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Synthesis of Planteose

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Planteose[1] was first isolated by Wattiez and Hans[2] in 1943 from the seeds of *Plantago major* and *Plantago ovata*. The structure has been established by French and his coworkers[3] in 1953 as *O*-α-D-galactopyranosyl-(1→6)-*O*-β-D-fructofuranosyl-(2→1)-α-D-glucopyranoside. The presence of this nonreducing trisaccharide in other plant sources was descirbed by Wada and Yamazaki[4] and by French and Wild.[5]

In connection with previous papers on sucrose chemistry[6–9], we have attempted to synthesize planteose (**4**) by a chemical method. The attractive starting material in this attempt was 2,3,4,6,1′,3′,4′-hepta-*O*-acetylsucrose (**2**) which was described by Otake[10] and more recently by Buchanan *et al.*[11]. **2** was condensed with tetra-*O*-benzyl-α-D-galactopyranosyl chloride[12] (**1**) giving *O*-(2,3,4,6-tetra-*O*-benzyl-α-D-ga-

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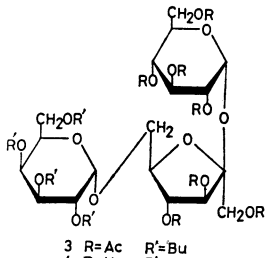
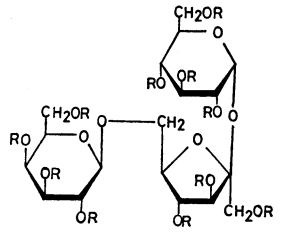


3 R=Ac R'=Bu
4 R=H R'=H
5 R=Ac R'=Ac



7 R=Ac
8 R=H

lactopyranosyl)-(1→6)-*O*-(1,3,4-tri-*O*-acetyl-β-D-fructofuranosyl)-(2→1)-2,3,4,6-tetra-*O*-acetyl-α-D-glucopyranoside (**3**) as an amorphous solid in 59% yield. Deacetylation of **3** in 0.1 M methanolic sodium methoxide and subsequent catalytic hydrogenolysis afforded a crude product of **4** in 44% yield.

The PMR spectrum of **4** revealed two doublets at δ 5.02 (J=2.7 Hz) and 5.46 (J=3.5 Hz) which were attributed to an anomeric proton of the α-D-galactopyranosyl group and that of the α-D-glucopyranosyl group respectively. The assignment of the signals was reasonably acceptable, because the corresponding proton of the α-D-galactopyranosyl group in melibiose showed its signal at δ 4.96 (J=2.9 Hz)[13] and that of the α-D-glucopyranosyl group in sucrose at δ 5.45 (J=3.2 Hz).[8,13].

4 was acetylated in the usual manner to give the crystalline undecaacetate (**5**) in 32% yield. The mp and the optical rotation were in good agreement with those described in the literature.[3] The PMR spectrum of **5** revealed eight sharp signals for the eleven acetoxy groups and a doublet at δ 5.75 (J=3.6 Hz) for an anomeric proton of the α-D-glucopyranosyl group, since the corresponding proton of sucrose octaacetate[14] and raffinose undecaacetate[9] resonated at δ 5.68 (J=3.5—3.7 Hz). Also a signal of the methylene bridge was observed at δ 3.69 and 3.98 supporting an existence of a bond between 0-6′ of sucrose and D-galactosyl residue, because the methylene bridge in 1-kestose undecaacetate was observed at δ 3.67 ($J_{geminal}$=9.5 Hz).[14]

On the other hand, when **2** was condensed with tetra-*O*-acetyl-α-D-galactopyranosyl bromide[15] (**6**) in nitromethane, an isomeric trisaccharide undecaacetate (**7**) was obtained in 22% yield.

The PMR spectrum of **7** revealed seven sharp signals in the δ 1.98—2.15 region for the eleven acetoxy groups and two doublets at δ 4.62 (J=7.5 Hz) and 5.60 (J=3.5 Hz) for an anomeric proton of the β-D-galactopyranosyl group and that of the α-D-glucopyranosyl group respectively. Because the corresponding proton of the β-D-galactopyranosyl group in β-allolactose octaacetate[9] showed its signal at δ 4.55 (J=7.4 Hz) as a doublet.

The undecaacetate **7** was deacetylated in 0.1 M methanolic sodium methoxide to give a trisaccharide (**8**).

The PMR spectrum of **8** revealed two doublets at δ 4.48 (J=7.2 Hz) and 5.44(J=3.4 Hz) which were attributed to an anomeric proton of the β-D-galactopyranosyl group and that of the α-D-glucopyranosyl group respectively, since the corresponding proton of the β-D-galactopyranosyl group in *O*-β-D-galactopyranosyl-(1→6)-*O*-α-D-glucopyranosyl-(1→2)-β-D-fructofuranoside[9] and allolactose[9,16] revealed their signals at δ 4.44 (J=7.5—7.9 Hz) as a doublet.

Experimental

General. Melting points were determined in capillary tubes and are corrected. Optical rotations were measured with a Japan Spectroscopic DIP-SL polarimeter. The PMR spectra were recorded at 100 MHz with a Varian HA-100D and at 60 MHz with a Varian A-60D spectrometer in deuteriochloroform or deuterium oxide with tetramethylsilane or sodium trimethylsilylpropanesulfonate as an internal standard. The peak positions are given in δ-values. Tlc was performed on silica gel plates (Wakogel B-10). Solutions were evaporated below 40°C under diminished pressure.

*Tetra-O-benzyl-α-D-galactopyranosyl Chloride (**1**).* The product was prepared by the method of Austin *et al.*[12]

*2,3,4,6,1′,3′,4′-Hepta-O-acetylsucrose (**2**).* The crude product was prepared by the method of Otake.[10] Recrystallization from toluene afforded the crystalline product of mp 159—160°C. $[\alpha]_D^{20}$ +50.1° (*c* 1.46, chloroform). Lit,[11] mp 160°C, $[\alpha]_D^{20}$ +49.5° (*c* 0.4, chloroform).

*O-(2,3,4,6-Tetra-O-benzyl-α-D-galactopyranosyl)-(1→6)-O-(1,3,4-tri-O-acetyl-β-D-fructofuranosyl)-(2→1)-2,3,4,6-tetra-O-acetyl-α-D-glucopyranoside (**3**).* To a solution of **1** (994 mg, 1.8 mmol) and **2** (498 mg, 0.8 mmol) in dry benzene (30 ml), mercuric cyanide (1.4 g, 5.5 mmol) and "Drierite" (1.4 g) were added and the mixture was heated for 40 hr under reflux with an exclusion of moisture. The reaction mixture was filtered and the filtrate was evaporated. The residue was dissolved in benzene, washed with water and again evaporated to give a residue (1.10 g). The residue was chromatographed on a silica gel column (Wakogel C-200, 4 g, 1.5×45 cm) in butanone-toluene (1 : 10, v/v). Fractions which showed a single spot on tlc at R_f 0.21 in the same solvent were combined and evaporated to give a solid product (538 mg, 59%). $[\alpha]_D^{20}$ +53,5° (c 0.93, chloroform). PMR (60 MHz, $CDCl_3$): δ 2.01 (s, 3H, OAc), 2.015 (s, 6H, OAc×2), 2.02 (s, 3H, OAc), 2.06 (s, 3H, OAc), 2.11 (s, 3H, OAc), 2.16 (s, 3H, OAc), 5.03 (d, 1H, J 3.6 Hz, H^{α}_{gal}—1), 5.80 (d, 1H, J 3.5 Hz, H^{α}_{glu}—1) and 7.25—7.34 (m, 20H, phenyl).

*O-α-D-Galactopyranosyl-(1→6)-O-β-D-fructofuranosyl-(2→1)-α-D-glucopyranoside (**4**).* **3** (538 mg) was dissolved in 0.1 M methanolic sodium methoxide (20 ml) and the solution was settled for 16 hr at room temperature. The solution was deionized with Amberlite IR-120 (H^+ type) until pH 7 and the solution was subsequently hydrogenated

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15) H. Ohle, W. Marecek, and W. Bourijau, *Ber.*, **62**, 833 (1929).
16) B. Helferich and G. Sparmberg, *ibid.*, **66**, 806 (1933).

with palladium black under hydrogen pressure (3.4 kg/cm^2) for 22 hr. The mixture was filtered to remove the catalyst and the filtrate was evaporated to give a solid product (211 mg), which showed a single spot on tlc at R_f 0.20 in chloroform–methanol (5 : 4, v/v). The product was dissolved in water, decolorized with active charcoal and again evaporated. The residue was dissolved in a small amount of water and ethanol was added to the solution. The solution was settled in a refrigerator to give precipitates (104 mg, 44%) which were collected by filtration. Mp 120—123°C, $[\alpha]_D^{20}$ +122.5° (*c* 1.42, water). PMR (60 MHz, D_2O): δ 5.02 (d, 1H, *J* 2.7 Hz, $H^{\alpha}_{gal}-1$) and 5.46 (d, 1H, *J* 3.5 Hz, $H^{\alpha}_{glu}-1$). The sample for an analysis was obtained by drying over phosphorus pentoxide at 75°C *in vacuo* overnight. The product did not reduce a Fehling's solution.

Found: C, 42.53; H, 6.35%. Calcd for $C_{18}H_{32}O_{16}$: C, 42.86; H, 6.39%.

Lit,[3] mp 124°C, $[\alpha]_D$ +129.0° (c 4, water).

*Planteose Undecaacetate (**5**).* **4** (112 mg) was acetylated with acetic anhydride and pyridine in the usual manner to give a glassy solid (179 mg). Recrystallization from *n*-butanol yielded **5** (69 mg, 32%), mp 134—135°C, $[\alpha]_D^{25}$ +97.2° (*c* 1.03 chloroform). PMR (100 MHz, $CDCl_3$): δ 1.99 (s, 3H, OAc), 2.01 (s, 3H, OAc), 2.04 (s, 6H, OAc×2), 2.08 (s, 9H, OAc×3), 2.10 (s, 3H, OAc), 2.135 (s 3H, OAc), 2.14 (s, 3H, OAc), 2.15 (s, 3H, OAc), 5.75 (d, 1H, *J* 3.6 Hz, $H^{\alpha}_{glu}-1$) and 3.69, 3.98 (o, 2H, $J_{geminal}$ 9.1, *J* 4.2, 5.6 Hz, CH_2 bridge).

Found: C, 49.47; H, 5.63%. Calcd. for $C_{40}H_{54}O_{27}$: C, 49.68; H, 5.63%.

Lit,[3] mp 135°C, $[\alpha]_D^{26}$ +97° (c 1, chloroform).

*Tetra-O-acetyl-α-D-galactopyranosyl Bromide (**6**).* The product was prepared by the method of Ohle *et al.*[15]

*O-(2,3,4,6-Tetra-O-acetyl-β-D-galactopyranosyl)-(1→6)-O-(1,3,4-tri-O-acetyl-β-D-fructofuranosyl)-(2→1)-2,3,4,6-tetra-O-acetyl-α-D-glucopyranoside (**7**).* A mixture of **6** (526 mg, 1.3 mmol), **2** (468 mg, 0.7 mmol), "Drierite" (1.1 g), mercuric cyanide (1.1 g, 4.4 mmol) and nitromethane (17 ml) was agitated for 24 hr at room temperature in the dark with an exclusion of moisture. Insoluble matters were removed from the mixture and the solution was evaporated. The residue was dissolved in chloroform (40 ml) and the solution was washed with water, dried over anhydrous sodium sulfate and evaporated. The residue was acetylated as usual and the acetylated product was chromatographed on a silica gel column (Wakogel C–200, 40 g, 1.5×45 cm) in butanone–toluene (1 : 5, v/v). Each fraction was monitored by tlc with the same solvent. Fractions having a single spot at R_f 0.34 were combined and evaporated to give a glassy solid (387 mg, 54%). The product was dissolved in a warm mixture of *n*-butanol and 50% aqueous ethanol (3 : 1, v/v) and the solution was settled in a refrigerator to give an amorphous product (157 mg, 22%), mp 87—89°C, $[\alpha]_D^{25}$ +44.9° (c 2.51, chloroform). PMR (100 MHz, $CDCl_3$): δ 1.98 (s, 3H, OAc), 2.02 (s, 3H, OAc), 2.04 (s, 6H, OAc×2), 2.06 (s, 3H, OAc), 2.09 (s, 3H, OAc), 2.11 (s, 9H, OAc×3), 2.15 (s, 6H, OAc×2), 4.62 (d, 1H, 7.5 Hz, $H^{\beta}_{gal}-1$) and 5.60 (d, 1H, *J* 3.5 Hz, $H^{\alpha}_{glu}-1$).

Found: C, 49.82; H, 5.95%. Calcd. for $C_{40}H_{54}O_{27}$: C, 49.68; H, 5.63%.

*O-β-D-Galactopyranoyl-(1→6)-O-β-D-fructofuranosyl-(2→1)-α-D-glucopyranoside (**8**).* **7** (235 mg) was deacetylated in 0.1 M methanolic sodium methoxide analogously as described in **4** to give a crude product (101 mg, 82%), $[\alpha]_D^{18}$ +51.3° (*c* 1.6, water). The product did not reduce Fechling's solution. PMR (60 MHz, D_2O): δ 4.48 (d, 1H, *J* 7.2 Hz, $H^{\beta}_{gal}-1$) and 5.44 (d, 1H, *J* 3.4 Hz, $H^{\alpha}_{glu}-1$). A sample for analysis was obtained by drying over phosphorus pentoxide at 50°C for 3 days *in vacuo*.

Found: C, 42.65; H, 6.45%. Calcd. for $C_{18}H_{32}O_{16}$: C, 42.86; H, 6.39%.

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