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New Synthesis of Columbianetin and Related Coumarins[1]

WARREN STECK
National Research Council of Canada, Prairie Regional Laboratory, Saskatoon, Saskatchewan

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2,4-Dihydroxy-3-(3-methyl-2-butenyl)benzaldehyde was obtained from 2,4-dihydroxybenzaldehyde with either 3-hydroxy-3-methyl-1-butene or 1-bromo-3-methyl-2-butene. Oxidation of the product in neutral medium with *m*-chloroperoxybenzoic acid gave (±)-2,3-dihydro-2-(1-hydroxy-1-methylethyl)-4-hydroxybenzofuran-5-aldehyde, whose condensation product with malonic acid was (±)-3-carboxycolumbianetin. Oxidation in acidic medium gave (±)-2,2-dimethyl-3,5-dihydroxybenzopyran-6-aldehyde, whose condensation product with malonic acid was (±)-3-carboxylomatin. (±)-Columbianetin and (±)-lomatin were obtained by decarboxylation.

Le dihydroxy-2,4 (méthyl-3 butènyl-2)-3 benzaldéhyde est obtenu par réaction du dihydroxy-2,4 benzaldéhyde avec soit l'hydroxy-3 méthyl-3 butène-1 ou le bromo-1 méthyl-3 butène-2. L'oxydation de ce produit par l'acide *m*-chloroperbenzoique en milieu neutre conduit au (±)-dihydro-2,3 (hydroxy-1 méthyl-1 éthyl)-2 hydroxy-4 benzofuraldéhyde-5 qui par condensation avec l'acide malonique fournit la (±)-carboxy-3 columbianétine. L'oxydation en milieu acide donne le (±)-diméthyl-2,2 dihydroxy-3,5 benzopyrannealdéhyde-6 qui par condensation avec l'acide malonique conduit à la (±)-carboxy-3 lomatine. La (±)-columbianétine et la (±)-lomatine sont obtenues par décarboxylation.

Canadian Journal of Chemistry, 49, 1197 (1971)

Introduction

Columbianetin (**4***b*) is a natural plant coumarin (1) which has been shown (2) to be a biogenetic precursor of angular furanocoumarins. It is apparently identical with the lactone zosimol (3) and is isomeric with the angular pyranocoumarin lomatin (4). The synthesis of racemic columbianetin has been reported recently by Shipchandler, *et al.* (5) who employed a ten-step route starting from 2,6-dihydroxybenzoic acid; the overall yield of product was about 2%. An alternative four-step synthesis starting from β-resorcylaldehyde (**1***a*) is described below. Lomatin (**3***a*) and dihydroseselin (**3***c*) were also synthesized similarly.

Results and Discussion

2,4-Dihydroxybenzaldehyde (**1***a*) was treated with 3-hydroxy-3-methyl-1-butene in the presence of boron trifluoride etherate (6) to obtain the 3-methyl-2-butenyl derivatives **1***b*, *c*, and *d*, which were separated by column chromatography on silicic acid. The conversion of starting material was always low, about 20–30%, so that yields in this step were poor. However, residual starting material could be recovered easily and recycled several times. Austin and Seshadri (6) reported **1***b* and *d* as the products of this reaction but their m.p. and n.m.r. data for the former compound were different from those obtained in this study. For example, my compound **1***b* melted abruptly at 140.5–141.0°, not at the reported 113–116°, and showed no broad peak (δ 9.0–9.8) in its n.m.r. spectrum. The t.l.c. and g.l.c. indicated it was pure. To ensure its identity it was cyclized in dilute acid to 2,2-dimethyl-7-hydroxychroman-6-aldehyde (**6***a*), a known compound (7); the cyclization product agreed with the literature report in m.p., had appropriate u.v. and n.m.r. spectra, and gave dihydroxanthyletin (**7***a*) on construction of a coumarin pyrone ring by usual methods (7).

Compound **1***c* has not been described previously as a product of the reaction, but was isolated in reasonable quantities in this study. Its structure follows not only from its u.v. and n.m.r. spectra in conjunction with elemental analysis, but also from its alternate preparation from the disodium salt of **1***a* and 1-bromo-3-methyl-2-butene, in which it was the major product. The structure **1***c* was confirmed by treating the product with phenyldiazomethane (8) to form **1***f*, which was the same compound as that obtained by boiling the sodium salt of **1***e* with 1-chloro-3-methyl-2-butene in toluene.

Oxidation of **1***c* in chloroform with 1 equiv of *m*-chloroperoxybenzoic acid gave a product which n.m.r. and u.v. spectra indicated was **5**. It could not be crystallized. The n.m.r. signals ($DCCl_3$) included a sharp methylene doublet (J = 8.5 Hz), an equally sharp methine triplet (J = 8.5 Hz) at low field (δ 4.76), and a rather

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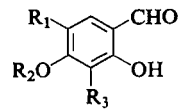
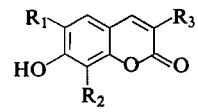


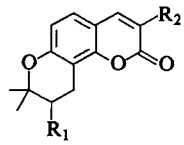
1

a $R_1 = H; R_2 = H; R_3 = H$
b $R_1 = -CH_2CH=C(CH_3)_2; R_2 = R_3 = H$
c $R_1 = R_2 = H; R_3 = -CH_2CH=C(CH_3)_2$
d $R_1 = R_3 = -CH_2CH=C(CH_3)_2; R_2 = H$
e $R_1 = H; R_2 = C_6H_5CH_2-; R_3 = H$
f $R_1 = H; R_2 = C_6H_5CH_2-; R_3 = -CH_2CH=C(CH_3)_2$
g $R_1 = -CH_2CH=C(CH_3)_2; R_3 = C_6H_5CH_2-; R_3 = H$



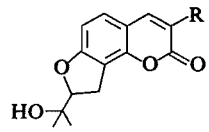
2

a $R_1 = H; R_2 = -CH_2CH=C(CH_3)_2; R_3 = COOH$
b $R_1 = H; R_2 = -CH_2CH=C(CH_3)_2; R_3 = H$ (osthenol)
c $R_1 = -CH_2CH=C(CH_3)_2; R_2 = R_3 = H$ (7-demethylsuberosin)



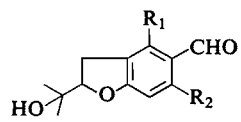
3

a $R_1 = OH; R_2 = H$ (lomatin)
b $R_1 = OH; R_2 = COOH$
c $R_1 = R_2 = H$ (dihydroseselin)



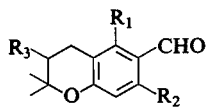
4

a R = COOH
b R = H (columbianetin)



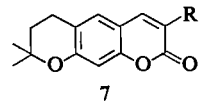
5

$R_1 = OH; R_2 = H$



6

a $R_1 = H; R_2 = OH; R_3 = H$
b $R_1 = OH; R_2 = H; R_3 = OH$



7

a R = H (dihydroxanthyletin)
b R = COOH

sharp hydroxyl singlet not coupled to this triplet. This suggested a five-membered ring and showed that no secondary hydroxyl was present, pointing to **5** as the only plausible structure. Oxidation of **1***c* similarly but with a trace of *p*-toluenesulfonic acid added to the reaction medium gave a different non-crystallized product, identified as **6***b*. The n.m.r. spectrum ($DCCl_3$) of this compound showed multiple signals for the methylene group, and a vague methine resonance (δ 3.84) strongly coupled also to a hydroxyl proton. When the secondary hydroxyl signal was removed with D_2O, the CH_2CH signals formed a clear ABX pattern. This was interpreted as indicating a six-membered ring.

These results are in accord with mechanistic considerations of the reactions involved. The peracid must attack the olefinic bond of the C_5 side chain of **1***c*, transforming it into an epoxide. Subsequent cyclization in neutral or basic medium would be expected to proceed by S_N2 mechanism, and take place at the less sterically hindered carbon of the epoxide bridge, giving **5**. An acid-catalyzed epoxide ring fission should, on the other hand, produce a carbonium ion which would be most favorably located at the tertiary carbon, so that ring closure in this case would produce a six-membered heterocycle.

Condensation of **5** with malonic acid in pyridine–aniline gave a carboxylic acid, m.p. 220–221°, which fluoresced a brilliant blue in u.v. light and had n.m.r. and u.v. spectra consistent with 3-carboxycolumbianetin (**4***a*). Decarboxylation of this acid in boiling quinoline, in presence of copper powder, yielded (±)-columbianetin (**4***b*), m.p. 168–169° [lit. 170–171° (5)], identical in its u.v. and n.m.r. spectra, and also in its chromatographic behavior, with natural (+)-columbianetin obtained by hydrolysis of columbianetin angelate isolated from roots of *Lomatium columbianum* (1).

Condensation of **6***b* similarly gave a carboxylic acid, m.p. 223–223.5°, with brilliant blue fluorescence. Its u.v. and n.m.r. spectra were consistent with 3-carboxylomatin (**3***b*). Decarboxylation of this compound in copper/quinoline afforded

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(±)-lomatin (**3***a*), m.p. 163–165.5° [lit. 165.5–7.0° (9)], with spectral properties identical with those described for (+)-lomatin (4). This is the first total synthesis of lomatin.

The advantages of these synthetic routes are three: first, the sequences are short and the overall yields reasonably high; second, the method permits optical resolution at all stages, particularly at the carboxylic acid stage; third, and of particular interest to this laboratory, carbon-14 can be conveniently introduced in the malonic acid condensation.

A synthesis of osthenol (**2***b*) from **1***c* also seemed feasible, either by reaction with sodium acetate and acetic anhydride, or via the carboxylic acid **2***a*. This last compound was obtained without difficulty with malonic acid in pyridine–aniline, but its decarboxylation was attended by ring closure, yielding dihydroseselin (**3***c*) (6). Reaction of **1***c* with sodium acetate and acetic anhydride under the conditions described (6) for the synthesis of 7-demethylsuberosin (**2***c*) gave none of the expected osthenol acetate. The synthesis of osthenol reported (10, 11) while this work was in progress would seem to be an effective alternative.

Experimental

All melting points are uncorrected. The n.m.r. spectra were measured with a Varian model HA-100 Spectrometer. All proton assignments below are supported by signal integration. Tetramethylsilane was the reference standard. *2,4-Dihydroxybenzaldehyde (**1***a*)* was purchased from Eastman Organic Chemicals, and *3-hydroxy-3-methyl-1-butene* and *m-chloroperoxybenzoic acid* from Aldrich Chemical Co.

*Compounds **1***b, c, and d*

Compound **1***a* (50 g) in 300 ml dioxan was added to a stirred fresh solution of 40 g 3-hydroxy-3-methyl-1-butene and 25 ml BF_3 etherate in 200 ml dioxan, and stirring was continued for 2.5 h at room temperature. Ether (2500 ml) was added and the resulting solution extracted with water (3 × 1000 ml). The remaining organic layer was dried (Na_2SO_4) before evaporation to dryness. The crystalline residue was extracted with six 100-ml portions of pentane or hexane, which dissolved the reaction products and left behind most unchanged starting material. After removal of the solvent, the mixed products were adsorbed upon 50 g silicic acid (Mallinckrodt 100 mesh, used as received) and chromatographed on a column of 450 g more silicic acid prepared either in ether–hexane (1:1) or in ethyl acetate – hexane (1:9). Fractions of 20 ml were continuously collected. In development with ether–hexane, fractions 30–40 contained mostly **1***d*, 41–50 mostly **1***b*, and 53–66 **1***c*. Later fractions gave a little **1***a*. All products crystallized on standing in the collection tubes. In development with ethyl acetate – hexane, fractions 12–23 contained **1***d*; 68–117 **1***b* (development with 15% EtOAc after fraction 80, 20% after 92, 25% after 120, 100% after 145); 118–128 mixed **1***b* and *c*; 129–165, **1***c*. Higher fractions held unchanged **1***a*.

Each compound was recrystallized once from benzene–hexane.

Compound **1***b*, (yield 6–9 g), colorless rods, m.p. 140.5–141.0° [lit. 113–116° (6)].

Anal. Calcd. for $C_{12}H_{14}O_3$: C, 69.9; H, 6.8. Found: C, 69.9; H, 6.8.

λ_{max}(EtOH) 237, 281, and 324 nm; λ_{max}(EtOH/KOH) 255 and 343 nm. The n.m.r. signals ($DCCl_3$) at δ 1.76–1.80 (singlets, 2 vinyl methyls); 3.28 (doublet, J = 7 Hz, CH_2); 5.26 (triplet, J = 7 Hz, =CH); 6.19 (singlet, 4-OH). This peak and one at 11.23 (2-OH) disappeared on shaking the sample with D_2O; 6.34 (singlet, H-3); 7.20 (singlet, H-6); 9.66 (singlet, CHO).

Compound **1***c*, (yield 2–4 g), colorless rods, m.p. 117–120°.

Anal. Calcd. for $C_{12}H_{14}O_3$: C, 69.9; H, 6.8. Found: C, 69.6; H, 6.8.

λ_{max}(EtOH) 235, 287, and 320 (sh) nm. The n.m.r. signals ($DCCl_3$): δ 1.76 (singlet, vinyl CH_3); 1.82 (singlet, vinyl CH_3); 3.42 (doublet, J = 7 Hz, CH_2); 5.25 (triplet, J = 7 Hz, =CH); 6.15 (singlet, 4-OH); 6.45 (doublet, J = 8 Hz, H-5); 7.28 (doublet, J = 8 Hz, H-6); 9.66 (singlet, CHO); 11.74 (singlet, 2-OH). Shaking with D_2O eliminated the hydroxylic signals. Irradiation at the frequency of the δ 5.25 proton collapsed also the CH_2 signal and the methyl signals to sharp singlets; irradiation at δ 7.28 collapsed the doublet at 6.45.

Compound **1***d*, (yield 6–8 g), along colorless needles, m.p. 113–117° [lit. 120–121° (6)].

Anal. Calcd. for $C_{17}H_{22}O_3$: C, 74.3; H, 8.1. Found: C, 73.8; H, 8.0.

λ_{max}(EtOH) 228, 236 sh, 278, and 327 (sh). The n.m.r. signals at δ 1.75–1.85 (12H, 4 methyls): 3.26 and 3.40 (doublets, J = 7 Hz, 2 methylenes); 5.23 and 5.27 (triplets, J = 7 Hz, 2 =CH); 6.30 (singlet, 4-OH); 7.09 (singlet, H-6); 9.64 (singlet, CHO); 11.60 (singlet, 2-OH).

*Alternate Methods for **1***c and d*

To a solution of 2,4-dihydroxybenzaldehyde (13.8 g) in 100 ml dry methanol was added 100 ml methanol containing dissolved sodium metal (4.6 g). The solvent was evaporated at once at reduced pressure and the residual light-tan disodium salt was dried, first by evaporation from ethanol–benzene and then by standing 1 h at 120°. Yield 18.2 g (100%).

This salt (9.0 g) and 1-bromo-3-methyl-2-butene (12.5 g) (13) were put into 250 ml benzene and heated under reflux for 4 h, then cooled and shaken with a mixture of ether and cold dilute acid. The organic layer was washed with water, dried and freed of solvent, leaving a dark semi-solid mass. This was chromatographed on silicic acid as described above to yield 1.1 g (10.6%) **1***c* and 1.0 g (7.4%) **1***d*, along with a larger quantity of unchanged starting aldehyde.

*Derivatives of **1***b*

*(a) Compound **6***a*

Compound **1***b* (1 g) was boiled 30 min in 50 ml 30% alcohol containing 2 ml H_2SO_4. The alcohol was evaporated and the aqueous suspension remaining was extrac-

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ted with 100 ml ether. After washing with water, the ether solution was dried (Na_2SO_4), treated with 10 ml hexane, and allowed to evaporate overnight. The deposited crystals of 2,2-dimethyl-7-hydroxychroman-6-aldehyde (**6***a*) (0.9 g), m.p. 103–104° from benzene [lit. 104° (7)], gave n.m.r. signals ($DCCl_3$) at δ 1.35 (singlet, 2 methyls); 1.80 (triplet, J = 6.5 Hz, CH_2); 2.72 (triplet, J = 6.5 Hz, benzylic CH_2); 6.28 and 7.16 (singlets, H-3 and -6); 9.63 (singlet, CHO); 11.53 (singlet, 2-OH).

(b) Dihydroxanthyletin

The above aldehyde (0.3 g) was kept for 16 h with 0.6 g malonic acid in 0.7 ml pyridine and 0.1 ml aniline, with occasional warming. The mixture was poured into ice/3 *N* HCl and the yellow precipitate filtered, giving 0.35 g crude 3-carboxydihydroxanthyletin (**7***b*), m.p. 140–158°; recrystallization from alcohol gave crystals, m.p. 158–159° [lit. 158–159° (7)].

λ_{max}(EtOH) 252, 262, and 356 nm. The n.m.r. signals (d_6-DMSO) at δ 1.72 (singlet, 2 methyls); 2.18 and 3.16 (triplets, J = 6.5 Hz, 2 adjacent CH_2's); 6.07 and 6.98 (singlets, H's of central ring); and 8.97 (singlet, H-4 of pyrone ring). The carboxyl proton was very broad, *ca.* δ 12–13.

The acid (0.15 g) was decarboxylated as described below for the preparation of columbianetin, giving 0.09 g dihydroxanthyletin (**7***a*), m.p. 122–123° from aqueous alcohol [lit. 124–125° (6)]. The mixed m.p. with authentic material, prepared by acid treatment of 7-demethylsuberosin (12), was undepressed, and the spectra were indistinguishable.

λ_{max}(EtOH) 249, 258, and 326 nm. The n.m.r. signals ($DCCl_3$) at δ 1.36 (singlet, 2 methyls); 1.83 and 2.81 (triplets, J = 6.5 Hz, 2 adjacent CH_2's); 6.17 and 7.54 (doublets, J = 9.5 Hz, pyrone ring protons); 6.71 and 7.14 (singlets, central ring protons).

Derivatives of **1***c*

(a) 2-Hydroxy-3-(3-methyl-2-butenyl)-4-benzyloxybenzaldehyde (Method 1)

Compound **1***c* (200 mg) was benzylated with phenyldiazomethane (8) in boiling ether. Gas chromatography of the reaction mixture showed a main component which matched (retention time, n.m.r. spectrum) the 4-benzyl ether (**1***f*).

(b) 2-Hydroxy-3-(3-methyl-2-butenyl)-4-benzyloxybenzaldehyde (Method 2)

The sodium salt of 4-benzyloxy-2-hydroxybenzaldehyde was prepared by treatment of the phenol **1***e* (15.5 g) in 100 ml methanol with 1.62 g sodium dissolved in 200 ml methanol, followed by rapid removal of the methanol and oven-drying of the product (15.6 g, 95%). The powdered salt was suspended in 300 ml dry benzene and refluxed 4 h with 7.5 g 3-methyl-1-chloro-2-butene. The filtered solution was evaporated to a syrup and dissolved in ether. This solution was adsorbed on 20 g silicic acid and chromatographed on a further 180 g silicic acid. Fractions of 20 ml were collected. Development with 1:9 ether–hexane gave 0.2 g **1***g*, m.p. 91–94.5° (fractions 40–43), 1.6 g **1***f*, m.p. 71.5–72.5° (fractions 46–53), and 2.6 g unchanged starting aldehyde (fractions 55 and onwards).

Anal. Calcd. for $C_{19}H_{20}O_3$ (**1***f*): C, 77.0; H, 6.8. Found: C, 76.8; H, 6.8.

The n.m.r. spectrum ($DCCl_3$) showed signals at δ 1.7 (singlets, 2 vinyl methyls); 3.41 (doublet, J = 7 Hz, CH_2 of butenyl chain); 5.16 (singlet, benzyl CH_2); 5.24 (triplet, J = 7 Hz, =CH); 6.58 and 7.30 (doublets, J = 8.5 Hz, H-5 and -6 of phenolic ring); 7.40 (singlet, phenyl); 9.70 (singlet, CHO); 11.46 (singlet, 2-OH).

The n.m.r. spectrum of **1***g* was similar to that of **1***f* except that the methyl signals were separated (δ 1.64, 1.74) and aromatic singlets at δ 6.48 and 7.25 replaced the doublets at 6.58 and 7.30.

(c) 3-Carboxyosthenol (2a)

Compound **1***c* (70 mg) and 120 mg malonic acid were warmed together 2 h at 50–60° in 1 ml 10% aniline in pyridine. After standing overnight the mixture was poured into 20 ml ice-cold 10% HCl; the yellow precipitate (50 mg, m.p. 180–204°) was filtered, washed with water, then chromatographed on a small column of Polyclar AT powder (General Aniline and Film Corporation), developing with increasing strengths of aqueous methanol. 3-Carboxyosthenol emerged as a brilliant blue-fluorescing band, melting at 209–212° after recrystallization from aqueous alcohol.

Anal. Calcd. for $C_{15}H_{14}O_5$: C, 65.7; H, 5.2. Found: C, 65.5; H, 5.2.

λ_{max}(EtOH) 262, 299 (sh), and 354 nm. The n.m.r. signals (d_6-DMSO) at δ 1.67 and 1.82 (singlets, 2 methyls); 3.40 (doublet, J = 7 Hz, CH_2); 5.18 (triplet, J = 7 Hz, =CH); 6.94 and 7.62 (doublets, J = 9 Hz, H-6 and -5 of coumarin system); 8.66 (singlet, H-4); 10.6–11.0 (broad singlet, 7-OH); the carboxyl proton was very broad, near δ 12–13.

(d) Dihydroseselin (3c)

Compound **2***a* (6 mg) was heated 5 min at 230–235° in 0.5 ml fresh quinoline containing a little copper powder. The cooled solution was diluted with 10 ml ether, decanted from the copper metal, and washed first with dilute HCl then twice with water. The blue-fluorescing solution was chromatographed on silicic acid, developing with ether. The major fluorescent band was dihydroseselin, co-chromatographing with authentic material and having the same spectral properties: λ_{max}(EtOH) 248, 258, 327 nm, unchanged by either $AlCl_3$ or NaOH.

The n.m.r. signals ($DCCl_3$) at δ 1.25 (singlet, 2 methyls); 1.83 and 2.88 (triplets, J = 7 Hz, 2 adjacent methylenes); 6.15 and 7.55 (doublets, J = 9.5 Hz, H-3 and -4 of coumarin ring system); 6.67 and 7.15 (doublets, J = 9 Hz, H-6 and -5 of coumarin ring system). No osthenol could be detected in the reaction mixture. Repeated attempts at decarboxylation of **2***a* in Cu–quinoline, using lower and higher temperatures, or in ethylene glycol, gave similar results. By heating *in vacuo* below 270°, 3-carboxyosthenol could be sublimed; above 270° a mixture containing some dihydroseselin (but no osthenol) was produced.

(±)-2,3-Dihydro-2-(1-hydroxy-1-methylethyl)-4-hydroxybenzofuran-5-aldehyde (5)

Compound **1***c* (0.5 g) in 20 ml chloroform was treated with 0.5 g technical (85%) *m*-chloroperoxybenzoic acid in 20 ml chloroform. After 24 h the solution was washed with dilute bicarbonate, then with water, and evaporated to a syrup. Gas chromatography showed a single component with n.m.r. signals ($DCCl_3$) at δ 1.24 and 1.36

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(singlets, methyls); 1.82 (singlet, alcoholic OH); 3.12 (doublet, J = 8.5 Hz, CH_2); 4.76 (triplet, J = 8.5 Hz, —CH); 6.45 and 7.35 (doublets, J = 8.5 Hz, H-5 and -6); 9.70 (singlet, CHO); 11.74 (singlet, 2-OH). Removal of the hydroxyl signals by shaking the sample with D_2O did not alter the shape or position of the —CH triplet.

(±)-3-Carboxycolumbianetin (4a)

The aldehyde **5** (1.4 g) was kept 24 h with 1.2 g malonic acid in 5 ml pyridine and 0.5 ml aniline, then the solution was poured slowly into ice-cold 10% HCl (50 ml) and the resulting solution or suspension was continuously extracted with ether. This extract was passed through a column of silicic acid developing with ethyl acetate–hexane. The product, 0.3 g white crystals of m.p. 220–221°, was dried at 120° overnight.

Anal. Calcd. for $C_{15}H_{14}O_6$: C, 62.1; H, 4.9. Found: C, 62.2; H, 4.9.

λ_{max}(EtOH) 263 and 353 nm. The n.m.r. signals (d_6-DMSO) at δ 1.33 and 1.36 (singlets, methyls); 2.79 (doublet, CH_2); 3.81 (triplet, —CH); 5.2 (broad singlet, alcoholic OH); 6.83 and 7.67 (doublets, J = 9 Hz, H-6 and -5); 8.70 (singlet, H-4). The carboxyl proton was very broad at δ 12–13.

(±)-Columbianetin (4b)

Compound **4***a* (30 mg) was refluxed 10 min with 30 mg copper powder in 1 ml fresh dry quinoline. The cooled solution was then diluted with 15 ml ethyl acetate and 15 ml ether, decanted from the copper, shaken with two portions of 3 *N* HCl, washed with two portions of water, and dried over Na_2SO_4. Evaporation of the clear yellow solution gave 18 mg crude (±)-columbianetin, m.p. 164–167°, raised to 168–169° by recrystallization from chloroform–hexane [lit. 170–171° (5)]. Direct comparison of the product with authentic (+)-columbianetin showed no differences in chromatographic behavior (paper chromatography, three systems; g.l.c.) or in u.v. and n.m.r. spectra.

λ_{max}(EtOH) 251, 262, and 327 nm. The n.m.r. signals ($DCCl_3$) at δ 1.25 and 1.37 (singlets, methyls); 1.75 (singlet, OH); 3.30 (doublet, J = 8 Hz, CH_2); 4.77 (triplet, J = 8 Hz, CH); 6.17 and 7.58 (doublets, J = 9.5 Hz, H-3 and -4 respectively of coumarin ring system); 6.72 and 7.22 (doublets, J = 9.0 Hz, H-6 and -5).

(±)-2,2-Dimethyl-3,5-dihydroxychroman-6-aldehyde (6b)

Compound **1***c* (0.6 g) and *p*-toluenesulfonic acid (0.01 g) in 20 ml $HCCl_3$ were treated with 85% *m*-chloroperoxybenzoic acid (0.6 g) in 15 ml $HCCl_3$ and kept 18 h at room temperature. Work-up as for **5** above gave a light brown syrup. After chromatography on silicic acid a colorless viscous syrup (0.45 g) was obtained which, although chromatographically homogeneous, still could not be crystallized. It showed n.m.r. signals ($DCCl_3$) at δ 1.46 (singlet, two methyls); 1.73 (broad singlet?, OH); 2.70 and 2.94 (doublets of doublets, J_{AB} = 16 Hz, —CH_2); 3.84 (after removal of coupled HO, doublet of doublets, J_{AX} = 5, J_{BX} = 6 Hz, —CH); 6.46 and 7.27 (doublets, J = 9 Hz, aromatic H-5 and -6); 9.66 (singlet, CHO) and 11.75 (singlet, 2-HO).

(±)-3-Carboxylomatin (3b)

The above aldehyde (0.35 g) was kept 24 h with malonic acid (0.5 g) in 1.5 ml pyridine containing a little aniline. The mixture was poured in 25 ml cold 3 *N* HCl and extracted with chloroform. The chloroform solution was washed once with water then dried and evaporated, leaving 0.28 g pale yellow crystals, m.p. 223–223.5° from methanol.

Anal. Calcd. for $C_{15}H_{14}O_6$: C, 62.1; H, 4.9. Found: C, 62.1; H, 4.9.

The n.m.r. signals (d_6-DMSO) at δ 1.29 and 1.32 (singlets, methyls); 2.70 and 2.99 (doublets of doublets, J_{AB} = 16 Hz, CH_2); 3.77 (doublet of doublets, J_{AX} = 5, J_{BX} = 6 Hz, —CH); 5.31 (broad singlet?, OH); 6.83 and 7.66 (doublets, J = 8.5 Hz, aromatic H-6 and -5); 8.70 (singlet, H-4); 12–13 (very broad, carboxyl).

(±)-Lomatin (3a)

Decarboxylation of **3***b* as for 3-carboxycolumbianetin gave (±)-lomatin in 30–50% yield, m.p. 163–165.5° from benzene [lit. m.p. 165.5–167.0° (9)].

λ_{max}(EtOH) 246, 256, and 325 nm. The n.m.r. signals ($DCCl_3$) at δ 1.35 and 1.41 (singlets, methyls); 2.0 (broad singlet, alcoholic OH); 2.92 and 3.14 (doublets of doublets, J_{AB} = 17 Hz, —CH_2); 3.89 (doublet of doublets, J_{AX} = 5.5, J_{BX} = 6 Hz, —CH); 6.21 and 7.60 (doublets, J = 9.5 Hz, H-3 and -4 respectively); 6.76 and 7.23 (doublets, H-6 and -5 respectively); all in agreement with literature values (4).

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