

## SYNTHESIS OF THE *allo*-ANALOGUE OF TREHALOSE\*†

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### ABSTRACT

Selective benzylation of HO-2 and HO-2' of 4,6-*O*-benzylidene- $\alpha$ -D-glucopyranosyl 4,6-*O*-benzylidene- $\alpha$ -D-glucopyranoside with *N*-benzoylimidazole led to the exclusive formation of 2-*O*-benzoyl-4,6-*O*-benzylidene- $\alpha$ -D-glucopyranosyl 2-*O*-benzoyl-4,6-*O*-benzylidene- $\alpha$ -D-glucopyranoside. Oxidation of either the dibenzoate or the corresponding ditosylate with methyl sulphoxide-phosphorus pentaoxide gave the 3,3'-diulose, and subsequent reduction with borohydride gave the 3,3'-diepimers having the *allo-allo* configuration. De-esterification and hydrolysis of the benzylidene substituents gave  $\alpha$ -D-allopyranosyl  $\alpha$ -D-allopyranoside.

### INTRODUCTION

The similarity in structure of  $\alpha,\alpha$ -trehalose to many natural food sugars and its unique molecular symmetry and conformational stability make it an ideal model in studies of the relationship between molecular geometry and organoleptic effect. Studies with methyl  $\alpha$ -D-glucopyranoside and  $\alpha,\alpha$ -trehalose and their derivatives<sup>2-4</sup> have indicated that only one half of the trehalose molecule is involved in binding to the taste-bud protein to produce the sweet and/or bitter taste. A knowledge of the chemical features which govern the strength of binding might allow prediction of the exact spatial requirement for binding to the taste receptor protein(s) and hence the sequence of amino acids at a specific binding-site.

We now describe the synthesis of a new trehalose analogue,  $\alpha,\alpha$ -*allo*-trehalose, which will help to extend these studies. Its sensory properties will be reported elsewhere.

\*Dedicated to the memory of Professor Edward J. Bourne.

†Chemical Modification of Trehalose: Part XVII. For Part XVI, see Ref. 1.

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TABLE I

<sup>1</sup>H-N.M.R. PARAMETERS<sup>a</sup>

| Compound           | 2 <sup>b</sup> | 4 <sup>b</sup> | 5 <sup>c</sup> | 9 <sup>b</sup> | 10 <sup>b</sup> | 13 <sup>c</sup> | 14 <sup>b</sup> | 17 <sup>c</sup> |
|--------------------|----------------|----------------|----------------|----------------|-----------------|-----------------|-----------------|-----------------|
| H-1                | {              | {              | {              | {              | {               | {               | {               | {               |
| H-1'               | 4.54 (d)       | 3.92 (d)       | 4.76 (d)       | 4.83 (d)       | 4.58 (d)        | 5.09 (d)        | 4.54 (d)        | 4.63 (d)        |
| H-2                | {              | {              | {              | {              | {               | {               | {               | {               |
| H-2'               | 4.98 (dd)      | 4.13 (dd)      | 5.47 (t)       | 5.34 (t)       | 4.85 (t)        | 5.77 (cm)       | 4.47 (t)        | 5.38 (t)        |
| H-3                | {              | {              | {              | {              | {               | {               | {               | {               |
| H-3'               | 4.68 (t)       | {              | 5.78 (cm)      | {              | 5.2-5.6 (cm)    | 6.04 (dd)       | 4.66 (t)        | 4.90 (t)        |
| H-4                | {              | {              | {              | {              | {               | {               | {               | {               |
| H-4'               | {              | 5.11 (dd)      | 5.59 (dd)      | 5.4-5.9 (cm)   | {               | {               | 6.0 (dd)        | 5.10 (dd)       |
| H-5                | {              | {              | {              | {              | {               | {               | {               | {               |
| H-5'               | 6.1-6.5 (cm)   | {              | 6.2-6.7 (cm)   | {              | 6.1-6.5 (cm)    | 6.4-6.7 (cm)    | 5.5-5.7 (cm)    | 5.5-6.0 (cm)    |
| H-6                | {              | {              | {              | {              | {               | {               | {               | {               |
| H-6'               | {              | 5.3-6.1 (cm)   | {              | 6.2-6.4 (cm)   | {               | {               | 6.4-6.6 (cm)    | {               |
| CHPh               | 4.54 (s)       | 4.26 (s)       | 5.53 (s)       | 4.41 (s)       | 4.41 (s)        | 4.74 (s)        | 4.38 (s)        | {               |
| J <sub>1,2</sub>   | {              | {              | {              | {              | {               | {               | {               | {               |
| J <sub>1',2'</sub> | 3.6            | 4.2            | 3.5            | 3.5            | 3.5             | 4.0             | 4.5             | 4.0             |
| J <sub>2,3</sub>   | {              | {              | {              | {              | {               | {               | {               | {               |
| J <sub>2',3'</sub> | 9.5            | {              | 3.5            | 4.0            | 4.0             | {               | 3.5             | 4.0             |
| J <sub>2,4</sub>   | {              | 1.2            | {              | {              | {               | {               | {               | {               |
| J <sub>3,4</sub>   | {              | {              | {              | {              | {               | {               | {               | {               |
| J <sub>3',4'</sub> | 9.5            | {              | 5.5            | {              | {               | 5.0             | 3.0             | 3.0             |
| J <sub>4,5</sub>   | {              | {              | {              | {              | {               | {               | {               | {               |
| J <sub>4',5'</sub> | {              | 9.8            | 12.5           | {              | {               | 9.0             | 10.0            | 10.0            |

<sup>a</sup>First-order chemical shifts ( $\tau$  values) and coupling constants at 100 MHz. Multiplicity indicated by the usual abbreviations; cm, complex multiplet. <sup>b</sup>In deuterioacetone. <sup>c</sup>In deuteriochloroform.

## RESULTS AND DISCUSSION

The use of *N*-benzoylimidazole<sup>5</sup> as a selective benzoylating agent was reported by Carey and Hodgson<sup>6</sup>, who prepared methyl 2-*O*-benzoyl-4,6-*O*-benzylidene- $\alpha$ -D-glucopyranoside in 78% yield. Treatment of 4,6:4',6'-di-*O*-benzylidene- $\alpha,\alpha$ -trehalose with this reagent under similar conditions gave the 2,2'-dibenzoate **2** (85%), together with small amounts of the mono- (**2**–5%), tri- (**21**, 5–7%), and tetra-benzoates (2–5%), which were isolated by chromatography.

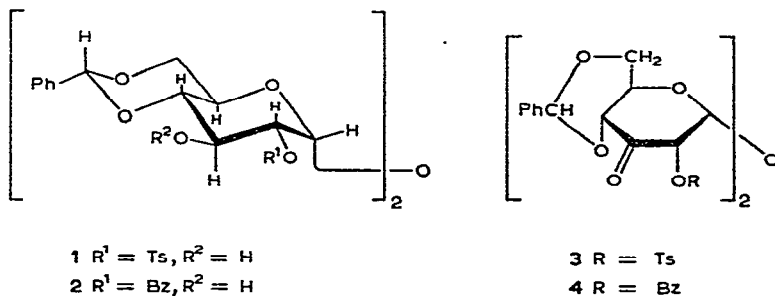


TABLE II

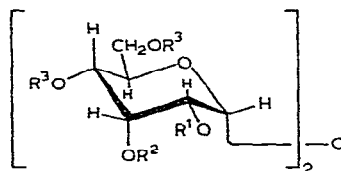
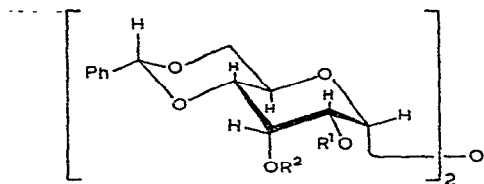
<sup>1</sup>H-N.M.R. PARAMETERS<sup>a</sup>

| Compound    | 18           | 19           | 20           |
|-------------|--------------|--------------|--------------|
| H-1         | 4.43 (d)     | 4.34 (d)     | 4.51 (d)     |
| H-1'        | 4.74 (d)     | 4.54 (d)     | 4.61 (d)     |
| H-2         | 4.48 (dd)    | 4.57 (dd)    | 4.93 (dd)    |
| H-2'        | 4.86 (dd)    | 4.61 (d)     | 4.90 (t)     |
| H-3         | 3.91 (t)     | 3.93 (t)     | 5.58 (t)     |
| H-3'        | 5.55 (t)     |              | 5.58 (t)     |
| H-4         | 4.20 (t)     |              |              |
| H-4'        |              |              |              |
| H-5         | 5.9–6.8 (cm) | 5.6–6.5 (cm) | 5.7–6.6 (cm) |
| H-5'        |              |              |              |
| H-6         |              |              |              |
| H-6'        |              |              |              |
| CHPh        | 4.64 (s)     | 4.27 (s)     | 4.60 (s)     |
|             | 4.66 (s)     | 4.29 (s)     | 4.62 (s)     |
| $J_{1,2}$   | 4.0          | 4.0          | 4.0          |
| $J_{1',2'}$ | 4.0          | 4.0          | 4.0          |
| $J_{2,3}$   | 9.5          | 9.5          | 10.0         |
| $J_{2',3'}$ | 9.5          |              | 4            |
| $J_{3,4}$   | 9.5          | 9.5          | 10.0         |
| $J_{3',4'}$ | 9.5          |              | 4            |
| $J_{4,5}$   | 9.5          |              |              |

<sup>a</sup>First-order chemical shifts ( $\tau$  values) and coupling constants at 100 MHz in deuteriochloroform. Multiplicity indicated by the usual abbreviations. The primed and non-primed hydrogens of **18** and **19** have been distinguished on the assumption that all the ring protons on the more highly acylated ring are more deshielded. In the case of **20**, the primed hydrogens have been assigned to the allopyranosyl ring while the non-primed hydrogens to the glucopyranosyl ring.

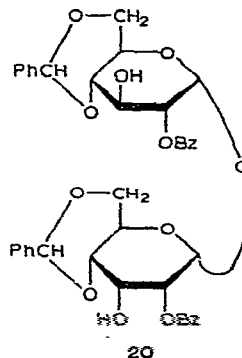
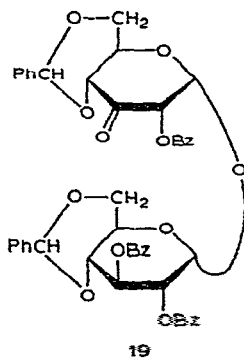
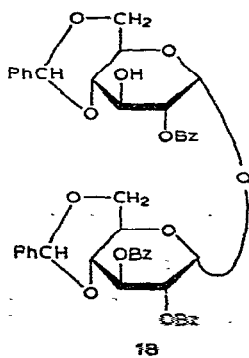
The structure of **2** was indicated by p.m.r. and mass-spectral data (Table I) and substantiated by chemical transformations.

As<sup>1</sup> with the ditosylate **1**, oxidation of the dibenzoate **2** with methyl sulphoxide (52 mol.) in the presence of phosphorus pentaoxide (5 mol.) in *N,N*-dimethylformamide for 2.5 h at 60° gave the symmetrical diulose **4**. Reduction of **4** with sodium borohydride gave the *allo*-analogue **10**, through approach of the borohydride from the equatorial direction<sup>7</sup>. There was also considerable, concomitant debenzoylation due, presumably, to the alkalinity of the reagent. Reduction of **4** in the presence of Biodeminrolit mixed-bed or Amberlite IR-120(H<sup>+</sup>) resins also led to considerable debenzoylation. Debzoylation was prevented by buffering the reaction mixture at pH 6.5 with acetic acid-sodium acetate. Reduction was not stereospecific<sup>8,9</sup> and ~10% of a compound of mobility slightly lower than that of **5** was isolated by column chromatography. Traces of a third component were also observed on t.l.c. The structure of the minor component was shown by p.m.r. studies (Table II) to be  $\alpha$ -D-glucopyranosyl  $\alpha$ -D-allopyranoside (**20**). The lack of symmetry in **20** was clearly shown by the multiplicity of resonances. The two benzylic hydrogen resonances were not coincident ( $\tau$  4.60 and 4.62). The two H-1 resonances were readily recognised as two low-field doublets at  $\tau$  4.51 and 4.61, both having a splitting of 4.0 Hz. One of the two H-2 resonances was a double doublet at  $\tau$  4.93, with  $J_{2,3}$  10.0 Hz in accord with



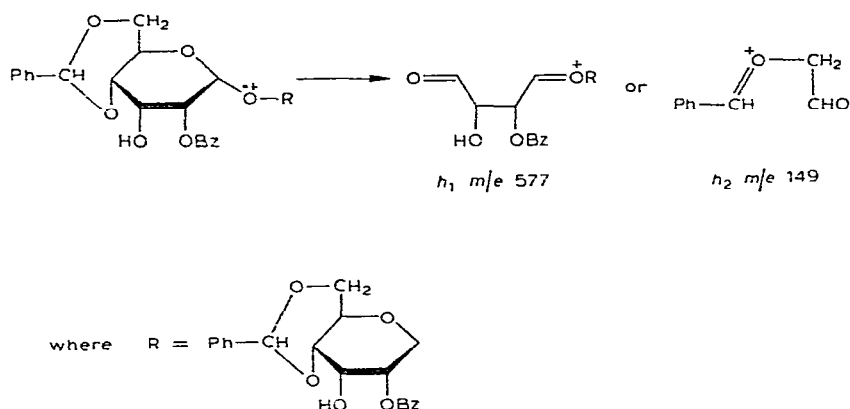
|  |   |
|--|---|
| 5 R <sup>1</sup> = Ts, R <sup>2</sup> = H  | 10 R <sup>1</sup> = Bz, R <sup>2</sup> = H  |
| 6 R <sup>1</sup> = Ts, R <sup>2</sup> = Ac | 11 R <sup>1</sup> = R <sup>2</sup> = Bz     |
| 7 R <sup>1</sup> = Ts, R <sup>2</sup> = Bz | 12 R <sup>1</sup> = R <sup>2</sup> = Ac     |
| 8 R <sup>1</sup> = Ts, R <sup>2</sup> = Ms | 13 R <sup>1</sup> = R <sup>2</sup> = H      |
| 9 R <sup>1</sup> = R <sup>2</sup> = Ts     | 14 R <sup>1</sup> = Bz, R <sup>2</sup> = Ms |

|  |
|--|
| 15 R <sup>1</sup> = R <sup>2</sup> = R <sup>3</sup> = H          |
| 16 R <sup>1</sup> = Ts, R <sup>2</sup> = Ms, R <sup>3</sup> = H  |
| 17 R <sup>1</sup> = Ts, R <sup>2</sup> = Ms, R <sup>3</sup> = Ac |



a diaxial relationship between H-2 and H-3. This, together with the H-3 triplet at  $\tau$  5.58 having  $J_{2,3} = J_{3,4} = 10.0$  Hz, clearly confirmed the *gluco* configuration of one of the glycosyl rings. The other H-2 and H-3 resonances were narrow-limbed triplets ( $\tau$  4.90 and 5.58, respectively), with  $J_{2,3} = J_{3,4} = \sim 4$  Hz, in accord with the *allo* configuration of the other glycosyl ring. The tosyl groups were not affected when 3 was reduced with borohydride.

The p.m.r. data (Table I) for 2,2'-di-*O*-benzoyl-4,6:4',6'-di-*O*-benzylidene- $\alpha,\alpha$ -*allo,allo*-trehalose (**10**) are consistent with the assigned structure, and the small ( $\sim 4$  Hz)  $J_{2,3}$  and  $J_{3,4}$  values are in accord with an equatorial H-3 in the  ${}^4C_1$  conformation. The mass spectrum of **10** showed a molecular ion at  $m/e$  726. Although the major fragmentation pathway involves the cleavage of the C-1-O-1 bonds (A series)<sup>10</sup> to give the two oxycarbonium ions (identical in symmetrical derivatives), a peak of moderate intensity was observed at  $m/e$  577, corresponding to the ion  $(M - 149)^+$ . This fragmentation pattern (*h*-rupture<sup>11</sup>) is typical of acetals or compounds of the general formula R-O-C-C-O-C-O-X, and is associated with the following mechanism:



The  $h_1$  and  $h_2$  fragments were similarly observed for each of the benzylidene derivatives studied previously<sup>1</sup>. Further ions arise from stepwise elimination of the benzylidene group and the substituents at C-2 and C-3. The presence of the ion  $m/e$  179 was again detected, and we are still unable to suggest the pattern of its formation or the detailed structure of this ion.

Acylation of the 2,2'-ditosylate **5** gave crystalline derivatives **6**, **7**, and **8**, which appeared to be homogeneous on t.l.c. but were shown to be mixtures by n.m.r. spectroscopy.

The tribenzoate **18** was also readily oxidised in methyl sulphoxide-phosphorus pentaoxide to give the asymmetrical derivative **19** which was characterised on the basis of n.m.r. and m.s. data. The lack of symmetry in **19** was clearly indicated by the multiplicity of resonances. Only one H-3 resonance was observed, a triplet downfield

of all other sugar ring resonances, at  $\tau$  3.93, with splittings ( $J_{2,3} = J_{3,4} = \sim 10$  Hz) typical of the *gluco* configuration. Furthermore, the benzylic resonances were not coincident (singlets at  $\tau$  4.20 and 4.22). Likewise, one of the two H-2 resonances was a triplet at  $\tau$  4.57, and the other was a doublet at  $\tau$  4.55 because of its proximity to the 3-keto grouping. The mass spectrum of **19** contained a pair of ions at  $m/e$  459 and 353, corresponding to the two glycosyloxy carbonium ions formed by the fragmentation of one or other of the two glycosidic bonds.

Attempts to displace the sulphonyloxy groups at C-3 and C-3' in **9** and **14** by azide have so far been unsuccessful.

## EXPERIMENTAL

For details of the general procedure, see Ref. 1.

Chloroform was purified by stirring a 3:1 mixture with conc. sulphuric acid until a sample when stirred with pure conc. sulphuric acid did not impart any colour to the latter. The chloroform was then distilled from calcium oxide.

*2-O-Benzoyl-4,6-O-benzylidene- $\alpha$ -D-glucopyranosyl 2-O-benzoyl-4,6-O-benzylidene- $\alpha$ -D-glucopyranoside (2).* — To a cooled solution of imidazole (13.6 g, 0.2 mol.) in purified chloroform (150 ml), benzoyl chloride (14.1 g, 0.1 mol.) was added dropwise. Imidazole hydrochloride was removed and the filtrate was added to a solution of 4,6:4',6'-di-*O*-benzylidene- $\alpha,\alpha$ -trehalose (25.9 g, 0.05 mol.) in purified chloroform (500 ml). The mixture was boiled under reflux for 8–12 h, and t.l.c. (benzene–ethyl acetate, 6:1) then showed the presence of one major and three minor compounds. The mixture was extracted with saturated, aqueous sodium hydrogen carbonate (50 ml) and aqueous sodium chloride (2  $\times$  50 ml), then dried ( $\text{Na}_2\text{SO}_4$ ), and concentrated. The crude product (85%) was crystallised twice from dichloromethane–methanol to give **2** (23.6 g, 65%), m.p. 256–259°,  $[\alpha]_D +186^\circ$  ( $c$  0.3, chloroform) (Found: C, 66.4; H, 5.2.  $\text{C}_{40}\text{H}_{38}\text{O}_{13}$  calc.: C, 66.1; H, 5.2%).

The combined filtrates from the recrystallisations were concentrated and the syrupy residue was eluted from a dry-packed column of silica gel (200 g) with benzene–ethyl acetate (20:1) to give, in sequence, (a) 2,3-di-*O*-benzoyl-4,6-*O*-benzylidene- $\alpha$ -D-glucopyranosyl 2,3-di-*O*-benzoyl-4,6-*O*-benzylidene- $\alpha$ -D-glucopyranoside (1.2 g, 2.4%), m.p. 237–239° (from ethanol),  $[\alpha]_D +214.5^\circ$  ( $c$  0.7, chloroform); lit.<sup>12</sup> m.p. 238–239°,  $[\alpha]_D +214^\circ$ ; (b) 2-*O*-benzoyl-4,6-*O*-benzylidene- $\alpha$ -D-glucopyranosyl 2,3-di-*O*-benzoyl-4,6-*O*-benzylidene- $\alpha$ -D-glucopyranoside (**18**; 2.0 g, 4.8%), m.p. 250–253° (dec.) (from ethanol),  $[\alpha]_D +202.5^\circ$  ( $c$  0.3, chloroform) (Found: C, 68.1; H, 5.3.  $\text{C}_{47}\text{H}_{42}\text{O}_{14}$  calc.: C, 67.95; H, 5.05%); (c) 2,2'-di-*O*-benzoyl-4,6:4',6'-di-*O*-benzylidene- $\alpha,\alpha$ -trehalose (**2**; 3.5 g, 9.6%); (d) 2-*O*-benzoyl-4,6-*O*-benzylidene- $\alpha$ -D-glucopyranosyl 4,6-*O*-benzylidene- $\alpha$ -D-glucopyranoside (slightly impure, even after several recrystallisations from ethanol) (0.65 g, 2.1%).

*2-O-Benzoyl-4,6-O-benzylidene- $\alpha$ -D-ribo-hexopyranosyl-3-ulose 2-O-benzoyl-4,6-O-benzylidene- $\alpha$ -D-ribo-hexopyranosid-3-ulose (4).* — To a stirred solution of **2** (13.3 g) in *N,N*-dimethylformamide (165 ml) were added phosphorus pentaoxide (13 g)

and methyl sulphoxide (67.5 ml). The mixture was stirred at 60–65° for 2 h and t.l.c. (benzene–ethyl acetate 6:1) then revealed a major and a minor product. The cooled mixture was poured into ice–water (containing some ethanol) and the white precipitate was collected, washed well with water, and dissolved in chloroform. The dried (MgSO<sub>4</sub>) solution was concentrated and the residue was recrystallised twice from dichloromethane–ethanol to give **4** (9.0 g, 68%), m.p. 234.5–235.5° (dec.),  $[\alpha]_D^{20} +120^\circ$  (c 0.3, chloroform) (Found: C, 66.6; H, 4.4. C<sub>40</sub>H<sub>34</sub>O<sub>13</sub> calc.: C, 66.5; H, 4.7%).

Attempts to isolate the minor product pure were unsuccessful.

In later preparations, it was found to be more convenient to oxidise the crude **2** obtained prior to recrystallisation. The overall yields of **4** were then ~75% (55–60% could be obtained by direct recrystallisation), and the monoulose tribenzoate **19** (see below) was obtained in ~5% overall yield by column chromatography.

*2,3-Di-O-benzoyl-4,6-O-benzylidene- $\alpha$ -D-glucopyranosyl 2-O-benzoyl-4,6-O-benzylidene- $\alpha$ -D-ribo-hexopyranosid-3-ulose (19).* — A solution of **18** (1.65 g) in *N,N*-dimethylformamide (50 ml) was treated with phosphorus pentaoxide (2.5 g) and methyl sulphoxide (2.5 ml) as described above. Recrystallisation of the product from ethanol gave **19** (1.2 g, 72%), m.p. 233–236° (dec.),  $[\alpha]_D^{20} +155^\circ$  (c 0.4, chloroform) (Found: C, 67.5; H, 4.95. C<sub>47</sub>H<sub>40</sub>O<sub>14</sub> calc.: C, 68.1; H, 4.8%).

*4,6-O-Benzylidene-2-O-tosyl- $\alpha$ -D-allopyranosyl 4,6-O-benzylidene-2-O-tosyl- $\alpha$ -D-allopyranoside (5).* — A solution of **3**<sup>1</sup> (5 g) in dichloromethane (100 ml) and methanol (50 ml) was treated portionwise with sodium borohydride (2 g), and the mixture was kept at room temperature for 1 h. The resulting solution was treated with Biodeminrolit mixed-bed (CO<sub>3</sub><sup>2-</sup>) resin and concentrated to dryness. Boric acid was removed from the residue by repeated distillation of methanol therefrom. Recrystallisation (twice) of the product from dichloromethane–ethanol gave **5** (3.5 g, 70%), m.p. 129–131°,  $[\alpha]_D^{23} +45^\circ$  (c 0.3, chloroform) (Found: C, 58.1; H, 5.1; S, 7.75. C<sub>40</sub>H<sub>42</sub>O<sub>15</sub>S<sub>2</sub> calc.: C, 58.1; H, 5.1; S, 7.75%).

*2-O-Benzoyl-4,6-O-benzylidene- $\alpha$ -D-allopyranosyl 2-O-benzoyl-4,6-O-benzylidene- $\alpha$ -D-allopyranoside (10).* — A solution of **4** (8 g) in dichloromethane (150 ml) was added to a methanolic solution of acetic acid–sodium acetate (pH 6.5, 100 ml). The stirred solution was treated portionwise with sodium borohydride (2.5 g) during 15 min. The pH of the reaction mixture was kept at 6.8 by the addition of 20% acetic acid in dichloromethane. The mixture was kept at room temperature for a further hour, and t.l.c. then showed the presence of one major and two minor compounds. The resulting solution was deionised with Biodeminrolit mixed-bed (CO<sub>3</sub><sup>2-</sup>) resin and concentrated to dryness, and the residue was treated as in the preparation of **5**, to give **10** (5.0 g, 62%), which, after two recrystallisations from dichloromethane–methanol, had m.p. 215–218°,  $[\alpha]_D^{23} +90^\circ$  (c 0.25, chloroform) (Found: C, 66.4; H, 5.2. C<sub>40</sub>H<sub>38</sub>O<sub>13</sub> calc.: C, 66.1; H, 5.25%).

The combined filtrates from the recrystallisations were concentrated and the syrupy residue was eluted from a column of dry-packed silica gel with benzene–ethyl acetate (20:1), to give (a) 2,2'-di-*O*-benzoyl-4,6:4',6'-di-*O*-benzylidene- $\alpha,\alpha$ -allo-

trehalose (**10**; 0.56 g, 7%); (b) 2-*O*-benzoyl-4,6-*O*-benzylidene- $\alpha$ -D-glucopyranosyl 2-*O*-benzoyl-4,6-*O*-benzylidene- $\alpha$ -D-allopyranoside (**20**; 0.8 g, 10%), m.p. 229–231° (from ethanol),  $[\alpha]_D^{25} + 153^\circ$  (*c* 0.34, chloroform) (Found: C, 65.9; H, 5.05.  $C_{40}H_{38}O_{13}$  calc.: C, 66.1; H, 5.25%). The third compound, present in only minute amounts, was not isolated but corresponded in t.l.c. mobility to 2,2'-di-*O*-benzoyl-4,6:4',6'-di-*O*-benzylidene- $\alpha,\alpha$ -trehalose (**2**).

*4,6-O-Benzylidene- $\alpha$ -D-allopyranosyl 4,6-O-benzylidene- $\alpha$ -D-allopyranoside (13).*

— (a) To a solution of **10** (0.75 g) in dichloromethane (20 ml), methanolic M sodium methoxide (0.5 ml) was added, and the solution was stored at room temperature for 2 h. The solution was deionised with Biodeminrolit mixed-bed ( $CO_3^{2-}$ ) resin and concentrated to dryness. The syrupy residue was washed with light petroleum ( $2 \times 10$  ml) and crystallised from ethanol to give **13** (0.42 g, 78%), m.p. 267–267.5° (dec.),  $[\alpha]_D^{23} + 145^\circ$  (*c* 0.3, acetone) (Found: C, 60.0; H, 6.0.  $C_{26}H_{30}O_{11}$  calc.: C, 60.25; H, 5.8%).

(b) To a solution of **5** (10 g) in dichloromethane (200 ml), methanolic M sodium methoxide (60 ml) was added, and the mixture was boiled under reflux for 5 h. The precipitate was dissolved by addition of acetone, the solution was deionised with Biodeminrolit mixed-bed ( $CO_3^{2-}$ ) resin, and concentrated to dryness. Recrystallisation of the residue from boiling ethanol gave **13** (5.0 g, 80%), identical to the product in (a).

*$\alpha$ -D-Allopyranosyl  $\alpha$ -D-allopyranoside (15).* — To a solution of **13** (1.2 g) in methanol (30 ml), methanolic 1% hydrogen chloride (20 ml) was added. The solution was stored at room temperature for 5 h, then deionised with Biodeminrolit mixed-bed ( $CO_3^{2-}$ ) resin, and concentrated. The syrupy residue was washed by decantation with light petroleum ( $3 \times 10$  ml), and then eluted from a column of silica gel (50 g) with ethanol–light petroleum (1:1). Concentration of the eluate to dryness afforded **15** as a syrup (0.64 g, 81%),  $[\alpha]_D + 158.5^\circ$  (*c* 0.35, water) (Found: C, 41.8; H, 6.2.  $C_{12}H_{22}O_{11}$  calc.: C, 42.1; H, 6.45%). The compound crystallised on standing. Recrystallisation (twice) from methanol gave **15**, m.p. 109–120° and 182–183° (double m.p. due to loss of solvent of crystallisation),  $[\alpha]_D^{25} + 173.9^\circ$  (*c* 0.4, water).

*4,6-O-Benzylidene-2,3-di-O-tosyl- $\alpha$ -D-allopyranosyl 4,6-O-benzylidene-2,3-di-O-tosyl- $\alpha$ -D-allopyranoside (9).* — A solution of **13** (1 g) in dry pyridine (10 ml) was treated with tosyl chloride (2.5 g) for 24 h at room temperature. The product **9** (0.98 g, 65%) crystallised as the monohydrate with m.p. 135–137° (from ethanol),  $[\alpha]_D^{23} + 47^\circ$  (*c* 0.3, chloroform) (Found: C, 56.3; H, 5.2; S, 10.65.  $C_{54}H_{54}O_{19}S_4 \cdot H_2O$  calc.: C, 56.25; H, 4.9; S, 11.1%).

*4,6-O-Benzylidene-2,3-di-O-benzoyl- $\alpha$ -D-allopyranosyl 4,6-O-benzylidene-2,3-di-O-benzoyl- $\alpha$ -D-allopyranoside (11).* — The tetrabenzoate **11** was prepared in the usual way from **10** and **13** (80–85%), m.p. 163–164° (ethanol),  $[\alpha]_D^{25} + 144.6^\circ$  (*c* 0.3, chloroform). (Found: C, 68.0; H, 5.2.  $C_{54}H_{46}O_{15} \cdot C_2H_5OH$  calc.: C, 68.6; H, 5.3%).

*2,3-Di-O-acetyl-4,6-O-benzylidene- $\alpha$ -D-allopyranosyl 2,3-di-O-acetyl-4,6-O-benzylidene- $\alpha$ -D-allopyranoside (12).* — Conventional treatment of **13** with pyridine–acetic anhydride gave **12** as a syrup (82%) which, when purified by chromatography



(benzene-ethyl acetate, 15:1), had  $[\alpha]_D^{23} +53^\circ$  (c 0.2, chloroform) (Found: C, 59.6; H, 5.9.  $C_{34}H_{38}O_{15}$  calc.: C, 59.5; H, 5.5%).

*2-O-Benzoyl-4,6-O-benzylidene-3-O-mesyl- $\alpha$ -D-allopyranosyl 2-O-benzoyl-4,6-O-benzylidene-3-O-mesyl- $\alpha$ -D-allopyranoside (14).* — A solution of **10** (2 g) in dry pyridine (15 ml) was treated with mesyl chloride (5 ml) in the conventional manner. Two recrystallisations of the product from dichloromethane-methanol gave **14** (1.65 g, 66%), m.p. 229–231°,  $[\alpha]_D^{23} +132^\circ$  (c 0.35, chloroform) (Found: C, 57.3; H, 5.1; S, 7.6.  $C_{42}H_{42}O_{17}S_2$  calc.: C, 57.5; H, 4.8; S, 7.3%).

*3-O-Mesyl-2-O-tosyl- $\alpha$ -D-allopyranosyl 3-O-mesyl-2-O-tosyl- $\alpha$ -D-allopyranoside (16).* — To a solution of impure **8** (1.4 g) in dichloromethane (14 ml), methanolic 1% hydrogen chloride (20 ml) was added. The solution was stored at room temperature for 12 h, and t.l.c. (butyl acetate-pyridine-water, 5:3:1) then indicated that methanolysis was complete. The solution was treated as described for **13**, and the product was recrystallised from ethanol to give **16** (1.0 g, 91%), m.p. 112–115°:  $[\alpha]_D^{23} +71^\circ$  (c 0.3, acetone) (Found: C, 42.2; H, 5.0; S, 15.0.  $C_{28}H_{38}O_{19}S_4$  calc., C, 41.7; H, 4.7; S, 15.9%).

The tetra-acetate (**17**) of **16** had m.p. 137–139° (from ethanol),  $[\alpha]_D^{23} +87^\circ$  (c 0.3, chloroform) (Found: C, 44.2; H, 4.85; S, 12.7.  $C_{36}H_{46}O_{23}S_4$  calc.: C, 44.35; H, 4.7; S, 13.1%).

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