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Pyranoid D-fructosyl and L-sorbosyl cyanides †

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ABSTRACT

The anomeric D-fructopyranosyl and L-sorbopyranosyl cyanides have been prepared via reaction of the respective 2-*O*-acetyl-1,3,4,5-tetra-*O*-benzoyl derivatives with BF_3–trimethylsilyl cyanide in nitromethane. Configurations of the products at the tertiary center were assigned on the basis of rotational comparisons, ^1H NMR data, and, in the case of β-D-fructosyl cyanide, by an X-ray structural analysis. From the conformational preferences of the 2-epimers — the cyano group invariably adopts an axial disposition entailing the $^5C_2$ conformation for the β-D-*fructo* and α-L-*sorbo* cyanides versus the alternative $^2C_5$ form for the α-D-*fructo* and β-L-*sorbo* anomers — the anomeric effect of a cyano group may be assessed to be of the same order of magnitude as that exerted by an acyloxy function.

INTRODUCTION

Of the vast array of methods developed for replacement of the anomeric hydroxyl group in sugars by carbon, cyanation of an acylated glycosyl halide has undoubtedly been the most practical one in terms of simplicity of reagents, work-up procedures, and yields[2–7]. Although not even mentioned in a recent extensive review on *C*-glycosyl compounds[8], many glycosyl cyanides derived from aldopento- or aldohexo-pyranoses have been prepared. They have proved to be useful intermediates for the synthesis of isosteric glycoside analogs of biochemical interest as fraudulent substrates[9,10] or as active-site-directed, irreversible inhibitors of glycosidases[11–13].

In spite of the biological importance of D-fructose, the synthesis of *C*-fructosyl compounds has received little attention[14], and neither furanoid nor pyranoid hexulosyl cyanides have yet been disclosed. Herein, we describe the ready preparation of the pyranoid α- and β-cyanides of D-fructose and L-sorbose, the unequivocal proof of their configurations at the tertiary carbon, and some derived products.

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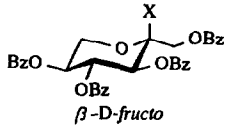
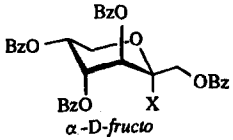
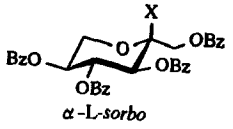
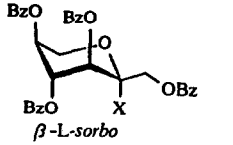
RESULTS AND DISCUSSION

Exposure of tetra-*O*-benzoyl-β-D-fructopyranosyl bromide (**1**), readily accessible from D-fructose in two high-yielding steps[15], to mercuric cyanide in nitromethane (2 days, 25°C) smoothly generated a ~9:1 mixture of anomeric fructosyl cyanides, from which the major product, isolated in 58% yield as colorless prisms of high negative rotation (−200°), proved to be the β-cyanide **3** (cf. below); the minor component, syrupy α-cyanide **4**, was obtained upon column chromatography in 6% yield and characterized as a syrup.

More favorable conditions for the acquisition of the β-cyanide **3** proved to be those developed by de las Heras and Fernández-Resa[6], i.e., the cyanation of the corresponding acetate **2** with trimethylsilyl cyanide–BF_3-etherate: an approximately 15:1 mixture of **3** and **4** was obtained, from which **3** was readily obtained in pure form (86% yield). It could be *O*-debenzoylated with sodium hydride–methanol to give **5** (84%), whilst stronger basic conditions (NaOH, 100°C) resulted in hydrolysis to the corresponding carboxylic acid, isolated after esterification as the 2-methoxycarbonyl-D-fructose tetraacetate (**6**), actually a 2-hydroxymethyl deriva-

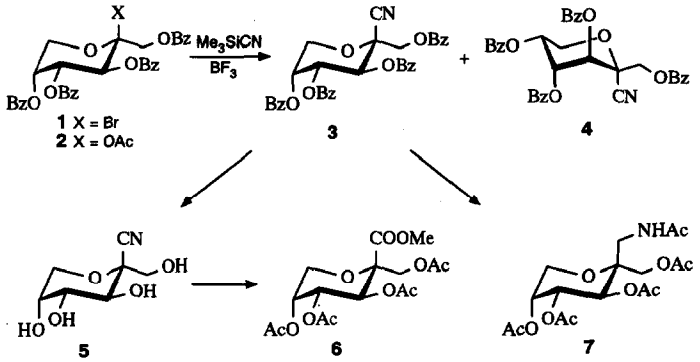
TABLE I

Selected physical data for anomeric D-fructo- and L-sorbo-pyranose derivatives

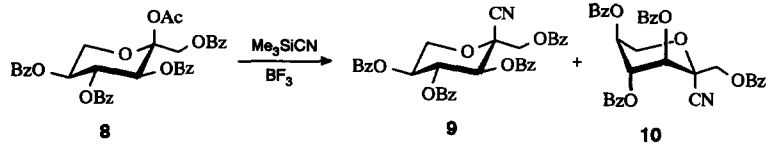
Compound		$[\alpha]_D^{20}$ (°) ($CHCl_3$)	$J_{3,4}$	$J_{4,5}$	Ring conformation
 β-D-*fructo*	**1** X = Br	−182.8	10.0	3.3	$^2C_5$
	2 X = OAc	−160.7	9.8	3.3	$^2C_5$
	3 X = CN	−200.2	10.2	3.3	$^2C_5$
 α-D-*fructo*	**4** X = CN	+1.8	3.7	3.3	$^5C_2$
	11 X = OAc	+2.4	4.2	3.7	$^5C_2$
	12 X = OBz	−3.1	3.5	3.7	$^5C_2$
 α-L-*sorbo*	**8** X = OAc [a]	+8.3	10.1	10.1	$^2C_5$
	9 X = CN	−36.9	9.9	9.9	$^2C_5$
	13 X = Br [a]	−8.2 [b]	9.8	9.8	$^2C_5$
 β-L-*sorbo*	**10** X = CN	+64.1	2.0	1.3	$^5C_2$
	14 X = OAc [a]	+58.5	4.0	3.7	$^5C_2$
	15 X = OBz	+59.6	2.8	0.5	$^5C_2$

[a] Data from ref 20. [b] In CH_2Cl_2.

tive of 2,6-anhydro-D-gluconic acid. Hydride reduction of **3** followed by acetylation generated the 2-acetamido-fructoside **7** uneventfully.



Whilst the trimethylsilyl cyanide–BF_3-induced cyanation of fructose acetate **2** proceeded with a high degree of stereoselectivity (15:1 in favor of the β-cyanide **3**), the same reaction as applied to the α-L-sorbose analogue **8**, in acetonitrile or nitromethane as solvent, was essentially devoid of any preference: a 1:1 anomeric mixture was invariably obtained, from which the syrupy α-L-sorbosyl cyanide **9** and the well-crystallized β-L isomer **10** were isolable by simple chromatography in 42 and 36% yield, respectively. Obviously, the lack of stereoselectivity on cyanation of **8** is due to the all-equatorial orientation of the benzoyloxy groups in the pyranoid ring which provides no steric hindrance to cyanide attack from either side at the anomeric carboxonium ion intermediate — in contrast to the fructose analogue **2**, in which the axially disposed 5-benzoyloxy moiety evidently exerts substantial steric hindrance for attack from the α-face.



Configurational assignments.—The configuration of **3** at the tertiary carbon atom rests on the following pieces of evidence. First, the rotational values for **1**, **2**, and **3**, in chloroform, are all strongly negative (Table I), indicating analogous anomeric disposition of OAc, Br, and CN substituents; second, the coupling patterns of **1**, **2**, and **3** bear close similarity ($J_{3,4}$ 9.8–10.2, $J_{4,5}$ 3.3 Hz; Table I), and clearly reveal a $^2C_5$ geometry for the pyranoid ring; finally, **3** was unequivocally identified as the β-cyanide by an X-ray crystallographic analysis (Fig. 1), exhibiting dihedral angles for the pyranoid ring (Table II) close to those observed for 1,2:4,5-di-*O*-isopropylidene-D-fructopyranose[16].

The α-D-*fructo* configuration for the minor component **4**, apart from being isomeric with **3**, was inferred from the small values for $J_{3,4}$ and $J_{4,5}$ (3.7 and 3.3 Hz, respectively), indicative of a $^5C_2$ conformation of the pyranoid ring; its

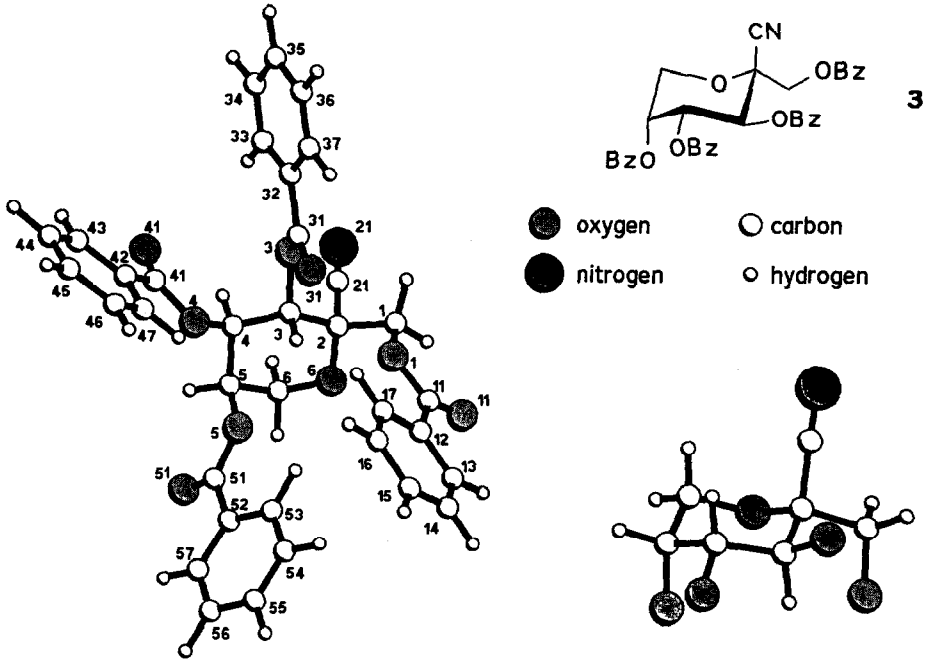


Fig. 1. Perspective view of the X-ray model of 1,3,4,5-tetra-*O*-benzoyl-β-D-fructopyranosyl cyanide (**3**) and numbering system. To facilitate visualization of the $^2C_5$ conformation of the pyranoid ring, a second view is given (lower right) in which the benzoyl groups are omitted for clarity.

adoption is obviously caused by the tendency of the anomeric cyano group to be axially disposed, even at the expense of two benzoyloxy groups being forced into axial dispositions. In that respect, **4** parallels the $^5C_2$ conformation for the anomeric acyloxy analogues **11** and **12**, as evidenced by closely similar couplings (Table I).

TABLE II

Selected torsional angles (°) for **3**

Pyranoid ring		Ring substituents	
O-6–C-2–C-3–C-4	−49.7	C-6–O-6–C-2–C-21	−65.2
C-2–C-3–C-4–C-5	48.9	C-6–O-6–C-2–C-1	179.1
C-3–C-4–C-5–C-6	−51.2	C-21–C-2–C-3–O-3	−46.1
C-4–C-5–C-6–O-1	55.4	C-21–C-2–C-3–C-4	72.8
C-5–C-6–O-6–C-2	−60.9	C-3–C-4–C-5–O-5	65.4
C-6–O-6–C-2–C-3	56.8	O-1–C-1–C-2–C-21	168.3
		O3–C-3–C-4–O-4	−70.5
Ring protons		O-4–C-4–C-5–O-5	−53.7
H-3–C-3–C-4–H-4	172.5		
H-4–C-4–C-5–H-5	−52.8		
H-5–C-5–C-6–H-61	56.5		
H-5–C-5–C-6–H-62	−63.2		

TABLE III

Atomic coordinates and equivalent isotropic displacement coefficients (Å^2)

Atom	x/a	y/b	z/c	U_{eq}
C-1	0.3833(05)	1.0070(06)	0.7407(04)	0.068(03)
C-2	0.3059(04)	1.1055(06)	0.7221(03)	0.053(03)
C-3	0.2300(04)	1.0993(06)	0.7622(03)	0.052(02)
C-4	0.1427(04)	1.1801(06)	0.7349(03)	0.051(02)
C-5	0.0950(04)	1.1722(06)	0.6575(03)	0.053(03)
C-6	0.1781(04)	1.1824(06)	0.6238(03)	0.058(03)
O-6	0.2552(03)	1.0979	0.6511(02)	0.057(02)
C-21	0.3664(05)	1.2151(07)	0.7396(03)	0.062(03)
N-21	0.4139(05)	1.2962(06)	0.7526(03)	0.092(04)
O-1	0.3285(03)	0.9035(05)	0.7382(02)	0.069(02)
C-11	0.3367(05)	0.8209(06)	0.6949(03)	0.061(03)
O-11	0.3887(04)	0.8311(06)	0.6580(02)	0.097(03)
C-12	0.2754(04)	0.7197(06)	0.6986(03)	0.057(03)
C-13	0.2744(05)	0.6289(07)	0.6559(03)	0.081(04)
C-14	0.2195(07)	0.5335(07)	0.6572(05)	0.109(05)
C-15	0.1638(07)	0.5261(07)	0.7021(04)	0.102(05)
C-16	0.1655(06)	0.6159(08)	0.7465(04)	0.094(04)
C-17	0.2203(05)	0.7135(07)	0.7439(03)	0.070(03)
O-3	0.2812(03)	1.1297(05)	0.8325(02)	0.061(02)
C-31	0.2841(05)	1.0531(07)	0.8832(03)	0.065(03)
O-31	0.2553(05)	0.9565(06)	0.8710(02)	0.100(03)
C-32	0.3268(04)	1.1043(07)	0.9523(03)	0.064(03)
C-33	0.3333(06)	1.2204(08)	0.9619(03)	0.089(04)
C-34	0.3710(07)	1.2638(09)	1.0282(04)	0.113(06)
C-35	0.4035(06)	1.1923(11)	1.0840(04)	0.103(06)
C-36	0.3961(06)	1.0764(11)	1.0740(04)	0.100(05)
C-37	0.3577(05)	1.0326(08)	1.0093(03)	0.085(04)
O-4	0.0693(03)	1.1518(05)	0.7678(02)	0.061(02)
C-41	0.0498(05)	1.2256(07)	0.8127(03)	0.057(03)
O-41	0.0808(04)	1.3227(05)	0.8189(02)	0.093(03)
C-42	−0.0116(04)	1.1744(06)	0.8511(03)	0.059(03)
C-43	−0.0511(05)	1.2422(07)	0.8916(03)	0.080(04)
C-44	−0.1070(07)	1.1954(10)	0.9280(04)	0.109(06)
C-45	−0.1290(06)	1.0791(11)	0.9229(05)	0.113(06)
C-46	−0.0930(07)	1.0123(09)	0.8824(05)	0.129(06)
C-47	−0.0353(06)	1.0589(07)	0.8458(04)	0.091(04)
O-5	0.0498(03)	1.0590(05)	0.6416(02)	0.054(02)
C-51	−0.0294(04)	1.0501(06)	0.5829(03)	0.052(03)
O-51	−0.0678(03)	1.1311(05)	0.5479(02)	0.067(02)
C-52	−0.0643(04)	0.9307(06)	0.5684(03)	0.056(03)
C-53	−0.0069(05)	0.8399(07)	0.6009(03)	0.073(04)
C-54	−0.0418(06)	0.7297(08)	0.5834(04)	0.090(05)
C-55	−0.1328(07)	0.7119(08)	0.5351(04)	0.101(05)
C-56	−0.1937(06)	0.8023(09)	0.5021(04)	0.091(05)
C-57	−0.1572(05)	0.9115(08)	0.5193(03)	0.073(04)

The anomeric L-sorbosyl cyanides **9** and **10** exhibit similar conformational preferences: the cyano group invariably adopts the axial orientation. This is to be expected for the *α*-L-*sorbo* derivative **9**, for which the large $J_{3,4}$ and $J_{4,5}$ values

(10.1 Hz each, Table I) prove that the pyranoid ring adopts the $^2C_5$ conformation with all ring substituents equatorial. The same conformational features are shown by the α-L-acetate **8** and its bromide **13**.

That compound **10** is the β-L-sorbosyl cyanide can already be deduced from the close correspondence of its rotational value with those of its β-L-acyloxy analogues **14** and **15** (Table I). As indicated by the small couplings of $J_{3,4}$ 2.0 and $J_{4,5}$ 1.8 Hz, the pyranose ring is in the $^5C_2$ conformation, which is noteworthy, since the cyano group as well as the three contiguous benzoyloxy moieties are all in axial arrangements. The same holds for the 2-acyloxy analogues **14** and **15** (cf. couplings in Table I), allowing the conclusion that *the anomeric effect of a cyano group is of the same order of magnitude as that exerted by an acyloxy function*. These data also show that three axially disposed benzoyloxy groups on a pyranoid ring exert comparatively little strain in terms of 1,3-diaxial interactions, reminiscent of a variety of tri-*O*-benzoyl-α-D-xylosyl halides[17] with an all-axial orientation of the substituents on the pyranoid ring.

EXPERIMENTAL

General.—Melting points were determined with a Bock hot-stage microscope and are not corrected. Optical rotations were measured with a Perkin–Elmer 241 polarimeter at 20°C. A Varian 311A spectrometer was used to obtain mass spectra. NMR spectra were recorded on a Bruker WM 300 spectrometer at 300 (^{1}H) and 755 MHz (^{13}C). TLC on Kieselgel $^{60}F_{254}$ plastic sheets (Merck, Darmstadt) was used to monitor the reactions and ascertain the purity of the products. The developers employed were *A*, 10:1 toluene–EtOAc; *B*, 40:1 toluene–acetone; *C*, 9:1 toluene–diisopropyl ether *D*, 1:1 cyclohexane–EtOAc. The spots were visualized by UV light or by spraying with aq 50% H_2SO_4 and charring at 120°C for 5 min. Column chromatography was performed on Silica Gel 60 (Merck, 63–200 μm).

1,3,4,5-Tetra-O-benzoyl-β-D-fructopyranosyl cyanide * (**3**).—To a solution of 2.1 g (3 mmol) of 2-*O*-acetyl-1,3,4,5-tetra-*O*-benzoyl-β-D-fructopyranose[18] (**2**) in nitromethane (30 mL) was added trimethylsilyl cyanide (1.2 mL, 9 mmol) and 0.1 mL (0.82 mmol) of an ethereal solution of BF_3-etherate, and the mixture was stirred for 1 h at ambient temperature. Quenching by stirring with satd aq $NaHCO_3$ (50 mL) for 15 min, dilution with $CHCl_3$ (100 mL), separation of the organic phase, extraction of the aqueous layer with $CHCl_3$ (3 × 50 mL), and evaporation in vacuo of the combined organic phases resulted in a syrup containing **3** (R_f 0.57, TLC in *A*) and its α anomer **4** (R_f 0.63) in a ratio of ~15:1.

Chromatography of the syrup from a silica gel column (3 × 30 cm) with 10:1 toluene–EtOAc and removal of the solvent from the first fraction gave 0.24 g (4%)

* The alternative name, i.e., 2,6-anhydro-3,4,5-tri-*O*-benzoyl-2-*C*-benzoyloxymethyl-D-gluconononitrile, is less descriptive and, hence, not used here.

of 1,3,4,5-tetra-*O*-benzoyl-α-D-fructopyranosyl cyanide (**4**) as a colorless syrup; $[\alpha]_D$ + 1.8° (*c* 0.8, $CHCl_3$); ^1H NMR data ($CDCl_3$): δ 4.33 (dd, 1 H, $J_{5,6a}$ 5.2, $J_{6a,6b}$ 11.3 Hz, H-6a), 4.44 (dd, 1 H, $J_{5,6b}$ 11.3 Hz, H-6b), 4.59 (d, 1 H, $J_{1a,1b}$ 11.2 Hz, H-1a), 4.84 (d, 1 H, H-1b), 5.69 (ddd, 1 H, $J_{4,5}$ 3.3, $J_{5,6a}$ 5.6, $J_{5,6b}$ 11.3 Hz, H-5), 5.91 (d, 1 H, $J_{3,4}$ 3.7 Hz, H-3), 6.00 (dd, 1 H, H-4), 7.31–8.35 (m, 20 H, 4 C_6H_5); ^{13}C NMR data ($CDCl_3$): δ 61.7 (C-6), 64.0 (C-1), 65.1 (C-5), 66.3 (C-4), 68.0 (C-3), 72.9 (C-1), 116.0 (CN), 125.3–134.3 (4 C_6H_5), 163.9, 165.1, 165.2 (4 COC_6H_5); MS (FD, 12 mA): *m/z* 605 (M^+).

The major fraction eluted next, on evaporation of the solvents in vacuo, gave 1.85 g (90%) of **3** as colorless prisms; mp 99–101°C; $[\alpha]_D$ − 200.2° (*c* 1.0, $CHCl_3$); ^1H NMR data ($CDCl_3$): δ 4.40 (m, 2 H, H-6a,6b), 4.64 (d, 1 H, $J_{1a,1b}$ 12 Hz, H-1a), 4.85 (d, 1 H, H-1b), 5.83 (dd, 1 H, $J_{3,4}$ 10.2, $J_{4,5}$ 3.3 Hz, H-4), 5.87 (m, 1 H, $J_{5,6a} = J_{5,6b} = 1.3$ Hz, H-5), 6.23 (d, 1 H, H-3), 7.15–8.19 (m, 20 H, 4 C_6H_5); ^{13}C NMR data ($CDCl_3$): δ 64.0 (C-1), 65.9 (C-3), 66.4 (C-6), 68.6 (C-5), 70.3 (C-4), 77.4 (C-2), 114.2 (CN), 127.83–134.0 (4 C_6H_5), 164.7, 165.2, 165.3 (4 CO). Anal. Calcd for $C_{35}H_{27}NO_9$ (605.6): C, 69.42; H, 4.49; N, 2.31. Found: C, 69.71; H, 4.62; N, 2.01.

The crystals of **3** were monoclinic, space group *C*2, with cell constants *a* = 13.861(1), *b* = 11.694(2), and *c* = 20.456(2) Å; *B* = 108.70(1)°, *V* = 3140.7 Å^3, *Z* = 4, *D* = 1.28 g cm^{-3}, μ(Mo*Kα*) = 0.79 cm^{-1}. Intensities were collected on a STOE STADI 4 diffractometer. Of the 2420 reflections measured, 2059 symmetry-independent reflections in the range $F_{hkl} \geq 4\sigma$ were used for structure elucidation, which was effected with the SHELX86 program[19]; *R* = 0.0397, R_w = 0.0397. The hydrogen atoms were positioned geometrically. The atomic coordinates are listed in Table III *.

β-D-Fructopyranosyl cyanide (**5**).—To a stirred suspension of **3** (3.0 g, 5.0 mmol) in MeOH (20 mL) was added 100 mg of a 60% NaH–paraffin oil dispersion, and the mixture was stirred for 2 h at room temperature. Neutralization by addition of an acidic ion-exchange resin (Amberlite IR-120, H^+-form), filtration, evaporation of the filtrate to dryness, and extraction of the residue with diisopropyl ether followed by trituration with MeOH gave a residue; further treatment with diisopropyl ether and MeOH resulted in crystallization. Recrystallization from MeOH gave **5** (0.79 g, 84%); mp 199–201°C; $[\alpha]_D$ − 85.2° (*c* 1, H_2O); ^{13}C NMR data (Me_2SO-d_6): δ 63.97 (C-1), 66.46 (C-3), 67.75 (C-5), 68.09 (C-6), 70.79 (C-4), 81.59 (C-2), 117.4 (CN). Anal. Calcd for $C_7H_{11}NO_5$ (189.2): C, 44.45; H, 5.86; N, 7.40. Found: C, 44.38; H, 5.75; *N*, 7.29.

1,3,4,5-Tetra-O-acetyl-2-deoxy-2-C-methoxycarbonyl-β-D-fructopyranose [methyl C-(1,3,4,5-tetra-O-acetyl-β-D-fructopyranosyl)formate] (**6**).—A solution of the β-cyanide **5** (570 mg, 3 mmol) in aq 50% NaOH (2 mL) was heated to 100°C for 12 h.

* Atomic coordinates for this structure have been deposited with the Cambridge Crystallographic Data Centre. The coordinates may be obtained, on request, from the Director, Cambridge Crystallographic Data Centre, 12 Union Road, Cambridge, CB2 1EZ, UK.

Dilution with water (30 mL), neutralization with AcOH, and evaporation to dryness in vacuo gave a syrup which was subjected to acetylation with pyridine–Ac_2O (2 mL each) overnight. Work up by stirring into ice–water (10 mL), acidification to pH 3 by M HCl, extraction with $CHCl_3$ (3 × 10 mL), and evaporation of the combined extracts to dryness left a residue which was dissolved in 10:1 MeOH–water (10 mL). An ethereal diazomethane solution was added, and the mixture was stirred for 2 h and then evaporated to dryness. Purification of the residual syrup by elution from a silica gel column (3 × 25 cm) with 1:1 cyclohexane–EtOAc and evaporation of the appropriate fraction afforded **6** (715 mg, 61%) as a colorless syrup, homogeneous by TLC; R_f 0.35 in *D*; $[\alpha]_D$ −79° (*c* 0.9, $CHCl_3$); ^1H NMR data ($CDCl_3$): δ 2.03, 2.05, 2.13, and 2.15 (4 s, each 3 H, 4 OAc), 3.82 (s, 3 H, OCH_3), 3.97 (dd, 1 H, $J_{5,6a}$ 3.3, $J_{6a,6b}$ 13.1 Hz, H-6a), 4.31 (d, 1 H, $J_{1a,1b}$ 12.2 Hz, H-1a), 4.38 (dd, $J_{5,6b}$ 2.0 Hz, H-6b), 4.44 (d, 1 H, H-1b), 5.37 (m, 1 H, H-5), 5.50 (dd, 1 H, $J_{3,4}$ 9.6, $J_{4,5}$ 3.1 Hz, H-4), 5.57 (d, 1 H, H-3); ^{13}C NMR data ($CDCl_3$): δ 20.6, 20.7, 20.9 (4 Ac-CH_3), 52.6 (OCH_3), 63.6, 64.6 (C-1,6), 65.9, 68.0, 68.4 (C-3,4,5), 80.1 (C-2), 168.3 ($COOCH_3$), 169.4, 169.8, 170.1, 170.3 (4 $COCH_3$). MS (FD, 5 mA): *m/z* 390 [M^+], 331 [$M^+ - COOCH_3$]. Anal. Calcd for $C_{16}H_{22}O_{11}$ (390.3): C, 49.23; H, 5.68. Found: C, 49.10; H, 5.56.

2-C-Acetamidomethyl-1,3,4,5-tetra-O-acetyl-2-deoxy-β-D-fructopyranose [N-acetyl-C-(1,3,4,5-tetra-O-acetyl-β-D-fructopyranosyl)methylamine] (**7**).—A solution of **3** [1.20 g, 2 mmol) in tetrahydrofuran (THF) (10 mL) was added to a solution of $LiAlH_4$ (470 mg, 6 mol equiv) in THF (5 mL), and the mixture was refluxed for 2 h. Quenching with water (3 mL) and aq 25% ammonia (5 mL) followed by filtration through a glass and evaporation of the filtrate to dryness afforded a syrup which was acetylated by exposure to pyridine–Ac_2O (5 mL each) overnight. Work up by stirring into ice–water (20 mL), extraction with $CHCl_3$ (3 × 20 mL), washing of the combined extracts with satd aq $NaHCO_3$ and water, drying ($MgSO_4$), and removal of the solvent gave an oily residue. Purification by elution from a silica gel column (3 × 30 cm) with 1:1 cyclohexane–acetone afforded 475 mg (59%) of **7** as a colorless syrup; $[\alpha]_D$ −53° (*c* 1, $CHCl_3$); ^1H NMR data ($CDCl_3$): δ 2.00, 2.02, 2.07, 2.11, 2.16 (5 s, each 3 H, 5 Ac), 3.53 (dd, 1 H, $J_{1'a,1'b}$ 15.1, $J_{1'a,NH}$ 6.5 Hz, H-1'a), 3.80 (dd, 1 H, $J_{1'b,NH}$ 5.1 Hz, H-1'b), 3.85 (dd, 1 H, $J_{5,6a}$ 2.6, $J_{6a,6b}$ 13.5 Hz, H-6a), 3.97 (dd, 1 H, $J_{5,6b}$ 1.3, H-6b), 4.07 (d, 1 H, $J_{1a,1b}$ 12.0 Hz, H-1a), 4.16 (d, 1 H, H-1b), 5.22 (dd, 1 H, $J_{3,4}$ 10.2, $J_{4,5}$ 3.5 Hz, H-4), 5.31 (m, 1 H, H-5), 5.57 (d, 1 H, H-3), 5.93 (m, 1 H, NH); ^{13}C NMR data ($CDCl_3$): δ 20.5, 20.6, 20.8 (4 OAc-CH_3), 23.2 (NAc-CH_3), 35.6 (CH_2N), 62.5, 64.8 (C-1,6), 67.7, 68.3, 68.4 (C-3,4,5), 76.9 (C-2), 169.3, 169.9, 170.1, 170.4 (5 $CHCH_3$). MS (FD, 12 mA): *m/z* 403 [M^+], 404 [$M^+ + 1$].

1,3,4,5-Tetra-O-benzoyl-α-L-sorbopyranosyl cyanide (**9**) *and 1,3,4,5-tetra-O-benzoyl-β-L-sorbopyranosyl cyanide* (**10**).—To a nitromethane solution of 2-*O*-acetyl-1,3,4,5-tetra-*O*-benzoyl-α-L-sorbopyranose[20] (**8**; 2.10 g, 3 mmol in 30 mL) was added trimethylsilyl cyanide (1.2 mL, 9 mmol) and BF_3-etherate in ether (0.1 mL). The mixture was stirred for 1 h at room temperature and then processed as

described for cyanation of **2** (cf. above). The crude syrup thus obtained, on the basis of TLC and ^{1}H NMR, contained **9** and **10** in an approximate 1:1 ratio. Separation was achieved by chromatography on a silica gel column (3 × 30 cm) with 20:1 toluene–di-isopropyl ether.

The fraction eluted first (R_f 0.59 in *C*), on evaporation to dryness, gave 760 mg (42%) of *α*-L-*sorbo* isomer **9** as a solid foam; $[\alpha]_D$ − 37° (*c* 0.8, $CHCl_3$); ^{1}H NMR data ($CDCl_3$): δ 4.06 (dd, 1 H. $J_{5,6a} = J_{6a,6b} = 11.5$ Hz, H-6a), 4.52 (dd, 1 H, $J_{5,6b}$ 5.7 Hz, H-6b), 4.66 (d, 1 H, $J_{1a,1b}$ 12.0 Hz, H-1a), 4.71 (d, 1 H, H-1b), 5.47 (ddd, 1 H, $J_{4,5}$ 9.9 Hz, H-5), 5.79 (d, 1 H, $J_{3,4}$ 9.9, H-3), 6.14 (dd, 1 H, H-4), 7.2–8.1 (m, 20 H, 4 C_6H_5); ^{13}C NMR data ($CDCl_3$): δ 64.3 (C-1), 64.7 (C-6), 68.88 (C-5), 68.9 (C-3), 71.4 (C-4), 77.0 (C-2), 113.9 (CN), 127.6–133.8 (4 C_6H_5), 164.5, 165.18, 165.2 (4 CO). MS (FD, 12 mA): *m/z* 605 [M^+].

The fraction eluted next (R_f 0.51 in *C*), on evaporation to dryness and crystallization of the residue by trituration with 1:1 EtOH–MeOH, yielded 655 mg (36%) of *β*-L-*sorbo* isomer **10**; mp 174–176°C; $[\alpha]_D$ +64.2° (*c* 1.1, $CHCl_3$); ^{1}H NMR data ($CDCl_3$): δ 4.43 (dd, 1 H, $J_{5,6a}$ 0.2, $J_{6a,6b}$ 13.9 Hz, H-6a), 4.61 (dd, 1 H, $J_{5,6b}$ 1.7 Hz, H-6b), 4.69 (d, 1 H, $J_{1a,1}$ 11.2 Hz, H-1a), 4.88 (d, 1 H, H-1b), 5.21 (m, 1 H, H-5), 5.68 (d, 1 H, $J_{3,4}$ 2.0 Hz, H-3), 5.70 (dd, 1 H, $J_{4,5}$ 1.3 Hz, H-4), 7.2–8.2 (m, 20 H, 4 C_6H_5); ^{13}C NMR data ($CDCl_3$): δ 63.9, 64.2 (C-1,6), 65.4, 65.8, 66.5 (C-3,4,5), 72.9 (C-2), 115.7 (CN), 128.1–133.8 (4 C_6H_5), 164.1, 164.2, 165.0 (4 CO). Anal. Calcd for $C_{35}H_{27}NO_9$ (605.6): C, 69.42; H, 4.49; N, 2.31. Found: C, 69.32; H, 4.42; N, 2.38.

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