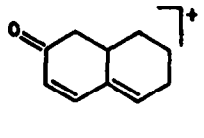
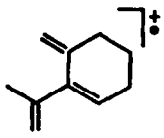


147



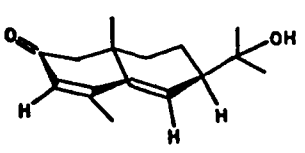
134

$Me_2C=\overset{+}{O}H$

59

$MeC=\overset{+}{O}$

43



6

The CD curve of **6** in hexane ($\Delta\varepsilon_{410} = -0.17$, $\Delta\varepsilon_{346} = +0.16$, $\Delta\varepsilon_{280} = -3.2$, $\Delta\varepsilon_{206} = +2.3$), and the coupling constant for the signal due to the olefinic proton on C_6 ($\delta = 6.30$ ppm, $J = 4$ Hz), confirm the configuration (7*R*, 10*S*)selin-3,5-dien-11-ol-2-one and the preferred conformation shown.

Most polar fractions of the MeOH extract from *Ch.botrys* is a mixture of polyols, very difficult to be directly managed.

Acetylation of this fraction at 20°, yields a partially acetylated product, which by preparative chromatography (SiO_2), affords pure samples of **17** (oil, $[\alpha]_D = +51°$), **18** (mp 152°, $[\alpha]_D = +20°$), **19** (mp 138°, $[\alpha]_D = -12°$), **20** (mp 176°, $[\alpha]_D = -19°$) and **21** (mp 191°, $[\alpha]_D = -14°$).

Treatment of all these polyhydroxymonoacetates with iAH, yields pure samples of three triols, **8**, **9** and **10** and two tetraols, **11** and **12**.

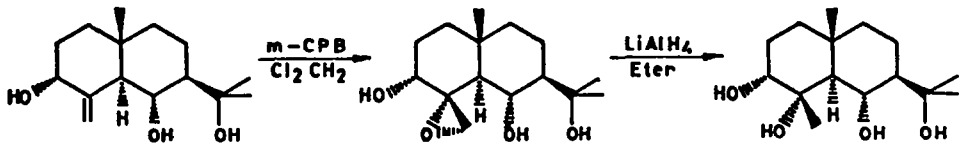
The IR spectrum of **8** (mp 137°, $[\alpha]_D = -30°$, *c*: 0.75, MeOH), shows the presence of secondary and tertiary-OH groups and one unsaturation (C=CH_2, 3090, 1640, 900 cm^{-1}). The ^{1}H-NMR spectrum is very like that exhibited by β-chenopodiol, but for the signal due to one additional geminal-OH proton at 4.26 ppm (*t*, $J = 3$ Hz, allylic equatorial *H*C—OH[12]). No MS molecular ion is observed, but prominent fragment ions which are accounted for by the loss of one Me group, one, two and three HOH molecules.

The spectral data of triol **9** (mp 163°, $[\alpha]_D = -12°$, *c*: 0.5, MeOH), are all, very like those exhibited by **8**. The only significant difference is the ^{1}H-NMR signal due to the *H*C—OH on C-3 (4.18 ppm, dd, $J = 9$ and 5 Hz), which is now assigned to one axially disposed allylic geminal-OH proton.[12]

The structures assigned to **8** and **9**, have been confirmed by partial synthesis from β-chenopodiol, **13**, which by SeO_2/Cl_2H_2 oxidation[15] affords a mixture of triols (48% and 25%) identical to the natural ones.

The MS of **10** (mp 110°, $[\alpha]_D = +35°$, *c*: 1.3, MeOH), shows a molecular ion M^+ 254, indicative that **10** is also a triol $C_{15}H_{26}O_3$, but no evidence of the presence of a double bond can be deduced from the IR spectrum, which only shows the presence of secondary and tertiary-OH groups. The ^{1}H-NMR spectrum of **10**, shows signals due to one equatorial allylic *H*C—OH (4.20 ppm, br. s, $W_{1/2} = 6$ Hz), one axial *H*C—OH (4.28 ppm, d, $J = 10$ Hz) and one Me—C=C (1.70 ppm, s) data which agree with the presence of one tetrasubstituted double bond on C-4. The signal at δ 1.02 (s, 3H, Me—C on C-10, deshielded by the effect of a β-γ double bond[14]) confirms the presence of the tetrasubstituted double bond.

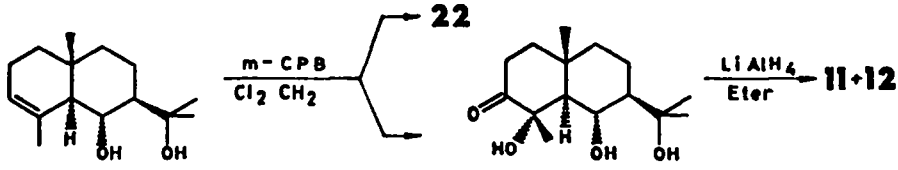
Tetraols **11** (mp 185°, $[\alpha]_D = +5.7°$, *c*: 0.7, MeOH) and **12** (mp 197°, $[\alpha]_D = +19°$, *c*: 0.9 MeOH) are saturated sesquiterpenes $C_{15}H_{28}O_4$, whose ^{1}H-NMR spectra are very like those exhibited by pygmol, **15**, but for the signals due to one extra geminal-OH proton, which in **11**, is shown as a broad singlet ($W_{1/2} = 6$ Hz, equatorial *H*C—OH) at δ 3.71 ppm, and in **12**, as a double doublet ($J = 11$ and 6 Hz, axyal *H*C—OH) at δ 3.71 ppm. The proposed structures for **11** and **12**, are confirmed by partial synthesis from chenopotriol, **8**, and α-chenopodiol[2] respectively:



8 **22** **11**

Epoxidation of **8**, is stereospecific, giving only the α-epoxide, **22**, because the orientation effect of the α-allylic-OH group[16]. Reduction of **22** with LAH, gives a tetraol identical to **11**.

Epoxidation of α-chenopodiol is rather interesting, and gives a mixture of **22** (65%) and **23** (35%), which are resolved by preparative chromatography on silica gel.

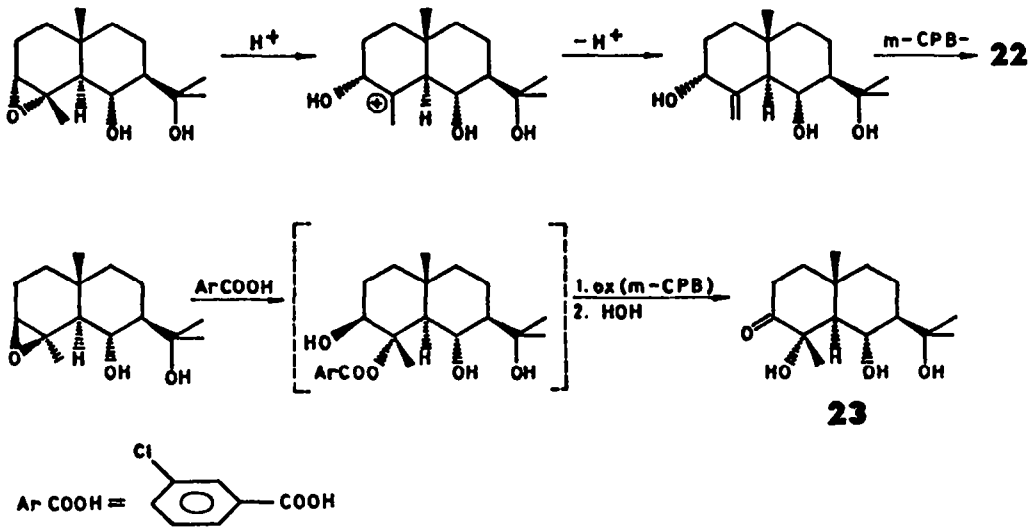


23

Compound **23**, is first eluded with benzene, as an oil, which IR spectrum shows a strong band at 1710 cm^{-1}. The ^{1}H-NMR spectrum show signals due to one angular Me group and three geminal-OH methyl groups at δ 0.90, 1.23, 1.30 and 1.32 ppm respectively.

Reduction of **23** with LAH, gives a mixture of **11** (60%) and **12** (40%) identical to the natural ones.

Formation of **22** and **23**, can be explained through the two possible epoxides for α-chenopodiol:



EXPERIMENTAL

Mps are uncorr. and were determined on a Kofler hot stage apparatus. UV spectra were recorded in EtOH on a Beckman DK-2 spectrometer. ^{1}H-NMR spectra were recorded on a Hitachi Perkin-Elmer R-24 (60 MHz) spectrometer using TMS as an internal standard, in $CDCl_3$. MS were obtained on a Hewlett-Packard Mod. 5930 A. CD curves were measured on a Jobin-Ybon Dichrograph III. Analytical TLC was performed on silica gel G (E. Merck No 7731), preparative TLC on silica gel $PF_{254+366}$ (E. Merck No 7748) and column chromatography on silica gel 60 (E. Merck No 7734).

Extraction and isolation. The ground material (0.5 Kg), previously extracted with hexane and benzene, was extracted with MeOH in a soxhlet and the concentrated extract poured on HOH, and extracted with $CHCl_3$. The $CHCl_3$ soln fract (20 g) was directly chromatographed on a dry column using benzene-ether (7:3) to afford six fractions. Each of them was rechromatographed on silica gel or silica gel coated with $AgNO_3$ (20%) columns, to afford the different components, which were finally purified by preparative tlc or crystallisation.

Fraction 1 (2.01 g) afforded cryptomeridiol (11) acetate, α-chenopodiol(6)monoacetate and **1**.*

Fraction 2 (3.90 g) afforded 6α-acetoxy-*cis*-guaiolo(14)-en-4α-ol, **2**, α- and β-chenopodiol.

Fraction 3 (4.38 g) afforded **3**, **4**, **5**.

Fraction 4 (3.72 g) afforded **6** and **7**.

Fraction 5 and 6 (5.99 g) afforded , **8**, **9**, **10**, **11**, and **12**.

β-Chenopodiol(6)monoacetate (**1**) was eluted with benzene-ether (95:5), 384 mg, mp 68° (hex), $[\alpha]_D$ −38° (*c*, 1.1, MeOH). IR (ν, cm^{-1}): 3400, 3230, 3080, 1705 (intramolecular associated C=O). 1640, 1450, 1370, 1250, 1160, 1025, 960, 900. ^{1}H-NMR (δ, ppm): 0.75 (s, 3H), 1.22 (s, 3H), 1.26 (s, 3H), 1.90 (s, 3H), 4.50 and 4.72 (2s, 2H), 5.15 (t, J = 10 Hz, 1H). MS *m/e* (rel. int.): 280 (M$^+$, 2), 265 (3), 262 (3), 220 (4), 162 (90), 147 (100), 119 (39), 105 (58), 91 (64), 79 (36), 59 (84).

11-Acetoxy-cis-guai-lo(14)-en-4-ol (**2**) was eluted with benzene-ether (8:2), oil, $[\alpha]_D$ +20° (*c*, 0.9, $CHCl_3$). IR (ν, cm^{-1}): 3380, 3080, 1715, 1630, 1450, 1360, 1250, 1120, 1010, 930, 880. ^{1}H-NMR (δ, ppm): 1.18 (s, 3H), 1.41 (s, 6H), 1.97 (s, 3H), 4.68 (s, 2H). MS *m/e* (rel. int.): 280 (M$^+$, 4), 220 (11), 205 (21), 203 (13), 187 (14), 162 (73), 145 (63), 133 (42), 119 (96), 109 (81), 93 (100), 81 (58), 59 (21). Reduction of 80 mg of **2**, with LAH, yielded 73 mg of *cis-guai-10(14-en-4,11-diol* (**7**), identical to the natural one: mp 117° (ether) $[\alpha]_D$ = −35° (*c*, 1.2, MeOH). IR (ν, cm^{-1}): 3300, 3080, 1640, 1450, 1370, 1170, 1140, 1020. ^{1}H-NMR (δ, ppm): 1.16 (s, 3H), 1.18 (s, 6H), 4.70 (s, 2H). MS *m/e* (rel. int.): 238 (M$^+$, 2), 220 (4), 205 (6), 202 (5), 162 (14), 147 (40), 119 (97), 117 (100), 107 (13), 91 (14), 82 (46), 59 (31).

Dehydrogenation of **7**. 35 mg of **7** was sealed under vacuum in a glass tube, with 35 mg of Pd/C (5%) and heated at 200° for 12 hr. Plc of the product (AcOEt) yielded 16 mg of *S*-guaizulene, UV λ_{max}^{EtOH} 244, 284, 289, 304, 349 and 367 nm.

α-Chenopodiol-2-one(6)-monoacetate (**3**) was eluted with chloroform-ether (9:1), 280 mg, mp 59–60° (hex.), $[\alpha]_D$ = +77, 1° (*c*, 0.9, $CHCl_3$). UV λ_{max}^{EtOH} 241 nm (ε, 14.728). IR (ν, cm^{-1}): 3480, 3015, 1730, 1655, 1600, 1450, 1370, 1240, 1190, 1160, 1130, 1020, 970, 880. ^{1}H-NMR (δ, ppm): 0.90 (s, 3H), 1.24 (s, 3H), 1.30 (s, 3H), 1.90 (s, 3H), 2.00 (s, 3H), 2.22 (s, 2H), 5.25 (t, J = 10 Hz), 5, 85 (br. s, $W_{1/2}$ = 6 Hz, 1H). MS *m/e* (rel. int.) 294 (M$^+$, 2), 234 (5), 219 (7), 206 (14), 201 (12), 176 (100), 161 (67), 134 (34), 123 (54), 59 (7), 43 (3). Saponification of 60 mg of **3**, yielded 40 mg of **14**.

Pygmol(4)monoacetate (**4**). The hydroxyacetate was obtained as a solid (235 mg), mp 84° and $[\alpha]_D$ +6.3° (*c*, 0.7, MeOH) by elution with $CHCl_3$-ether (95:5). IR (ν, cm^{-1}): 3400, 1720, 1450, 1370, 1250, 1170, 1110, 1015, 960. ^{1}H-NMR (δ, ppm) 0.84 (s, 3H), 1.24 (s, 3H), 1.30 (s, 3H), 1.51 (s, 3H), 1.94 (s, 3H), 4.26 (t, J = 10 Hz). MS *m/e* (rel. int.): 283 (M$^+$ − 15, 2), 280 (3), 262 (4), 238 (9),

* The substances without any number, were already isolated from the hexane or benzene extracts. See refs 2 and 3.

220 (36), 205 (82), 202 (21), 165 (100), 162 (76), 147 (55), 135 (34), 119 (42), 109 (32), 91 (26), 59 (24), 43 (8). Reduction of 100 mg of **4** with LAH, yielded 87 mg of **15**.

Selin-4(15)-en-3β,11-diol (**5**). By elution with $CHCl_3$-ether (8:2), mp 107–8° (benzene), $[\alpha]_D$ −4.5 (*c*, 0.6, $CHCl_3$). IR (*ν*, cm^{-1}): 3280, 3080, 1645, 1450, 1380, 1170, 1150, 1060, 970, 900. ^{1}H-NMR (δ, ppm): 0.74 (s, 3H), 1.18 (s, 6H), 4.10 (m, $W_{1/2}$ = 17 Hz, 1H), 4.63 and 4.87 (2s, 2H). MS *m/e* (rel. int.) 238 (M^+, 3), 220 (25), 205 (15), 202 (18), 187 (12), 163 (53), 160 (100), 145 (76), 119 (38), 109 (53), 91 (27), 59 (87), 43 (10). Acetylation of 67 mg of **5** at room T°, yielded 70 mg of **16** as an oil of $[\alpha]_D$ = +14° (*c*, 0.9, $CHCl_3$). IR (*ν*, cm^{-1}): 2450, 3080, 1730, 1645, 1450, 1370, 1250, 1160, 1130, 1020, 950, 910, 860. ^{1}H-NMR (δ, ppm): 0.76 (s, 3H), 1.20 (s, 6H), 2.04 (s, 3H), 4.75 and 5.03 (2s, 2H), 5.25 (m, $W_{1/2}$ = 17 Hz, 1H).

Chenopodienolone (**6**). By elution with benzene-ether (9:1), 307 mg of **6** are isolated, as an oil of $[\alpha]_D$ −13.6 (*c*, 1.1, MeOH). UV λ_{max}^{EtOH} 293 nm (ε, 14.500). IR (*ν*, cm^{-1}): 3400, 3010, 1650, 1610, 1575, 1260, 1200, 1180, 1115, 900, 870, 840, ^{1}H-NMR (δ, ppm): 1.10 (s, 3H), 1.19 (s, 3H), 1.30 (s, 3H), 2.06 (s, 3H), 2.22 (s, 2H), 5.85 (s, 1H), 6.30 (d, J = 4 Hz, 1H). MS *m/e* (rel. int.): 235 (M^+ + 1, 4), 219 (4), 201 (2), 190 (23), 176 (85), 161 (100), 147 (17), 119 (16), 105 (20), 91 (26), 59 (49), 43 (14).

Acetylation of fractions 5 and 6 from the dry column chromatography. 3.0 g from fractions 5 and 6 were acetylated with Ac_2O/pyridine at room temp, and gave 3.4 g of a crude mixture of hydroxyacetates, which were chromatographed on silica gel to afford pure samples of the hydroxymonoacetates.

Isochenopotriol(3)*monoacetate* (**19**) was eluted with benzene-ether (9:1), 363 mg, which after crystallisation from ether gave a solid, mp 138–40° and $[\alpha]_D$ −20° (*c*, 0.75, MeOH). IR (*ν*, cm^{-1}): 3200, 1730, 1380, 1360, 1240, 1130, 1100, 1060, 1020, 940. ^{1}H-NMR (δ, ppm): 1.03 (s, 3H), 1.25 (s, 3H), 1.40 (s, 3H), 1.75 (s, 3H), 2.00 (s, 3H), 3.75 (d, J = 10 Hz, 1H), 4.90 (br. s, 1H). MS *m/e* (rel. int.): 281 (M^+ − 15, 4), 278 (3), 260 (2), 236 (9), 221 (16), 218 (8), 160 (100), 145 (83), 123 (53), 109 (46), 95 (66), 81 (52), 59 (60), 43 (55).

Isochenopotriol (**10**). Reduction of 65 mg of **19** with LAH, yielded 60 mg of **10**: mp 110° (ether), $[\alpha]_D$ + 35° (*c*, 1.3, MeOH). IR (*ν*, cm^{-1}): 3400, 1450, 1370, 1160, 1115, 1040, 970, 910. ^{1}H-NMR (δ, ppm): 1.02 (s, 3H), 1.19 (s, 3H), 1.24 (s, 3H), 1.70 (s, 3H), 3.45 (br. s, 3H), 4.20 (br. s, $W_{1/2}$ = 6 Hz, 1H), 4.28 (d, J = 10 Hz, 1H). MS *m/e* (rel. int.): 254 (M^+, 4), 239 (8), 236 (38), 218 (18), 203 (16), 200 (14), 160 (28), 154 (100), 121 (53), 107 (47), 81 (37), 59 (57), 43 (16).

Chenopotriol(3) *monoacetate* (**17**). By elution with benzene-ether (1:1) 482 mg of **17**, as a viscid oil, was isolated: $[\alpha]_D$ + 51° (*c*, 0.8, MeOH). IR (*ν*, cm^{-1}): 3300, 3090, 1730, 1640, 1450, 1370, 1240, 1160, 1090, 1020, 950, 900, 890. ^{1}H-NMR (δ, ppm): 0.76 (s, 3H), 1.20 (s, 3H), 1.26 (s, 3H), 2.06 (s, 3H), 2.36 (d, J = 10 Hz, 1H), 4.00 (t, J = 10 Hz, 1H), 4.96 and 5.28 (2s, 2H), 5.33 (br. s, $W_{1/2}$ = 6 Hz, 1H). MS *m/e* (rel. int.): 281 (M^+ − 15, 7), 278 (3), 263 (3), 260 (2), 253 (2), 236 (4), 203 (5), 160 (44), 148 (68), 145 (100), 132 (34), 105 (31), 91 (63), 59 (40), 43 (20), 31 (20).

Chenopotriol (**8**). Treatment of 150 mg of **17** with LAH, yielded 135 mg of **8**: mp 136–37°, $[\alpha]_D$ −30° (*c*, 0.75, MeOH). IR (*ν*, cm^{-1}): 3300, 3090, 1640, 1450, 1360, 1260, 1160, 1100, 1050, 1020, 950, 900. ^{1}H-NMR (δ, ppm): 0.70 (s, 3H), 1.34 (6H, s), 1.75 (d, J = 3 Hz, 2H), 2.44 (d, J = 10 Hz, 1H), 3.96 (t, J = 10 Hz, 1H), 4.26 (t, J = 3 Hz, 1H), 4.74 and 5, 13 (2s, 2H). MS *m/e*, (rel. int.): 239 (M^+ − 15, 2), 236 (2), 218 (3), 200 (29), 185 (22), 163 (19), 160 (38), 145 (56), 119 (17), 107 (20), 93 (21), 59 (100).

3-*Epichenopotriol*(3)*monoacetate* (**18**) was eluted with benzene-ether (2:1), 350 mg, mp 152°, $[\alpha]_D$ + 20° (*c*, 0.7, MeOH). IR (*ν*, cm^{-1}): 3280, 3080, 1730, 1640, 1380, 1360, 1240, 1160, 1115, 1090, 1020, 970, 910, 875. ^{1}H-NMR (δ, ppm): 0.80 (s, 3H), 1.24 (s, 3H), 1.26 (s, 3H), 2 (s, 3H), 2.75 (d, J = 10 Hz, 1H), 4.00 (t, J = 10 Hz, 1H), 4.90 and 5.15 (2s, 2H), 5.06 (m, $W_{1/2}$ = 17 Hz, 1H). MS *m/e* (rel. int.): 281 (M^+ − 15, 2), 278 (4), 260 (4), 236 (8), 218 (12), 160 (57), 145 (100), 119 (23), 107 (46), 105 (38), 91 (23), 59 (53).

3-*Epichenopotriol* (**9**). Treatment of 100 mg of **18** with LAH, yielded 90 mg of **9**: mp 163°, $[\alpha]_D$ −12° (*c*, 0.5, MeOH). IR (*ν*, cm^{-1}): 3300, 3080, 1640, 1450, 1370, 1150, 1110, 1090, 1040, 960, 935, 890. ^{1}H-NMR (δ, ppm): 0.73 (s, 3H), 1.24 (s, 3H), 1.26 (s, 3H), 2.46 (d, J = 10 Hz, 1H), 4.00 (t, J = 10 Hz, 1H), 4.18 (dd, J = 9 and 5 Hz, 1H), 4.81 and 5.10 (2s, 2H). ME *m/e* (rel. int.): 254 (M^+, 6), 239 (8), 239 (8), 236 (14), 218 (12), 200 (4), 195 (63), 160 (49), 145 (100), 131 (26), 123 (64), 109 (49), 91 (28), 81 (29), 59 (28).

Synthesis of **8** *and* **9** *from β-chenopodiol*. To a magneticly stirred soln of 150 mg of **13** in 4 ml CH_2Cl_2, 100 mg of SeO_2 in 10 ml CH_2Cl_2 was added. The soln was kept stirred for 2 hr under reflux and one addictional hr at room temp. The black precipitated selenium was filtered off, and the solvent was removed *in vacuo*. The residue was chromatographed on silica gel to afford 30 mg of **13**, 48 mg of **8** and 25 mg of **4**, identical to the natural ones.

Chenopotetraol(3)*monoacetate* (**20**) was eluted with benzene-ether (1:1), 285 mg, mp 176° (ether), $[\alpha]_D$ −19° (*c*, 1.0, MeOH). IR (*ν*, cm^{-1}): 3360, 1735, 1450, 1380, 1240, 1185, 1080, 1060, 1020, 940, 910. ^{1}H-NMR (δ, ppm) 0.88 (s, 3H), 1.19 (s, 3H), 1.26 (s, 3H), 1.32 (s, 3H), 2.10 (s, 3H), 4.16 (t, J = 10 Hz, 1H), 4.80 (s, 1H). MS *m/e* (rel. int.): 299 (M^+ − 15), 296 (5), 278 (2), 260 (5), 239 (20), 220 (24), 160 (83), 145 (100), 119 (41), 107 (23), 105 (18), 91 (15), 59 (76).

Chenopotetraol (**11**). Treatment of 90 mg of **20** with LAH_4 yielded 80 mg of **11**: mp 185° (ether), $[\alpha]_D$ + 5.7° (*c*, 0.7, MeOH). IR (*ν*, cm^{-1}): 3300, 1450, 1380, 1290, 1180, 1120, 1050, 1020, 960, 860. ^{1}H-NMR (δ, ppm): 0.75 (s, 3H), 1.18 (s, 3H), 1.25 (s, 3H), 1.38 (s, 3H), 3.71 (br. s, $W_{1/2}$ = 6 Hz, 1H), 4.20 (t, J = 10 Hz, 1H). MS *m/e* (rel. int.): 257 (M^+ − 15, 4), 254 (5), 236 (7), 218 (6), 200 (20), 160 (64), 145 (100), 119 (37), 107 (14), 91 (25), 81 (75), 59 (92).

Synthesis of **11** *from* **8**. To a stirred soln of **8** in 3 ml of CH_2Cl_2, 95 mg of *m*-CPB in 5 ml of CH_2Cl_2 was added, while stirred for 1 hr. Then a 10% soln of Na_2SO_3 was added dropwise and the CH_2Cl_2 soln was washed three times with a 5% $Na\,CO_3$ aq, dried and evaporated. The residue, 93 mg, was purificated by crystallisation from dry ether, to afford the **22**: mp 157–8°, $[\alpha]_D$ −14° (*c*, 1.4, MeOH). IR (*ν*, cm^{-1}): 3380, 1410, 1370, 1230, 1180, 1050, 1020, 970, 940, 830. ^{1}H-NMR (δ, ppm): 0.87 (s, 3H), 1.15 (s, 3H), 1.21 (s, 3H), 2.40 (d, J = 10 Hz, 1H), 2.80 and 3.20 (2d, J = 4 Hz, 2H), 3.35 (t, J = 2 Hz, 1H), 3.75 (t, J = 10 Hz, 1H).

Reduction of 93 mg of **22**, with LAH_4, yielded 88 mg of a tetraol, identical to **11**.

3-*Epichenopotetraol*(3)*monoacetate* (**21**). By elution with benzene-ether (1:1), **21** (364 mg) was also isolated, mp 191° (ether) and $[\alpha]_D$ −14° (*c*, 0.7, MeOH). IR (*ν*, cm^{-1}): 3200, 1730, 1250, 1180, 1120, 1060, 1030, 890. ^{1}H-NMR (δ, ppm): 0.90 (s, 3H), 1.20 (s, 3H), 1.26 (s, 3H), 1.35 (s, 3H), 2.06 (s, 3H), 4.20 (t, J = 10 Hz, 1H), 4.78 (m, $W_{1/2}$ = 20 Hz). MS *m/e* (rel. int.): 299 (M^+ − 15), 296 (2), 281 (4), 278 (2), 260 (3), 239 (8), 220 (17), 203 (11), 178 (100), 160 (66), 145 (46), 119 (29), 107 (48), 91 (38), 59 (62), 43 (95).

3-*Epichenopotetraol* (**12**). Treatment of 90 mg of **21** with LAH_4 yielded 80 mg of **12**: mp 197 (ether), $[\alpha]_D$ + 19° (*c*, 0.9, MeOH). IR (*ν*, cm^{-1}): 3300, 1450, 1370,

1280, 1190, 1175, 1060, 1030, 870, 830. ^{1}H-NMR (δ, ppm): 0.88 (s, 3H), 1.24 (s, 3H), 1.30 (s, 3H), 1.32 (s, 3H), 3.71 (dd, J = 11 and 6 Hz, 1H), 4.20 (t, J = 10 Hz, 1H). ME *m/e* (rel. int.): 257 ($M^+ - 15$, 4), 254 (5), 236 (8), 221 (24), 218 (16), 200 (8), 178 (61), 160 (100), 145 (60), 119 (15), 107 (32), 105 (22), 91 (40), 59 (68).

Epoxidation of α-chenopodiol. To a stirred soln of 200 mg of α-chenopodiol in 5 ml CH_2Cl_2, 180 mg *m*-CPB in 7 ml CH_2Cl_2 was added. By proceeding as was before, a mixture (198 mg) of two substances (tlc) was obtained. The mixture was chromatographed on 10 g silica gel and **23** was first eluted (benzene) as an oil (60 mg). IR (ν, cm^{-1}): 3390, 1710, 1450, 1380, 1190, 1175, 1060, 1020, 880. ^{1}H-NMR (δ, ppm): 0.90 (s, 3H), 1.23 (s, 3H), 1.30 (s, 3H), 1.32 (s, 3H), 2.40 (m, 2H), 3.93 (t, J = 10 Hz). Finally, 130 mg of a substance identical to **22** was eluted.

Reduction of **23**: *Chenopotetraol and 3-epichenopotetraol.* Reduction of 60 mg of **23**, with LAH/dry ether, afforded 55 mg of a mixture which by tlc gave pure samples of **11** and **12**.

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