Alternative syntheses of methylated sugars. XV.* Chemical synthesis of methyl β-xylobioside

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Condensation of 2,3,4-tri-*O*-acetyl-1-bromo-1-deoxy-α-D-xylopyranose with methyl 2,3-anhydro-β-D-ribopyranoside afforded methyl 2,3-anhydro-4-*O*-(2,3,4-tri-*O*-acetyl-β-D-xylopyranosyl)-β-D-ribopyranoside. Its deacetylation and treatment of the formed crystalline methyl 2,3-anhydro-4-*O*-(β-D-xylopyranosyl)-β-D-ribopyranoside with aqueous potassium hydroxide gave methyl β-xylobioside.

Конденсацией 2,3,4-три-*O*-ацетил-1-бром-1-деокси-α-D-ксилопиранозы с метил-2,3-ангидро-β-D-рибопиранозидом был получен метил- 2,3-ангидро -4-*O*-(2,3,4-три-*O*-ацетил-β-D-ксилопиранозил)-β-D--рибопиранозид. Деацетилированием последнего и последующим щелочным гидролизом полученного кристаллического метил-2,3-ангидро--4-*O*-(β-D-ксилопиранозил)-β-D-рибопиранозида был обнаружен метил-β-ксилобиозид.

When plant xylans are hydrolyzed under controlled conditions a mixture of oligosaccharides is formed from which 4-*O*-(β-D-xylopyranosyl)-D-xylopyranose (xylobiose) can be isolated [1—3]. Acetylation of xylobiose of such on origin, subsequent conversion of the acetate to the corresponding glycosyl halide and its reaction with methanol produced methyl β-xylobioside per-*O*-acetate from which *Whistler et al.* [1] prepared for the first time crystalline methyl β-xylobioside.

Since isolation of xylobiose from natural sources is tedious the above-mentioned procedure is impractical for large-scale preparation of its derivatives. Methyl β-xylobioside (*V*) was needed as a model in studies related to the chemical processing of wood and here we describe a simple synthesis of the substance (Scheme 1) from readily obtainable starting materials *I* and *II*.

The opening of the epoxide ring in alkyl 2,3-anhydro-β-D-ribopyranosides under alkaline conditions has been investigated in detail. In all systems studied so far the

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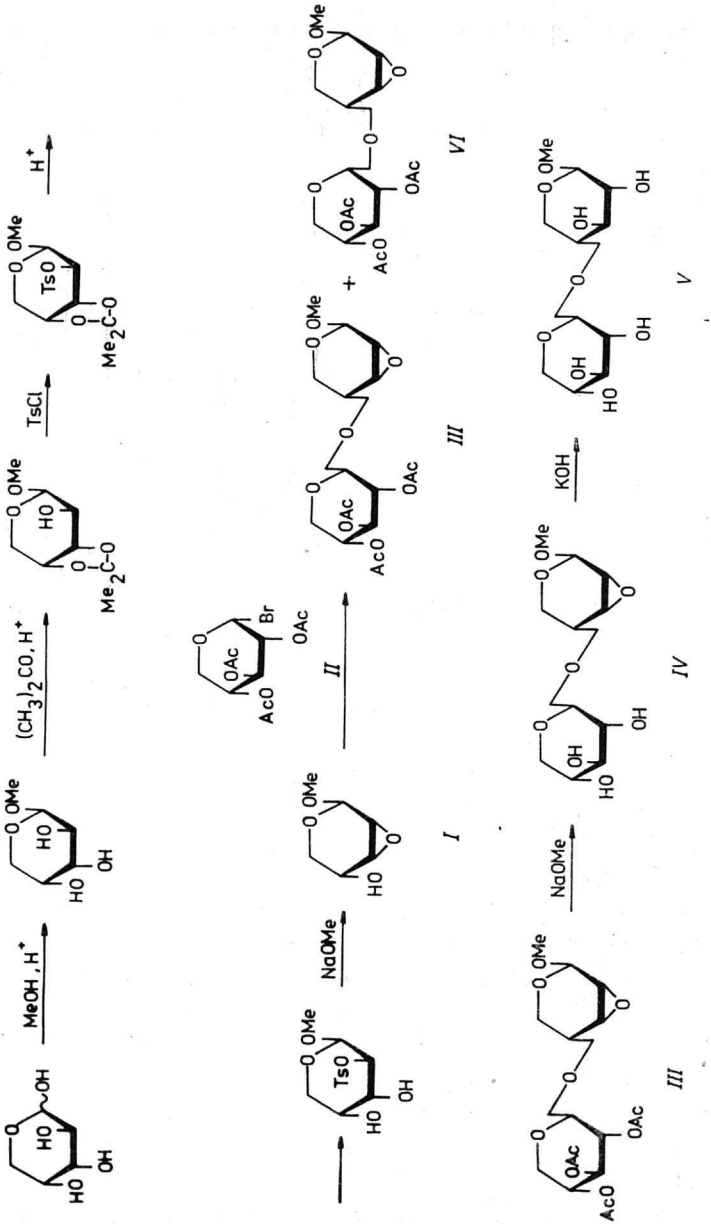

Scheme 1

attack of the nucleophile occurred predominantly at C-3 and the corresponding D-xylose derivative was formed in high yield [4]. The reaction can be used to convert easily accessible derivatives of 2,3-anhydro-D-ribose to certain D-xylose derivatives which, otherwise, would be obtainable only with difficulties. The chemical syntheses of xylobiose and its derivatives have been accomplished in this way [5] but, to our knowledge, methyl β-xylobioside has not been obtained by this simple procedure.

The starting materials in the present synthesis of *V* were methyl 2,3-anhydro-β-D-ribopyranoside (*I*), prepared from D-arabinose [6, 7], and 2,3,4-tri-*O*-acetyl-1-bromo-1-deoxy-α-D-xylopyranose (*II*) which on condensation produced crystalline oligosaccharide *III* in ~50% yield. Monitoring the reaction by t.l.c. showed that, in addition to *III*, by-products were also formed which according to their mobility could be 1→1 linked xylobioses and/or the α-isomer of the major product. One of the by-products, isolated in the crystalline state, was assigned the structure *VI* on the basis of the more positive specific rotation, as compared with the rotation of *III*, taking into account the fact that *III* and *VI* produced qualitatively identical mass spectra; this was indicative of the structural difference merely in the stereochemistry of the interglycosidic linkage. Weak molecular ion peaks at *m/e* 404 and those of baA_1 [8] and $[M—AcOH]^+$ ions at *m/e* 373 and 284, respectively, confirmed the molecular weight of the isomers (404). The masses of the individual cycles were deduced from the A_1 and bA_1 ion peaks at *m/e* 259 and 129, respectively. The origin of the other peaks present in the spectra was analogous to that described in the fragmentation of methyl 2,3,4-tri-*O*-acetyl-β-D-xylopyranoside [9].

Deacetylation of *III*, affected with a catalytic amount of sodium methoxide in methanol gave crystalline oligosaccharide *IV* which on alkaline hydrolysis with potassium hydroxide produced methyl β-xylobioside in good yield. Compound *V* is obviously dimorphous. The found melting point (148.5—149°C) is by ~45°C higher than that found previously [1] for the substance. The specific rotation, however, found for the substance described herein is in full agreement with the value observed for the substance prepared by the conversions of xylobiose of natural origin. The identity of *V* with methyl β-xylobioside of *Whistler et al.* [1] was confirmed also by the physical constants observed for the per-*O*-acetate of *V* which are in good agreement with those given by the original authors.

The mass spectrum of methyl β-xylobioside per-*O*-acetate proved its molecular weight by the presence of baA_1, $[M—AcOH]^+$, and $[M—2AcOH]^+$ ion peaks at *m/e* 475, 446, and 386, respectively. The cycle masses were depicted by the aA_1 and bA_1 ion peaks at *m/e* 259 and 231, respectively, from which the molecular weight of the substance (506) was calculated [9] as $M = aA_1 + bA_1 + 16$. Other peaks in the spectrum originated [9] from further disintegration of aA_1 and bA_1 ions.

Experimental

Melting points were determined on a Kofler hot-stage. Optical rotations were measured with a Perkin—Elmer automatic polarimeter, Model 141. Mass spectra (70 eV) were obtained using a JMS 100 D spectrometer. Thin-layer chromatography on Silica gel G and preparative chromatography on columns of dry-packed Kieselgel 60 (Merck, A. G., Darmstadt, 100-fold with respect to the amount of the chromatographed material; prior to packing, the gel was equilibrated with 40% (v/w) of the mobile phase, instead of the recommended [10] 10%) was done with: *A.* carbon tetrachloride—acetone 4:1, *B.* dichloromethane—acetone 20:1, *C.* carbon tetrachloride—acetone 10:1, and *D.* chloroform—methanol 5:1. Detection was affected by charring with 5% (v/v) sulfuric acid in ethanol. Solutions were concentrated at 40°C/2 kPa.

Methyl 2,3-anhydro-4-O-(2,3,4-tri-O-acetyl-α- (VI) and -β-D-xylopyranosyl)-β-D-ribopyranoside (III)

A mixture of methyl 2,3-anhydro-β-D-ribopyranoside (*I*, 3 g) in dry acetonitrile, Drierite (15 g), mercuric cyanide (1.2 g), and bromide *II* (3.35 g) [11] (60 ml) was stirred at room temperature with the exclusion of moisture for 1 h. T.l.c. (solvent *A* and *B*) showed then the absence of *II* and the presence of unreacted *I* in a small amount only. After filtration and concentration, the solution of the residue in chloroform was washed with 1 M potassium bromide solution to remove mercuric salts and the organic phase was concentrated. Chromatography (solvent *C*) of the crude product gave first the α-linked oligosaccharide *VI* (1.1 g; 13.2%) which crystallized from ether, m.p. 123—124°C, $[\alpha]_D^{20} + 130°$ (*c* 1.25, chloroform).

For $C_{17}H_{24}O_{11}$ (404.36) calculated: 50.49% C, 5.98% H; found: 50.41% C, 5.73% H.

Subsequently eluted was the β-linked substance *III* (4.2 g; 50.4%), m.p. 102—103°C (from ethanol), $[\alpha]_D^{20} - 52°$ (*c* 1.25, chloroform).

Found: 50.30% C, 6.08% H.

Methyl 2,3-anhydro-4-O-(β-D-xylopyranosyl)-β-D-ribopyranoside (IV)

Methanolic 1 M sodium methoxide (1 ml) was added to a solution of *III* (2.15 g) in dry methanol (50 ml) and the solution was left at 20°C for 2 h after which time t.l.c. (solvent *D*) showed complete conversion of the starting material to one product. After neutralization with Dowex 50 W $(H)^+$ resin, filtration and concentration the solid residue was recrystallized from methanol to give 1.26 g (85.1%) of pure *IV* melting at 181—181.5°C and having $[\alpha]_D^{20} - 50°$ (*c* 1.15, water).

For $C_{11}H_{18}O_8$ (275.25) calculated: 47.48% C, 6.52% H; found: 47.22% C, 6.39% H.

Methyl 4-O-(β-D-xylopyranosyl)-β-D-xylopyranoside (V)

A solution of *IV* (1.5 g) in 10% aqueous potassium hydroxide (75 ml) was heated at 95—100°C with the exclusion of atmospheric carbon dioxide for 5 h. The solution was

cooled, diluted with water and neutralized at 0°C with Dowex 50 W (H^+) resin. After concentration t.l.c. showed that the conversion of the starting material was complete. Minor impurities were removed by elution of the crude product from a column of silica gel to give methyl β-xylobioside (*V*) (R_f 0.15, solvent *D*, 1.33 g, 83%) as a sirup. When the solution of pure *V* in hot dry ethanol was allowed to cool slowly to room temperature the solute crystallized and after recrystallization from the same solvent *V* melted at 148.5—149°C, $[\alpha]_D^{20}$ −74.3° (*c* 2.95, water). Ref. [1] m.p. 103—104°C and $[\alpha]_D^{25}$ −74.7° (*c* 3, water). Methyl 2,3-di-*O*-acetyl-4-*O*-(2,3,4-tri-*O*-acetyl-β-D-xylopyranosyl)-β-D-xylopyranoside, obtained on conventional acetylation of *V*, showed m.p. 145.5—146.5°C and $[\alpha]_D^{20}$ −94° (*c* 5, chloroform). Ref. [1] m.p. 145—146°C and $[\alpha]_D^{25}$ −99.7° (*c* 5, chloroform).

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References

1. Whistler, R. L., Bachrach, J., and Tu, C. C., *J. Amer. Chem. Soc.* ***74***, 3059 (1952).
2. Timell, T. E., *Sv. Papperstidn.* ***65***, 435 (1962).
3. Marchessault, R. H. and Timell, T. E., *J. Polym. Sci.*, Part *C*, ***1963***, 49.
4. Guthrie, R. D., in *The Carbohydrates*, 2nd Edition, p. 451. (Pigman, W. and Horton, D., Editors.) Academic Press, New York, 1972.
5. Aspinall, G. O. and Ross, K. M., *J. Chem. Soc.* ***1961***, 3674.
6. Kent, P. W., Stacey, M., and Wiggins, L. F., *J. Chem. Soc.* ***1949***, 1232.
7. Hough, L. and Jones, J. K. N., *J. Chem. Soc.* ***1952***, 4349.
8. Kováčik, V., Bauer, Š., Rosík, J., and Kováč, P., *Carbohyd. Res.* ***8***, 282 (1968).
9. De Jongh, C. D. and Biemann, K., *J. Amer. Chem. Soc.* ***85***, 2289 (1963).
10. Loev, B. and Goodman, M. M., *Chem. Ind.* (London) ***1967***, 2026.
11. Schroeder, L. R., Counts, K. M., and Haigh, F. C., *Carbohyd. Res.* ***37***, 368 (1974).

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