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PREPARATION OF SOME ACYLATED 4-DEOXYHEX-3-ENOPYRANOSIDULOSES AND γ-PYRONE FORMATION THEREFROM*

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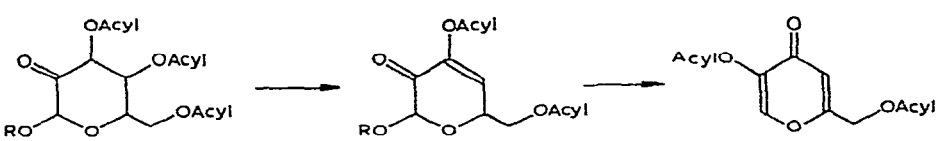
ABSTRACT

Acylated 4-deoxyhex-3-enopyranosiduloses carrying benzoyl and/or acetyl groups (*i.e.*, enolones **9**, **10**, and **14**) were prepared by methyl sulfoxide–acetic anhydride oxidation of methyl 3,4,6-tri-*O*-acetyl-β-D-glucoside and of methyl 3-*O*-benzoyl-4,6-*O*-benzylidene-α-D-glucoside, the latter reaction being followed by debenzylidenation, acylation, and β-elimination of a carboxylic acid. The enolones, as well as the intermediate hexosiduloses, were readily characterized by spectral data and as their 2,4-dinitrophenylhydrazones. In basic and, less readily, in acidic medium, the enolones **9**, **10**, and **14** are converted into the γ-pyrone system. The mechanistic implications of these conversions are discussed.

INTRODUCTION

The propensity of peracylated hexopyranosuloses for β-elimination of acyloxy groups is known to be exceptionally facile. On treatment with aqueous sodium hydrogen carbonate, hex-3-enopyranosuloses ("3,2-enolones"**) are readily formed (**1a** → **2a**)[1–3], whilst under slightly more-forcing conditions (pyridine[1] at 40°, or sodium acetate–acetic acid[2] at 50°), the γ-pyrone system is elaborated by loss of two



1
a-series: R = Ac
b-series: R = Me

2
Acyl = acetyl, benzoyl

3

*Dedicated to the memory of Professor Edward J. Bourne.
Simplified designation for unsaturated glycopyranosuloses of type **2, in view of their derivation from the mono-enol form of 2,3-diketo-pyranoses.

equivalents of carboxylic acid (**1a** → **3a**). The direct, high-yield formation of kojic acid diacetate on methyl sulfoxide oxidations of 1,3,4,6-tetra-*O*-acetyl-α-D-hexoses having the *gluco*[4–6], *galacto*[4,6], and *manno* configuration[6] similarly indicates the lability of peracyl-uloses and their enolones towards elimination processes.

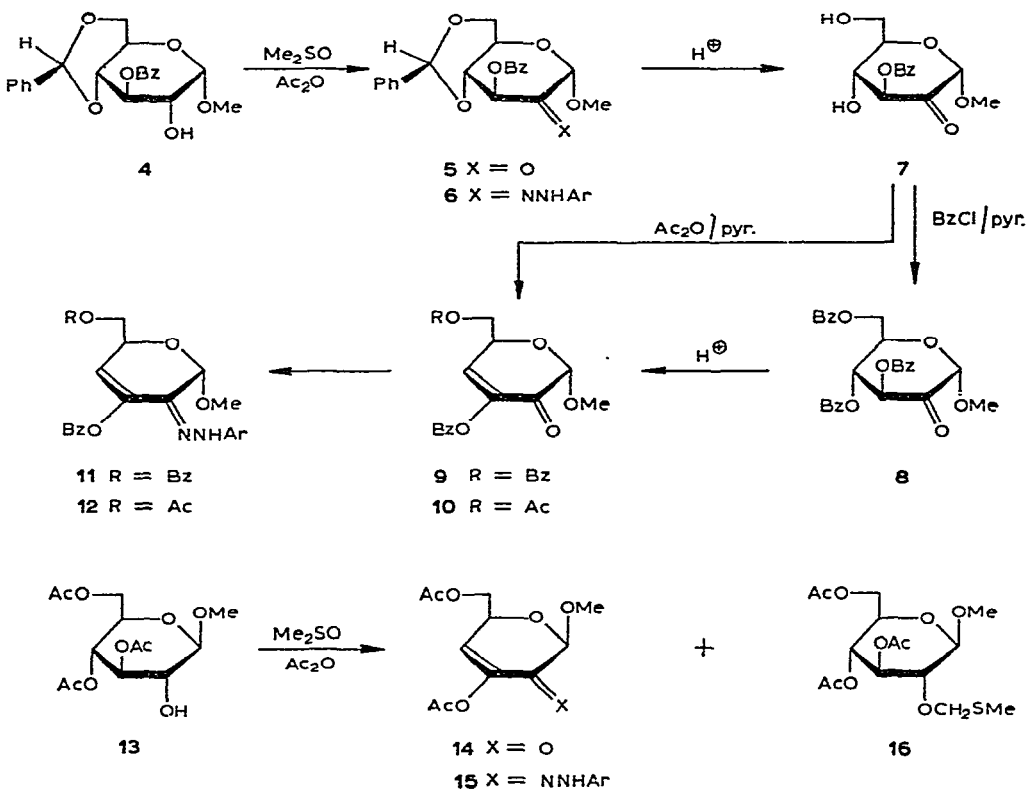
For **1b**, *i.e.*, glycosides of hexosuloses, the first elimination step to the respective enolones **2b** occurs as readily under mild conditions, *e.g.*, on silica gel chromatography[7], under the conditions of acetylation[8,9] or of methyl sulfoxide oxidation[5,10,11], or thermally during g.l.c.[12]. The enolone → kojic acid conversion (**2b** → **3b**), however, requires more-rigorous conditions than in the ulose series, undoubtedly due to the presence of a poor leaving-group at the anomeric carbon, thus making 3,2-enolones of type **2b** interesting substrates for probing γ-pyrone formation. Accordingly, in addition to an efficient, stepwise preparation of some 3,2-enolones from readily accessible educts, an assessment of the conditions required for γ-pyrone formation is now presented, together with the mechanistic implications.

RESULTS AND DISCUSSION

When methyl 3-*O*-benzoyl-4,6-*O*-benzylidene-α-D-glucopyranoside (**4**), readily available from its 2-benzoate[13] by alkali-induced 2-*O*→3-*O*-benzoyl migration, was treated with methyl sulfoxide–acetic anhydride, oxidation proceeded smoothly to give, on aqueous work-up, crystalline methyl 3-*O*-benzoyl-4,6-*O*-benzylidene-α-D-*arabino*-hexopyranosidulose (**5**) in 81% yield. The structure of **5** clearly followed from the n.m.r. data (a singlet for the anomeric proton at δ 4.61 as compared to a 3.5-Hz doublet at δ 4.81 for H-1 in the precursor **4**), and from the formation of a 2,4-dinitrophenylhydrazone (**6**). Debenzylidenation was conveniently effected by treatment with 9:1 trifluoroacetic acid–water[14], yielding the hexosidulose **7**. Under mild conditions of benzoylation, *i.e.*, benzoyl chloride–pyridine in tetrahydrofuran, **7** was readily converted into methyl 3,4,6-tri-*O*-benzoyl-α-D-*arabino*-hexopyranosidulose (**8**, 83%), the physical data of which (m.p., $[\alpha]_D$, and n.m.r. spectrum) correlated well with those reported for the product from oxidation of methyl 3,4,6-tri-*O*-benzoyl-α-D-glucopyranoside with ruthenium tetraoxide[7]. As noted previously[7], the hexosidulose **8** was very susceptible towards acidic treatment, resulting in β-elimination of benzoic acid to form the known[7,11] methyl 3,6-di-*O*-benzoyl-4-deoxy-α-D-*glycero*-hex-3-enopyranosidulose (**9**). Accordingly, trituration of the tribenzoate **8** with acetic acid (4 h, 25°), or, for example, with methyl sulfoxide–acetic acid (30 min, 25°), resulted in quantitative formation of the enolone **9** as evidenced by t.l.c. For preparative purposes, however, the conversion **8** → **9** was best performed by treating **8** in a gently refluxing suspension of silica gel in chloroform overnight, to afford **9** in 76% yield.

A similar, yet higher sensivity towards acid must be attributed to the 4,6-di-*O*-acetyl analog of **8**, which would be expected to arise on acetylation of the hexosidulose **7**. In fact, the product could not be isolated. Owing to the greater ease of displacement of an acetoxyl group at C-4, as compared to a C-4 benzoyloxy substituent as in **8**, the

acetylation conditions (acetic anhydride–pyridine in tetrahydrofuran) sufficed to eliminate acetic acid from the intermediate 4,6-diacetate to directly yield (73%) the 6-*O*-acetyl-enolone **10**. For analogous reasons, the methyl sulfoxide–acetic anhydride oxidation of methyl 3,4,6-tri-*O*-acetyl-β-D-glucopyranoside (**13**) could not be intercepted at the hexosidulose stage; instead, aside from some methylthiomethyl ether **16**, the 3,2-enolone **14** (characterized as the 2,4-dinitrophenylhydrazone **15**) was obtained.



The enolone structure for compounds **9**, **10**, and **14** was indicated by their ready conversion into the corresponding 2,4-dinitrophenylhydrazones; these exhibited large, positive, specific rotations in the α series (**11** and **12**), whereas the β anomer **15** had an equally high, negative rotation (*cf.* Table I). Although these high values are due to Cotton effects, the detailed pattern of which needs further evaluation, the present findings strongly suggest that the anomeric configuration of 3,2-enolones can be deduced from the rotational values of their 2,4-dinitrophenylhydrazones. Additional structural proof could be derived from the chemical shifts and the coupling

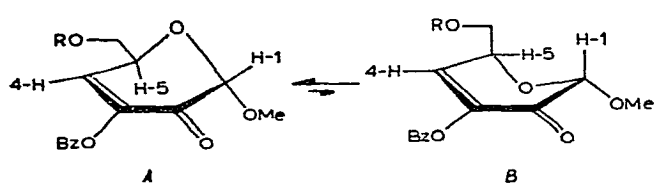
TABLE I

P.M.R.[a] AND OPTICAL ROTATION DATA FOR THE HEXENOPYRANOSIDULOSES **9**, **10**, AND **14**, AND THEIR 2,4-DINITROPHENYLHYDRAZONES **11**, **12**, AND **15**

Compound[b]	*H-1* (*s*)	*H-4* (*d*)	($J_{4,5}$)	*H-5* (*sx*)	*6-CH₂*[c]	*OMe*	*OAc*	$[\alpha]_D^{20}$ (c, *chloroform*)
9	4.98	6.88[d]	(2.0)	5.17	4.60	3.61	—	+33° (1.0)
10	4.96	6.77	(2.0)	5.01	4.37	3.59	2.09	+24° (0.8)
14	4.93	6.69	(3.3)	?	?	3.55	2.30 2.10	?
11	5.70	6.33	(2.0)	5.16	4.62	3.74	—	+390° (0.1)
12	5.67	6.23	(2.0)	4.99	4.38	3.74	2.12	+480° (0.1)
15	5.52	6.08	(3.3)	4.81	4.32	3.76	2.31 2.11	−592° (0.1)

[a]In $CDCl_3$: δ scale. [b]Benzoyl protons generally give a 2-proton multiplet at ~8.1 (*o*-protons) and a 3-proton multiplet centered at δ 7.6 p.p.m. (*m* and *p* protons); 2,4-dinitrophenylhydrazo residues give signals at ~11.5 (s, 1H, NH), 9.1 (d, 1H, *J* 2 Hz, H-3), 8.2 (dd, 1H, H-5) and 7.4 p.p.m. (dd, 1H, H-6), of which the latter two overlap with the benzoyl protons. [c]The expected octets for H-6 and H-6′ are usually only partially resolved. [d]Of the two values reported[7] for H-4 in CCl_4 (τ 3.09 and 3.27), the former seems to be more appropriate, as the CCl_4 and $CDCl_3$ data are then commensurable within 0.5 p.p.m. for all resonances.

patterns of the three ring-protons, comprising a singlet for H-1, a sextet for H-5, and, most characteristically, a doublet (*J* 2 Hz for the α anomers **9** and **10**, and 3.3 Hz for **14**) for the olefinic proton (H-4), in accord with previous data on other 3,2-enolones[1,2]. The value of 2 Hz for $J_{4,5}$ for the α anomers is consistent with the adoption of a sofa conformation[15] *A* with H-5 perpendicular to the ring, rather than the alternative form *B*, whereas the somewhat larger values for the β anomer (3.3 Hz) indicate some deviation from the ideal sofa form *A* towards the alternative conformation.



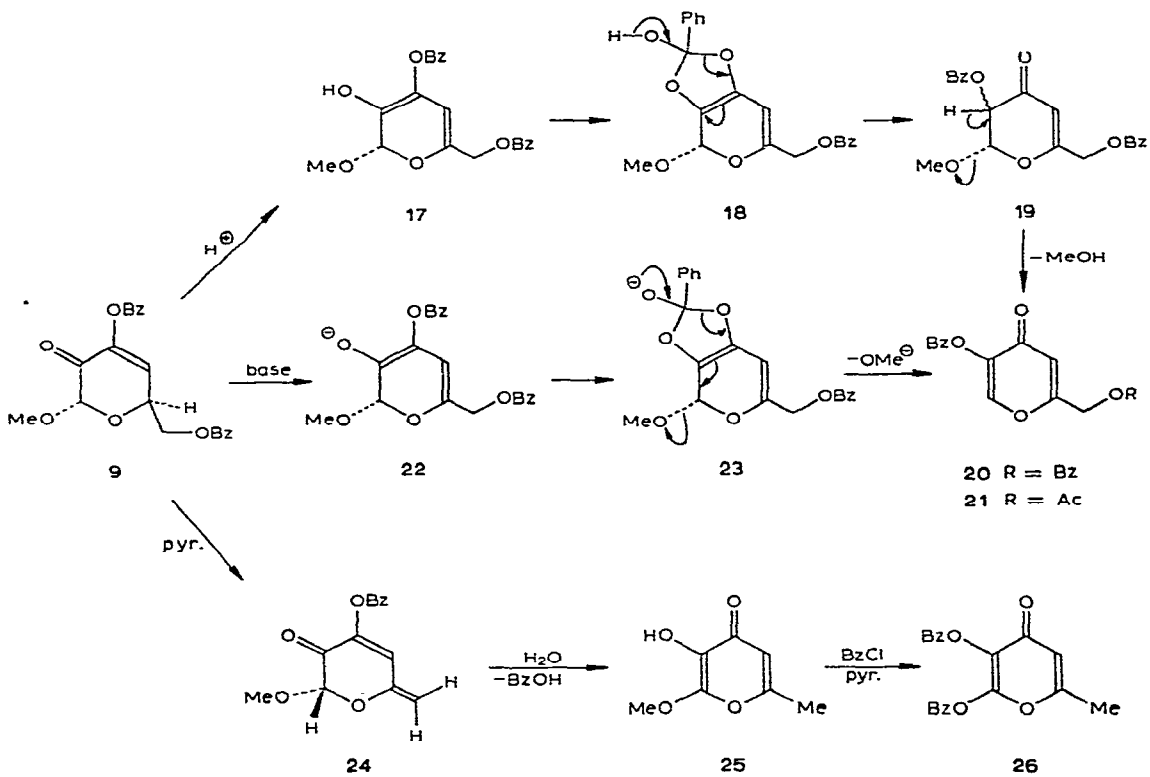
γ-Pyrone formation. — The enolones **9**, **10**, and **14** are remarkably insensitive towards acidic conditions, *e.g.*, no changes in rotation and on t.l.c. were observed in absolute trifluoroacetic acid or 2M methanolic hydrochloric acid during 4 h at room temperature. Strong, aqueous acids, such as 4M hydrochloric acid, slowly induce γ-pyrone formation from the enolones **9**, **10**, and **14** on warming (40°), to give mixtures of kojic acid and the corresponding 7-*O*-acyl and 5,7-di-*O*-acyl derivatives. Very clean conversions are effected by heating with sodium acetate in acetic acid or in acetic

anhydride (10 min, 100°), resulting in the exclusive formation of the corresponding di-*O*-acylkojic acids, *i.e.*, the dibenzoate **20** from **9**, its 7-*O*-acetyl-5-*O*-benzoyl derivative **21** from **10**, and kojic acid diacetate from **14**.

On exposure of enolones **9** and **10** to methanolic sodium methoxide, *O*-deacylation is effected to give products that have not yet been identified; kojic acid or its derivatives were not detectable in the reaction mixture. Under milder basic conditions, *i.e.*, 0.5M piperidine in chloroform or in ethanol at room temperature, **9** and **10** are slowly transformed into mixtures of the respective di-*O*-acyl- and 7-*O*-acylkojic acids; ~50% conversion was achieved after 24 h.

Mechanistically, the base-induced enolone→γ-pyrone conversions can be rationalized on the basis that abstraction of the acidic proton vinylogous to the carbonyl group is the initial step, the resulting carbanion being delocalized to form enolate **22**. This is followed by intramolecular O-3→O-2 benzoyl migration *via* an enediol–orthoacid intermediate **23** which is subsequently stabilized by expulsion of the anomeric substituent.

For the comparatively slow, acid-catalyzed γ-pyrone-conversions of enolones **9**, **10**, and **14**, a vinylogous enolization of the type **9**→**17**, presumably initiated by protonation of the carbonyl group, appears to be the only way to abstract the proton at C-5 and is apt to proceed much less easily than the corresponding base-catalyzed



enolization **9**→**23**. Thus, the formation of diacylkojic acids as well as the relative stability of the enolones towards acidic conditions are readily accounted for. The enol **17**, once formed, is then subject to acyl migration to give a 5,6-dihydropyranone (**17**→**18**→**19**), understandably not isolable under the strongly acidic conditions, from which **20** originates *via* elimination of methanol.

Unexpectedly, on treatment of enolone **9** in pyridine at room temperature (24 h), an entirely different reaction pathway is followed, namely, elimination of the terminal benzoyloxy group with the formation of an ~2:1 mixture of dienone-intermediate **24** and another product alongside some minor components. Evidence for the presence of **24** was clearly deducible from a p.m.r. spectrum of **9** in pyridine-d_5 after 24 h; this exhibited a singlet at δ 5.36 (anomeric H) and two 2-Hz doublets at 5.20 and 5.01 (exomethylene protons), whilst the enolone signals (3.5-Hz doublet at δ 7.30 for H-4, singlet at 5.31 for H-1) had disappeared. The presence of a second major component was indicated by another set of signals, namely, two 4-Hz doublets at δ 5.85 and 6.38 and two multiplets at 5.97 and 5.15, each of equal intensity, which may arise from the enol-form of **24**, but may also be due to an open-chain compound. Both products are stable in pyridine solution. On addition of water, however, or on conducting the entire reaction in pyridine–piperidine (100:1), methoxy-allomaltol **25** is formed together with substantial proportions of as yet unidentified, highly polar products that conceivably originate from ring-opening and/or loss of the methoxyl group. Thus, the yield on **25**, readily characterized by p.m.r. and mass-spectral data, was rather modest (25%). That the methoxyl group in **25** is indeed very susceptible towards replacement is exemplified by its benzoylation: treatment with benzoyl chloride–pyridine at room temperature left **25** unaffected, whilst short heating (50°) afforded the dibenzoate **26** rather than the expected monobenzoyl derivative of **25**. Further reactions of **25**, *e.g.*, formation of pyridine derivatives on treatment with liquid ammonia, will be reported elsewhere.

EXPERIMENTAL

Melting points were determined on a Bock Monoskop and are uncorrected. Spectral measurements were effected with Perkin–Elmer 125 (i.r.), Perkin–Elmer 141 (rotations), and Varian A-60A (p.m.r.) instruments. T.l.c. was performed on Kieselgel F_{254} (Merck), and used to monitor the reactions and to ascertain the purity of the products, using *A* chloroform–ethyl acetate (1:1), *B* chloroform–ethyl acetate (5:1), *C* dichloromethane–ethyl acetate (20:1), and detection with u.v. light or by charring with sulphuric acid. Column chromatography was carried out on Kieselgel 60 (70–230 mesh, Merck).

*Methyl 3-O-benzoyl-4,6-O-benzylidene-α-*D*-arabino-hexopyranosidulose* (**5**). — A solution of 3.9 g (10 mmol) of methyl 3-*O*-benzoyl-4,6-*O*-benzylidene-α-D-gluco-pyranoside[13] (**4**) in methyl sulphoxide (30 ml) and acetic anhydride (20 ml) was kept at ambient temperature for 24 h. After dilution of the reaction mixture with 100 ml of chloroform, water (100 ml) was added with vigorous stirring (45 min), and the

organic layer was separated, dried (Na_2SO_4), and concentrated *in vacuo*. Water (2 × 20 ml) was twice evaporated from the residue, which was then recrystallized from hexane–ethanol (1:3) to give **5** (3.2 g, 81%) as colourless prisms, m.p. 114–116°, $[\alpha]_D^{20}$ −8° (*c* 0.9, chloroform). P.m.r. data (Me_2SO-d_6): δ 8.08 and 7.50 (2 m, 2 H and 8 H, 2 Ph), 5.93 (d, 1 H, $J_{3,4}$ 9 Hz, H-3), 5.88 (s, 1 H, PhC*H*), 5.04 (s, 1 H, H-1), 4.5–3.9 (complex m, 4 H, H-4,5,6,6'), 3.53 (s, 3 H, OMe).

Anal. Calc. for $C_{21}H_{20}O_7 \cdot H_2O$: C, 62.68; H, 5.51. Found: C, 63.50; H, 5.55.

Methyl 3-O-benzoyl-4,6-O-benzylidene-α-D-arabino-hexopyranosidulose 2,4-dinitrophenylhydrazone (**6**). — A mixture of an ethanolic solution of **5** (200 mg in 5 ml) with 8 ml of 0.1M 2,4-dinitrophenylhydrazine in phosphoric acid–ethanol[16] was kept for 2–3 h at ambient temperature. The product was collected, and recrystallized from ethyl acetate to give **6** (110 mg, 35%) as yellow needles, m.p. 228°, $[\alpha]_D^{20}$ +132° (*c* 0.1, chloroform). P.m.r. data ($CDCl_3$): δ 11.45 (s, 1 H, NH), 10.08 (d, 1 H, *J* 2 Hz, H-3'), 8.30 (dd, 1 H, H-5'), 8.1–7.3 (broad m, 11 H, 2 Ph, H-6'), 6.15 (m, 1 H, H-3), 5.66 (s, 1 H, PhC*H*), 5.54 (s, 1 H, H-1), 4.6–3.8 (m, 4 H, H-4,5,6,6'), 3.69 (s, 3 H, OMe).

Anal. Calc. for $C_{27}H_{24}N_4O_{10}$: C, 57.44; H, 4.28; N, 9.93. Found: C, 57.20; H, 4.34; N, 9.85.

Methyl 3-O-benzoyl-α-D-arabino-hexopyranosidulose (**7**). — To a solution of **5** (1 g, 2.6 mmol) in anhydrous trifluoroacetic acid (9 ml), 1 ml of water was added. After 30 min at room temperature, the mixture was concentrated *in vacuo*, and water was repeatedly evaporated from the residue which was then triturated with dichloromethane to give **7** (0.7 g, 89%) as fine platelets, m.p. 64°, $[\alpha]_D^{20}$ +46° (*c* 0.8, chloroform). P.m.r. data (Me_2SO-d_6): δ 8.10 and 7.65 (2 m, 2 H and 3 H, Ph), 5.65 (m, 1 H, H-3), 4.88 (s, 1 H, H-1), 4.70 (broad m, 4 H, 2 OH and H_2O of crystallization; the signal disappears on addition of trifluoroacetic acid), 3.48 (s, 3 H, OMe).

Anal. Calc. for $C_{14}H_{16}O_7 \cdot H_2O$: C, 53.50; H, 5.77. Found: C, 53.70; H, 5.74.

Methyl 3,4,6-tri-O-benzoyl-α-D-arabino-hexopyranosidulose (**8**). — Benzoyl chloride (0.6 ml, 7 mmol) was added to a solution of **5** (850 mg, 2.7 mmol) in tetrahydrofuran (10 ml) containing 0.6 ml of pyridine, and the mixture was kept at room temperature for 40 min. The solution was filtered, and concentrated *in vacuo* to a yellowish syrup which was eluted from a column of neutral aluminium oxide with chloroform–ethyl acetate (1:1). Concentration of the appropriate fractions and trituration of the residue with methanol afforded **8** (1.13 g, 83%) as prismatic needles, m.p. 150–151°, $[\alpha]_D^{22}$ +53° (*c* 0.8, chloroform); lit.[7] m.p. 150–151°, $[\alpha]_D$ +52.7°. P.m.r. data ($CDCl_3$): δ 8.10 and 7.50 (2 m, 2 H and 3 H, Ph), 5.95 (d, 1 H, $J_{3,4}$ 9 Hz, H-3), 4.82 (s, 1 H, H-1), 4.70 (m, 2 H, 6-CH_2), 4.30 (m, 2 H, H-4,5), 3.51 (s, 3 H, OMe).

Methyl 3,6-di-O-benzoyl-4-deoxy-α-D-glycero-hex-3-enopyranosidulose (**9**). — A solution of **8** (600 mg, 1.2 mmol) in acetic acid (20 ml) was kept at room temperature for 4 h, and then diluted with water (60 ml). The syrup which separated slowly crystallized. Recrystallization from water–methanol (2:1) and, subsequently, from

light petroleum (b.p. 50–70°) afforded **9** (210 mg, 61%) as matted needles, m.p. 124–125° alone or in admixture with a sample prepared *via* an alternate route[11], $[\alpha]_D^{22}$ +33° (*c* 0.6, chloroform). C.d. data (methanol): 235 nm ($\Delta\varepsilon$ −5.9), 336 (−0.80). P.m.r. data are given in Table I. The rotation (−13°, chloroform) given previously[11] for the product prepared by methyl sulphoxide–acetic anhydride oxidation of methyl 3,4,6-tri-*O*-benzoyl-α-D-glucopyranoside is erroneous.

On stirring **8** with a suspension of silica gel in chloroform at room temperature, or on elution from a column of silica gel (30 g, Merck Kieselgel 60, 70–230 mesh, 100 mg of **8**) with 4:1 dichloromethane–ethyl acetate (conditions which previously were found effective to convert **8** into **9**[7]), mixtures of **8** and **9** resulted due to only partial elimination of benzoic acid. This difference in behaviour must be due to differences in the respective silica gels used.

*Methyl 3,6-di-*O*-benzoyl-4-deoxy-α-*D*-glycero-hex-3-enopyranosidulose 2,4-dinitrophenylhydrazone* (**11**). — To a solution of **9** (200 mg, 0.52 mmol) in ethanol (4 ml) was added 8 ml of a 0.1M solution of 2,4-dinitrophenylhydrazine in phosphoric acid–ethanol[16], and the mixture was kept at room temperature for 2 h. The yellow precipitate was collected and recrystallized from ethyl acetate to give **11** (180 mg, 63%) as yellow needles, m.p. 233–234°, $[\alpha]_D^{20}$ +390° (*c* 0.1, chloroform).

Anal. Calc. for $C_{27}H_{22}N_4O_{10}$: C, 57.65; H, 3.94; N, 9.96. Found: C, 57.55; H, 3.84; N, 10.01.

*Methyl 6-*O*-acetyl-3-*O*-benzoyl-4-deoxy-α-*D*-glycero-hex-3-enopyranosidulose* (**10**). — Acetic anhydride (0.65 ml) and pyridine (0.6 ml) were added with cooling to a solution of **7** (1.0 g, 3.3 mmol) in tetrahydrofuran (10 ml), and the mixture was kept at ambient temperature for 2 h. Concentration *in vacuo* then left a yellow syrup, a solution of which in a little chloroform was treated with activated carbon and then applied to a column (50×4 cm) of silica gel. Elution with 1:1 chloroform–ethyl acetate and concentration of the appropriate fractions *in vacuo* (finally 0.1 mmHg) yielded **10** (770 mg, 73%) as a homogeneous syrup (t.l.c.; R_F 0.53, solvent *B*), $[\alpha]_D^{20}$ +24° (*c* 0.8, chloroform).

Anal. Calc. for $C_{15}H_{16}O_7$: C, 58.44; H, 5.23. Found: C, 58.26; H, 5.09.

*Methyl 6-*O*-acetyl-3-*O*-benzoyl-4-deoxy-α-*D*-glycero-hex-3-enopyranosidulose 2,4-dinitrophenylhydrazone* (**12**). — Treatment of **10** with 2,4-dinitrophenylhydrazine, as described above for **11**, afforded **12** (54%) as yellow needles, m.p. 176°, $[\alpha]_D^{20}$ +480° (*c* 0.1, chloroform).

Anal. Calc. for $C_{22}H_{20}N_4O_{10}$: C, 52.80; H, 4.03; N, 11.20. Found: C, 52.64; H, 3.91; N, 11.10.

*Methyl sulphoxide–acetic anhydride oxidation of methyl 3,4,6-tri-*O*-acetyl-β-*D*-glucopyranoside* (**13**). — A solution of **13**[17] (1 g, 3.1 mmol) in methyl sulphoxide (10 ml) and acetic anhydride (3 ml) was kept at ambient temperature for 16 h. The mixture was then diluted with chloroform (30 ml), thoroughly washed with ice–water (5×10 ml), dried ($NaSO_4$), and concentrated to dryness. Benzene was repeatedly evaporated from the residue. The resulting, yellowish syrup (*A*) consisted (t.l.c. and

p.m.r.) of a ~2:1 mixture of the enolone **14** (p.m.r. data, *cf.* Table I) and the methylthiomethyl ether **16** that could not be satisfactorily separated by elution from a column of silica gel with 5:1 chloroform–methanol. Attempts to reproduce earlier findings[5], *i.e.*, to isolate a product of m.p. 139–142°, were unsuccessful. To a solution of syrup *A* in 10 ml of ethanol, a 0.1M solution of 2,4-dinitrophenylhydrazine in phosphoric acid–ethanol[16] was added. After 2 h, the precipitate was collected and recrystallized from ethanol to give methyl 3,6-di-*O*-acetyl-4-deoxy-α-D-*glycero*-hex-3-enopyranosidulose 2,4-dinitrophenylhydrazone (**15**) (410 mg, 30%), m.p. 165–166°, $[\alpha]_D^{20}$ −592° (*c* 0.1, chloroform).

Anal. Calc. for $C_{17}H_{18}N_4O_{10}$: C, 46.58; H, 4.14; N, 12.78. Found: C, 46.57; H, 4.23; N, 11.73.

Syrup *A*, when triturated with water, gave a solid product, which was collected and recrystallized from ethanol to afford methyl 3,4,6-tri-*O*-acetyl-2-*O*-methylthiomethyl-β-D-glucopyranoside (**16**; 0.4 g, 32%) as shiny needles, m.p. 108–109°, $[\alpha]_D^{20}$ +81° (*c* 1, chloroform). P.m.r. data ($CDCl_3$): δ 4.80 (s, 2 H, OCH_2S), 4.38 (d, 1 H, $J_{1,2}$ 7 Hz, H-1), 3.65 (s, 3 H, OMe), 2.10, 2.07, 2.05, and 2.01 (4 s, 12 H, SMe and 3 AcO).

Anal. Calc. for $C_{15}H_{24}O_9S$: C, 47.36; H, 6.36; S, 8.43. Found: C, 47.76; H, 6.31; S, 8.44.

*2-Acetoxymethyl-5-benzoyloxy-4*H*-pyran-4-one* (*7-O-acetyl-5-O-benzoylkojic acid*) (**21**). — A mixture of **10** (310 mg, 1 mmol), freshly fused sodium acetate (0.5 g), and glacial acetic acid (2 ml) was heated for 30 min at 100°, then cooled, and stirred into ice-water. A solution of the oily product in chloroform was washed with water three times, dried, and purified by elution from a column (2 × 10 cm) of silica gel with chloroform–ethyl acetate (1:1). Concentration of the eluate afforded **21** (190 mg, 65%) as colourless platelets, m.p. 143°; lit.[18] m.p. 143–144°. P.m.r. data ($CDCl_3$): δ 8.04 (s, 1 H, H-6), 6.57 (s, 1 H, H-3), 4.60 (s, 2 H, CH_2), 2.17 (s, 3 H, OAc).

Treatment of 7-*O*-acetylkojic acid[19] with benzoyl chloride–pyridine (30 min, 25°), with work-up as described above (without column chromatography), gave a product (80%) identical (m.p. and p.m.r. data) with **21**.

Treatment of **10** with 90% trifluoroacetic acid for 24 h at 40° gave a mixture of kojic acid (R_F 0.03, solvent *A*), 7-*O*-acetylkojic acid (R_F 0.25), and **21** (R_F 0.40).

*5-Benzoyloxy-2-benzoyloxymethyl-4*H*-pyran-4-one* (*di-O-benzoylkojic acid*) (**20**). — Heating a mixture of **9** (240 mg) with sodium acetate (400 mg) in acetic acid (2 ml) for 30 min at 100°, with processing of the resulting mixture as described for the conversion **10**→**21**, afforded **20** (160 mg, 72%), m.p. 134–135° alone and in admixture with an authentic[19] sample. P.m.r. data ($CDCl_3$): δ 8.60 (s, 1 H, H-6), 6.74 (s, 1 H, H-3), 5.32 (s, 2 H, CH_2). No other products were detectable in the reaction mixture (t.l.c., solvents *A*–*C*).

Similar results were obtained on brief heating with sodium acetate/acetic anhydride, whereas refluxing in acetic anhydride alone left **10** unaffected.

*3-Hydroxy-2-methoxy-6-methyl-4*H*-pyran-4-one* (*6-methoxyallomaltol*) (**25**). —

To a solution of **9** (1 g, 2.6 mmol) in pyridine (40 ml) was added 0.4 ml of piperidine, and the mixture was kept at room temperature for 12 h. T.l.c. (15:1 chloroform–methanol) then indicated the nearly complete conversion of **9** (R_F 0.71) into a mixture of **25** (R_F 0.27), and more polar, as yet unidentified, products (R_F 0.01). The yellow solution was concentrated with toluene (3 × 30 ml) to give a syrup which partially crystallized on trituration with toluene. The product was collected and recrystallized from ethanol to afford **25** (98 mg, 24%) as needles, m.p. 169°. P.m.r. data ($CDCl_3$): δ 6.16 (s, 1 H, H-5), 3.54 (s, 3 H, OMe), 2.26 (s, 3 H, 6-Me).

Anal. Calc. for $C_7H_8O_4$: C, 53.84; H, 5.16. Found: C, 53.78; H, 5.04.

On treatment with ferric chloride solution, **25** gives an intense violet color; this is also a sensitive method for its detection on t.l.c.

2,3-Bis-benzoyloxy-6-methyl-4H-pyran-4-one (5-O-benzoyl-6-benzoyloxyallomaltol) (**26**). — To a solution of **25** (100 mg) in pyridine (3 ml), benzoyl chloride (0.2 ml) was added with cooling. Since no reaction had occurred after 12 h at ambient temperature (t.l.c. in *C*), the mixture was kept at 50° for 1.5 h, resulting in an approximately 1:1 mixture of **26** (R_F ~0.7 in *C*) and a more polar product (R_F 0.03). Ice was added to the mixture followed by concentration to dryness at ~30° (bath)/1 mmHg, and toluene was repeatedly evaporated from the residue. The residue solidified on trituration with ethanol and was recrystallized from ethanol to give **26** (65 mg, 25%), as colourless crystals, m.p. 129–130°. P.m.r. data ($CDCl_3$): δ 8.1 and 7.6 (2 m, 4 H and 6 H, 2 Ph), 6.27 (d, 1 H, *J* 0.9 Hz, H-5), 2.28 (d, 3 H, Me).

Anal. Calc. for $C_{20}H_{14}O_6$: C, 68.57; H, 4.03. Found: C, 68.48; H, 4.12.

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