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STEREOSELECTIVE SYNTHESIS OF OPTICALLY ACTIVE FORMS OF δ-MULTISTRIATIN, THE ATTRACTANT FOR EUROPEAN POPULATIONS OF THE SMALLER EUROPEAN ELM BARK BEETLE†

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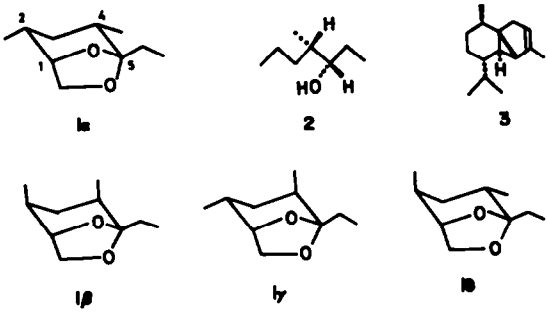
Abstract—A stereoselective synthesis of highly optically pure enantiomers of δ-multistriatin [(1*S*,2*S*,4*S*,5*R*)-2,4-dimethyl-5-ethyl-6,8-dioxabicyclo[3.2.1]octane and its antipode] was accomplished starting from tartaric acid enantiomers.

(−)-α-Multistriatin **1α**, (−)-4-methylheptan-3-ol **2** and (−)-α-cubebene **3** are pheromone components responsible for the aggregation of North American populations of the smaller European elm bark beetle, *Scolytus multistriatus* Marsham.[1,2] The former two, **1α** and **2**, are produced by the female beetles, while **3** is produced by the host elm tree. The absolute stereochemistry of (−)-α-multistriatin was established as 1*S*,2*R*,4*S*,5*R*(**1α**) by synthesising it, although in low optical purity.[3-5] The absolute configuration of (−)-4-methylheptan-3-ol was 3*S*,4*S*(**2**) as revealed by the synthesis of its antipode.[6]

Multistriatin exists in eight stereoisomeric forms, **1α**, **1β**, **1γ** and **1δ** and their respective antipodes.[1,7] For North American populations of *S. multistriatus*, (−)-α-multistriatin **1α** was attractive.[1] However, populations of *S. multistriatus* endemic to forests in the Upper Rhine Valley did not aggregate in response to **1α**. Instead, (−)-δ-multistriatin **1δ** proved attractive when combined with **2** and **3**.[8] This observation made us to synthesise



1α **2** **3**

1β **1γ** **1δ**

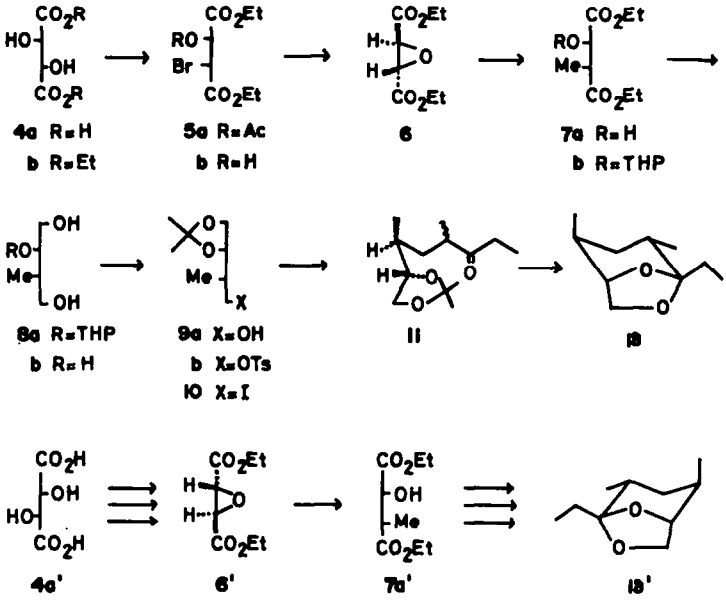
highly optically pure enantiomers of δ-multistriatin, **1δ** and **1δ'**, to study relationship between chirality and biological activity. Although a synthesis of pure (−)-α-multistriatin **1α** from D-glucose has recently been reported,[9] no synthesis of pure **1δ** and its antipode **1δ'** has been accomplished. In this paper we describe a stereoselective synthesis of δ-multistriatin enantiomers **1δ** and **1δ'**.

(1*S*,2*S*,4*S*,5*R*)-δ-Multistriatin **1δ** is an intramolecular acetal of a keto diol derivable from **11**, in which the vicinal OH and Me groups are in *erythro* relationship. In the key reaction of our synthesis, this *erythro* configuration was generated by cleaving the epoxy ring of **6** with Me_2CuLi to give **7a**. As our starting material, D-(−)-tartaric acid **4a** was chosen.

Diethyl D-(−)-tartrate [diethyl (2*S*,3*S*)-*threo*-2,3-dihydroxysuccinate] **4b**[10] was treated with HBr–AcOH.[11] The resulting acetoxy bromide **5a** was heated with EtOH containing a small amount of HBr to give an *erythro*-hydroxy bromide **5b** in 72% yield from **4b**. Another Walden inversion was effected with NaOEt in EtOH to give the desired *threo*-epoxy ester **6** in 77% yield. This was treated with 3 eq of Me_2CuLi in ether at −55 to −20° for 4 hr to give diethyl (2*S*,3*R*)-*erythro*-3-methylmalate **7a** in 78% yield, whose purity was shown to be 94.7% by glc. After protecting the OH group of **7a** as a THP ether, the resulting **7b** was reduced with LAH to give **8a**. The protection of OH was necessary to increase the solubility of the reduction product in organic solvents to facilitate isolation. The THP ether **8a** was treated with MeOH containing a small amount of *p*-TsOH to give a triol **8b**. The *vic*-diol system of **8b** was protected as an acetonide (Me_2CO/*p*-TsOH) to give **9a** in 76% yield from **7a**. Later steps to δ-multistriatin **1δ** were carried out in a similar manner as described by Fried for the stereoselective synthesis of (±)-α-multistriatin **1α**.[12] The acetonide alcohol **9a** was converted to an iodide **10** in 76% yield via the corresponding tosylate **9b**. Lithium enolate of Et_2CO generated by LDA in THF was alkylated with **10** to give **11**. Finally acid treatment (10% HCl–MeCN) of **11** gave crude **1δ**. In the same manner, L-(+)-tartaric acid **4a'** gave the antipodal epoxy ester **6'**, which was converted via **7a'** to crude (+)-δ-multistriatin **1δ'**. Glc analysis revealed that the isomeric ratio of our multistriatin was >99% δ and <1% β. Evidently the final intramolecular acetalisation yielded the more stable δ-isomer **1δ** in preference to β-multistriatin **1β** to avoid 1,3-diaxial interaction between two Me groups of **1β**. The synthesis was thus proved to be highly stereoselective.

These crude δ-multistriatin enantiomers were purified by preparative glc (20% PEG 20 M, 2 m × 6 mm) to give pure (1*S*,2*S*,4*S*,5*R*)-(−)-δ-multistriatin **1δ**, $[\alpha]_D^{20}$ −83.5° (*n*-pentane) and (1*R*,2*R*,4*R*,5*S*)-(+)-δ-multistriatin, **1δ'**, $[\alpha]_D^{20}$ +82.4° (*n*-pentane). The IR and NMR spectra of our

†Pheromone Synthesis—XXXV. Part XXXIV, M. Uchida, K. Nakagawa and K. Mori, *Agric. Biol. Chem.* 43, 1919 (1979). The experimental part of this work was taken from the forthcoming M.Sc. thesis of H.I. (1980).



materials were entirely identical with the authentic spectra of our previously synthesised (−)-*δ*-multistriatin **1***δ*, $[\alpha]_D^{23}$ −31.1° (ether).[3] Since the specific rotation of 100% optically pure (+)-*δ*-multistriatin **1***δ*′ was calculated to be 89° (*n*-hexane),[4] the optical purity of our (−)-*δ*-multistriatin **1***δ* was 94% and that of the (+)-isomer **1***δ*′ was 93%.

In conclusion we were able to obtain pure *δ*-multistriatin enantiomers **1***δ* and **1***δ*′ in sufficient amounts for biological study (210 mg of **1***δ* and 130 mg of **1***δ*′). The biological activity of both the enantiomers on *S. multistriatus* is now under investigation by Professor J. P. Vité, University of Freiburg.

EXPERIMENTAL

All b.ps and m.ps were uncorrected. IR spectra refer to films and were determined on a Jasco IRA-1 spectrometer. NMR spectra were recorded as CCl_4 solns at 60 MHz with TMS as an internal standard on a Hitachi R-24A spectrometer. Optical rotations were measured on a Jasco DIP-4 polarimeter. Glc analyses were performed on a Yanaco G 80 and G 550-F gas chromatographs.

Diethyl erythro-2-*acetoxy*-3-*bromosuccinate*

(a) (2*S*,3*R*)-*Isomer* **5a**. A 30% soln of HBr in AcOH (292 ml) was added dropwise to stirred and ice-cooled **4b** (99.4 g). After 15 min, the ice-bath was removed and the mixture was stirred at room temp. for 4 hr. Then it was poured into ice-water (1.2 l) and extracted with ether. The ether extract was washed with water and brine, dried ($MgSO_4$) and concentrated *in vacuo* to give 139 g (93%) of crude **5a**, ν_{max} 3000 (m), 1765 (s), 1380 (s), 1280 (s), 1210 (s), 1160 (m), 1010 (m), 970 (s), 930 (w), 900 (w), 855 (m) cm^{-1}; *δ* 1.20 (6 H, t, J = 7 Hz), 2.10 (3 H, s), 4.20 (4 H, q, J = 7 Hz), 4.57 (1 H, d, J = 6 Hz), 5.33 (1 H, d, J = 6 Hz). This was employed for the next step without further purification.

(b) (2*R*,3*S*)-*Isomer* **5a**′. This was prepared from **4b**′ (85.7 g) in quantitative yield.

Diethyl erythro-2-*hydroxy*-3-*bromosuccinate*

(a) (2*S*,3*R*)-(+)-*Isomer* **5b**. A 30% soln of HBr in AcOH (39 ml) was added to a soln of **5a** (139 g) in 99% EtOH (1180 ml) and the soln was heated under reflux for 4 hr. Subsequently the soln was concentrated *in vacuo* and the residue was distilled to give 94.6 g (73% from **4b**) of **5b**. This was further purified by SiO_2 chromatography and distillation to give pure **5b**, b.p. 113–114°/0.25 mm, $n_D^{22.5}$ 1.4633; $[\alpha]_D^{23}$ +30.7° (neat); ν_{max} 3500 (m), 3000 (m), 1750 (s), 1470 (m), 1450 (m), 1375 (s), 1275 (s), 1230 (s), 1160 (s), 1120 (s), 1100 (s), 1025 (s), 860 (m) cm^{-1}; *δ* 1.30 (6 H, t, J = 7 Hz), 3.73 (1 H, s), 4.18 (4 H, q, J = 7 Hz), 4.45 (2 H, s).

(b) (2*R*,3*S*)-(−)-*Isomer* **5b**′. This was prepared from **5a**′ (prepd. from 85.7 g of **4a**′) in 72% yield from **4a**′ (80.1 g), b.p. 123–125°/0.6 mm, n_D^{23} 1.4628; $[\alpha]_D^{23}$ −28.9° (neat).

Diethyl threo-2,3-*epoxysuccinate*

(a) (2*S*,3*S*)-(+)-*Isomer* **6**. A soln of **5b** (58.16 g) in 99% EtOH (50 ml) was added dropwise to a stirred and ice-cooled soln of NaOEt (from 5.82 g of Na) in 99% EtOH (145 ml). The mixture was stirred for 1 hr at room temp., neutralised with AcOH and concentrated *in vacuo* at low temp. The residue was diluted with ice-water and extracted with ether. The ether soln was washed with water and brine, dried ($MgSO_4$) and concentrated *in vacuo*. The residue was distilled to give 31.3 g (76.9%) of **6**, b.p. 98–99°/3 mm, n_D^{22} 1.4341; $[\alpha]_D^{23}$ +105.49° (*c* = 1.413, ether); ν_{max} 3020 (m), 2960 (m), 1760 (s), 1480 (m), 1460 (m), 1405 (m), 1345 (s), 1330 (s), 1290 (s), 1270 (s), 1240 (s), 1215 (s), 1105 (m), 1035 (s), 950 (w), 905 (m), 860 (w), 840 (w), 780 (w), 760 (w) cm^{-1}; *δ* 1.30 (6 H, t, J = 6 Hz), 3.47 (2H, s), 4.13 (4 H, q, J = 6 Hz); glc (Column, 5% Carbowax 20 M 1.5 m × 3 mm at 150°; Carrier gas, N_2, 1.0 kg/cm^2): R_t 7.8 min (95%), 12.4 min (0.4%), 16.8 min (4.6%). (Found: C, 50.82; H, 6.46. $C_8H_{12}O_5$ requires: C, 51.06; H, 6.43%). Attempted purification of this epoxide on grade II neutral alumina led to decomposition.

(b) (2*R*,3*R*)-(−)-*Isomer* **6**′. This was prepared from **5b**′ (94.4 g) in 70.4% yield (46.6 g), b.p. 100–104°/4 mm, n_D^{23} 1.4354; $[\alpha]_D^{21.5}$ −88.47° (*c* = 1.030, ether); (Found: C, 50.66; H, 6.49. $C_8H_{12}O_5$ requires: C, 51.06; H, 6.43%).

Diethyl erythro-3-*methylmalate*

(a) (2*S*,3*R*)-(−)-*Isomer* **7a**. MeLi soln was prepared from Li (5.07 g), MeBr (41.1 g) and dry ether (366 ml). This was added to a stirred and cooled suspension of Cu_2I_2 (5.71 g) in dry ether (30 ml) at −20 to −30° under Ar and the mixture was stirred for 30 min at this temp. A soln of **6** (2.35 g) in dry ether (20 ml) was added to the soln of Me_2CuLi with stirring and cooling at −55 to −53°. The reaction temp. was gradually raised (10°/hr) to −20° during 4 hr. Then the mixture was poured into sat NH_4Cl soln and ice. The ether layer was separated and the aq layer was extracted with ether. The ether soln was washed with sat NH_4Cl soln and brine, dried ($MgSO_4$) and concentrated *in vacuo*. The residue was distilled to give 2.00 g (78.3%) of **7a**, b.p. 96–97°/4 mm, $n_D^{20.5}$ 1.4340; $[\alpha]_D^{20.5}$ −9.54° (*c* = 0.968, ether); ν_{max} 3470 (m), 2970 (m), 2820 (m), 1735 (s), 1465 (m), 1370 (m), 1345 (m),

1260 (s), 1200 (s), 1140 (m), 1100 (m), 1065 (w), 1020 (m), 960 (w), 910 (w), 860 (m), 805 (w) cm^{-1}; δ 1.27 (6 H, t, J = 6Hz), 1.23 (3 H, d, J = 6 Hz), 2.63–3.03 (1 H, m), 3.17 (1 H, br. s), 4.10 (4 H, q, J = 7 Hz), ~4 (1 H); glc (Column, LAC-2R-446, 1.5 m × 3 mm at 152°; Carrier gas, N_2, 1.2 kg/cm^2): R_t 7.8 min (94.7%), 9.8 min (0.8%), 10.6 min (4.5%). (Found: C, 52.60; H, 7.80. $C_9H_{16}O_5$ requires: C, 52.93; H, 7.90%).

(b) (2*R*,3*S*)-(+)-*Isomer* **7a'**. This was prepared from **6'** (5.73 g) in 64.2% yield (3.99 g), b.p. 105–112°/5 mm, $n_D^{28.7}$ 1.4338; $[\alpha]_D^{28}$ +9.75° (*c* = 1.896, ether); glc (Column, LAC-2R-446, 1.5 m × 3 mm at 153°; Carrier gas, N_2, 1.3 kg/cm^2): R_t 7.2 min (95.3%), 9.8 min (4.7%).

Diethyl erythro-3-*methylmalate THP ether*

(a) (2*S*,3*R*)-*Isomer* **7b**. Dihydropyran (4.04 g) and *p*-TsOH (*ca.* 10 mg) were added to a soln of **7a** (8.18 g) in dry ether (65 ml) and the mixture was stirred overnight at room temp. The soln was washed with sat $NaHCO_3$ aq and brine, dried (K_2CO_3) and concentrated *in vacuo* to give 11.71 g (quantitative) of **7b**, ν_{max} 2970 (m), 2930 (m), 1740 (s), 1470 (m), 1455 (m), 1390 (m), 1375 (m), 1275 (m), 1210 (s), 1180 (s), 1130 (s), 1080 (m), 1040 (s), 970 (m), 910 (m), 870 (m), 820 (m) cm^{-1}. This was employed for the next step without further purification.

(b) (2*R*,3*S*)-*Isomer* **7b'**. This was prepared from **7a'** (4.98 g) in 96.5% yield (6.66 g). This was directly employed for the next step.

erthro-3-*Methylbutane*-1,2,4-*triol* 2-*THP ether*

(a) (2*S*,3*S*)-*Isomer* **8a**. A soln of **7b** (11.71 g) in dry ether (50 ml) was added dropwise to a suspension of LAH (2.2 g) in dry ether (130 ml) with stirring and ice-cooling. The mixture was stirred overnight at room temp. Then H_2O (6 ml) and 15% NaOH aq (2 ml) were added dropwise to the stirred and ice-cooled mixture. After 30 min, the mixture was filtered and the filter-cake was washed four times with THF. The combined filtrate and washings were dried over K_2CO_3 and concentrated *in vacuo* to give 9.03 g (quantitative) of **8a**, ν_{max} 3360 (s), 2920 (s), 2860 (s), 1450 (m), 1440 (m), 1380 (m), 1350 (m), 1280 (m), 1270 (w), 1210 (m), 1160 (m), 1135 (s), 1070 (s), 1020 (s), 980 (m), 940 (w), 900 (m), 870 (m), 805 (m) cm^{-1}. This was directly employed for the next step.

(b) (2*R*,3*R*)-*Isomer* **8a'**. This was prepared from **7b'** (5.55 g) in 87.4% yield (4.14 g).

erythro-3-*Methylbutane*-1,2,4-*triol*

(a) (2*S*,3*S*)-*Isomer* **8b**. *p*-TsOH (50 mg) was added to a soln of **8a** (9.03 g) in MeOH (80 ml) and the mixture was stirred overnight at room temp. The soln was neutralised with $NaHCO_3$, filtered and concentrated *in vacuo* to give 5.07 g (quantitative) of **8b**, ν_{max} 3320 (s), 2900 (s), 2860 (s), 1650 (w), 1460 (m), 1220 (m), 1120 (m), 1050 (s), 1030 (s), 980 (m), 915 (w), 870 (m) cm^{-1}. This was employed for the next step without further purification.

(b) (2*R*,3*R*)-*Isomer* **8b'**. This was prepared from **8a'** (4.14 g) in 77.3% yield (1.87 g).

erythro-3-*Methylbutane*-1,2,4-*triol* 1,2-*acetonide*

(a) (2*S*,3*S*)-(+)-*Isomer* **9a**. *p*-TsOH (20 mg) was added to a soln of **8b** (5.07 g) in acetone (100 ml) and the mixture was stirred overnight at room temp. The soln was neutralised with $NaHCO_3$, filtered and concentrated *in vacuo*. The residue was distilled to give 4.88 g (76% from **7a**) of **9a**, b.p. 73–75°/3 mm, n_D^{28} 1.4401; $[\alpha]_D^{28.5}$ +14.0° (*c* = 0.980, C_6H_6); ν_{max} 3400 (s), 2980 (s), 2920 (s), 2880 (s), 1460 (m), 1385 (s), 1370 (s), 1250 (s), 1220 (s), 1160 (s), 1065 (s), 900 (w), 850 (m) cm^{-1}; δ 0.83 (3 H, d, J = 6 Hz). 1.30 (3 H, s), 1.35 (3 H, s), 1.50–2.00 (1 H, m), 3.00 (1 H, br. –OH), 3.40–4.07 (5 H, m, 3.52, 3.70, 3.78, 3.82, 3.86, 3.92, 3.96, 4.06); glc (5% FFAP, 1.5 m × 2 mm at 110° + 4°/min after 3 min.; Carrier gas, N_2, 1.0 kg/cm^2): R_t 5.2 min (7.7%), 6.4 min (82.3%), 7.1 min (4.5%), 15.2 min (4.5%). (Found: C, 59.41; H, 9.89. $C_8H_{16}O_3$ requires: C, 59.98; H, 10.07%).

(b) (2*R*,3*R*)-(−)-*Isomer* **9a'**. This was prepared from **8b'** (1.87 g) in 82.1% yield b.p. 87–92°/7 mm, n_D^{28} 1.4398; $[\alpha]_D^{28.5}$ −15.7° (*c* = 0.883, C_6H_6); glc (5% FFAP, 1.5 m × 2 mm at 110° + 4°/min after 3 min; Carrier gas, N_2, 1.0 kg/cm^2): R_t 5.8 min (6.4%) 6.9 min (87.2%), 7.4 min (6.4%).

erythro-4-*Tosyloxy*-3-*methylbutane*-1,2-*diol acetonide*

(a) (2*S*,3*S*)-*Isomer* **9b**. *p*-TsCl (7.82 g) was added to a stirred and ice-cooled soln of **9a** (4.70 g) in dry pyridine (24 ml). The mixture was left overnight in a refrigerator, then poured into ice-water and extracted with ether. The ether soln was washed with $CuSO_4$ soln, water, $NaHCO_3$ soln and brine, dried ($MgSO_4$) and concentrated *in vacuo* to give 9.07 g (98.4%) of **9b**, ν_{max} 3040 (w), 2960 (m), 2900 (m), 2860 (m), 1590 (m), 1490 (w), 1450 (m), 1360 (s), 1190 (s), 1175 (s), 1090 (m), 1060 (m), 965 (m), 850 (m), 830 (m), 810 (m), 785 (m), 665 (m) cm^{-1}; δ 0.90 (3 H, d, J = 7 Hz), 1.22 (3 H, s), 1.25 (3 H, s), 2.43 (3 H, s), 3.30–4.20 (6 H, m), 7.25 (2 H, d, J = 8 Hz), 7.70 (2 H, d, J = 8 Hz).

(b) (2*R*,3*R*)-*Isomer* **9b'**. This was prepared from **9a'** (3.74 g) in 98.4% yield (7.22 g).

erythro-4-*Iodo*-3-*methylbutane*-1,2-*diol acetonide*

(a) (2*S*,3*R*)-(−)-*Isomer* **10**. NaI (4.56 g) was added to a soln of **9b** (5.03 g) in acetone (70 ml). The mixture was stirred at room temp. for 6 days and filtered. The filtrate was diluted with water and extracted with ether. The ether soln was washed with Na_2SO_3 aq, water and brine, dried ($MgSO_4$) and concentrated *in vacuo*. The residue was distilled to give 4.56 g (76%) of **10**, b.p. 79–82°/4 mm, n_D^{28} 1.4980; $[\alpha]_D^{28}$ −11.2° (*c* = 1.239, C_6H_6); ν_{max} 2970 (s), 2920 (m), 2860 (m), 1455 (m), 1380 (s), 1370 (s), 1260 (s), 1220 (s), 1170 (m), 1070 (s), 960 (w), 860 (m), 800 (w) cm^{-1}; δ 0.91 (3 H, d, J = 6 Hz), 1.27 (3 H, s), 1.30 (3 H, s), ~1.60 (1 H, m), 3.00–4.20 (5 H, m); glc (Column, 5% FFAP, 1.5 m × 2 mm at 120° + 4°/min after 2 min; Carrier gas, N_2, 1.1 kg/cm^2): R_t 5.0 min (99%), 6.2 min (1%). (Found: C, 35.26; H, 5.47. $C_8H_{15}O_2I$ requires: C, 35.57; H, 5.61%).

(b) (2*R*,3*S*)-(+)-*Isomer* **10'**. This was prepared from **9b'** (5.17 g) in 72.7% yield (3.23 g), b.p. 78–82°/5 mm, $n_D^{28.5}$ 1.5008; $[\alpha]_D^{28.5}$ +6.5° (*c* = 1.024, C_6H_6). The reason for this small value was unclear. It might be due to the presence of levorotatory impurities. Glc (Column, 5% FFAP, 1.5 m × 2 mm at 120° + 4°/min after 2 min; Carrier gas, N_2, 1.1 kg/cm^2): R_t 5.0 min (95%), 6.2 min (3%), 7.6 min (2%). (Found: C, 35.05; H, 5.49. $C_8H_{15}O_2I$ requires: C, 35.57; H, 5.61%).

2,3-erythro-3,5-*Dimethyl*-6-*oxooctane*-1,2-*diol acetonide*

(a) (2*S*,3*S*)-*Isomer* **11**. A soln of LDA was prepared by the addition of 1.63 M *n*-BuLi (29 ml) to a stirred soln of i-Pr_2NH (6.66 ml) in dry THF (30 ml) at −60 to −52° under Ar. The soln was stirred for 30 min. A soln of Et_2CO (4.09 g) in THF (30 ml) was added to the stirred and cooled LDA soln at −70 to −65°. After stirring for 30 min, a soln of **10** (2.55 g) in THF (30 ml) was added at −50 to −40° with stirring. The temp. was gradually raised to room temp. The mixture was further stirred for 4 days. Then it was diluted with water and extracted with ether. The ether soln was washed with dil HCl, $NaHCO_3$ soln and brine, dried ($MgSO_4$) and concentrated *in vacuo*. The residue was distilled to give 3.30 g of crude **11** contaminated with **10** and other impurities (the yield based on the consumed **10** was 69.1%), b.p. 101–107°/6 mm; ν_{max} 2970 (s), 2920 (s), 2860 (m), 1710 (s), 1460 (m), 1380 (s), 1370 (s), 1250 (m), 1220 (m), 1160 (m), 1065 (s), 970 (w), 860 (w), 800 (m) cm^{-1}; glc (Column, 3% SE-30, 1.5 m × 2 mm at 100° + 4°/min after 5 min upto 120°; Carrier gas, N_2, 1.2 kg/cm^2): R_t 2.6 min (**10**, 17.6%), 6.4 min (6.1%), 7.2 min (**11**, 75.7%), 9.9 min (0.6%).

(b) (2*R*,3*R*)-*Isomer* **11'**. This was prepared from **10'** (2.55 g) in 41% yield (1.57 g of crude **11'**) as based on the consumed **10'**, b.p. 102–117°/9 mm, glc (3% SE-30, 1.5 m × 2 mm at 100° + 4°/min after 5 min upto 120°; Carrier gas, N_2, 1.2 kg/cm^2): R_t 1.5, 1.7, 1.9 min (5.8%), 2.6 min (**10'**, 48.9%), 5.3, 6.4 min (6.3%), 7.3 min (**11'**, 39.0%). These crude **11** and **11'** were used directly for the final step.

δ-Multistriatin (2,4-*dimethyl*-5-*ethyl*-6,8-*dioxabicyclo*[3.2.1] *octane*)

(a) (1*S*,2*S*,4*S*,5*R*)-(−)-*Isomer* **1δ**. A soln of crude **11** (3.30 g) in MeCN (44 ml) and 10% HCl (22 ml) was stirred overnight at room temp. The soln was saturated with NaCl by the addition of NaCl

powder, poured into brine and extracted with ether. The ether extract was washed with water, $NaHCO_3$aq and brine, dried ($MgSO_4$) and concentrated to give 1.68 g (90%) of crude 1δ. this was chromatographed over Woelm neutral alumina (grade II, 20 g). Elution with *n*-pentane gave 0.8 g (43%) of 1δ. This was further purified by preparative glc (Column, 20% PEG 20 M, 2.0 m × 6 mm at 110°; Carrier gas, N_2, 1.1 kg/cm²): R_t 34–46 min. Pure 1δ weighed 210 mg, n_D^{20} 1.4496; $[\alpha]_D^{20}$ −83.5° (*c* = 0.256, *n*-pentane); ν_{max} 2960 (s), 2920 (s), 2860 (s), 1480 (m), 1460 (s), 1440 (w, sh), 1380 (m), 1360 (w), 1330 (w), 1305 (w), 1280 (w), 1250 (m), 1200 (m), 1170 (m), 1130 (m), 1110 (m), 1045 (s), 1025 (m), 1020 (m), 990 (m), 980 (m), 955 (m), 910 (s), 890 (s), 860 (w), 810 (w), 770 (w), 680 (w) cm^{-1}; δ (100 MHz) 0.74 (3 H, d, J = 6 Hz), 0.86 (3 H, t, J = 7 Hz), 1.10 (3 H, d, J = 7 Hz), 1.2–2.0 (6 H, m), 3.68 (2 H, d, J = 4 Hz), 4.08 (1 H, m); MS (*m/e*): 28 (93%), 29 (61%), 41 (30%), 43 (63%), 55 (40%), 57 (100%, base peak), 170 (M^+, $C_{10}H_{18}O_2$); glc (10% PEG 20 M, 2 m × 3 mm at 100° + 3°/min upto 220°; Carrier gas, N_2, 1.0 kg/cm²): R_t 8.6 min (unidentified impurity, 4.3%), 9.4 min (1δ, 95.7%).

(b) *(1R,2R,4R,5S)-(+)-Isomer* 1δ'. This was prepared from crude 11' (1.57 g) in 80% crude yield (0.36 g). Glc purification afforded 130 mg of pure 1δ', $[\alpha]_D^{20}$ + 82.4° (*c* = 0.205, *n*-pentane); glc (10% PEG 20 M, 2 m × 3 mm at 100° + 3°/min upto 220°; Carrier gas, N_2, 1.0 kg/cm²): R_t 9.8 min (unidentified impurity, 2.4%), 11.0 min (1δ', 97.2%), impurities (0.4%) at 16.0 and 19.2 min. The spectral data of 1δ and 1δ' were identical with the authentic data.[3]

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REFERENCES

[1]G. T. Pearce, W. E. Gore, R. M. Silverstein, J. W. Peacock, P. A. Cuthbert, G. N. Lanier and J. B. Simeone, *J. Chem. Ecol.* 1, 115 (1975).
[2]Review: K. Beck, *J. Chem. Educ.* 55, 567 (1978).
[3]K. Mori, *Tetrahedron* 32, 1979 (1976).
[4]G. T. Pearce, W. E. Gore and R. M. Silverstein, *J. Org. Chem.* 41, 2797 (1976).
[5]G. J. Cernigliaro and P. J. Kocienski, *Ibid.* 42, 3622 (1977).
[6]K. Mori, *Tetrahedron* 33, 289 (1977).
[7]W. E. Gore, G. T. Pearce and R. M. Silverstein, *J. Org. Chem.* 40, 1705 (1975).
[8]B. Gerken, S. Grüne, J. P. Vité and K. Mori, *Naturwissenschaften* 65, 110 (1978).
[9]Phaik-Eng Sum and L. Weiler, *Canad. J. Chem.* 56, 2700 (1978).
[10]K. Mori, *Tetrahedron* 30, 4223 (1974).
[11]B. T. Golding, D. R. Hall and S. Sakrikar, *J. Chem. Soc.* Perkin I 1214 (1973).
[12]W. J. Elliott and J. Fried, *J. Org. Chem.* 41, 2475 (1976).