Carbohydrate Research, 190 (1989) 13–21
Elsevier Science Publishers B.V., Amsterdam – Printed in The Netherlands

A FACILE CONVERSION OF 3,4-*O*-ISOPROPYLIDENE-β-D-GALACTOPYRANOSIDES INTO 4-DEOXY-α-L-*threo*-HEX-4-ENOPYRANOSIDE AND L-*arabino*-HEXOS-5-ULOSE DERIVATIVES

PIER LUIGI BARILI, GIANCARLO BERTI*, GIORGIO CATELANI†, FABRIZIA COLONNA, AND FELICIA D'ANDREA

Istituto di Chimica Organica, Facoltá di Farmacia, Universitá di Pisa, Via Bonanno 33, 56126 Pisa (Italy)

(Received October 7th, 1988; accepted for publication, December 12th, 1988)

ABSTRACT

Treatment of *O*-protected 3,4-*O*-isopropylidene-β-D-galactopyranosides with *tert*-BuOK in *N,N*-dimethylformamide or methyl sulfoxide produces 4-deoxy-α-L-*threo*-hex-4-enopyranosides in good yields. The corresponding α-anomers and the non-*O*-protected derivatives are resistant to this treatment. Reaction of methyl 4-deoxy-2,6-di-*O*-methyl-α-L-*threo*-hex-4-enopyranoside with 3-chloroperbenzoic acid in CH_2Cl_2 gave a crystalline adduct that was hydrolyzed to 2,6-di-*O*-methyl-L-*arabino*-hexos-5-ulose.

INTRODUCTION

Several, not always satisfactory, methods of synthesis are known[1] for 4-deoxyhex-4-enopyranosides. Representatives of this group are present in the antibiotic sisamicin[2] and in the diterpene glycosides[3] virescenosides D, E, H, and L. 4,5-Unsaturated uronic acids are often produced by enzymic degradation of polysaccharides containing uronic acid residues[4]. 4-Deoxyhex-4-enopyranosides are versatile and reactive starting materials for the synthesis of modified carbohydrates and are chiral synthons. They yield 4-deoxyhexos-5-uloses on hydrolysis, 4-deoxyhexopyranosides on hydrogenation, and hexopyranosides on hydroboration–oxidation[1]. The 4,5-epoxides are hydrolyzed easily to hexos-5-uloses, intermediates for the biomimetic synthesis of inososes and inositols[5].

We now report on a serendipitous observation, made in the course of an investigation on alternative approaches to the synthesis of 2-*O*-glycosylgalactopyranosides, that provided an easy access to the title compounds.

*Author for correspondence.
†Present address: Dipartimento di Scienze Farmaceutiche, Universitá di Ferrara, Via Scandiana 21, 44100 Ferrara, Italy.

0008-6215/89/$ 03.50

RESULTS AND DISCUSSION

When benzyl 2-*O*-allyl-3,4-*O*-isopropylidene-6-*O*-(1-methoxy-1-methylethyl)-β-D-galactopyranoside (**1**), easily prepared from benzyl β-D-galactopyranoside[6], was treated with *tert*-BuOK in *N,N*-dimethylformamide, only a minor amount of the expected *cis*-propenyl derivative **2** was obtained, the main product (60% isolated yield) being benzyl 4-deoxy-6-*O*-(1-methoxy-1-methylethyl)-2-*O*-(*cis*-1-propenyl)-α-L-*threo*-hex-4-enopyranoside (**3**). The structure of **3** was proved by elemental analysis, the formation of the monoacetate **4**, and the ^{1}H-n.m.r. spectrum (see Table I).

When the simpler substrate methyl 3,4-*O*-isopropylidene-2,6-di-*O*-methyl-β-D-galactopyranoside (**5**) was heated for 1 h at 80° under argon with *tert*-BuOK in *N,N*-dimethylformamide, 80% of methyl 4-deoxy-2,6-di-*O*-methyl-α-L-*threo*-hex-4-enoyranoside (**6**) was obtained and converted into the 3-acetate **7**. Similar yields were obtained when methyl sulfoxide was used as the solvent.

Methyl 3,4-*O*-isopropylidene-β-D-galactopyranoside (**8**) and the 6-*O*-(1-methoxy-1-methylethyl) derivative **9** were inert to this treatment.

The ^{1}H-n.m.r. data for **4** and **7** (Table I) accorded with those for other 4-deoxy-α-*threo*-hex-4-enopyranosides[7] and confirmed a high preference for the all-axial conformation **10**, which reflects the anomeric and so-called allylic effects[8]. The 3-acetates **4** and **7** exhibit long-range W and allylic couplings. Thus, the signal for H-3 is simplified by selective irradiation of H-1,2,4,6.

Eliminations of cyclic acetal functions under strongly basic conditions in carbohydrates have been reviewed[9]. Butyl-lithium is the base used most frequently and several different types of cyclic and acyclic products have been obtained *via* the

TABLE I

^{1}H-N.M.R. DATA (C_6H_6)

Chemical shifts (δ)

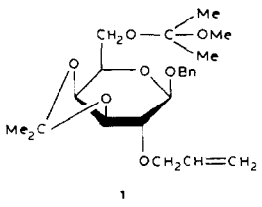
Compound	*H-1*	*H-2*	*H-3*	*H-4*	*H-6,6'*	*Ac*
4	5.01	4.03	5.54	5.22	3.86	1.65
7	4.74	3.55	5.49	5.14	3.67	1.69

Others: **4**, CMe_2 1.21, =CH*Me* 1.63, OMe 3.06, =C*H*Me 4.43, OCH_2Ph 4.43, 4.80, OCH= 6.18, Ph 7.05; **8**, OMe 3.07, 3.21, 3.32.

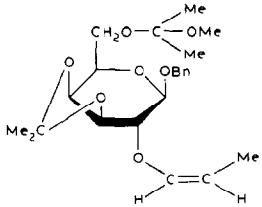
Coupling constants (Hz)

Compound	$J_{1,2}$	$J_{1,3}$	$J_{2,3}$	$J_{2,4}$	$J_{3,4}$	$J_{3,6}$	$J_{4,6}$
4	4.6	0.6	4.1	0.7	3.7	1.7	1.3
7	4.6	0.7	3.8	0.8	3.9	1.0	1.0

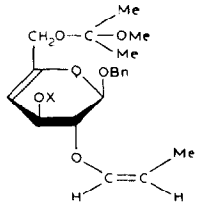
Others: **4**, OCH=CH 6.2, CH=CMe 1.7, CHMe 6.8, CH_2Ph 12.2.



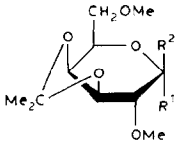
1



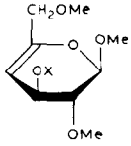
2



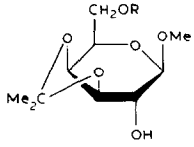
3 X = H
4 X = Ac



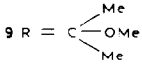
5 R^1 = H, R^2 = OMe
13 R^1 = OMe, R^2 = H



6 X = H
7 X = Ac

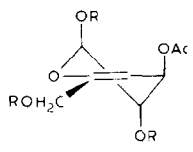


8 R = H

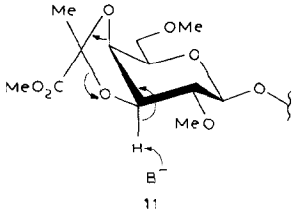


9 R =

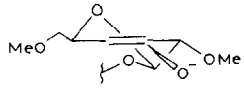
formation of carbanions at one of the dioxolane rings or adjacent carbons. Yields are often poor and secondary alkylations by butyl-lithium can occur. Low yields (7–30%) of allylic alcohols resembling **3** and **6** have been reported for the butyl-lithium treatment of isopropylidene derivatives of arabinopyranose and fructopyranose[10], but not for galactose derivatives. The selective degradation of terminal 3,4-*O*-(1-methoxycarbonylethylidene)galactopyranosyl units (**11**) of the methylated capsular polysaccharide of *Klebsiella* type 33, under the conditions of the Hakomori methylation, was reported[11] to give the enolate **12**, but experimental proof was not provided. Because of the similarity of **11** and **5**, this reaction is more likely to involve the formation of 4-deoxy-hex-4-enopyranoside units.



10



11



12

The facile base-catalyzed elimination of acetone from 3,4-*O*-isopropylidene derivatives of galactopyranosiduronic acid to give hex-4-enopyranosiduronic acids has been observed, but the β-elimination was facilitated by conjugation in the products[12].

The reactions reported here evidently involve an E-2 type elimination of acetone, initiated by attack of base at C-5 and are favored strongly by the approxi-

mately antiperiplanar disposition of the C-5–H and C-4–O bonds. The lack of reactivity of the acyclic acetal function in **1** confirms the importance of a favorable stereoelectronic disposition and of the release of ring strain for the conversion **1**→**3**. Surprisingly, the α-analogue **13** of **5** was recovered unchanged after treatment with *tert*-BuOK in *N,N*-dimethylformamide for 36 h at 80°. The stability of **13** towards butyl-lithium has also been observed[10]. The non-reactivity of **13** may reflect steric hindrance by the axial MeO-1 to the attack by base on the *syn*-axial H-5. Moreover, the observation that the 2-*O*-propenyl derivative **2** was not converted into **3** on protracted treatment with *tert*-BuOK in *N,N*-dimethylformamide provides further proof for the sensitivity of the formation of the 5-carbanion to changes in the molecular environment. Although the *cis*-propenyloxy group is bulkier than an allyloxy group, it is surprising that, when in an equatorial 2 position, it can hinder attack at axial H-5 by base.

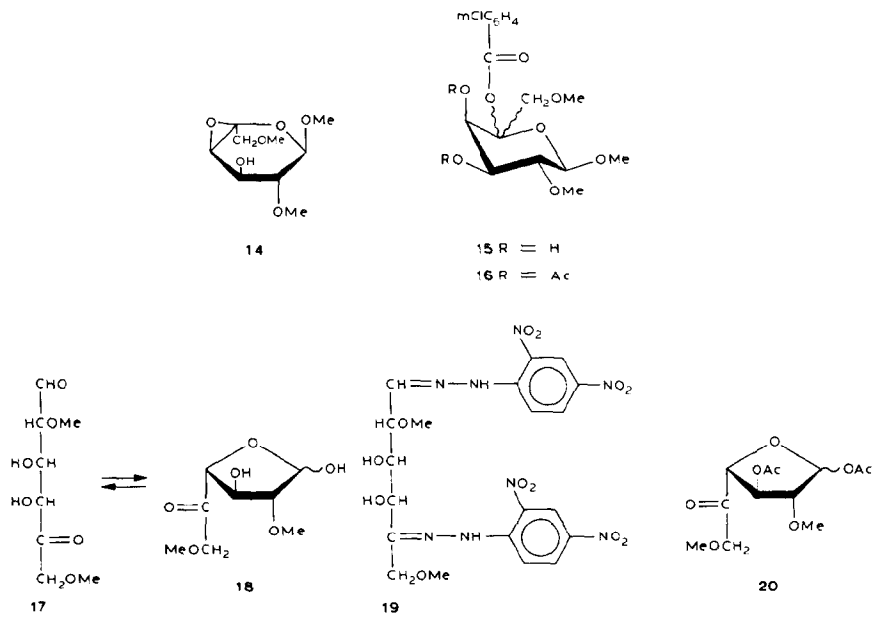
The non-reactivity of **8** and **9** is accounted for by the presence of unsubstituted hydroxyl groups, the oxy-anions of which decrease the acidity of the C–H groups.

The elimination reaction described in this paper provides an easy access to the 4-deoxyhex-4-enopyranosides.

Some preliminary experiments have been carried out on the epoxidation of **6**. Reaction with 3-chloroperbenzoic acid in CH_2Cl_2 gave a complex mixture from which 45% of crystalline **15** was isolated. The ^{1}H-n.m.r. spectra of **15** and its 3,4-diacetate **16** showed the configuration at C-4 to be *R* on the basis of the $J_{1,2}$, $J_{2,3}$, and $J_{3,4}$ values (7.8, 10.3, and 3.2 Hz for **16**), which indicate H-1,2,3 to be axial and H-4 to be equatorial. The formation of **15** accords with the well-known[13] *syn*-directing effect of an allylic hydroxy group, favoring the formation of the epoxide **14**, that undergoes regiospecific nucleophilic attack by 3-chlorobenzoic acid at the tertiary centre C-5 to give **15**. The configuration at C-5 in **15** has not yet been established, but it is not relevant if the compound is hydrolyzed to the corresponding hexos-5-ulose derivative. Hydrolysis of **15** with an acidic resin in acetonitrile–water gave an almost quantitative yield of 2,6-di-*O*-methyl-L-*arabino*-hexos-5-ulose (**17**). In deuterated pyridine, **17** exists as a 75:25 α,β-mixture of furanose forms **18**, as shown by the presence of a strong i.r. band at 1720 cm^{-1} (C=O) and by the n.m.r. spectra in $CDCl_3$ and C_5D_5N. Significant differences in coupling constants (see Experimental) point to different conformations of the furanose ring in these solvents.

Compound **18** was converted into the bis(2,4-dinitrophenylhydrazone) **19** and into the 1,3-diacetate **20** (90%). The 300-MHz ^{1}H-n.m.r. spectrum of **20** showed that it consisted of an 80:20 α,β-mixture.

Thus, an easy access to L-*arabino*-hexos-5-ulose derivatives is provided. Although ketohexoses of the D-*lyxo* series have been studied[14], much less is known of the corresponding *arabino* compounds, and the parent L-*arabino*-hexos-5-ulose has not been described hitherto. Although optimization of yields was not attempted, the overall yield in the conversion of **6**→**18** is ~40%. This reaction is being studied further.



EXPERIMENTAL

General methods. — Melting points were determined with a Kofler apparatus and are uncorrected. Optical rotations were measured at 20 ±2° on a Perkin–Elmer 241 polarimeter. ^{1}H-N.m.r. spectra (internal Me_4Si) were recorded with a Varian CFT-20 instrument and, for **20**, with a Varian VXR-300 instrument. All reactions were followed by t.l.c. on Kieselgel 60 F_{254} with detection by u.v. light or with ethanolic 10% phosphomolybdic acid and heating. Kieselgel 60 (Merck, 70–230 or 230–400 mesh) was used for column chromatography. Solvents were distilled and stored over 4 Å molecular sieves activated by heating for at least 24 h at 400°. All reactions were conducted under argon.

*Benzyl 2-O-allyl-3,4-O-isopropylidene-6-O-(1-methoxy-1-methylethyl)-β-*D*-galactopyranoside* (**1**). — A solution of benzyl 3,4-*O*-isopropylidene-6-*O*-(1-methoxy-1-methylethyl)-β-D-galactopyranoside[6] (2.18 g, 5.7 mmol) in dry *N,N*-dimethylformamide (90 mL) at 0° was treated with 80% NaH in mineral oil (1.5 g, 50 mmol) that had been washed with hexane. The suspension was stirred for 15 min at 0° and 30 min at room temperature, then cooled to 0°, and stirred with allyl bromide (1.5 mL, 18 mmol) for 15 min at 0° and then for 2 h at room temperature. Excess of NaH was decomposed by the addition of MeOH at 0°, the solution was concentrated under reduced pressure to ~1 mL, the residue was partitioned between ice–water (30 mL) and CH_2Cl_2 (100 mL), the water layer was extracted with CH_2Cl_2 (4 × 50 mL), and the combined organic layers were dried ($MgSO_4$) and concentrated to give **1** (2.3 g, 95%) as an oil, $[\alpha]_D$ −6.1° (*c* 1.05, chloroform),

R_F 0.67 (hexane–ethyl acetate, 3:1). ^{1}H-N.m.r. data (C_6D_6): δ 1.22 and 1.43 (2 s, 6 H, 2 dioxolane Me), 1.31 (s, 6 H, OC*Me*$_2$OMe), 3.19 (s, 3 H, OMe), 3.56–4.10 and 4.33–4.43 (2 m, 8 H, H-2–H-6 and OC*H*$_2$CH=CH$_2$), 4.31 (d, 1 H, $J_{1,2}$ 7.8 Hz, H-1), 4.61 and 4.92 (ABq, 2 H, *J* 12.1 Hz, OC*H*$_2$Ph), 5.06 and 5.18 (2 m, 2 H, OCH$_2$CH=C*H*$_2$), 6.01 (m, 1 H, OCH$_2$C*H*=CH$_2$), 7.23–7.40 (m, 5 H, Ph).

Anal. Calc. for $C_{23}H_{34}O_7$: C, 65.4; H, 8.1. Found: C, 65.0; H, 8.3.

*Methyl 3,4-O-isopropylidene-2,6-di-O-methyl-β-*D*-galactopyranoside* (**5**). — A solution of methyl 3,4-*O*-isopropylidene-β-D-galactopyranoside[15] (1.38 g, 5.9 mmol) in dry *N,N*-dimethylformamide was treated as described above, except that methyl iodide (3 mL, 48 mmol) was used as the alkylating agent to give **5** (95%), m.p. 54–56° (from hexane), $[\alpha]_D$ −5.8° (*c* 0.95, chloroform); lit.[16] m.p. 56–57°, $[\alpha]_D$ −4.46° (chloroform). ^{1}H-N.m.r. data (C_6D_6): δ 1.23 and 1.44 (2 s, 6 H, 2 dioxolane Me), 3.16, 3.36, and 3.55 (3 s, 9 H, 3 OMe), 3.36–3.96 (m, 6 H, H-2–H-6), 4.03 (d, 1 H, $J_{1,2}$ 7.8 Hz, H-1).

Anal. Calc. for $C_{12}H_{22}O_6$: C, 54.9; H, 8.4. Found: C, 55.1; H, 8.3.

Treatment of **1** *with* tert-*BuOK*. — A solution of **1** (148 mg, 0.35 mmol) and *tert*-BuOK (110 mg, 0.98 mmol) in dry *N,N*-dimethylformamide (3 mL) was stirred for 6 h at 80°. T.l.c. (hexane–ethyl acetate, 8:2) showed that **1** had disappeared and that there was a major (R_F 0.38) and a minor product (R_F 0.30). Prolonged heating did not change the relative intensities of the two spots. Water (30 mL) was added, the solution was extracted with CH_2Cl_2 (4 × 50 mL), and the combined extracts were washed with water, dried, and concentrated *in vacuo*. Column chromatography (70–230 mesh silica gel; hexane–ethyl acetate, 8:2) of the oily residue (110 mg) gave, first, benzyl 3,4-*O*-isopropylidene-6-*O*-(1-methoxy-1-methylethyl)-2-*O*-propenyl-β-D-galactopyranoside (**2**, 10 mg). ^{1}H-N.m.r. data (C_6D_6): δ 1.19 and 1.37 (2 s, 6 H, 2 dioxolane Me), 1.30 (s, 6 H, OC*Me*$_2$OMe), 1.77 (dd, 3 H, J_{vic} 6.8, J_{all} 1.7 Hz, OCH=CH*Me*), 3.17 (s, 3 H, OMe), 3.54–4.02 (m, 6 H, H-2–H-6), 4.28 (d, 1 H, $J_{1,2}$ 7.8 Hz, H-1), 4.42 (dq, 1 H, J_{cis} 6.2 Hz, OCH=C*H*Me), 4.60, 4.89 (ABq, 2 H, *J* 12.4 Hz, OC*H*$_2$Ph), 6.39 (dq, 1 H, OC*H*=CHMe), 7.16–7.40 (m, 5 H, Ph).

Further elution gave benzyl 4-deoxy-6-*O*-(1-methoxy-1-methylethyl)-2-*O*-propenyl-α-L-*threo*-hex-4-enopyranoside (**3**), isolated as a colorless oil (77 mg, 60%) that was treated with Ac_2O (1 mL) and pyridine (2 mL) for 3 h at room temperature. Co-evaporation of the solvent with toluene (3 × 30 mL) gave a quantitative yield of the 3-acetate **4**, as an oil, $[\alpha]_D$ −25° (*c* 0.68, chloroform), R_F 0.38 (hexane–ethyl acetate, 8:2). See Table I for the ^{1}H-n.m.r. data.

Anal. Calc. for $C_{22}H_{30}O_7$: C, 65.0; H, 7.4. Found: C, 65.3; H, 7.1.

*Methyl 4-deoxy-2,6-di-*O*-methyl-α-*L*-*threo*-hex-4-enopyranoside* (**6**). — The reaction of **5** (221 mg, 0.84 mmol) with *tert*-BuOK (416 mg, 3.7 mmol) in dry *N,N*-dimethylformamide (20 mL) was complete after 1 h at 80°. Work-up, as described above, gave **6** (139 mg, 81%) as an oil which gave a single spot in t.l.c. (R_F 0.56; hexane–ethyl acetate, 4:6) and had $[\alpha]_D$ −63° (*c* 1.05, chloroform). ^{1}H-N.m.r. data (C_6D_6): δ 2.68 (d, 1 H, $J_{3,OH}$ 10.9 Hz, OH), 3.05, 3.08, and 3.09 (3 s, 9 H, 3 OMe), 3.47 (ddd, 1 H, $J_{1,2}$ 2.8, $J_{2,3}$ 2.4, $J_{2,4}$ 1.3 Hz, H-2), 3.60 (m, 1 H, $J_{6,6'}$ 12.8, $J_{3,6}$ 1.0,

$J_{4,6}$ 0.4 Hz, H-6), 3.78 (m, 1 H, $J_{3,6'}$ 0.6, $J_{4,6'}$ 0.4 Hz, H-6'), 4.07 (m, 1 H, $J_{3,4}$ 4.0, $J_{1,3}$ 1.2 Hz, H-3), 4.85 (dd, 1 H, H-1), 5.21 (m, 1 H, H-4). These values were obtained by D_2O exchange, double-resonance experiments and computer simulation.

Anal. Calc. for $C_9H_{16}O_5$: C, 52.9; H, 7.9. Found: C, 52.7; H, 7.9.

When the reaction was conducted in methyl sulfoxide, 80% of **6** was obtained.

Compound **6** was converted into the 3-acetate **7**, R_F 0.76 (hexane–ethyl acetate, 4:6), $[\alpha]_D$ +17.5° (*c* 0.98, chloroform). See Table I for the ^{1}H-n.m.r. data.

Anal. Calc. for $C_{11}H_{18}O_6$: C, 53.7; H, 7.4. Found: C, 53.7; H, 7.5.

When methyl 3,4-*O*-isopropylidene-2,6-di-*O*-methyl-α-D-galactopyranoside[17] (**13**) was treated with *tert*-BuOK in *N,N*-dimethylformamide under the above conditions, t.l.c. revealed only the slow formation of traces of side-products, and **13** could be recovered after 36 h at 80°.

Similar treatment of methyl 3,4-*O*-isopropylidene-β-D-galactopyranoside[15] (**8**) and methyl 3,4-*O*-isopropylidene-6-*O*-(1-methoxy-1-methylethyl)-β-D-galactopyranoside[6] (**9**) led to the recovery of unchanged starting materials.

Methyl 5-C-(3-chlorobenzoyloxy)-2,6-di-O-methyl-β-D-galacto(or -α-L-altro)-pyranoside (**15**). — A solution of **6** (125 mg, 0.61 mmol) in CH_2Cl_2 (4.5 mL) at 0° was treated with 73% 3-chloroperbenzoic acid (160 mg, 0.67 mmol) and stored for 60 h at 4°. The mixture was filtered, NEt_3 (0.3 mL) was added, and the solution was concentrated to dryness *in vacuo*. Column chromatography [70–230 mesh silica gel (50 g); 1:9 hexane–ethyl acetate] of the oily residue gave **15** (103 mg, 45%), m.p. 91–93°, $[\alpha]_D$ −33° (*c* 1.1, chloroform), R_F 0.54. ^{1}H-N.m.r. data (C_6D_6): δ 3.03, 3.38, and 3.44 (3 s, 9 H, 3 OMe), 3.52 (dd, 1 H, $J_{1,2}$ 7.8, $J_{2,3}$ 9.4 Hz, H-2), 4.05 (dd, 1 H, $J_{3,4}$ 3.2 Hz, H-3), 4.17 and 4.52 (ABq, 2 H, *J* 10.3 Hz, H-6,6'), 4.42 (d, 1 H, H-4), 4.62 (d, 1 H, H-1), 6.68 (dd, 1 H, $J_{4,5}$ 7.8, $J_{5,6}$ 8.0 Hz, H-5 Ar), 7.16 (ddd, 1 H, $J_{2,6}$ 2.1, $J_{4,6}$ 1.2 Hz, H-6 Ar), 7.90 (ddd, 1 H, $J_{2,4}$ 1.5 Hz, H-4 Ar), 8.11 (dd, 1 H, H-2 Ar).

Anal. Calc. for $C_{16}H_{21}ClO_8$: C, 51.0; H, 5.6. Found: C, 51.1; H, 5.6.

Conventional treatment of **15** with Ac_2O in pyridine gave the 3,4-diacetate **16**, m.p. 107–109°, $[\alpha]_D$ −93° (*c* 0.86, chloroform), R_F 0.66 (hexane–ethyl acetate, 7:3). ^{1}H-N.m.r. data (C_6D_6): δ 1.69 and 1.80 (2 s, 6 H, 2 AcO), 2.90, 3.39, and 3.47 (3 s, 9 H, 3 OMe), 3.73 and 4.60 (ABq, 2 H, *J* 10.7 Hz, H-6,6'), 3.79 (dd, 1 H, $J_{1,2}$ 7.8, $J_{2,3}$ 10.3 Hz, H-2), 4.77 (d, 1 H, H-1), 5.83 (dd, 1 H, $J_{3,4}$ 3.2 Hz, H-3), 6.16 (d, 1 H, H-4), 6.63 (dd, 1 H, $J_{4,5}$ 7.8, $J_{5,6}$ 8.0 Hz, H-5 Ar), 7.00 (ddd, 1 H, $J_{2,6}$ 2.1, $J_{4,6}$ 1.2 Hz, H-6 Ar), 7.91 (ddd, 1 H, $J_{2,4}$ 1.5 Hz, H-4 Ar), 8.23 (dd, 1 H, H-2 Ar).

Anal. Calc. for $C_{20}H_{25}ClO_{10}$: C, 52.1; H, 5.5. Found: C, 52.0; H, 5.4.

2,6-Di-O-methyl-L-arabino-hexofuranos-5-ulose (**18**). — A solution of **15** (105 mg) in MeCN (5 mL) and water (2.5 mL) was stirred at room temperature with Amberlyst 15 (H^+) resin (2 g) that had been washed with MeCN. After 15 h, t.l.c. (hexane–ethyl acetate, 2:8) revealed that **15** had disappeared. After filtration, the solvent was evaporated *in vacuo*, a solution of the residue in water (2 mL) was

filtered and concentrated *in vacuo*, and the residue was freed from traces of tar by repeated extraction with benzene at room temperature. Evaporation of the solvent gave **18** (56 mg, 97%), R_F 0.31 (hexane–ethyl acetate, 2:8), $[\alpha]_D$ −6.8° (*c* 1.2, chloroform). ^{1}H-N.m.r. data ($CDCl_3$): α anomer, δ 3.33 and 3.39 (2 s, 6 H, 2 OMe), 3.73 (dd, 1 H, $J_{1,2}$ 0.6, $J_{2,3}$ 1.2 Hz, H-2), 4.38 (s, 2 H, H-6,6′), 4.46 (dd, 1 H, $J_{3,4}$ 1.4 Hz, H-3), 4.69 (d, 1 H, H-4), 5.43 (d, 1 H, H-1); β anomer, δ 3.43 and 3.47 (2 s, 6 H, 2 OMe), 5.51 (d, 1 H, $J_{1,2}$ 3.3 Hz, H-1); (C_5D_5N): α anomer, δ 3.37 and 3.40 (2 s, 6 H, 2 OMe), 4.23 (dd, 1 H, $J_{1,2}$ 1.2, $J_{2,3}$ 2.5 Hz, H-2), 4.68 (s, 2 H, H-6,6′), 4.87 (m, 1 H, $J_{3,4}$ 4.5 Hz, H-3), 5.19 (d, 1 H, H-4), 5.98 (m, 1 H, H-1) [double-resonance experiments were used for a complete analysis of the spectrum, and there was a long-range coupling (0.5 Hz) between H-1 and H-3]; β anomer, δ 3.33 and 3.50 (2 s, 6 H, 2 OMe), 3.57 (dd, 1 H, $J_{1,2}$ 3.5, $J_{2,3}$ 4.5 Hz, H-2), 6.05 (d, 1 H, H-1).

*2,6-Di-O-methyl-*L-arabino-*hexo-5-ulose bis(2,4-dinitrophenylhydrazone)* (**19**). — Compound **18** (30 mg, 0.15 mmol) and 2,4-dinitrophenylhydrazine (64 mg, 0.32 mmol) were dissolved in 2M HCl (8.5 mL). The orange precipitate (35 mg), collected after 1 h, had m.p. 88–91°.

Anal. Calc. for $C_{20}H_{22}N_8O_{12}$: C, 42.4; H, 3.9; N, 19.8. Found: C, 42.3; H, 3.8; N, 19.1.

*1,3-Di-O-acetyl-2,6-di-O-methy-α- and -β-*L-arabino-*hexofuranos-5-ulose* (**20**). — Crude **18** (78 mg) was treated with Ac_2O (2 mL) and pyridine (4 mL) for 12 h at room temperature. The mixture was concentrated to dryness *in vacuo* after the addition of toluene (3 × 10 mL), to give an oily residue (100 mg, 91%), $[\alpha]_D$ −40° (*c* 1.8, chloroform), R_F 0.39 (hexane–ethyl acetate, 1:1), the ^{1}H-n.m.r. spectrum of which contained signals for α- and β-**20**. ^{1}H-N.m.r. data (300 MHz, C_6D_6): α anomer, δ 1.57 and 1.58 (2 s, 6 H, 2 AcO), 3.01 and 3.11 (2 s, 6 H, 2 OMe), 3.66 (dd, 1 H, $J_{1,2}$ <0.3, $J_{2,3}$ 0.7 Hz, H-2), 4.17 and 4.26 (ABq, 2 H, *J* 10.8 Hz, H-6,6′), 4.64 (d, 1 H, $J_{3,4}$ 2.1 Hz, H-4), 5.54 (m, 1 H, H-3), 6.39 (m, 1 H, H-1) [double-resonance experiments were used for a complete analysis of the spectrum, and there was a long-range coupling (0.5 Hz) between H-1 and H-3]; β anomer, δ 1.53 and 1.67 (2 s, 6 H, 2 AcO), 2.99 and 3.11 (2 s, 6 H, 2 OMe), 3.61 (dd, 1 H, $J_{1,2}$ 4.0, $J_{2,3}$ 5.5 Hz, H-2), 4.04 and 4.32 (ABq, 2 H, *J* 10.3 Hz, H-6,6′), 4.35 (d, 1 H, $J_{3,4}$ 4.3 Hz, H-4), 5.78 (dd, 1 H, H-3), 6.36 (d, 1 H, H-1).

ACKNOWLEDGMENTS

This work was supported by grants from Consiglio Nazionale delle Ricerche and Ministero della Pubblica Istruzione. We thank Dr. G. Uccello Barretta for recording of 300-MHz spectra.

REFERENCES

1 R. J. FERRIER, *Adv. Carbohydr. Chem. Biochem.*, 24 (1969) 252–255; R. J. FERRIER, in W. PIGMAN AND D. HORTON (Eds.), *The Carbohydrates, Chemistry and Biochemistry*, Vol. 1B, Academic Press, New York, 1980, pp. 856–874.

2 D. J. COOPER, R. S. JARET, AND H. REIMANN, *J. Chem. Soc., Chem. Commun.*, (1971) 285–286.
3 N. CAGNOLI-BELLAVITA, P. CECCHERELLI, M. RIBOLDI, J. POLONSKY, Z. BASKEVITCH-VARON, AND J. VARENNE, *J. Chem. Soc., Perkin Trans. 1*, (1977) 351–354; P. CECCHERELLI, N. CAGNOLI-BELLAVITA, J. POLONSKY, Z. BASKEVITCH, AND M. RIBOLDI, *Gazz. Chim. Ital.*, 107 (1977) 51–53.
4 O. THEANDER, in W. PIGMAN AND D. HORTON (Eds.), *The Carbohydrates, Chemistry and Biochemistry*, Vol. 1B, Academic Press, New York, 1980, p. 1030.
5 D. E. KIELY AND H. G. FLETCHER, JR., *J. Org. Chem.*, 34 (1969) 1386–1390.
6 P. L. BARILI, G. BERTI, G. CATELANI, F. COLONNA, AND A. MARRA, *Tetrahedron Lett.*, 27 (1986) 2307–2310.
7 J. ALFÖLDI, R. PALOVČIK, C. PECIAR, J. HIRSCH, AND P. KOVÁČ, *Carbohydr. Res.*, 44 (1975) 133–137; R. BLATTNER, R. J. FERRIER, AND P. C. TYLER, *J. Chem. Soc., Perkin Trans. 1*, (1980) 1535–1539; R. BLATTNER AND R. J. FERRIER, *ibid.*, (1980) 1523–1527; A. HASEGAWA, E. TONAHASHI, Y. GOH, AND M. KISO, *Carbohydr. Res.*, 103 (1982) 273–280.
8 R. J. FERRIER AND G. H. SANKEY, *J. Chem. Soc., C*, (1966) 2345–2349.
9 J. GELAS, *Adv. Carbohydr. Chem. Biochem.*, 39 (1981) 71–156.
10 A. KLEMER, G. RODEMAYER, AND F. J. LINNENBAUM, *Chem. Ber.*, 109 (1976) 2849–2861.
11 B. LINDBERG, F. LINDH, J. LÖNNGREN, AND W. NIMMICH, *Carbohydr. Res.*, 70 (1979) 135–144.
12 P. KOVÁČ, J. HIRSCH, AND V. KOVÁČIK, *Carbohydr. Res.*, 32 (1974) 360–365.
13 G. BERTI, *Top. Stereochem.*, 7 (1972) 130–152.
14 Ref. 4, pp. 1063–1068.
15 G. CATELANI, F. COLONNA, AND A. MARRA, *Carbohydr. Res.*, 182 (1988) 299–302.
16 J. W. H. OLDHAM AND D. J. BELL, *J. Am. Chem. Soc.*, 60 (1938) 323–325.
17 H. H. BAER AND S. A. ABBAS, *Carbohydr. Res.*, 77 (1979) 117–129.