Carbohydrate Research, 65 (1978) 209–217

SYNTHESIS OF MONO- AND DI-BENZYL ETHERS OF BENZYL α-L-RHAMNOPYRANOSIDE

ANDRÁS LIPTÁK, PÉTER FÜGEDI, AND PÁL NÁNÁSI
Institute of Biochemistry, L. Kossuth University, H-4010, Debrecen (Hungary)
(Received September 29th, 1977; accepted for publication, October 14th, 1977)

ABSTRACT

Benzylidenation of benzyl α-L-rhamnopyranoside (**1**) gave the *exo*- (**2**) and *endo*-2,3-*O*-benzylidene diastereomers (**3**), hydrogenolysis of which afforded the 3-benzyl and 2-benzyl ethers of **1**, respectively. Hydrogenolysis of the 4-*O*-benzyl derivatives (**14** and **15**) of **2** and **3** yielded the 3,4-di-benzyl and 2,4-dibenzyl ethers of **1**, whereas hydrolysis of **14** and **15** gave the 4-benzyl ether of **1**. The 2,3-dibenzyl ether of **1** was synthesised *via* the 4-*O*-allyl derivative of **1**.

INTRODUCTION

L-Rhamnose is widespread in Nature, being a component of some plant glycosides and bacterial polysaccharides of immunological importance[1]. In recent years, syntheses have been accomplished of several oligosaccharides that contain L-rhamnose and were obtained from natural products by hydrolysis[2–11]. The synthesis of disaccharides that contain L-rhamnose as the aglycon requires L-rhamnose derivatives having a free hydroxyl group at the desired position. Only derivatives having HO-4 unsubstituted are known and have been obtained from suitable 2,3-*O*-isopropylidene-α-L-rhamnopyranosides[3–7]. Recently, the 2,3-*O*-benzylidene derivative was used in disaccharide synthesis[11]. Mainly 4-*O*-glycosyl-L-rhamnoses have been obtained by using the above derivatives.

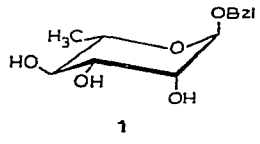
The few 2-*O*- and 3-*O*-glycosyl-L-rhamnose disaccharides that have been synthesised were prepared[8,9] by methods that gave a mixture of products which required fractionation and proof of the structures of the components. Because of the lack of partially protected L-rhamnose derivatives, multistep routes had to be worked out for the syntheses of certain natural products[12].

In the synthesis of complex oligosaccharides, partially benzylated benzyl glycosides are preferred, because of the stability of the benzyl groups in glycosidation reactions and because they can be removed easily[13].

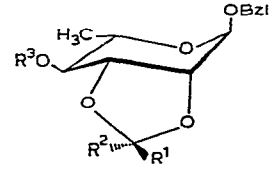
Our investigations[14–16] on the reductive opening of dioxolane-type benzylidene acetals by the $LiAlH_4$–$AlCl_3$ reagent have revealed a high degree of regioselectivity which depends on the configuration of the acetal carbon. We now report on the utilisation of this reaction in the syntheses of the title compounds.

RESULTS AND DISCUSSION

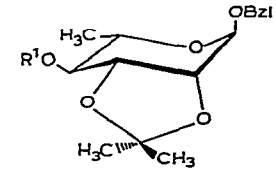
Treatment of benzyl α-L-rhamnopyranoside[17] (**1**) with benzaldehyde in the presence of zinc chloride gave a ~1:1 mixture of benzyl *exo*- (**2**) and *endo*-2,3-*O*-benzylidene-α-L-rhamnopyranoside (**3**). The configuration of the benzylidene acetal carbon in these compounds can be determined by n.m.r. spectroscopy[18,19]. The *CH*-Ph signal for the *exo*-phenyl isomer (δ 6.13) occurs at lower field than the corresponding signal (δ 5.86) for the *endo*-phenyl isomer. The *exo* isomer **2** was isolated from the mixture of isomers by crystallisation.



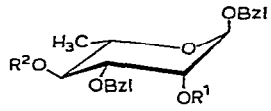
1



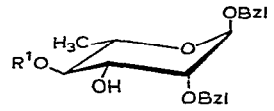
2 R^1 = Ph, R^2 = H, R^3 = H
3 R^1 = H, R^2 = Ph, R^3 = H
4 R^1 = Ph, R^2 = H, R^3 = Ac
5 R^1 = H, R^2 = Ph, R^3 = Ac
9 R^1 = Ph, R^2 = H, R^3 = Allyl
14 R^1 = Ph, R^2 = H, R^3 = Bzl
15 R^1 = H, R^2 = Ph R^3 = Bzl



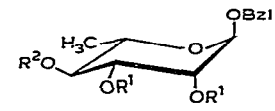
11 R^1 = H
12 R^1 = Bzl
19 R^1 = Allyl



6 R^1 = H, R^2 = H
7 R^1 = Ac, R^2 = Ac
10 R^1 = H, R^2 = Allyl
16 R^1 = H, R^2 = Bzl



8 R^1 = H
17 R^1 = Bzl



13 R^1 = H, R^2 = Bzl
18 R^1 = Bzl, R^2 = H
20 R^1 = H, R^2 = Allyl
21 R^1 = Bzl, R^2 = Allyl

Acetylation of the mixture of **2** and **3** gave a mixture of the 4-*O*-acetyl derivatives, from which benzyl 4-*O*-acetyl-*exo*-2,3-*O*-benzylidene-α-L-rhamnopyranoside (**4**, $\delta_{CH\text{-}Ph}$ 6.19) was isolated by crystallisation. Column chromatography of the mother liquor gave benzyl 4-*O*-acetyl-*endo*-2,3-*O*-benzylidene-α-L-rhamnopyranoside (**5**, $\delta_{CH\text{-}Ph}$ 5.85). Deacetylation[20] of **5** then gave **3**.

Treatment of **2** with the $LiAlH_4$–$AlCl_3$ (1:1) reagent in ether–dichloromethane at 45° was complete within 10 min. The syrupy product was resistant to periodate and hence was benzyl 3-*O*-benzyl-α-L-rhamnopyranoside (**6**), which was characterised as the crystalline diacetate (**7**). Only traces of benzyl 2-*O*-benzyl-α-L-rhamnopyranoside (**8**) were formed; the ratio of **6** to **8** after acetylation was 98:2 (g.l.c.). A similar selectivity, but reverse product distribution, was found on hydrogenolysis of the *endo* isomer (**3**), the major product being **8** (98%), which was oxidised by periodate.

Allylation of **2** gave benzyl 4-*O*-allyl-*exo*-2,3-*O*-benzylidene-α-L-rhamnopyranoside (**9**, $\delta_{CH\text{-}Ph}$ 6.00) which, with $LiAlH_4$–$AlCl_3$, gave two products in the ratio

~85:15 (t.l.c.); the major product was benzyl 4-*O*-allyl-3-*O*-benzyl-α-L-rhamnopyranoside (**10**). Isomerisation of the allyl group of **10** by potassium *tert*-butoxide, followed by hydrolysis[21], gave **6**.

The third mono-*O*-benzyl derivative of **1**, benzyl 4-*O*-benzyl-α-L-rhamnopyranoside[23] (**13**), was prepared by benzylating benzyl 2,3-*O*-isopropylidene-α-L-rhamnopyranoside[22] (**11**) followed by mild, acid hydrolysis of the 4-*O*-benzyl derivative[23] (**12**).

Benzylation of **2** and **3** gave crystalline benzyl 4-*O*-benzyl-*exo*- (**14**, $\delta_{CH\text{-}Ph}$ 6.04) and -*endo*-2,3-*O*-benzylidene-α-L-rhamnopyranoside (**15**, $\delta_{CH\text{-}Ph}$ 5.87). When a mixture of **2** and **3** was benzylated, **14** could be isolated by crystallization, but **15** could be isolated only by chromatography.

Benzylidenation of **13** also gave an ~1:1 mixture of **14** and **15** (n.m.r. and g.l.c.), the ratio of the *exo* to the *endo* isomer therefore being not significantly influenced by the substituent at position 4. Removal of the benzylidene group from **14** and **15** by acid hydrolysis gave **13**.

Hydrogenolysis of **14** gave benzyl 3,4-di-*O*-benzyl-α-L-rhamnopyranoside (**16**) and benzyl 2,4-di-*O*-benzyl-α-L-rhamnopyranoside (**17**) in the ratio 94:6 (g.l.c.); **16** and **17** were separated by chromatography. Acid hydrolysis of **16** gave a product that was oxidised by periodate, whereas the corresponding product from **17** was resistant. These data prove the structures of **16** and **17**, which were also formed by hydrogenolysis of **15** but in the ratio 18.5:81.5 (g.l.c.).

The third di-*O*-benzyl derivative of **1**, benzyl 2,3-di-*O*-benzyl-α-L-rhamnopyranoside (**18**), was synthesised by the following sequence: **11** → benzyl 4-*O*-allyl-2,3-*O*-isopropylidene-α-L-rhamnopyranoside (**19**) → benzyl 4-*O*-allyl-α-L-rhamnopyranoside (**20**) → benzyl 4-*O*-allyl-2,3-di-*O*-benzyl-α-L-rhamnopyranoside (**21**) → **18**; the allyl group was removed from **21** by the usual method[21].

The ratio of products obtained on hydrogenolysis of **2**, **3**, **9**, **14**, **15**, and other compounds[15,16] establishes that the direction of the reductive opening of the dioxolane ring is determined by the configuration of the acetal carbon. In the *exo* isomers, the site of attack of the AlH_2Cl reagent[24], leading to an oxocarbonium ion[25], is the oxygen of the dioxolane ring which is axial in relation to the pyranoid ring, yielding a product having *equatorial* benzyl/*axial* hydroxyl groups. In the *endo* isomers, the reagent attacks the *equatorial* oxygen, giving products containing *axial* benzyl/*equatorial* hydroxyl groups. Similar observations have been made by Sinaÿ *et al.*[26].

Reduction of benzylidene acetals with the $LiAlH_4$–$AlCl_3$ reagent makes possible the regioselective synthesis of benzyl ethers. As the hydrogenolysis can be accomplished in the presence of allyl[16] and glycosyl[27] groups, this procedure can be utilized in the syntheses of branched oligosaccharides.

EXPERIMENTAL

Melting points (uncorrected) were determined with a Kofler apparatus. Kieselgel G was used for column chromatography and t.l.c., with the solvent systems

given in parentheses. Detection in t.l.c. was effected by charring with sulphuric acid. G.l.c. was performed with a Hewlett–Packard 5830 A instrument with helical stainless-steel columns (0.4 mm i.d.) packed with (*a*) 10% UCW-982 (Chromosorb WAW-DMCS, 80–100 mesh), 2 ft; (*b*) 10% OV-1 (Chromosorb WAW, 80–100 mesh), 6 ft; and (*c*) 10% UCW-982 (Chromosorb WAW/DMCS, 80–100 mesh), 2 ft. The temperature programmes were 220° at 2.5°/min for column (*a*), 225° at 0.5°/min for column (*b*), and 250° at 2.5°/min for column (*c*). The carrier gas was nitrogen at 20 ml/min. $[\alpha]_D$ values were measured on solutions in chloroform with a Bendix automatic polarimeter. ^{1}H-N.m.r. spectra were recorded with a Jeol MH-100 spectrometer for solutions in $CDCl_3$ (internal Me_4Si).

Benzylidenation of benzyl α-L-rhamnopyranoside (**1**). — A mixture of **1**[17] (5.08 g), freshly fused $ZnCl_2$ (5 g), and benzaldehyde (25 ml) was shaken overnight and then diluted with chloroform, washed with water, and steam-distilled in the presence of a small amount of $NaHCO_3$. The residue was extracted with chloroform, and the extract was washed with water, dried (Na_2SO_4), and concentrated. N.m.r. spectroscopy and g.l.c. of the solid product (4.2 g, 61.5%) indicated a 1:1 mixture of **2** and **3**. Successive recrystallisations from ethanol and chloroform–light petroleum (b.p. 60–80°) gave benzyl *exo*-2,3-*O*-benzylidene-α-L-rhamnopyranoside (**2**; 1.7 g, 25%), m.p. 132–133°, $[\alpha]_D$ −67° (*c* 0.42, chloroform), R_F 0.58 (benzene–methanol, 9:1), *T* 4.81 min [column (*a*)]. N.m.r. data: δ 7.30–7.10 (m, 10 H, aromatic), 6.13 (s, 1 H, PhC*H*), 5.10 (s, 1 H, H-1), 4.60 (q, 2 H, PhCH_2), 4.50–3.40 (m, 4 H, H-2,3,4,5), 2.75 (d, 1 H, HO-4), and 1.28 (d, 3 H, Me).

Anal. Calc. for $C_{20}H_{22}O_5$: C, 70.16; H, 6.48. Found: C, 69.62; H, 6.59.

The 4-*p*-nitrobenzoate of **2** had m.p. 113–114°, $[\alpha]_D$ −9° (*c* 0.39, chloroform), R_F 0.78 (benzene–methanol, 98:2).

Anal. Calc. for $C_{27}H_{25}NO_8$: C, 65.98; H, 5.13. Found: C, 65.73; H, 5.20.

Benzyl 4-O-acetyl-exo- (**4**) *and* -endo-*2,3-O-benzylidene-α-L-rhamnopyranoside* (**5**). — The crude product (2.5 g) of the foregoing benzylidenation was treated conventionally with pyridine (10 ml) and acetic anhydride (10 ml) overnight. The product (2.40 g, 86%) was recrystallised from ethanol and then from cyclohexane to give **4** (0.82 g, 29%), m.p. 103–104°, $[\alpha]_D$ −55° (*c* 0.55, chloroform), R_F 0.75 (benzene–methanol, 96:4) and 0.40 (light petroleum–ethyl acetate, 4:1), *T* 7.83 min [column (*a*)]. N.m.r. data: δ 7.50–7.20 (m, 10 H, aromatic), 6.19 (s, 1 H, PhC*H*), 5.14 (s, 1 H, H-1), 5.10–3.70 (m, 6 H, H-2,3,4,5 and PhCH_2), 2.09 (s, 3 H, OAc), and 1.22 (d, 3 H, Me).

Anal. Calc. for $C_{22}H_{24}O_6$: C, 68.74; H, 6.29. Found: C, 68.59; H, 6.23.

The mother liquors of the above crystallisations were concentrated, and the residue was eluted from a column of Kieselgel G (80 g) with light petroleum–ethyl acetate (4:1) to give **4** (0.2 g; total yield 1.02 g, 36%), a mixture (0.34 g) of **4** and **5**, and, finally, syrupy **5** (0.75 g, 27%), $[\alpha]_D$ −11° (*c* 0.71, chloroform), R_F 0.35 (light petroleum–ethyl acetate, 4:1), *T* 7.38 min [column (*a*)]. N.m.r. data: δ 7.60–7.20 (m, 10 H, aromatic), 5.85 (s, 1 H, PhC*H*), 5.17 (s, 1 H, H-1), 5.05–3.70 (m, 6 H, H-2,3,4,5 and PhCH_2), 2.03 (s, 3 H, OAc), and 1.16 (d, 3 H, Me).

Anal. Found: C, 68.46; H, 6.25.

Benzyl endo-*2,3*-O-*benzylidene*-α-L-*rhamnopyranoside* (**3**). — Zemplén deacetylation[20] of **5** (0.75 g), followed by neutralisation with Dowex 50 (H^+) resin and concentration, gave syrupy **3** (0.65 g, 97%), $[\alpha]_D$ −68° (*c* 1.18, chloroform), R_F 0.58 (benzene–methanol, 9:1), *T* 4.38 min [column (*a*)]. N.m.r. data: δ 7.50–7.20 (m, 10 H, aromatic), 5.86 (s, 1 H, PhC*H*), 5.15 (s, 1 H, H-1), 4.62 (q, 2 H, PhCH_2), 4.30–3.20 (m, 4 H, H-2,3,4,5), 2.80 (d, 1 H, HO-4), and 1.23 (d, 3 H, Me).

Anal. Calc. for $C_{20}H_{22}O_5$: C, 70.16; H, 6.48. Found: C, 69.75; H, 6.51.

Benzyl 3-O-*benzyl*-α-L-*rhamnopyranoside* (**6**). — To a solution of **2** (0.85 g) in ether (20 ml) and dichloromethane (30 ml) was added $LiAlH_4$ (0.12 g). The mixture was boiled and stirred, and a solution of $AlCl_3$ (0.5 g) in ether (10 ml) was added during 2 min. Boiling was continued until the starting material disappeared (10 min). The mixture was cooled, excess of reagent was decomposed with ethyl acetate, and then $Al(OH_3)$ was precipitated with water. The ether–dichloromethane layer was decanted and the precipitate was extracted with ether (2 × 25 ml). The combined organic layers were washed with water (3 × 25 ml), dried (Na_2SO_4), and concentrated. Conventional treatment of a portion (10 mg) of the syrupy residue with pyridine (1 ml) and acetic anhydride (1 ml), with g.l.c. of the resulting acetates on column (*b*), revealed a 98:2 mixture of two components having *T* 24.39 and 26.31 min, respectively.

Column chromatography of the syrup (benzene–acetone, 8:2) gave syrupy **6** (0.70 g, 82%), $[\alpha]_D$ −48° (*c* 0.51, chloroform), R_F 0.35 (benzene–acetone, 8:2), *T* 24.39 min [column (*b*)]. N.m.r. data: δ 7.50–7.20 (m, 10 H, aromatic), 4.89 (s, 1 H, H-1), 4.76–4.32 (m, 4 H, 2 PhCH_2), 4.00–3.50 (m, 4 H, H-2,3,4,5), 3.20 (broad, 2 H, 2 OH), and 1.30 (d, 3 H, Me).

Anal. Calc. for $C_{20}H_{24}O_5$: C, 69.75; H, 7.02. Found: C, 69.69; H, 7.08.

Compound **6** was resistant to periodate, and gave a diacetate (**7**), m.p. 93–94° (from cyclohexane), $[\alpha]_D$ −11° (*c* 0.92, chloroform), R_F 0.70 (benzene–methanol, 96:4).

Anal. Calc. for $C_{24}H_{28}O_7$: C, 67.27; H, 6.59. Found: C, 67.13; H, 6.51.

Benzyl 2-O-*benzyl*-α-L-*rhamnopyranoside* (**8**). — Hydrogenolysis of **3** (0.85 g), as described for **2**, with g.l.c. of the acetylated product, revealed two components in the ratio 98:2, having *T* 26.31 and 24.39 min, respectively. Recrystallisation of the crude product from ethyl acetate–light petroleum gave **8** (0.55 g, 64%), which could be oxidised by periodate and had m.p. 73–74°, $[\alpha]_D$ −39° (*c* 0.88, chloroform), R_F 0.26 (benzene–acetone, 8:2), *T* 26.31 [column (*b*)]. N.m.r. data: δ 7.50–7.20 (m, 10 H, aromatic), 4.95–3.30 (m, 9 H, H-1,2,3,4,5 and 2 PhCH_2), 2.95 (broad, 1 H, OH), 2.64 (broad, 1 H, OH), and 1.30 (d, 3 H, Me).

Anal. Calc. for $C_{20}H_{24}O_5$: C, 69.75; H, 7.02. Found: C, 69.63; H, 6.98.

Benzyl 4-O-*allyl*-exo-*2,3*-O-*benzylidene*-α-L-*rhamnopyranoside* (**9**). — A mixture of **2** (1.37 g), methyl sulphoxide (6 ml), and NaH (0.5 g) was stirred for 1 h. Allyl bromide (1 ml) was then added and stirring was continued for 16 h. Excess of NaH was decomposed with methanol (5 ml), and the mixture was poured into water (200 ml). The aqueous solution was extracted with chloroform (3 × 100 ml), and the

combined extracts were washed with water (5×30 ml), dried (Na_2SO_4), and concentrated to dryness. Recrystallisation of the residue from hexane (12 ml) gave **9** (1.34 g, 87%), m.p. 68–69°, $[\alpha]_D$ −46° (*c* 0.97, chloroform), R_F 0.79 (benzene–methanol, 96:4).

Anal. Calc. for $C_{23}H_{26}O_5$: C, 72.23; H, 6.85. Found: C, 71.59; H, 6.59.

*Benzyl 4-O-allyl-3-O-benzyl-α-*L*-rhamnopyranoside* (**10**). — Compound **9** (1.15 g) was hydrogenolysed in 1:1 ether–dichloromethane (30 ml) with an ethereal solution of $LiAlH_4$ (0.35 g) and $AlCl_3$ (1 g), as described for **6**. The reaction was complete within 15 min, yielding (t.l.c.) two components in the ratio ~85:15 (R_F 0.54 and 0.63, benzene–methanol, 95:5). Chromatography of the mixture on a column of Kieselgel G (60 g) with benzene–methanol (95:5) gave syrupy **10** (0.68 g, 59%), $[\alpha]_D$ −56° (*c* 0.76, chloroform), R_F 0.54 (benzene–methanol, 95:5).

Anal. Calc. for $C_{23}H_{28}O_5$: C, 71.85; H, 7.34. Found: C, 71.47; H, 7.28.

Compound **10** (0.1 g) was treated with a solution of potassium *tert*-butoxide (0.1 g) in methyl sulphoxide (3 ml) at 100° for 2 h. The mixture was then diluted with chloroform, washed with water, dried, and concentrated. A solution of the residue in 9:1 acetone–water (10 ml) was stirred with a solution of $HgCl_2$ (0.1 g) in 9:1 acetone–water and then washed with 5% aqueous KI and water, dried, and concentrated. The resulting syrup was identical with **6** (t.l.c.; benzene–acetone, 8:2).

*Benzyl 4-O-benzyl-*exo- (**14**) *and* -endo-*2,3-O-benzylidene-α-*L*-rhamnopyranoside* (**15**). — (*a*) The crude product of the benzylidenation of **1** (1.84 g) was stirred with powdered KOH (2 g) and benzyl chloride (15 ml) at 105° for 6 h. The mixture was then diluted with chloroform, filtered, washed with water, and, after the addition of a small amount of $NaHCO_3$, steam-distilled. The residue was extracted with chloroform, and the extract was washed with water, dried (Na_2SO_4), and concentrated. Two recrystallisations of the residue (2.07 g, 89%) from hexane gave **14** (0.63 g, 27%), m.p. 124–125°, $[\alpha]_D$ −81° (*c* 0.96, chloroform), R_F 0.80 (benzene–methanol, 96:4), 0.32 (benzene–chloroform, 1:1), *T* 8.19 min [column (*c*)]. N.m.r. data: δ 7.30–7.10 (m, 15 H, aromatic), 6.04 (s, 1 H, PhC*H*), 5.09 (s, 1 H, H-1), 5.00–3.20 (m, 8 H, H-2,3,4,5 and 2 PhCH_2), and 1.33 (d, 3 H, Me).

Anal. Calc. for $C_{27}H_{28}O_5$: C, 74.98; H, 6.52. Found: C, 74.72; H, 6.42.

The mother liquor was concentrated and the residue was chromatographed on a column of Kieselgel G (100 g) with benzene–chloroform (1:1). Eluted first was **14** (0.2 g; total yield 0.83 g, 36%), followed by a mixture of **14** and **15**, and finally the *endo*-isomer (**15**), which was recrystallised from hexane (3 ml) to give material (0.65 g, 28%), m.p. 53–54°, $[\alpha]_D$ −57° (*c* 0.88, chloroform), R_F 0.25 (benzene–chloroform, 1:1), *T* 7.75 min [column (*c*)]. N.m.r. data: δ 7.60–7.10 (m, 15 H, aromatic), 5.87 (s, 1 H, PhC*H*), 5.17 (s, 1 H, H-1), 4.90–3.20 (m, 8 H, H-2,3,4,5 and 2 PhCH_2), and 1.25 (d, 3 H, Me).

Anal. Found: C, 74.96; H, 6.48.

A 1:1 mixture of **14** and **15** (3.5 g) was hydrolysed in a mixture of ethanol (20 ml) and 50% acetic acid (10 ml) for 16 h at 80°. The mixture was then concentrated, and a solution of the residue in chloroform was washed with water, dried, and

concentrated. Recrystallisation of the residue from cyclohexane (20 ml) gave 2.60 g (93%) of benzyl 4-*O*-benzyl-α-L-rhamnopyranoside (**13**), m.p. 85–86°, $[\alpha]_D$ −93° (*c* 0.53, chloroform); lit.[23] m.p. 86–88°, $[\alpha]_D$ −88.8° (acetone).

(*b*) Compound **13** (0.64 g) was treated with $ZnCl_2$ (0.7 g) and benzaldehyde (7 ml) as described for the benzylidenation of **1**. The crystalline product (0.6 g, 75%), which exhibited two n.m.r. signals for benzylidene protons of approximately equal intensity at δ 6.04 and 5.87, was a ~1:1 mixture of **14** and **15**.

*Benzyl 3,4-di-*O*-benzyl-α-*L*-rhamnopyranoside* (**16**). — Compound **14** (0.43 g) was hydrogenolysed as described for **6**. T.l.c. (benzene–methanol, 95:5) of the resulting syrupy product revealed minor (R_F 0.66) and major (R_F 0.54) components. Acetylation of a small portion of the syrup and g.l.c. [column (*c*)] of the resulting acetates revealed two components (*T* 6.55 and 7.39 min) in the ratio 94:6.

The syrup was chromatographed on a column of Kieselgel G (30 g) by elution with benzene–methanol (95:5) to give syrupy **16** (0.3 g, 69%), $[\alpha]_D$ −58° (*c* 0.6, chloroform), R_F 0.54 (benzene–methanol, 95:5), *T* 6.55 min [column (*c*)].

Anal. Calc. for $C_{27}H_{30}O_5$: C, 74.63; H, 6.96. Found: C, 74.85; H, 7.09.

Compound **16** (10 mg) was hydrolysed in 5 ml of 0.25M sulphuric acid in 50% ethanol at 100°. The mixture was neutralised with barium carbonate, filtered, and extracted with chloroform, and the extract was washed with water, dried, and concentrated. The product was oxidised with sodium periodate in 50% ethanol. T.l.c. (benzene–methanol, 9:1) revealed that the hydrolysate (R_F 0.46) was oxidised to a product having a higher R_F (0.70).

*Benzyl 2,4-di-*O*-benzyl-α-*L*-rhamnopyranoside* (**17**). — Compound **15** (0.8 g) was hydrogenolysed as described for **6**. T.l.c. of the resulting syrupy product showed two spots identical to those obtained by the reduction of **14**. Acetylation of a small portion of the syrup and g.l.c. of the resulting acetates [column (*c*)] revealed two components (*T* 6.55 and 7.39 min) in the ratio 18.5:81.5. The syrup was chromatographed on a column of Kieselgel G (120 g) with benzene–methanol (95:5) to give, first, **17** (0.61 g, 76%), and then **16** (0.11 g, 14%). Compound **17** had $[\alpha]_D$ −42° (*c* 0.64, chloroform), R_F 0.66 (benzene–methanol, 95:5), *T* 7.39 min [column (*c*)].

Anal. Calc. for $C_{27}H_{30}O_5$: C, 74.63; H, 6.96. Found: C, 74.45; H, 6.89.

When **17** (10 mg) was hydrolysed with 0.25M sulphuric acid as described above, the product was resistant to periodate (t.l.c.).

*Benzyl 4-*O*-allyl-2,3-*O*-isopropylidene-α-*L*-rhamnopyranoside* (**19**). — A stirred mixture of **11** (1 g) and anhydrous *N*,*N*-dimethylformamide (20 ml) was treated with NaH (0.4 g). After cooling to 0°, allyl bromide (1.5 ml) was added. The mixture was allowed to attain room temperature and then stirred for a further 24 h. Excess of NaH was decomposed with methanol, and the solution was concentrated to dryness. A solution of the residue in chloroform (100 ml) was washed with water (5 × 50 ml), dried, and concentrated to give syrupy **19** (0.95 g, 84%), $[\alpha]_D$ −51° (*c* 0.49, chloroform), R_F 0.75 (benzene–methanol, 96:4). N.m.r. data: δ 7.40–7.20 (m, 5 H, aromatic), 6.10–5.70 (m, 1 H, allyl –C*H*=), 5.40–5.00 (m, 2 H, allyl =CH_2), 5.03 (s, 1 H, H-1),

4.57 (q, 2 H, PhCH_2), 4.40–3.00 (m, 6 H, H-2,3,4,5 and allyl –CH_2), 1.52 and 1.35 (2 s, 6 H, CMe_2), and 1.28 (d, 3 H, Me).

Anal. Calc. for $C_{19}H_{26}O_5$: C, 68.24; H, 7.84. Found: C, 68.21; H, 7.67.

Benzyl 4-O-allyl-α-L-rhamnopyranoside (**20**). — Compound **19** (2.15 g) was stirred with 50 ml of 50% aqueous ethanol containing conc. sulphuric acid (0.2 ml) for 2 h at ~100°. The cooled solution was neutralised with Varion AD (HO^-) resin and concentrated, and the residue was crystallised from cyclohexane (8 ml) to give **20** (1.72 g, 91%), m.p. 56°, $[\alpha]_D$ −67° (*c* 0.89, chloroform), R_F 0.30 (benzene–methanol, 9:1). N.m.r. data: δ 7.40–7.20 (m, 5 H, aromatic), 6.20–5.10 (m, 3 H, allyl –CH=CH_2), 4.88 (s, 1 H, H-1), 4.62 (q, 2 H, PhCH_2), 4.30–3.20 (m, 6 H, H-2,3,4,5 and allyl –CH_2), 3.10 (broad, 2 H, OH), and 1.31 (d, 3 H, Me).

Anal. Calc. for $C_{16}H_{22}O_5$: C, 65.29; H, 7.53. Found: C, 65.18; H, 7.49.

Benzyl 2,3-di-O-benzyl-α-L-rhamnopyranoside (**18**). — Compound **20** (1.4 g) was benzylated with a mixture of dry *N,N*-dimethylformamide (14 ml), NaH (0.46 g), and benzyl chloride (2.3 ml) by the usual method. Work-up gave benzyl 4-*O*-allyl-2,3-di-*O*-benzyl-α-L-rhamnopyranoside (**21**; 1.86 g, 82%) as a syrup that was chromatographically homogeneous, $[\alpha]_D$ −55° (*c* 2.55, chloroform), R_F 0.77 (benzene–methanol, 96:4).

Compound **21** (1.54 g; R_F 0.68, ether–pentane, 1:2) was isomerised in dry methyl sulphoxide (8 ml) with potassium *tert*-butoxide (2 g) at 100° for 2 h into the propenyl derivative (R_F 0.76). The mixture was diluted with chloroform (100 ml), washed with water (5 × 50 ml), and concentrated. The residue was hydrolysed with a solution of $HgCl_2$ (1.16 g) in 90% aqueous acetone (30 ml) for 30 min at room temperature. The mixture was diluted with chloroform (100 ml), washed with 5% aqueous KI (3 × 20 ml) and water (5 × 30 ml), dried, and concentrated. The residue was eluted from a column of Kieselgel G (60 g) with benzene–methanol (9:1) to give syrupy **18** (0.96 g, 68%), $[\alpha]_D$ −30° (*c* 0.94, chloroform), R_F 0.58 (benzene–methanol, 95:5). N.m.r. data: δ 7.40–7.10 (m, 15 H, aromatic), 4.84 (s, 1 H, H-1), 4.70–4.20 (m, 6 H, PhCH_2), 3.80–3.40 (m, 4 H, H-2,3,4,5), 2.20 (broad, 1 H, OH), and 1.24 (d, 3 H, Me).

Anal. Calc. for $C_{27}H_{30}O_5$: C, 74.63; H, 6.96. Found: C, 74.31; H, 6.80.

REFERENCES

1 R. SCHAFFER, in W. PIGMAN AND D. HORTON (Eds.), *The Carbohydrates*, Vol. IA, 2nd edition, Academic Press, New York, 1972, pp. 69–111.
2 A. LIPTÁK AND P. NÁNÁSI, *Carbohydr. Res.*, 44 (1975) 313–316.
3 G. M. BEBAULT AND G. G. S. DUTTON, *Can. J. Chem.*, 50 (1972) 3373–3378.
4 G. M. BEBAULT AND G. G. S. DUTTON, *Can. J. Chem.*, 52 (1974) 678–680.
5 J. M. BERRY AND G. G. S. DUTTON, *Can. J. Chem.*, 52 (1974) 681–683.
6 G. M. BEBAULT, G. G. S. DUTTON, AND C. K. WARFIELD, *Carbohydr. Res.*, 34 (1974) 174–179.
7 G. M. BEBAULT AND G. G. S. DUTTON, *Can. J. Chem.*, 52 (1974) 3844–3846.
8 R. R. KING AND C. T. BISHOP, *Can. J. Chem.*, 52 (1974) 3913–3917.
9 R. R. KING AND C. T. BISHOP, *Carbohydr. Res.*, 32 (1974) 239–249.
10 N. K. KOCHETKOV, B. A. DMITRIEV, N. N. MALYSHEVA, A. YA. CHERNYAK, E. M. KLIMOV, N. E. BAYRAMOVA, AND V. I. TORGOV, *Carbohydr. Res.*, 45 (1975) 283–290.
11 G. EKBORG, J. LÖNNGREN, AND S. SVENSSON, *Acta Chem. Scand., Ser. B*, 29 (1975) 1031–1035.

12 N. K. KOCHETKOV, B. A. DMITRIEV, AND L. V. BACKINOWSKY, *Carbohydr. Res.*, 51 (1976) 229–237.
13 C. M. MCCLOSKEY, *Adv. Carbohydr. Chem.*, 12 (1957) 137–156.
14 A. LIPTÁK, I. JODÁL, AND P. NÁNÁSI, *Carbohydr. Res.*, 44 (1975) 1–11.
15 A. LIPTÁK, *Tetrahedron Lett.*, (1976) 3551–3554.
16 A. LIPTÁK, P. FÜGEDI, AND P. NÁNÁSI, *Carbohydr. Res.*, 51 (1976) c19–c21.
17 J. S. BRIMACOMBE, M. C. COOK, AND L. C. N. TUCKER, *J. Chem. Soc.*, (1965) 2292–2294.
18 N. BAGGETT, K. W. BUCK, A. B. FOSTER, AND J. M. WEBBER, *J. Chem. Soc.*, (1965) 3401–3407.
19 P. M. COLLINS AND N. N. OPARAECHE, *Carbohydr. Res.*, 33 (1974) 35–46.
20 G. ZEMPLÉN, *Ber.*, 59 (1926) 1254–1266.
21 R. GIGG AND C. D. WARREN, *J. Chem. Soc., C*, (1968) 1903–1911.
22 J. S. BRIMACOMBE AND L. C. N. TUCKER, *Carbohydr. Res.*, 5 (1967) 36–44.
23 A. H. HAINES, *Carbohydr. Res.*, 1 (1965) 214–228.
24 E. C. ASHBY AND J. PRATHER, *J. Am. Chem. Soc.*, 88 (1966) 729–733.
25 B. E. LEGGETTER AND R. K. BROWN, *Can. J. Chem.*, 42 (1964) 990–1004.
26 P. ROLLIN AND P. SINAŸ, *C.R. Acad. Sci., Ser. C*, 284 (1977) 65–68.
27 A. LIPTÁK, I. JODÁL, AND P. NÁNÁSI, *Carbohydr. Res.*, 52 (1976) 17–22.