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HIGHER ISOPRENOIDS—IX
DITERPENOIDS FROM THE OLEORESIN OF *HARDWICKIA PINNATA* PART 2: KOLAVIC, KOLAVENIC, KOLAVENOLIC AND KOLAVONIC ACIDS†

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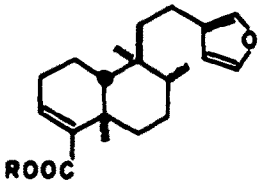
Abstract—Structure determination of four new diterpene acids from the oleoresin of *Hardwickia pinnata* Roxb. is described. All four acids belong to *ent*-clerodane type and have been chemically correlated with (−)-hardwickiic acid of proven absolute stereochemistry. One of these acids, kolavonic acid, is shown to be a bisnor diterpenoid.

In an earlier communication,[1] we described the isolation of five diterpene acids from the oleoresin of *Hardwickia pinnata* Roxb. and also presented evidence leading to the absolute stereostructure of the main acid—(−)-hardwickiic acid (1). We now report on the absolute stereostructures of the remaining four acids—kolavic acid (3), kolavenic acid (5), kolavenolic acid (7) and the nor acid, kolavonic acid (9). The structures 3 and 5 have been disclosed earlier, in preliminary communications.[2]



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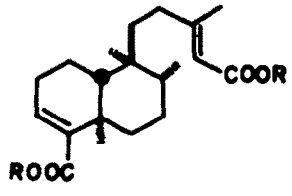
2: R = Me



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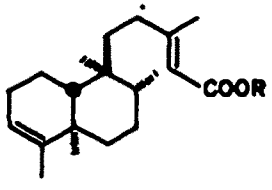

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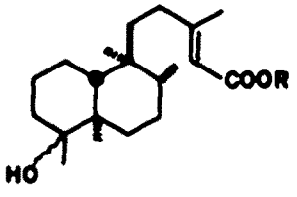

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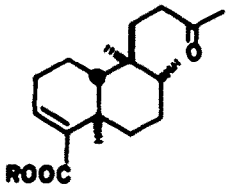

9: R = H
10: R = Me

Kolavic acid (3)

Kolavic acid, m.p. 228–230°, analyses for $C_{20}H_{30}O_4$ and from the PMR spectrum (Table 1) of the derived (CH_2N_2) ester is clearly dibasic. From the intensity of UV absorption of the acid (λ_{max} 216 nm, ϵ 21,000) as well as that of its dimethyl ester (λ_{max} 217 nm, ϵ 21,400) it is obvious that both carboxyl functions, must be $\alpha\beta$-unsaturated. On catalytic hydrogenation over Pt it yielded a tetrahydro acid, m.p. 223–225°, which gave a negative tetranitromethane (TNM) test. Thus, kolavic acid must contain only two ethylenic linkages and must be carbobicyclic. On dehydrogenation with Pd-C, kolavic acid, like hardwickiic acid, yielded both 1,2-dimethyl- and 1,2,5-trimethylnaphthalene in a 1:1 ratio, thus suggesting that kolavic acid may have the same carbon-framework as hardwickiic acid (1). This conclusion receives support from the fact that Me signals in the PMR spectra of dimethyl kolavate and methyl hardwickiate occur at very similar field strengths (Table 1).

The PMR spectrum of dimethyl kolavate also displays signals which, when considered along with the data disclosed earlier, are readily assigned to: C–C(Me)=CH– COOMe (3H, d, 2.13 ppm, J = 1.5 Hz; 1 H, bs, 5.55 ppm), C–CH_2–CH=C(C)–COOMe (1 H, t, 6.53 ppm, J = 3.5 Hz).

Keeping in mind the structure of hardwickiic acid (1), the above data for kolavic acid suggested its gross formulation as 11. Confirmation of this provisional structure was sought by a correlation with hardwickiic acid (1), which could be achieved by two distinct routes.

Exposure of methyl hardwickiate to Adam's PtO_2 catalyst in AcOH, in the usual manner, led to uptake of ~3.3 mole equivalents of hydrogen to furnish besides, the previously described[1] hexahydro derivative 12 (~25%), three hydrogenolysis products. The least polar of these (~15%) is clearly 13 from its analytical and spectral data (IR, PMR). The remaining two (TLC) compounds (~50%) could not be properly resolved,

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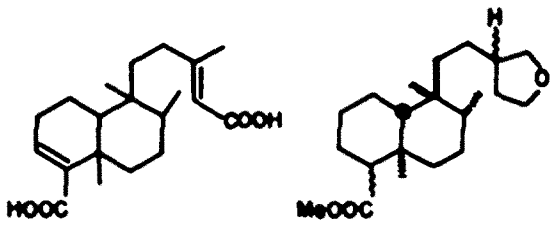
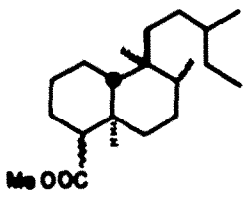


11 12



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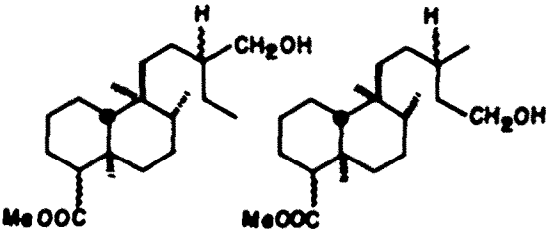
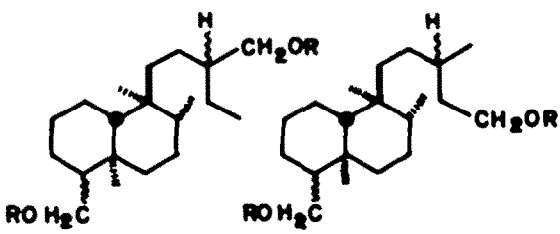


14 15

but from the IR (OH 3450, 1042 cm^{-1}; COOMe 1735, 1142 cm^{-1}) of the mixture were considered to be 14 and 15. This material was reduced by LAH to furnish a mixture of glycols (IR 3400, 1030 cm^{-1}), which could be separated into almost equal amounts of a solid (m.p. 131–133°) and liquid fractions. Both these products were converted to the corresponding acetates (17/18), which showed superimposable IR spectra, but displayed minor differences in PMR spectra and $[\alpha]_D$. The diacetate from the liquid glycol was found to be essentially indistinguishable (IR, PMR, $[\alpha]_D$) from a sample prepared from dimethyl dihydrokolavate by LAH reduction, followed by acetylation. Since, the presence of sidechain C–C=CH–COOH in kolavic acid has been deduced
|
Me



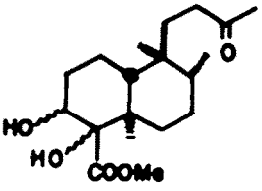
16: R = H 18: R = H
17: R = Ac 19: R = Ac

Table 1. PMR spectral (CCl_4) data for methyl esters of various acids from *Hardwickia pinnata* Roxb.

No.	Compound	δ (ppm)					
		Me-C- (s)	Me-C- (s)	Me-CH (d, J = Hz)	COOMe (s)	C=CH	Others
1.	Dimethyl kolavate (4)	0.77	1.23	0.82	3.62 3.62	5.55 (bs) 6.53(t, J=3.5Hz)	2.13(d, J=1.5Hz; Me-C=CH)
2.	Methyl kolavenate (5)	0.73	0.98	0.80	3.62	5.57 (bs) 5.12(diffused t)	2.13(d, J=1.5Hz; Me-C=CH) 1.57(d, J=1.0Hz; Me-C=CH)
3.	Methyl kolavenolate (8)	0.75	1.00	0.80	3.65	5.61 (bs)	2.15(d, J=1.5Hz; Me-C=CH) 1.23 (s; Me-C(OH)-O)
4.	Methyl kolavonate (10)	0.80	1.23	0.83	3.63	6.53(t, J=3.5Hz)	2.06 (s; MeC(=O)-C)
5.	Methyl hardwickiate (2)	0.80	1.27	0.85	3.65	6.57(t, J=4Hz)	7.17(bs; Furan-4H) 7.32(t, J=1.5Hz; Furan-5H) 6.17 (s; Furan-3H)

earlier, this correlation[a] not only suffices to confirm the gross structure 11, but also establishes its absolute stereochemistry as depicted in 3; the geometry of the side-chain as shown in 3, is clearly evident from the chemical shift of the vinylic Me (2.13 ppm), the relatively down-field value of which necessitates a *cis*-relationship between the COOR and Me functions.[3,4]

In the second approach, methyl kolavate was oxidised with RuO_4,[3] when besides a glycol, formulated as 20 on the basis of elemental analysis, IR, PMR, it furnished (after esterification) a keto diester, identified (tlc, IR, PMR, $[\alpha]_D$) as 21, a well-characterised compound from ozonolysis of (−)-hardwickiic acid.[1] Compound 21 was also obtained by ozonolysis of kolavic acid. This correlation independently leads to formulation of kolavic acid[b] as 3.



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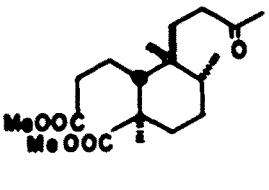
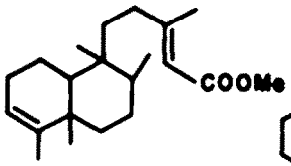


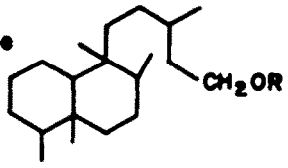
21

Kolavenic acid (5)

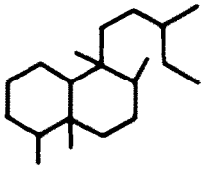
This acid was isolated as its methyl ester. The methyl ester analyses for $C_{21}H_{34}O_2$ and displays the following spectral characteristics. λ_{max} 219 nm, ε15,600 (C=C-COOMe). IR: 1733, 1230, 1158 cm^{-1} (COOMe); 1650, 870 cm^{-1} (C=CH). PMR: (see Table 1 for values) two Me–C<, one Me–CH, two Me–C=C one COOMe, two olefinic protons. From a comparison of the PMR spectral characteristics of this ester with those of methyl kolavate (Table 1) it appears reasonable to assume their close relationship. The comparison also shows that, in all probability, the grouping $C-CH_2-CH=C(-C)-COOMe$ (t, 6.53) in methyl kolavate (4), stands replaced by $C-CH_2-CH=C(-C)-Me$ (t, 5.12) in the new ester, $\Delta\delta$(1.41 ppm) being consistent[7] with the replacement of –COOMe by –Me. These considerations suggest gross structure 22 for methyl kolavenate, in which the side-chain double bond has the same geometry as in 4. It may also be noted that the shift of tertiary Me signal from 1.23 ppm in methyl kolavate (4) to 0.98 ppm in methyl kolavenate is in accord[8] with the formulation 22, wherein the C-5 Me is now being deshielded only by the adjacent olefinic linkage: as expected[8] this signal shifted to δ 0.78 ppm in the tetrahydro derivative, described below.



22



23: R = H
24: R = Ts

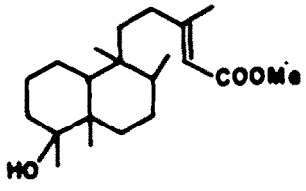


25

Confirmation of 22 and its further refinement to 6 was readily achieved by a direct correlation with kolavic acid (3). Methyl kolavenate on catalytic hydrogenation over Pt yielded the corresponding tetrahydro derivative, which on LAH reduction furnished the saturated alcohol 23 (IR: 3380, 1060 cm^{-1}). This was tosylated and the product (24) exposed to LAH to yield the hydrocarbon 25. An authentic sample of 25 was prepared from the diol 18 (from kolavic acid) by tosylation, followed by LAH reduction. The two preparations were indistinguishable (glc, IR, PMR).[c]

Kolavenolic acid (7)

This acid possibly occurs in the oleoresin as methyl ester, as it was isolated[1] from the neutral fraction of the oleoresin. The ester, m.p. 95–96°, analyses for $C_{21}H_{36}O_3$ and is clearly an hydroxy $\alpha\beta$-unsaturated ester (IR: OH 3510 cm^{-1}; C=O 1715 cm^{-1}; C=C 1650 cm^{-1}) closely related to methyl kolavenate (6), as was apparent from a comparison of the PMR spectral characteristics (Table 1) of the two esters. It is also apparent from its PMR spectrum, that it has the same side-chain as has been established for kolavenic ester, and since it has only one vinylic Me, and has, in addition, Me–C(–O)< function, structure 26 appeared most attractive.



26

Confirmation of structure 26 was forthcoming, when dehydration of methyl kolavenolate with pyridine-treated alumina[11] at 200–230°, furnished (after esterification), as the main product, methyl kolavenate (6), identified in the

[a] It may be noted that spectral data of the glycols or their acetates do not enable a distinction to be made between the structures 16(17) and 18(19), assigned to the products derived from hardwickiic acid. However, this correlation which is independent of this ambiguity, also establishes structure 18 for the "liquid glycol".

[b] Since the publication of the preliminary communications,[3] its monomethyl ester has been isolated[9] from the wood of *Gossweilerodendron balsamiferum* Harms.

[c] Since our preliminary reporting[2] on the structure of kolavenic acid, this acid has been isolated from *Solidago elongata* Nutt[9] and from the oleoresin of *Araucaria bidwillii*.[10]

usual manner. This correlation also leads to the absolute stereostructure 8, in which configuration at C-4 is yet to be defined.

Kolavonic acid (9)

This acid also could be isolated as its Me ester, which analyses for $C_{19}H_{30}O_3$ and has the following structural features: $-CH_2-C\underset{|}{H}=C(C)-COOMe$ (λ_{max} 217 nm, ε, 8080. IR: C=O 1715 cm^{-1}; C=C 1648 cm^{-1}. PMR: 1 H, t, 6.53 ppm, J = 3.5 Hz; 3 H, s, 3.63 ppm), MeCO (2,4-dinitrophenylhydrazone, m.p. 172–173°. IR: C=O 1715 cm^{-1}. PMR: 3 H, s, 2.06 ppm), besides (see Table 1) two Me-C- and one Me-CH. From a comparison of its PMR spectral characteristics with those of other members (Table 1) discussed so far, it is clear that this nor compound is also closely related to these compounds and, in fact, may be 10. That this is indeed so, was established when partial ozonolysis of methyl kolavate (4) furnished a methyl ketone, identical in all respects (glc, IR, PMR) with the naturally occurring compound.

Conceivably, kolavonic acid (9) could arise in nature from a suitable C-20 precursor by a biological equivalent of a retro-aldol reaction. Several similar C-18 nor-diterpenoids are known at present.[13]

EXPERIMENTAL

For general remarks see Ref. 1.

Kolavic acid (3)

IR (Nujol): 2660, 2600, 1685, 1650, 1278, 1260, 1175, 942, 882, 710 cm^{-1}. *Dimethyl ester* (4) was prepared by exposure to CH_2N_2 in ether–MeOH: b.p. 193–194°/0.4 mm, n_D^{25} 1.5179, $[\alpha]_D^{25}$–126.1° ($CHCl_3$, *c* 3.15%). IR(liq.): 1720, 1650, 1252, 1230, 1200, 1158, 1080, 1064, 1032, 870, 763 cm^{-1}. (Found: C, 72.98; H, 9.10; OMe, 18.0. $C_{22}H_{34}O_4$ requires: C, 72.89; H, 9.45; OMe, 17.12%).

Tetrahydrokolavic acid

Kolavic acid (200 mg) in AcOH (10 ml) was hydrogenated over pre-reduced PtO_2 catalyst (40 mg), when it absorbed 36 ml H_2 (2.05 double bond equivalent) at 28°/710 mm during 6 hr. Usual work-up gave a product, which was crystallised from MeOH: white needles, m.p. 223–225°, $[\alpha]_D^{25}$–47.28° (EtOH, *c* 1.62%). IR (Nujol): 2730, 2650, 1717, 1700, 1300, 1278, 1238, 1201, 951, 690 cm^{-1}. (Found: C, 71.03; H, 10.2. $C_{20}H_{34}O_4$ requires: C, 70.97; H, 10.13%). *Dimethyl ester* (CH_2N_2): b.p. 170–180° (bath)/0.2 mm, n_D^{25} 1.4890, $[\alpha]_D^{25}$–45.22° ($CHCl_3$, *c* 3.18%). IR (liq.): 1745, 1260, 1220, 1193, 1170, 1145, 1102 cm^{-1}. (Found: C, 71.31; H, 10.45. $C_{22}H_{38}O_4$ requires: C, 72.09; H, 10.45%).

Dehydrogenation of kolavic acid

A mixture of kolavic acid (1.0 g) and 10% Pd-C (0.5 g) was heated at 300–320° in a current of CO_2 till evolution of H_2 ceased (8 hr). The reaction mixture was worked up and the products identified exactly as described earlier[1] for hardwickiic acid.

Hydrogenation-hydrogenolysis of methyl hardwickiate

Methyl hardwickiate (2.5 g, 0.0075 mole) was hydrogenated over pre-reduced PtO_2 catalyst (250 mg) in AcOH (15 ml) at 27°/710 mm till further absorption of H_2 had ceased (30 hr; H_2 uptake 645 ml ≈ 3.3 mol. equiv.). Usual work-up furnished a product (2.4 g), which was distilled at 190–210° (bath)/0.4 mm to give a viscous liquid (2.1 g) showing on tlc (solvent: 5% EtOAc in C_6H_6) at least four components of RR_f 0.24, 0.34, 0.58 and 1.00. The product was chromatographed over Al_2O_3/II (18.5 cm × 2.2 cm):

Fraction 1	Light pet.	25 ml × 10	40 mg, mixture
Fraction 2	Light pet.	25 ml × 5	129 mg, RR_f 1.00
Fraction 3	10–50% C_6H_6 in light pet.	25 ml × 16	349 mg, mixture, RR_f 1.00, 0.58
Fraction 4	75% C_6H_6 in light pet.	25 ml × 14	295 mg, RR_f 0.58
Fraction 5	C_6H_6	25 ml × 4	27 mg, mixture
	1% MeOH in C_6H_6	25 ml × 4	
Fraction 6	3% MeOH in C_6H_6	25 ml × 6	899 mg, mixture, RR_f 0.34, 0.24

Ester 13. Fraction 2 was distilled to furnish 13 (125 mg): b.p. 160–162° (bath)/0.2 mm, n_D^{25} 1.4860, $[\alpha]_D^{25}$–51.08° ($CHCl_3$, *c* 3.4%). IR (liq.): 1748, 1320, 1195, 1170, 1145 cm^{-1}. PMR (CCl_4): Me-C-(3 H singlets at 0.70, 0.98 ppm), Me-CH (d, 0.78 ppm, J = 6 Hz; d, 0.88 ppm, J = 6 Hz), Me-CH_2 (t, 0.80 ppm, J = 4.5 Hz), COOMe (3 H, s, 3.57 ppm). (Found: C, 77.91; H, 11.91. $C_{21}H_{36}O_2$ requires: C, 78.20; H, 11.88%).

Methyl hexahydrohardwickiate (12). Fraction 4 on distillation yielded 12 (290 mg): b.p. 180–190° (bath)/0.4 mm, n_D^{25} 1.5024, $[\alpha]_D^{25}$–56.5° ($CHCl_3$, *c* 2.3%). IR, PMR identical with earlier data.[1]

Ester alcohol 14, 15. Distillation of fraction 6 furnished mixture of 14, 15 (890 mg): b.p. 175–185° (bath)/0.2 mm, n_D^{25} 1.4986, $[\alpha]_D^{25}$–45° ($CHCl_3$, *c* 4.9%). IR (liq.): 3450, 1735, 1320, 1272, 1192, 1172, 1142, 1042, 1010, 988, 780 cm^{-1}. (Found: C, 74.47; H, 11.47. $C_{21}H_{36}O_3$ requires: C, 74.51; H, 11.32%).

Glycol 18

(*i*) *From dimethyl tetrahydrokolavate.* Dimethyl tetrahydrokolavate (195 mg) in dry ether (5 ml) was reduced with a slurry of LAH (150 mg) in ether (50 ml) in the usual manner and the product distilled to get a colourless gum (180 mg): b.p. 160–165° (bath)/4.8 × 10^{-4} mm, n_D^{25} 1.5122, $[\alpha]_D^{25}$–20.2° ($CHCl_3$, *c* 2.45%). IR (Nujol): 3400, 1050, 1030, 995 cm^{-1}. PMR (CCl_4): Me-C-(3 H singlets at 0.70, 0.82 ppm), CH_3-CH (3 H, d, 0.73 ppm, J = 6 Hz; 3 H, d, 0.90 ppm, J = 6 Hz), CH_2OH (4 H, m, 3.0–4.0 ppm) (Found: C, 77.62; H, 12.66. $C_{20}H_{38}O_2$ requires: C, 77.36; H, 12.34%). *Acetate* (19) (Ac_2O, pyridine; 48 hr at 20–27°): b.p. 210–215° (bath)/0.5 mm, n_D^{25} 1.4859, $[\alpha]_D^{25}$–21.4°. IR (liq.): 1750, 1240, 1039, 972 cm^{-1}. PMR (CCl_4): Me-C- (3 H singlets at 0.68, 0.86 ppm), two Me-CH (0.70–0.93 ppm), MeCOO (3 H, s, 1.93 ppm; 3 H, s, 1.97 ppm), CH_2OAc (4 H, m, 3.5–4.3 ppm). (Found: C, 73.69; H, 10.86. $C_{24}H_{42}O_4$ requires: C, 73.05; H, 10.73%).

(*ii*) *From mixture of ester alcohols* 14, 15. Ester alcohol mixture (890 mg) was reduced with LAH (680 mg) in dry ether (100 ml), first at 0° (1 hr), then at 25° (1 hr) and finally at reflux (12 hr). Usual work-up (with EtOAc, followed by H_2SO_4 aq) furnished a product (830 mg), which slowly solidified. Crystallization from CH_3CN afforded needles (350 mg), m.p. 131–133°, $[\alpha]_D^{25}$–18.9° ($CHCl_3$, C, 2.7%). This is *considered* to be *glycol* 16. IR(Nujol): 3500, 3385, 1035, 1000, 970, 948 cm^{-1}. (Found C, 77.80; H, 12.38. $C_{20}H_{38}O_2$ requires: C, 77.36; H, 12.34%). *Acetate* (17): b.p. 190–200° (bath)/0.1 mm, n_D^{25} 1.4862, $[\alpha]_D^{25}$–35.1° ($CHCl_3$, *c* 1.1%). IR, almost superimposable on that of 19. PMR: minor differences with respect to that of 19. (Found: C, 73.60; H, 10.67. $C_{24}H_{42}O_4$ requires: C, 73.05; H, 10.73%).

The mother liquor after removal of the solid glycol, on work-up gave 300 mg of a gum, which was acetylated and the crude product (320 mg) chromatographed on Al_2O_3/II (12 g): 10% C_6H_6 in light pet. (10 ml × 15) eluted 208 mg of tlc pure material, which was distilled: b.p. 210–215° (bath)/0.5 mm, n_D^{20} 1.4859, $[\alpha]_D^{20}$ −20.71° ($CHCl_3$, c, 4.9%). IR, PMR superimposable on those of 19. (Found: C, 73.60; H, 10.67. $C_{26}H_{42}O_4$ requires: C, 73.05; H, 10.73%).

Keto diester 21

(*i*) RuO_4 *oxidation of methyl kolavate.* Methyl kolavate (800 mg) in acetone (60 ml) was oxidised with RuO_4 (RuO_2 200 mg, and a total of 8.2 g of $NaIO_4$) at 25–27° during 6 hr, by following the general procedure described earlier.[1] The total product in EtOAc (100 ml) was separated by Na_2CO_3 aq into neutral (446 mg) and acidic (400 mg) fractions. The acidic fraction was esterified (CH_2N_2) and the product chromatographed (*vide infra*) over SiO_2-gel/II to furnish 21, identified in the usual manner (tlc, IR, $[\alpha]_D$).[1]

The neutral portion was also chromatographed over SiO_2-gel/III (32 cm × 1.1 cm): 20% EtOAc in C_6H_6 (10 ml × 6) eluted a crystalline compound (212 mg), which was recrystallised from light pet.: m.p. 104–105°, $[\alpha]_D^{20}$ + 16.3° ($CHCl_3$, c 1.14%). IR (Nujol): 3335, 1733, 1701, 1277, 1244, 1215, 1053, 1020, 925 cm^{-1}.

PMR (CCl_4): Me–C(=)– (3 H singlets at 0.87, 1.15 ppm), Me–CH (3 H, d, 0.82 ppm, J = 6 Hz), MeCO (3 H, s, 2.17 ppm), $COOMe$ (3 H, s, 3.9 ppm), CH_2OH (1 H, s, 4.2 ppm). (Found: C, 67.48; H, 9.27. $C_{19}H_{32}O_3$ requires: C, 67.03; H, 9.47%).

(*ii*) *Ozonolysis of kolavic acid.* Kolavic acid (2.5 g) in AcOH (50 ml) was ozonized with cooling (−15°) in the usual manner. The solvent was removed under suction (at 40–50°) and the residue dissolved in K_2CO_3 aq, mixed with H_2O_2 aq (30%, 20 ml), water (30 ml), and heated on a steam-bath for 4 hr. The reaction mixture was worked up in the usual manner to get an acid, which after esterification (CH_2N_2) furnished crude ester (2.33 g). This material was chromatographed over SiO_2 gel/II (20 cm × 2.7 cm) using C_6H_6 and, C_6H_6 containing increasing quantities (2–10%) of EtOAc: 2% EtOAc in C_6H_6 (50 ml × 12) furnished 763 mg of 21: b.p. 200–210° (bath)/0.8 mm, n_D^{20} 1.4886. (IR, PMR).[1]

Methyl kolavenate (6)

IR (liq.): 1735, 1650, 1280, 1230, 1156, 1102, 1058, 1035, 1000, 980, 924, 870, 856, 798 cm^{-1}. Mass (70 eV): *m/e* 318 (M^+, 30%), 189 (100%), 121 (45%), 120 (45%), 107 (65%), 95 (80%), 93 (42%), 81 (37%), 69 (55)%, 55 (35%).

Methyl tetrahydrokolavenate

Methyl kolavenate (293 mg) in AcOH (10 ml) was hydrogenated over pre-reduced Adam's Pt catalyst (50 mg) at 28°/711 mm, when a total of 50 ml H_2 (~2 mole equiv.) was taken up during 5 hr. Usual work-up gave, after distillation, a colourless liquid (285 mg): b.p. 180–185° (bath)/0.2 mm, n_D^{20} 1.4860, $[\alpha]_D^{20}$ + 1.45° ($CHCl_3$, c, 4%). IR (liq.): 1748, 1260, 1230, 1220, 1192, 1175, 1160, 1012 cm^{-1}. PMR (CCl_4): Me–C(=)– (3 H singlets at 0.70, 0.78 ppm), CH_3–CH (3 H, d, 0.7 ppm, J = 6 Hz; 3 H, d, 0.84 ppm, J = 5 Hz), $COOMe$ (3 H, s, 3.62 ppm). (Found: C, 78.57; H, 11.66. $C_{21}H_{36}O_2$ requires: 78.20; H, 11.88%).

Tetrahydrokolavenol (23)

Methyl tetrahydrokolavenate (4.03 g, 0.124 mole) in ether (40 ml) was reduced with a slurry of LAH (2.0 g, 0.053 mole) in ether (150 ml), first at ice-bath (0.5 hr), then at 27–29° (0.5 hr) and finally at reflux (7 hr). The mixture was worked up in the usual manner (first EtOAc, then H_2SO_4 aq) to furnish crude alcohol (4.0 g), which was chromatographed over Al_2O_3/II (23 cm × 2.5 cm) using light pet. containing increasing (10→75%) quantities of C_6H_6: material (2.64 g) eluted with 50% C_6H_6 in light pet. (100 ml × 20) was distilled to get tlc pure (solvent: 10% EtOAc in C_6H_6) 23: b.p. 130–140° (bath)/0.02 mm, n_D^{20} 1.4989, $[\alpha]_D^{20}$ + 6.4° ($CHCl_3$, c, 2.85%). IR (liq.) : 3380, 1060, 1008 cm^{-1}. PMR (CCl_4): Me–C(=)– (3 H singlets at 0.70, 0.78 ppm), CH_3–CH (3 H, d, 0.78 ppm, J = 6 Hz; 3 H, d, 1.00 ppm, J = 5 Hz), CH_2OH (2 H, t, 3.60 ppm, J = 6 Hz). (Found: C, 81.89; H, 13.07. $C_{20}H_{38}O$ requires: C, 81.56; H, 13.01%).

Hydrocarbon 25

(*i*) *From tetrahydrokolavenol.* Tetrahydrokolavenol (0.5 g) was exposed to tosyl chloride (0.65 g) in anhyd pyridine (5 ml) for 28 hr at room temp. (20–27°). The mixture was worked up in the usual manner to get the required tosylate (24) as a gum (340 mg). This material was reduced with LAH (200 mg) in refluxing THF (50 ml) for 8 hr and worked up in the usual manner to furnish a liquid (220 mg), which was chromatographed over Al_2O_3/II (16 cm × 0.8 cm), while monitoring with $AgNO_3$–SiO_2-gel tlc (solvent: hexane). The major cut eluted with light pet. (2 ml × 3), gave a glc (diethylene glycol polysuccinate column, 200°) and tlc pure liquid (160 mg) as the desired product: b.p. 150–153° (bath)/1.6 mm, n_D^{20} 1.4851; $[\alpha]_D^{20}$ + 5.7° ($CHCl_3$, c, 2.6%). IR (liq.): 1160, 1125, 1108, 1090, 1055, 1038, 1022, 990, 945 cm^{-1}. PMR (CCl_4): Me–C(=)– (3 H singlets at 0.73, 0.82 ppm), CH_3–CH, CH_3–CH_2 (~12 H, 0.73–0.95 ppm). (Found: C, 86.70; H, 13.42. $C_{20}H_{38}$ requires: C, 86.25; H, 13.75%).

(*ii*) *From tetrahydrokolanol* (18). Diol 18 (0.503 g) in pyridine (5 ml) was treated with tosyl chloride (1.16 g) at ~27° for 28 hr and then worked up in the usual manner to furnish bis-tosylate as a gum (0.503 g). This material was reduced by LAH (500 mg) in THF (50 ml) exactly, as above, to furnish after work-up, followed by chromatography, as above, the required hydrocarbon (25): colourless liquid (120 mg), b.p. 150–155° (bath)/1.6 mm, n_D^{20} 1.4857, $[\alpha]_D^{20}$ ≈ 0. IR, PMR exactly identical with those of sample from (i) above.

Methyl kolavenolate (8)

IR (Nujol): 3510, 1715, 1650, 1335, 1230, 1162, 1120, 1098, 1081, 1050, 1010, 948, 930, 870, 845, 792, 745 cm^{-1}.

Dehydration of 8 *to methyl kolavenate* (6)

Ester 8 (200 mg) and pyridine-modified Al_2O_3[11] (1.0 g) were mixed and heated at 200–230° under reduced pressure (~10 mm) for 0.5 hr. The reaction mixture was cooled and extracted with 5% Na_2CO_3 aq–MeOH, the extract acidified, the product taken up in ether and esterified with CH_2N_2. Work-up furnished a product (98 mg), which was chromatographed on Al_2O_3/II (12 × 0.7 cm). Light pet. eluted a liquid (46 mg), which was further purified by preparative-layer-chromatography (PLC) on $AgNO_3$–SiO_2 gel (solvent: C_6H_6) to furnish 6 (IR, PMR).

Methyl kolavonate (10)

IR (liq.): 1715, 1648, 1280, 1258, 1238, 1200, 1160, 1082, 1064, 1040, 1024, 995, 945, 778, 757 cm^{-1}. *2,4-Dinitrophenylhydrazone* (diglyme method),[13] yellow orange needles (EtOH), m.p. 172–173°.

Ozonolysis of dimethyl kolavate (4) *to* 10

A soln of dimethyl kolavate (0.532 g; 0.0015 mole) in dry EtOAc (60 ml) was treated with ozonized oxygen (0.28 g O_3/hr) at −20° for 15 min only. The solvent was flashed off under suction at room temp. (~27°). The residue (0.60 g) was heated with 30% H_2O_2 aq (2 ml) and water (8 ml) at 60° for 2 hr, and then worked up with ether to get a product (0.60 g), which was chromatographed on Al_2O_3/II (21 cm × 0.9 cm), with tlc (solvent: 10% EtOAc in C_6H_6). Benzene (10 ml × 10) eluted 122 mg of a material, which was further purified by PLC (SiO_2 gel; solvent, 10% EtOAc in C_6H_6) to get 40 mg of a material identified (tlc, glc, IR) as 10: b.p. 180–185° (bath)/0.1 mm, n_D^{20} 1.5109, $[\alpha]_D^{20}$ −102.3° ($CHCl_3$, c 1.5%). (Found: C, 74.44; H, 9.56. $C_{19}H_{30}O_3$ requires: C, 74.47; H, 9.87%).

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