TOTAL SYNTHESIS OF PROTECTED FORM OF FUNGI METABOLITE CORTALCERONE

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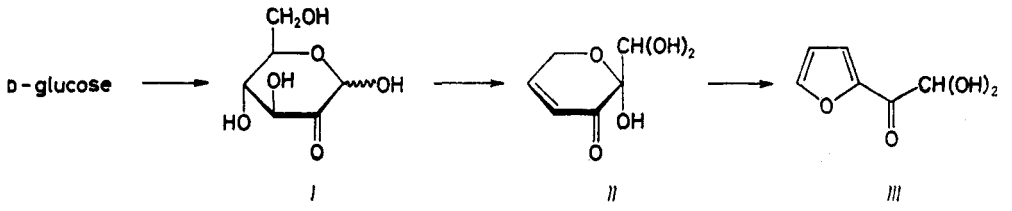
Dedicated to Dr Miroslav Protiva on the occasion of his 70th birthday.

Synthesis of methyl 4,5-dideoxy-D,L-hex-4-enos-2-ulopyranosid-3-ulose ethylene acetal, derivative of the first natural sugar with dihydropyranone moiety, from 5-acetoxymethylfurfural is described. It was shown that 1,3-transposition of the allylic alcohol in the dihydropyran ring, a key step of the synthesis, can be carried out via an intermediate allylic selenoxide with excellent regio- and stereoselectivity.

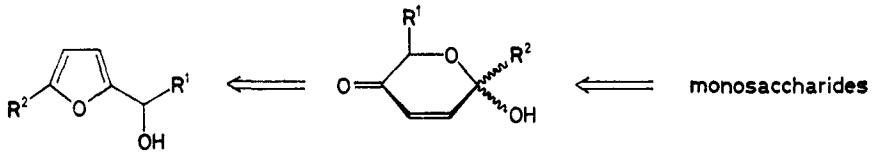
A strain of the lignicolous fungus cultivated in the D-glucose solution produces an antibacterial compound which was named cortalcerone and identified as 4,5-dideoxy--D,L-hex-4-enos-2-ulopyranos-3-ulose hydrate[1,2] (*II*). It has been found that this biotransformation is specific for D-glucose, proceeds in two steps with D-glucosone (*I*) as the intermediate[3] and can be carried out by other macrofungi[4] (Scheme 1).



SCHEME 1

The dihydropyran moiety of cortalcerone (*II*), which can be viewed as an unsaturated keto-sugar, in addition to the double bond comprises three consecutive carbonyl groups: one free and two masked as a hydrate and hemiketal, respectively. This unusual structural feature to our knowledge has not been encountered before in natural products. On the other hand it was recently demonstrated that vinyl 1,2,3-vicinal tricarbonyl compounds can be used as versatile synthons for the total synthesis

of natural products[5-7]. The foregoing consideration and the interest in the chemistry of rare sugars induced us to synthesize[8] cortalcerone derivative *XXI*. Our approach was based on the general method of monosaccharides synthesis from furan compounds[9] (Scheme 2), which appeared particularly appropriate in case of cortalcerone because of its easy acidic degradation[1] to 2-furylglyoxal hydrate (*III*) (ref.[1]).



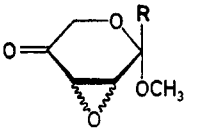
IV *V*

SCHEME 2

In the present communication we report on the stereochemical course and full experimental details of the synthesis* (Scheme 3).

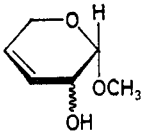
As a starting 6-carbon furan compound the readily available 5-acetoxymethylfurfural (*VI*) was used. Protection of formyl group in *VI* with ethylene glycol and deacetylation gave alcohol *VIII* which was oxidized with *m*-chloroperbenzoic acid to afford pyranosid-5-ulose *IX*. Methylation of the latter gave glycoside *X*. The spectrometric data (^{1}H NMR, IR, MS) of compounds *IX* and *X* were consistent with the assigned structures.

The α,β-unsaturated system of the dihydropyran moiety resulting in the oxidative rearrangement of furan compounds is regioisomeric to the one encountered in cortalcerone (cf. *II* and *V*). To achieve the dihydropyran functions transposition at first a method not requiring 5-keto group reduction was examined. A model keto-epoxide *XXIII* when treated with hydrazine and acetic acid according to the known procedure[10] gave expected allylic alcohol[11] *XXV*. The reaction, judged by the rate of the gas (N_2) evolution, was sluggish in comparison to that of e.g. isophorone oxide and the yield was low (15%). Nevertheless we applied the same conditions on the keto-epoxide *XXIV* required for the synthesis of cortalcerone.



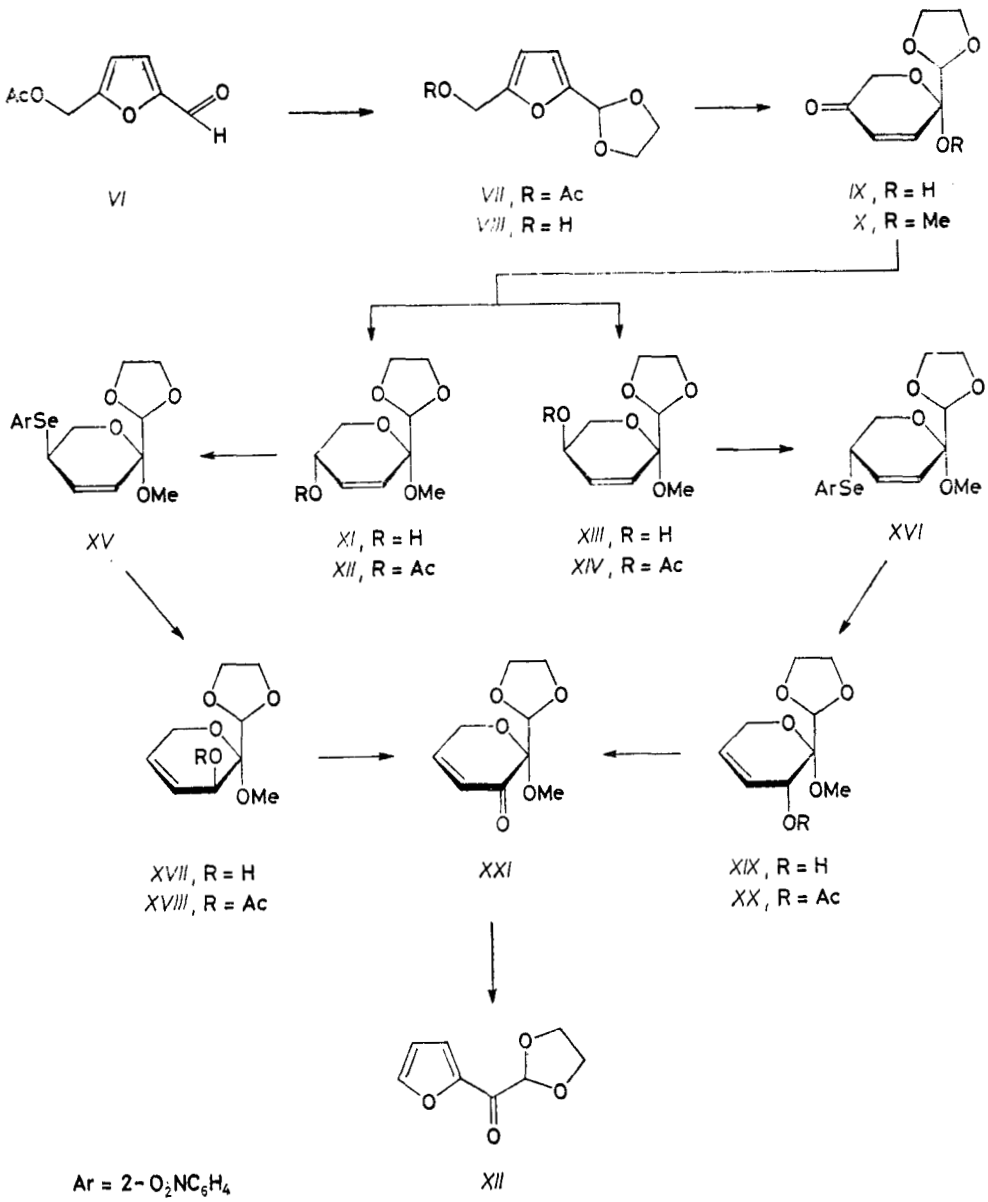
XXIII, R = H

XXIV, R = 



XXV

* All chiral compounds were obtained as racemic mixtures. For the sake of clarity their formulae depict relative configuration of (2*R*)-enantiomers.



SCHEME 3

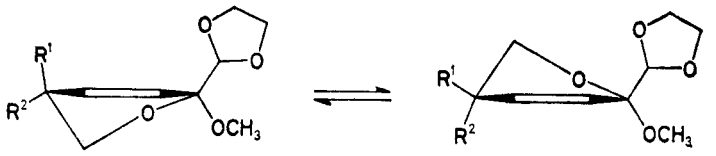
In this case no rearrangement was noted (no gas evolution) and no identifiable products were isolated. Therefore we have turned to the alternate approach based on the selenoxide chemistry[12]. The method which was successfully executed consisted

in the reduction of the carbonyl group and 1,3-transposition of an allylic alcohol, via an intermediate selenoxide[13].

Reduction of the carbonyl group in glycoside *X* unlike in the case of other pyranosiduloses[14] proceeded with low stereoselectivity. Reduction of *X* with lithium aluminium hydride and DIBAL yielded epimeric alcohols *XI* and *XIII* in the 1 : 1 and 4·6 : 1 ratio, respectively. Moderate stereoselectivity achieved in the reduction of the glycoside *X* was not detrimental to the efficacy of the synthetic scheme since both alcohols *XI* and *XIII* could be used for further transformations, ultimately yielding the desired product. However, to examine the steric course of the synthesis all steps were carried out on each alcohol separately. Flash chromatography on silica gel of the DIBAL reduction product gave alcohols *XI* and *XIII* which were also characterized as their acetates *XII* and *XIV*. The minor reduction product, alcohol *XIII*, was obtained from the major one by acetylation with Mitsunobu reagent[15] (diethyl azodicarboxylate–triphenylphosphine–acetic acid) and subsequent deacetylation. Due to the quaternary nature of C-2 only one set of vicinal and allylic couplings was available and consequently the configuration of acetates *XII* and *XIV* (or alcohols *XI* and *XIII*) could not be deduced from their ^{1}H NMR spectra. Their stereochemistry was based on the configuration of the major reduction product *XI* established by the X-ray single crystal diffraction method*. The analysis showed also that in the solid state dihydropyran ring in *XI* has a sofa conformation with C-6 atom 71 pm below the average plane defined by the C-2, C-3, C-4, C-5 and O atoms and H-5 occupying pseudoaxial position (Scheme 4, S_6). At this point it should be noted that values of vicinal and allylic coupling constants of acetate *XII* ($J(4,5)$ = = 3·91 Hz, $J(3,5)$ = 1·21 Hz) as well as acetate *XIV* ($J(4,5)$ = 4·83 Hz, $J(3,5)$ = = 0·98 Hz) indicated that both compounds in solution appear in an equilibrium of presumably also sofa conformations with pseudoaxial and pseudoequatorial position of H-5. Though it is difficult to assess quantitatively the position of these equilibria on the basis of the coupling constants it appears that for both acetates it is shifted towards the S_6, i.e. the conformation of the dihydropyran ring of alcohol *XI* in the solid state.

Alcohol *XI* treated with *o*-nitrophenylselenocyanate and tributylphosphine[16] gave cleanly selenide *XV*. Oxidation of the latter with 30% H_2O_2 in CH_2Cl_2–pyridine solution[12] proceeded with concommitant rearrangement and elimination to afford alcohol *XVII* as a single product. Analogously, from alcohol *XIII* selenide *XVI* was obtained, which in turn via oxidation–elimination reactions afforded alcohol *XIX*. Thus for both compounds 1,3-transposition of allylic alcohol system was highly regio- and stereoselective yielding in each case cleanly only one product. Their stereochemistry was not unequivocaly evident from their ^{1}H NMR spectra but it could be predicted from the reaction mechanism.

* The full details of the X-ray structure determination will be published separately.

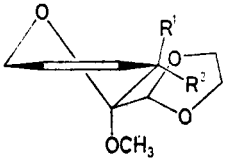


$^{S}_{6}$ ^{6}S

XII, R^1= H ; R^2= OAc
XIV, R^1= OAc ; R^2= H

SCHEME 4

Formation of selenides is known to proceed with inversion of configuration[17] whereas their oxidation and rearrangement introduces the hydroxyl group on the same face of the allylic grouping[12]. This expected steric course of the reactions sequence has been proven by the X-ray structure determination* of the acetate *XVIII* derived from the alcohol *XI* which structure, as was already mentioned, has also been established by the X-ray analysis. With relative configuration of acetates *XVIII* and *XX* firmly established from their ^{1}H NMR data prevailing conformation of the dihydropyran ring in solution could be deduced. Vicinal and allylic coupling constants amounting to $J(3,4) = 5{\cdot}34$ Hz and $J(3,5) \sim 0$ Hz in the spectrum of acetate *XVIII* and $J(3,4) = 2{\cdot}81$ Hz and $J(3,5) = 2{\cdot}19$ Hz found for acetate *XX*, indicated pseudoequatorial and pseudoaxial position of H-3 atom, respectively. Hence dihydropyran ring of both acetates in solution occurs in the $^{O}H_2$ half-chair conformation analogous to that established for the crystal of acetate *XVIII* by X-ray analysis.



$^{O}H_2$

XVIII, R^1= OAc ; R^2= H
XX, R^1= H ; R^2= OAc

Oxidation of either *XVII* or *XIX* with MnO_2 in dichloromethane gave in each case the same single product, derivative of cortalcerone; methyl 4,5-dideoxy-D,L-

* The full details of the X-ray structure determination will be pusblished separately.

hex-4-enos-2-ulopyranosid-3-ulose ethylene acetal (*XXI*). Compound *XXI* had spectroscopic properties consistent with its structure (cf. Experimental) and similarly to cortalcerone (*II*) (Scheme 1) readily underwent acidic degradation to furan compound: 2-(2-furyl)glyoxal ethylene acetal (*XXII*).

Intermediate alcohols *XI* and *XIII* could be considered as derivatives of 4,5-unsaturated osones[18]. Hence the present synthesis constitutes also a route to this class of monosaccharides.

EXPERIMENTAL

Melting points were determined on a Kofler hot-stage apparatus and are uncorrected. Boiling points refer to the air-bath temperature. IR spectra were obtained with Matson Polaris FT-IR spectrometer on $CHCl_3$ or CCl_4 solutions, unless otherwise stated (wavenumbers in cm^{-1}). ^1H NMR spectra were obtained with Bruker WH-270 (270 MHz), Bruker MSL-300 (300 MHz) and Bruker AM-500 (500 MHz) spectrometers with internal TMS as reference; chemical shifts are given in ppm (δ-scale), coupling constants (J) in Hz. Mass spectra were recorded with Kratos MS-80 RFA instrument. Column chromatography was accomplished on Merck silica gel 60 (230–400 mesh); TLC analysis was performed on the precoated with silica gel 60 (0·2 mm) aluminium sheets. Solvents were removed on the rotary evaporator under reduced pressure. Potassium selenocyanate (ref.[19]) and (*o*-nitrophenyl)selenocyanate (ref.[20]) were obtained according to the literature procedures.

5-Acetoxymethylfurfural Ethylene Acetal (*VII*)

Acetoxymethylfurfural (*VI*) (16·8 g, 0·1 mol), ethylene glycol (12·4 g, 0·2 mol) and catalytic amount of *p*-toluenesulfonic acid in benzene (150 ml) were refluxed for 6 h using Dean–Stark apparatus. The reaction mixture was washed with water, saturated $NaHCO_3$ solution and water, dried ($MgSO_4$) and distilled to give 17·8 g (84%) of *VII* as a pale yellow oil, b.p. 110°C/ /47 Pa which solidified. After recrystallization from ether–pentane m.p. 47–49·5°C. IR spectrum (KBr): 1 740, 1 390, 1 250, 830. ^1H NMR spectrum (100 MHz, $CDCl_3$): 6·44 AB system (furan, J = 3·2); 5·95 s, 1 H (O—CH—O); 5·09 s, 2 H (CH_2O); 4·22–3·90 m, 4 H (OCH_2—CH_2O); 2·09 s, 3 H ($COCH_3$). For $C_{10}H_{12}O_5$ (212·2) calculated: 56·6% C, 5·7% H; found: 56·3% C, 5·5% H.

5-Hydroxymethylfurfural Ethylene Acetal (*VIII*)

To a solution of *VII* (17·6 g, 0·083 mol) in methanol (300 ml) small lump of sodium was added, the mixture was left for 40 min at room temperature, neutralized with acetic acid and taken to dryness in vacuo. The residue was dissolved in benzene and filtered through a short silica-gel column. Evaporation of the solvent and distillation afforded 17·85 g (91%) of *VIII* as colourless oil, b.p. 111–113°C/40 Pa, which was used in the next step without further characterization.

3,4-Dideoxy-D,L-hex-3-enos-2-ulopyranos-5-ulose Ethylene Acetal (*IX*)

To a solution of *VIII* (12·85 g, 75·5 mmol) in methylene chloride (150 ml), cooled to 10°C, *m*-chloroperbenzoic acid (20 g, 116 mmol) in methylene chloride (150 ml) was added dropwise and the reaction mixture was kept at room temperature for 18 h. After cooling *m*-chlorobenzoic acid was removed by filtration and the solution concentrated to about 1/3 of initial volume. Precipitated

m-chlorobenzoic acid was filtered off, the solution diluted with methylene chloride (250 ml) and washed successively with 20% KI, 30% $Na_2S_2O_3$, saturated $NaHCO_3$ solution and water. Combined water layers were saturated with NaCl and extracted 3 times with methylene chloride (100 ml). Organic extracts were dried ($MgSO_4$) and evaporated to give 13·0 g (92·5%) of *IX* as thick oil, solidifying in the freezer. Recrystallization from ether–hexane afforded coulourless crystals, m.p. 76–77°C. IR spectrum (Nujol): 3 400, 1 685, 1 625, 1 120. ^{1}H NMR spectrum (500 MHz, $CDCl_3$): 7·00 d, 1 H (H-3, $J(3,4) = 10·44$); 6·22 d, 1 H (H-4, $J(4,6') = 0·6$); 4·97 s, 1 H (H-1); 4·60 d, 1 H (H-6, $J(6,6') = 16·88$); 4·20 dd, 1 H (H-6'); 4·18–4·00 m, 4 H (OCH_2—CH_2O); 3·41 s, 1 H (OH). For $C_8H_{10}O_5$ (186·2) calculated: 51·6% C, 5·4% H; found: 51·4% C, 5·5% H.

Methyl 3,4-Dideoxy-D,L-hex-3-enos-3-ulopyranosid-5-ulose Ethylene Acetal (*X*)

Methyl iodide (20 ml, 320 mmol) and silver oxide (30 g, 130 mmol) were added to a solution of *IX* (9·6 g, 51 mmol) in anhydrous ether (300 ml) and reaction mixture was stirred for 10 h at room temperature. Inorganic material was filtered off and washed with ether. The combined ether solutions were concentrated and the residue distilled to give 9·6 g (93%) of *X* as a pale-yellow oil, b.p. 90–95°C/8 Pa. IR spectrum (film): 1 690, 1 640, 1 110. ^{1}H NMR spectrum (270 MHz, $CDCl_3$): 6·89 dd, 1 H (H-3, $J(3,4) = 10·4$); 6·29 d, 1 H (H-4); 5·10 s, 1 H (H-1); 4·41 s, 2 H (H-6, H-6'); 4·07–3·93 m, 4 H (OCH_2—CH_2O); 3·49 s, 3 H (OCH_3). Mass spectrum for $C_8H_9O_4$ (M – OCH_3) calculated: *m/z* 169·0501; found: *m/z* 169·0501.

Methyl 3,4-Dideoxy-α-and β-D,L-Glycerohex-3-enos-2-ulopyranoside Ethylene Acetal (*XI* and *XIII*) and their 5-O-Acetyl Derivatives (*XII* and *XIV*)

A solution of DIBAL (4·62 g, 32·5 mmol) in dry THF (40 ml) was added with stirring to a solution of *X* (5·2 g, 26 mmol) in dry THF (200 ml) at –75°C over 1·5 h under argon and kept for additional 0·5 h at –75°C. Then the reaction was quenched by slow addition of methanol (7 ml) and saturated solution of potassium sodium tartrate tetrahydrate (15 ml), diluted with ether (150 ml) and allowed to warm to room temperature. Inorganic material was filtered off and washed with ether. Combined organic solutions were dried ($MgSO_4$) and concentrated to give 5·3 g (100%) of a semi-solid which was crystallized twice from ether yielding 3·14 g (60%) of *XI*, m.p. 74·5–76·5°C. IR spectrum (CCl_4): 3 580, 1 080. ^{1}H NMR spectrum (500 MHz, $CDCl_3$): 6·25 ddd, 1 H (H-4, $J(3,4) = 10·38$, $J(4,5) = 3·06$, $J(4,6) = 0·75$); 5·77 dd, 1 H (H-3, $J(3,5) = 1·56$); 4·94 s, 1 H (H-1); 4·24 m, 1 H (H-5); 4·15 ddd, 1 H (H-6, $J(5,6) = 4·86$, $J(6,6') = 11·03$); 3·72 dd, 1 H (H-6', $J(5,6') = 7·0$); 3·88–4·03 m, 4 H (OCH_2—CH_2O); 3·41 s, 3 H (OCH_3); 1·76 d, 1 H (OH, $J(5,OH) = 7·89$). For $C_9H_{14}O_5$ (202·2) calculated: 53·5% C, 7·0% H; found: 53·5% C, 7·1% H.

The residue after crystallization of *XI* was treated with pyridine (2 ml) and acetic anhydride (2 ml). The mixture was left for 15 h, concentrated and distilled to give 2·05 g of *XII* and *XIV*. Chromatography on a silica-gel column eluted with hexane–ethyl acetate (8 : 2) afforded:

Methyl 5-O-*acetyl*-3,4-*dideoxy*-α-D,L-*glycerohex*-3-*enos*-2-*ulopyranoside ethylene acetal* (XII); 0·81 g (12·8%), b.p. 110°C/5 Pa. IR spectrum (CCl_4): 1 735, 1 375, 1 225. ^{1}H NMR spectrum (500 MHz, $CDCl_3$): 6·26 dd, 1 H (H-4, $J(3,4) = 10·38$, $J(4,5) = 3·91$); 5·87 dd, 1 H (H-3, $J(3,5) = 1·21$); 5·18 m, 1 H (H-5); 4·93 s, 1 H (H-1); 4·25 dd, 1 H (H-6, $J(6,6') = 11·66$, $J(5,6) = 4·23$); 4·02–3·85 m, 4 H (OCH_2—CH_2O); 3·88 dd, 1 H (H-6', $J(5,6') = 5·35$); 3·39 s, 3 H (OCH_3); 2·08 s, 3 H ($COCH_3$). Mass spectrum for $C_{10}H_{13}O_5$ (M – OCH_3) calculated: *m/z* 213·0763; found: *m/z* 213·0780.

Methyl 5-O-*acetyl*-3,4-*dideoxy*-β-D,L-*glycerohex*-3-*enos*-2-*ulopyranoside ethylene acetal* (XIV); 1·04 g (16·4%), b.p. 110°C/5 Pa. IR spectrum (CCl_4): 1 740, 1 375, 1 240. ^{1}H NMR spectrum (500 MHz, $CDCl_3$): 6·20 ddd, 1 H (H-4, $J(3,4) = 10·28$, $J(4,5) = 4·83$, $J(4,6') = 1·01$); 6·00 dd, 1 H (H-3, $J(3,5) = 0·98$); 5·06 m, 1 H (H-5); 5·02 s, 1 H (H-1); 4·13 dd, 1 H (H-6, $J(6,6') = 12·52$, $J(5,6) = 3·40$); 4·07–3·90 m, 5 H (H-6', OCH_2—CH_2O); 3·41 s, 3 H (OCH_3); 2·09 s, 3 H ($COCH_3$). Mass spectrum for $C_{10}H_{13}O_5$ (M – OCH_3) calculated: m/z 213·0763; found: m/z 213.0781.

Deacetylation of *XIV* with sodium methoxide in methanol gave *XIII*, b.p. 140°C/5 Pa. IR spectrum (CCl_4): 3 460, 1 100. ^{1}H NMR spectrum (500 MHz, $CDCl_3$): 6·51 ddd, 1 H (H-4, $J(3,4) = 10·18$, $J(4,5) = 6·0$, $J(4,6) = 1·13$); 5·80 d, 1 H (H-3); 4·99 s, 1 H (H-1); 4·08–3·90 m, 8 H (H-5, H-6, H-6', OH, OCH_2—CH_2O); 3·40 s, 3 H (OCH_3).

Inversion of Configuration of Acetate *XII*: Acetate *XIV*

To a solution of *XII* (775 mg, 3·18 mmol) in methanol (30 ml) small lump of sodium was added. After 20 min at room temperature the reaction was neutralized with 2 drops of acetic acid and evaporated to dryness. The residue was dissolved in anhydrous THF (30 ml), acetic acid (0·42 g, 7 mmol) and triphenylphosphine (1·66 g, 6·36 mmol) were added followed by diethyl azodicarboxylate (1·11 g, 6·36 mmol) in THF (1 ml). After 24 h the reaction mixture was evaporated to dryness and the residue chromatographed on silica gel. Elution with hexane–ethyl acetate gave 600 mg (77·4%) of *XIV*.

Methyl 5-(*o*-Nitrophenyl)seleno-3,4,5-trideoxy-β-D,L-glycerohex-3-enos-2-ulopyranoside Ethylene Acetal (*XV*)

Tributylphosphine (5·65 g, 27·9 mmol) was added slowly to a solution of alcohol *XI* (3·14 g, 15·5 mmol) and *o*-nitrophenyl selenocyanate (5·3 g, 23·3 mmol) in dry THF (75 ml) at room temperature under argon. The reaction mixture was stirred for 1 h, concentrated and chromatographed on silica gel. Elution with benzene–ethyl acetate (9 : 1), evaporation and trituration with ether afforded 5·1 g (85%) of *XV* as a yellow solid, m.p. 102·5–105°C. IR spectrum ($CHCl_3$): 1 520, 1 330, 1 100, 1 045. ^{1}H NMR spectrum (270 MHz, $CDCl_3$): 8·27 bd, 1 H (H-3 aromatic, $J = 8·12$); 7·57–7·54 m, 2 H (aromatic); 7·38–7·32 m, 1 H (aromatic), 6·38 ddd, 1 H (H-4, $J(3,4) = 10·20$, $J(4,5) = 5·47$, $J(4,6) = 1·10$); 5·91 dd, 1 H (H-3, $J(3,5) = 1·25$); 5·06 s, 1 H (H-1); 4·45 dd, 1 H (H-6, $J(6,6') = 11·70$, $J(5,6) = 3·18$); 4·17 ddd, 1 H (H-6', $J(5,6') = 2·10$); 4·1–3·9 m, 4 H (OCH_2—CH_2O); 4·01 m, 1 H (H-5); 3·45 s, 3 H (OCH_3). Mass spectrum for $C_9H_{13}O_4$ (M – 202 = loss of $NO_2C_6H_4Se$) calculated: m/z 185·0814; found: m/z 185·0794.

Methyl 5-(*o*-Nitrophenyl)seleno-3,4,5-trideoxy-α-D,L-glycerohex-3-enos-2-ulopyranoside Ethylene Acetal (*XVI*)

Reaction of alcohol *XIII* (3·14 g, 15·5 mmol) with tributylphosphine (5·65 g, 27·9 mmol) and *o*-nitrophenyl selenocyanate carried out as described for *XI* gave 1·75 g (83·2%) of *XVI* as yellow solid, m.p. 100–102·5°C. IR spectrum ($CHCl_3$): 1 520, 1 335, 1 110. ^{1}H NMR (270 MHz, $CDCl_3$): 8·28 dd, 1 H (H-3 aromatic, $J = 8·34$, $J = 1·37$); 7·64–7·51 m, 2 H (aromatic); 7·40–7·34 m, 1 H (aromatic); 6·36 dd, 1 H (H-4, $J(3,4) = 10·40$, $J(4,5) = 3·12$); 5·85 dd, 1 H (H-3, $J(3,5) = 1·80$); 4·97 s, 1 H (H-1); 4·45 dd, 1 H (H-6, $J(6,6') = 10·42$, $J(5,6) = 3·54$); 4·15–3·90 m, 6 H (H-5, H-6', OCH_2—CH_2O); 3·43 s, 3 H (OCH_3). Mass spectrum for $C_9H_{13}O_4$ (M – 202 = loss of $O_2NC_6H_4Se$) calculated: m/z 185·0814; found: m/z 185·0744.

Methyl 4,5-Dideoxy-β-D,L-glycerohex-4-enos-2-ulopyranoside Ethylene Acetal (*XVII*)

A 30% hydrogen peroxide solution (50 ml, 0·49 mol) was slowly added to the selenide *XV* (5·05 g, 13 mmol) and pyridine (60 ml) in methylene chloride (600 ml) at 15°C. The reaction mixture was stirred at room temperature for 3 h, then quenched with saturated NH_4Cl solution (50 ml) and solid NH_4Cl (10 g). Organic layer was washed with saturated NH_4Cl solution (50 ml) and brine (2 × 100 ml). Water layer was saturated with NH_4Cl and extracted back with methylene chloride (200 ml). Combined organic extracts were dried ($MgSO_4$), evaporated and chromatographed on silica gel. Elution with benzene–ethyl acetate (7 : 3) afforded 1·55 g (59%) of *XVII*, b.p. 140°C/8 Pa. After crystallization from ether m.p. 69–71°C. IR spectrum (CCl_4): 3 583, 3 493, 1 110, 1 066. ^{1}H NMR spectrum (500 MHz, $CDCl_3$): 6·00–5·93 m, 2 H (H-4, H-5); 5·28 s, 1 H (H-1); 4·31 dm, 1 H (H-6, $J(6,6') = 16·8$); 4·21 dm, 1 H (H-6'); 4·16–4·05 and 4·00–3·99 m, 5 H (H-3, OCH_2—CH_2O); 2·35 bs, 1 H (OH).

Methyl 3-O-Acetyl-4,5-dideoxy-β-D,L-glycerohex-4-enos-2-ulopyranoside Ethylene Acetal (*XVIII*)

Sample of *XVII* was acetylated with acetic anhydride–pyridine mixture to give after crystallization from ether–pentane *XVIII*, m.p. 78–80°C. IR spectrum ($CHCl_3$): 1 751, 1 230. ^{1}H NMR spectrum (500 MHz, $CDCl_3$): 6·04 ddd, 1 H (H-5, $J(4,5) = 10·42$, $J(5,6) = 3·0$, $J(5,6') = 2·0$); 5·94 ddt, 1 H (H-4, $J(3,4) = 5·34$, $J(4,6) = J(4,6') = 2·24$); 5·17 s, 1 H (H-1); 5·10 dd, 1 H (H-3, $J(3,6') = 2·0$); 4·37 m, 1 H (H-6, $J(6,6') = 17·42$); 4·25 dm, 1 H (H-6'); 4·08–3·88 m, 4 H (OCH_2—CH_2O); 3·55 s, 3 H (OCH_3), 2·06 s, 3 H ($COCH_3$). Mass spectrum for $C_{10}H_{13}O_5$ (M − OCH_3) calculated: *m/z* 213·0763; found: *m/z* 213·0751.

Methyl 4,5-Dideoxy-α-D,L-glycerohex-4-enos-2-ulopyranoside Ethylene Acetal (*XIX*)

Treatment of selenide *XVI* (540 mg, 1·4 mmol) with 30% hydrogen peroxide (5 ml) and pyridine (6 ml) in methylene chloride (100 ml) solution and working up a reaction mixture as described for *XVII* afforded 136 mg (48%) of *XIX*, b.p. 140°C/8 Pa. IR spectrum (CCl_4): 3 565, 1 100, 1 047. ^{1}H NMR spectrum (300 MHz, $CDCl_3$); 5·75 m, 1 H (H-4); 5·64 m, 1 H (H-5); 5·14 s, 1 H (H-1); 4·44 m, 1 H (H-4); 4·11–3·86 m, 6 H (H-6, H-6', OCH_2—CH_2O); 3·50 s, 3 H (OCH_3); 2·53 bs, 1 H (OH).

Methyl 3-O-Acetyl-4,5-dideoxy-α-D,L-glycerohex-4-enos-2-ulopyranoside Ethylene Acetal (*XX*)

Sample of *XIX* was acetylated (acetic anhydride–pyridine) to yield *XX*, b.p. 140°C/5 Pa. IR spectrum (CCl_4): 1 750, 1 250, 1 100. ^{1}H NMR spectrum (500 MHz, $CDCl_3$): 5·89 ddt, 1 H (H-4, $J(4,5) = 10·50$, $J(3,4) = 2·81$, $J(4,6) = J(4,6') = 2·26$); 5·83–5·81 m, 1 H (H-3); 5·55 dq, 1 H (H-5, $J(3,5) = J(5,6) = J(5,6') = 2·19$); 5·09 s, 1 H (H-1); 4·19 m, 1 H (H-6); 4·17 m, 1 H (H-6'); 4·11–4·07 m, 1 H and 3·98–3·93 m, 2 H and 3·89–3·83 m, 1 H (OCH_2—CH_2O); 3·55 s, 3 H (OCH_3); 2·12 s, 3 H ($COCH_3$).

Methyl 4,5-Dideoxy-D,L-hex-4-enos-2-ulopyranosid-3-ulose Ethylene Acetal (*XXI*)

To the solution of alcohol *XVII* (1·01 g, 5 mmol) in dichloromethane (300 ml) MnO_2 (6·5 g, 75 mmol) was added and reaction mixture was stirred for 30 h at room temperature. Then inorganic material was filtered off, washed with dichloromethane and evaporated. The residue was filtered through silica-gel column in benzene–ether (8 : 2) solution and kugelrohred to give

0·826 g (82·6%) of *XXI*, b.p. 130°C/4 Pa. IR spectrum ($CHCl_3$): 1 725, 1 250, 1 060. ^1H NMR spectrum (300 MHz, $CDCl_3$): 7·05 ddd, 1 H (H-5, $J(4,5) = 10·53$, $J(5,6) = 2·35$, $J(5,6') = 3·38$); 6·14 ddd, 1 H (H-4, $J(4,6) = 2·24$, $J(4,6') = 1·91$); 5·37 s, 1 H (H-1); 4·58 ddd, 1 H (H-6, $J(6,6') = 19·36$); 4·49 ddd, 1 H (H-6'); 4·11–3·86 m, 4 H (OCH_2—CH_2O); 3·50 s, 1 H (OCH_3). Mass spectrum for $C_9H_{13}O_5$ (M + 1) calculated: *m/z* 201·0763; found *m/z* 201·0759.

Identical product was obtained by the MnO_2 oxidation carried out in the same fashion from alcohol *XIX*.

2-(2-Furyl)glyoxal Ethylene Acetal (*XXII*)

Uloside *XXI* (67 mg, 0·33 mmol) in 0·1M hydrochloric acid (5 ml) was refluxed for 3·5 h. The reaction mixture was neutralized with $NaHCO_3$, extracted twice with 30 ml of ethyl acetate, dried ($MgSO_4$) and evaporated. The residue was filtered through silica gel column, evaporated and kugelrohred to give 35 mg (73·6%) of *XXII* b.p. 100°C/40 Pa. ^1H NMR spectrum (500 MHz, $CDCl_3$): 7·63 dd, 1 H (H-5, $J(4,5) = 1·69$, $J(3,5) = 0·76$); 7·40 dd, 1 H (H-3, $J(3,4) = 3·65$); 6·59 dd, 1 H (H-4); 5·80 s, 1 H (O—CH—O); 4·14–4·12 m, 4 H (OCH_2—CH_2O).

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