Carbohydrate Research, 127 (1984) 217–226
Elsevier Science Publishers B.V., Amsterdam – Printed in The Netherlands

STUDIES OF THE KNOEVENAGEL REACTION OF 2,5-ANHYDRO-3,4-*O*-ISOPROPYLIDENE-D-ARABINOSE

FIDEL JORGE LOPEZ HERRERA, MARIA VALPUESTA FERNANDEZ, AND RAFAEL GARCIA SEGURA
Department of Organic Chemistry, University of Málaga (Spain)
(Received July 25th, 1983; accepted for publication, October 24th, 1983)

ABSTRACT

The Knoevenagel reactions of 2,5-anhydro-3,4-*O*-isopropylidene-D-arabinose with methyl acetoacetate or 2,4-pentanedione were studied in connection with the further cyclisation of the reaction products to the spiro-glycosides (4*R*,5*R*,8*R*)-2,2-dimethyloxolano[4,3-*d*][1,3]dioxolane-5-spiro-2′-(4-methoxycarbonyl-5-methyl-2,3-dihydrofuran), (4*R*,5*S*,8*R*)-2,2-dimethyloxolano[4,3-*d*]-[1,3]dioxolane-5-spiro-2′-(4-methoxycarbonyl-5-methyl-2,3-dihydrofuran), and (4*R*,5*S*,8*R*)-2,2-dimethyloxolano[4,3-*d*][1,3]dioxolane-5-spiro-2′-(4-acetyl-5-methyl-2,3-dihydrofuran). A different *C*-glycoside, (4*R*,5*S*)-5-(2,3-*O*-isopropylidene-α-D-erythrofuranosyl)-4-methoxycarbonyl-3-methylcyclohex-2-en-1-one, results from the prolonged Knoevenagel reaction of **1** with 2 equiv. of methyl acetoacetate. Configurations and conformations have been assigned on the basis of ^{1}H-n.m.r. data.

INTRODUCTION

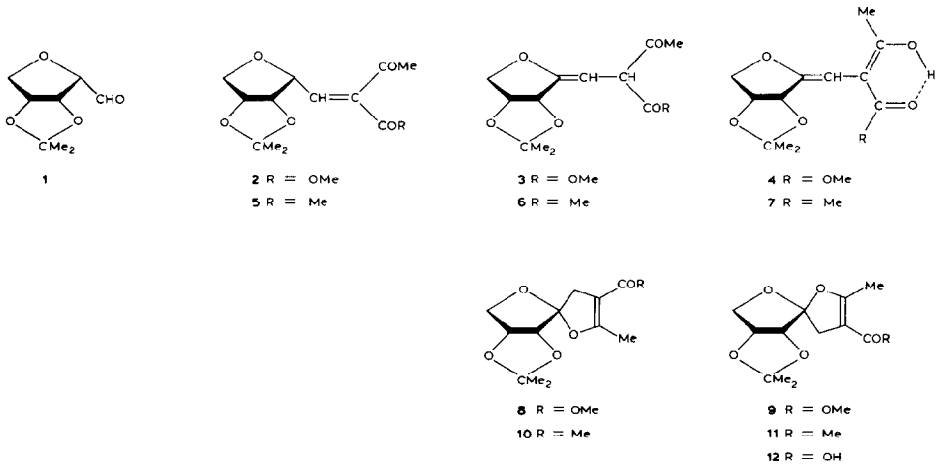
The Knoevenagel reaction of aldehydo sugars with active methylene compounds has been studied in connection with the syntheses of modified carbohydrates[1]. We have reported[2] several examples of this reaction on 2,3-*O*-isopropylidene-D-glyceraldehyde, including the first examples of spiro compounds resulting from the easy cyclisation of the normal reaction products (the α,β- and β,γ-unsaturated derivatives and the corresponding enols).

The reaction has been extended[3] to other aldehydo sugars, and we now report results with 2,5-anhydro-3,4-*O*-isopropylidene-D-arabinose[4] (**1**).

RESULTS AND DISCUSSION

The reaction of **1** with an equimolecular amount of methyl acetoacetate in the presence of piperidine as catalyst gave 63% of a mixture of the isomers **2**–**4**. ^{1}H-N.m.r. spectroscopy indicated this mixture to contain **2** (~25%), **3** (~60%), and **4** (~15%). The greater abundance of **3** may be explained by greater steric hindrance

0008-6215/84/$ 03.00



at the α face in **2**, which is lessened in **3** by formation of the exocyclic double-bond.

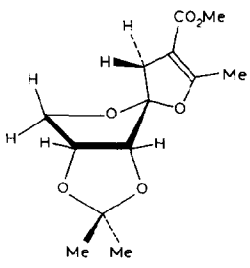
Similar reaction of **1** with 2,4-pentanedione gave the corresponding mixture **5–7**, but with a higher proportion of the enolic form **7** (~90%), probably because of minor steric hindrance of the exocyclic double-bond, as noted above, and the higher enolic character of β-diketones.

The outcome of the treatment of the mixture **2–4** with trifluoroacetic acid in carbon tetrachloride depended on the temperature and reaction time. Thus, for a reaction time of ~45 min at room temperature with 2% acid, the two isomers **8** and **9** were formed and isolated by column chromatography. Longer reaction times, higher temperatures, or higher concentrations of acid gave only the thermodynamic product **9**. Treatment of the kinetic product **8** with 0.01% acid effected almost quantitative isomerisation into **9** (g.l.c. analysis).

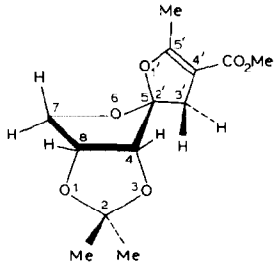
The configurations at the spiro-carbon (anomeric centre) in **8** and **9** were assigned tentatively on the basis of the following considerations. The quasi E_0 conformation reported[5] for several 2,3-*O*-isopropylideneglycofuranosyl *C*-glycosides having *endo* substituents at C-1 and/or C-4 suggests the same conformation for **8** and **9**. An E_0 conformation with the spiro-carbon slightly up can resemble the more stable conformer, as shown in **13** and **14**. The two hydrogens of the dihydrofuran methylene group of **14** have non-symmetrical environments, as reflected by the ^{1}H-n.m.r. data. The more polar isomer **13** (by t.l.c.) would be expected to have O-1′ *endo*, as in some α-D-ribofuranosides[6].

Greater differences in chemical shift between the signals for the isopropylidene methyl groups would be expected for **13** because of the deshielding effect of the *endo* O-1′ on the *endo*-methyl group, which accords with the ^{1}H-n.m.r. data. The higher thermodynamic stability of **9** (**14**) reflects the anomeric effect associated with glycosides having O-1,2 *trans*-diaxial.

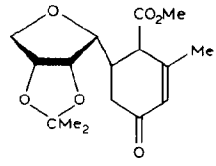
Likewise, treatment of the mixture **5–7** with trifluoroacetic acid in carbon tetrachloride yielded a single compound, which was characterised as (4*R*,5*S*,8*R*)-



13



14



15

2,2-dimethyloxolano[4,3-*d*][1,3]dioxolane-5-spiro-2′-(4-acetyl-5-methyl-2,3-dihydrofuran) (**11**); isomer **10** was not detected even under very mild conditions of reaction. The ^{1}H-n.m.r. spectrum of **11** was very similar to that of **9**; consequently, the same spiro configuration was assigned.

Basic hydrolysis of **9** gave the expected spiro-acid **12** in excellent yield, and its stability was consistent with an enolic derivative of a β-keto acid. The similarity of the ^{1}H-n.m.r. spectra of **9**, **11**, and **12** allowed the assignment of configuration to **12**, which was confirmed by the conversion of **11** into **12** by the haloform reaction.

When **1** was treated under Knoevenagel reaction conditions with 2 equiv. of methyl acetoacetate for a prolonged period, the main product was crystalline and the structure **15** was assigned by analogy with similar products[7] of the Knoevenagel reaction.

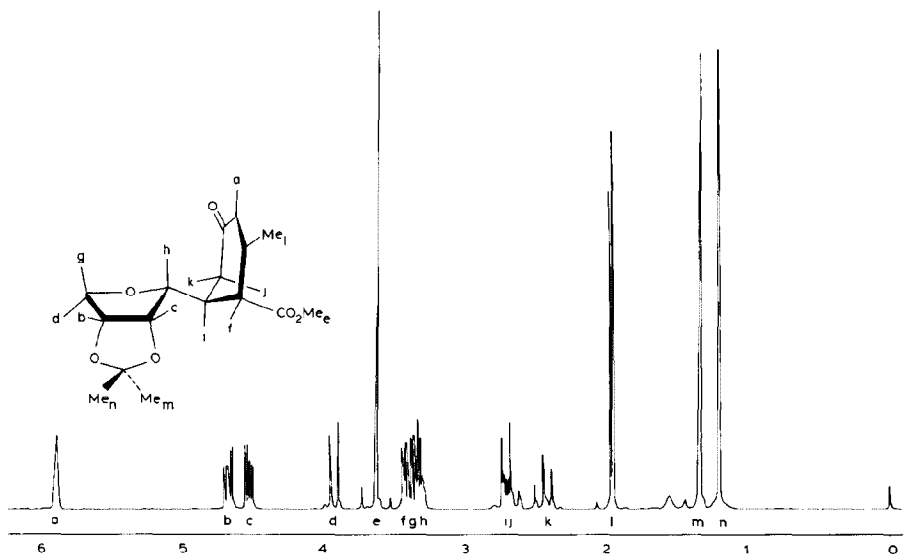


Fig. 1. 200-MHz, 1-D ^{1}H-N.m.r. spectrum of **15**: H_a = H-2, H_b = H-3′, H_c = H-2′, H_d = H-4′*endo*, H_e = OMe, H_f = H-4, H_g = H-4′*exo*, H_h = H-1′, H_i = H-5, H_j = H-6 *cis* to CO_2Me, H_k = H-6 *trans* to CO_2Me, H_l = Me-C=C, H_m *endo*-Me of CMe_2, H_n *exo*-Me of CMe_2.

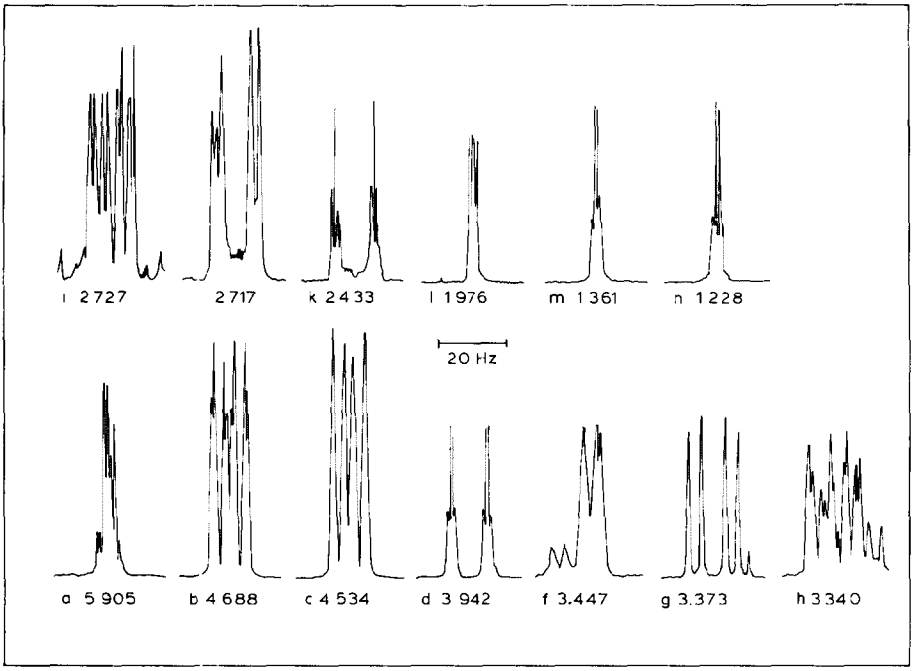


Fig. 2. 200-MHz, 2-D ^{1}H-n.m.r. data (WP-200SY) for **15**; J-resolved 2-D experiment.

The ^{1}H-1-D (Fig. 1) and ^{13}C-n.m.r. spectra of **15** confirmed the assigned structure as well as the configuration and conformation of the sugar moiety. The coupling constants $J_{1',2'}$ 3.5, $J_{2',3'}$ 6.25, $J_{3',4'endo}$ 0, and $J_{3',4'exo}$ 3.5 Hz are characteristic of a 2,3-*O*-isopropylidene-α-glycofuranosyl *C*-nucleoside derivative with a quasi E_0 conformation (C-2 slightly up) that lessens the interaction of the bulkier *endo*-aglycon group. The alternative ^0E conformation does not accord with the $J_{3',4'endo}$ value of 0 Hz, whereas the $J_{1',2'}$ value of 3.5 Hz is characteristic of α-^0E structures.

Configurational and conformational analysis of the aglycon was based on 200-MHz, J-resolved, 2-D (Fig. 2) and homonuclear, scalar-shift-correlated experiments (COSY, Fig. 3, and NOESY, Fig. 4). Fig. 2 shows the J-resolved cross-sections for the 13 multiplets present [methyl group (**e**) at 3.652 p.p.m. shows no coupling]; the multiplets **f**,**g**,**h**, and **i**,**j** were strongly overlapping in the normal 1-D spectrum (Fig. 1). The signal assignments were made by considering the shift correlations shown in Fig. 2, where several important correlations are labelled.

Several important points can be made about **15**. Numerous long-range couplings were detected which were not resolvable in the 1-D spectrum, for example, **a**–**l**, **f**–**l**, **f**–**i**, **f**–**k**, **h**–**k**, **h**–**f**, **i**–**h**, **i**–**k**, and **i**–**j**. Due to these couplings, the complexity of signals **a**–**l** is increased (Fig. 2). In the corresponding stacked plot of Fig. 3, a few weak correlations (**a**–**f**, **b**–**d**, **c**–**d**) can be seen that do not appear in the contour

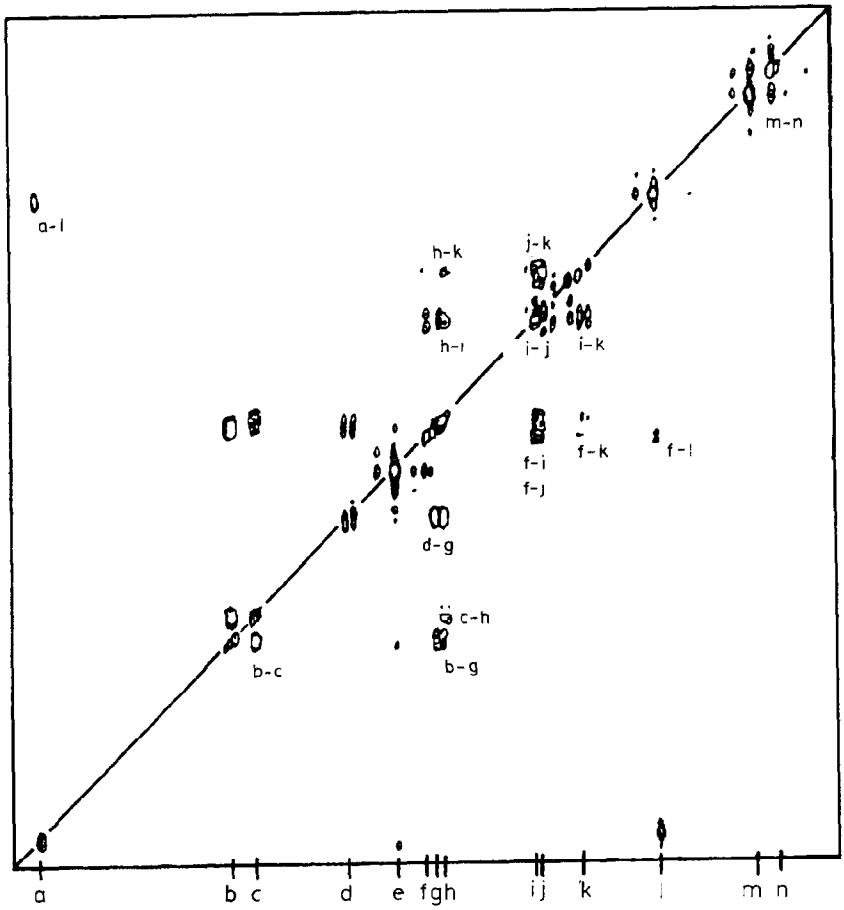
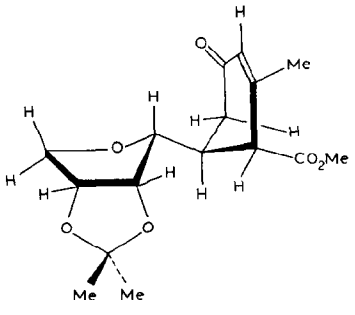
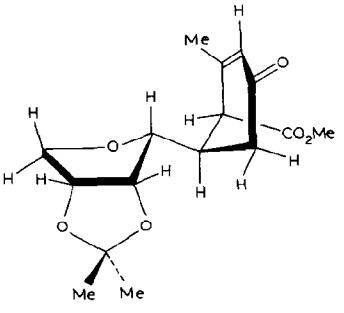


Fig. 3. Scalar shift-correlated experiment for **15** (COSY-90, N-type selection). Contour plot.



16



17

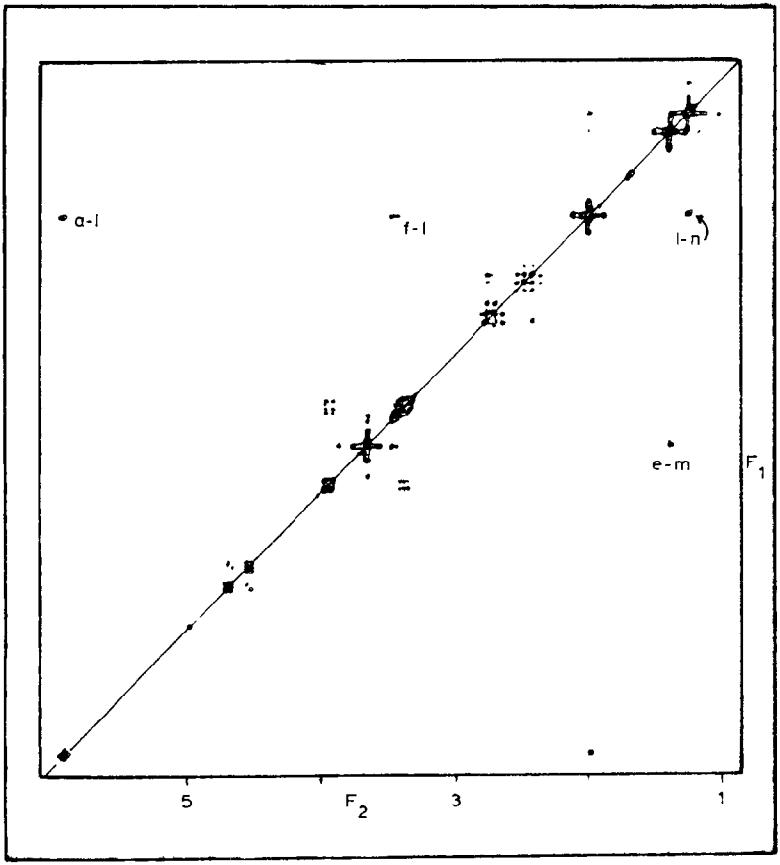


Fig. 4. Symmetry correlation of NOESY experiment for **15**, to remove F_1-noise and quad imperfections.

plot. These weak couplings can also be observed in Fig. 2. The methyl groups **m** and **n** are coupled and show distinguishable n.O.e. effects (Fig. 4), but their assignments are still tentative.

The configurations of the chiral centers C-4 and C-5 as well as the conformation in the cyclohex-2-en-1-one moiety in **15** result in a half-twist conformation, similar to that accepted for cyclohex-2-en-1-one, having C-1,2,3,4,6 in plane and C-5 out of plane. Taking into account the long-range coupling observed between **f** and **k** (suggesting W-geometry) and the absence of a $J_{5,6}$ *trans*-diaxial coupling constant, only two spatial representations (**16** and **17**) seemed to be logical, each of which has a *trans*-diaxial relationship at C-4,5. Structure **17** was rejected on the basis of the n.O.e. effects observed (Fig. 4) between **m** and **e**, and between **n** and **l**, which are compatible only with the absolute configuration **16** for the cyclohex-2-en-1-one moiety.

EXPERIMENTAL

General methods. — Melting points were determined with a Gallenkamp instrument and are uncorrected. Optical rotations were measured with a Perkin–Elmer 241 polarimeter, using a 1-dm standard cell. I.r. spectra were recorded with a Beckman Aculab 4 spectrophotometer. U.v. spectra were recorded with a Beckman DB-GT spectrophotometer. ^{1}H-N.m.r. spectra were recorded for solutions in CCl_4 or $CDCl_3$ (internal Me_4Si) with a Perkin–Elmer Hitachi R-24B (60 MHz) or Bruker WP-200SY (200 MHz) spectrometer. The ^{13}C-n.m.r. spectrum was recorded with a Bruker WP-200SY spectrometer. Chemical shifts are given on the δ scale, and coupling constants in Hz. The mass spectrum was recorded with a Kratos MS-25 spectrometer. Column chromatography was performed on Silica Gel 60 (0.063–0.200 mm) (Merck). T.l.c. was performed on Silica Gel GF_{254} (Merck) with detection by u.v. absorption or by charring with sulphuric acid. All evaporations were performed in a rotary evaporator under diminished pressure at 40°. G.l.c. was carried out on a Hewlett-Packard 5710A chromatograph equipped with a flame-ionisation detector and a stainless-steel column (50.0 cm × 3.0 mm i.d.) packed with 10% of UCW-982 on Chromosorb WAW-DMCS B 79 (80–100 mesh). The helium flow-rate was 30 mL/min, the injection-port temperature 250°, and the zone-detector temperature 300°.

*Piperidine-catalysed reaction of 2,5-anhydro-3,4-O-isopropylidene-*D*-arabinose* (**1**) *with methyl acetoacetate.* — When **1** (11.6 g, 67 mmol), methyl acetoacetate (7.83 g, 67.5 mmol), and piperidine (0.6 mL) were mixed, the temperature rose to 50°. The mixture was kept in the dark for 24 h, and then distilled to yield **1** (2.86 g), and a second fraction (11.36 g, 63%), b.p. 120–130°/0.2 Torr, which appeared to be a mixture of (*a*) the α,β-unsaturated ketoester **2** [^{1}H-n.m.r. data (CCl_4): δ 6.82, 6.68 (2 d, *J* 6 Hz, H-3 of *Z*- and *E*-isomers), 2.29, and 2.24 (2 s, MeCO of *Z*- and *E*-isomers)]; (*b*) the β,γ-unsaturated ketoester **3** [^{1}H-n.m.r. data: δ 2.15 and 2.10 (2 s, MeCO of *Z*- and *E*-isomers)]; and (*c*) the enol **4** [^{1}H-n.m.r. data: δ 12.5 (bs, OH), and 1.92 (s, Me-C=)].

The n.m.r. data indicated the mixture to contain **2** (25%), **3** (60%), and **4** (15%). It had ν_{max}^{film} 3300–3200, 2990, 2960, 1740, 1720, 1630, 1430, 1370, 1240, 1200, 1140, 1080, 1050, 980, 850, and 720 cm^{-1}.

Anal. Calc. for $C_{13}H_{18}O_6$: C, 57.77; H, 6.71. Found: C, 57.96; H, 6.89.

Piperidine-catalysed reaction of **1** *with pentane-2,4-dione.* — This reaction was performed as described above, starting from **1** (2.6 g, 15 mmol), pentane-2,4-dione (1.54 g, 13.5 mmol), and piperidine (0.25 mL), to give **1** (0.6 g, 23%) and a mixture of isomers **5**–**7** (1.6 g, 48.2% from unrecovered **1**), b.p. 130–140°/0.1 Torr. The n.m.r. data indicated **7** to be the principal product (>90%), which had ν_{max}^{film} 3400–3200, 2990, 2920, 1720, 1680, 1620, 1450, 1420, 1380, 1270, 1220, 1150, 1100, 1050, 990, 850, and 720 cm^{-1}. ^{1}H-N.m.r. data (CCl_4) for **7**: δ 16.2 (bs, OH), 5.30 (s, H-3), 2.05 (s, Me-C=), 1.98 (s, MeCO), 1.38, and 1.25 (2 s, Me_2C).

Anal. Calc. for $C_{13}H_{18}O_5$: C, 61.40; H, 7.14. Found: C, 61.65; H, 7.14.

*(4*R,*5*S,*8*R*)-2,2-Dimethyloxolano[4,3-*d][*1,3*]*dioxolane-5-spiro-2'-(4-methoxycarbonyl-5-methyl-2,3-dihydrofuran)* (**9**) *and its 5(*R*) epimer* (**8**). — A solution of the mixture **2**–**4** (2 g, 7.4 mmol) in CCl_4 (10 mL) and trifluoroacetic acid (0.2 mL) was kept at room temperature. After 45 min, t.l.c. (ethyl acetate–hexane, 1:3) revealed two products (R_F 0.4 and 0.6). The mixture was then washed with saturated, aqueous Na_2CO_3 (10 mL) and cold water (10 mL), dried (Na_2SO_4), filtered, and concentrated. Column chromatography (ethyl acetate–hexane, 1:4) of the residue on silica gel (150 g) gave **9** (0.588 g, 30%) and **8** (0.664 g, 34%).

Compound **8** had m.p. 52–54° (from ethyl acetate–hexane), $[\alpha]_D^{20}$ +20° (*c* 1, chloroform), R_F 0.4 (ethyl acetate–hexane, 1:3); λ_{max}^{EtOH} 245 nm (ε 26,000); ν_{max}^{film} 2990–2925, 2850, 1700, 1650, 1460, 1445, 1385, 1350, 1295, 1260, 1245, 1220, 1200, 1160, 1120, 1100, 1080, 1020, 980, 940, 900, 860, 800, 780, 760, and 680 cm^{-1}. ^{1}H-N.m.r. data (200 MHz, $CDCl_3$): δ 4.88 (ddd, 1 H, *J* 7, 5, and 3 Hz, H-8), 4.52 (d, 1 H, *J* 7 Hz, H-4), 4.20 (dd, 1 H, *J* 10.5 and 5 Hz, H-7), 4.10 (dd, 1 H, *J* 10.5 and 3 Hz, H-7'), 3.70 (s, 3 H, MeO), 3.01, 2.93 (2 dq, 2 H, *J* 16 and 2 Hz, CH_2-C=), 2.27 (t, 3 H, *J* 2 Hz, Me-C=), 1.60, and 1.37 (2 s, 6 H, Me_2C).

Anal. Calc. for $C_{13}H_{18}O_6$: C, 57.77; H, 6.71. Found: C, 58.19; H, 6.56.

Compound **9** had m.p. 72–74° (from hexane), $[\alpha]_D^{20}$ −150° (*c* 0.1, chloroform), R_F 0.6; λ_{max}^{MeOH} 245 nm (ε 16,000); ν_{max}^{KBr} 2950, 2900, 2850, 1700, 1650, 1460, 1440, 1380, 1330, 1310, 1280, 1270, 1230, 1210, 1190, 1160, 1135, 1100, 1090, 1065, 1045, 1000, 965, 930, 890, 865, 840, 820, 790, 765, 750, and 675 cm^{-1}. ^{1}H-N.m.r. data: δ 4.84 (ddd, 1 H, *J* 6, 3.5, and 1 Hz, H-8), 4.50 (d, 1 H, *J* 6 Hz, H-4), 3.96 (dm, 1 H, *J* 10 Hz, H-7*endo*), 3.90 (dd, 1 H, *J* 10 and 3.5 Hz, H-7*exo*), 3.63 (s, 3 H, MeO), 3.20 (dq, 1 H, *J* 16.5 and 2 Hz, H-3'*endo*), 2.78 (dq, 1 H, *J* 16.5 and 2 Hz, H-3'*exo*), 2.12 (t, 3 H, *J* 2 Hz, Me-C=), 1.40, and 1.27 (2 s, 6 H, Me_2C).

Anal. Found: C, 57.90; H, 6.78.

Treatment of the mixture **2**–**4** (3 g) with boiling CCl_4 (15 mL) and trifluoroacetic acid (0.3 mL) for 30 min afforded **9** (2 g, 67%; after recrystallisation from hexane).

A solution of **8** (2.16 mg) in CCl_4 (0.2 mL) was added to a solution (2 μL) of 1% trifluoroacetic acid in CCl_4, and the reaction was monitored by g.l.c. (oven temperature, 200°). After 42 min, practically complete epimerisation (99.8%) of **8** (*T* 2.78 min) into **9** (*T* 1.90 min) had occurred.

*(4*R,*5*S,*8*R*)-2,2-Dimethyloxolano[4,3-*d][*1,3*]*dioxolane-5-spiro-2'-(4-carboxy-5-methyl-2,3-dihydrofuran)* (**12**). — Aqueous 10% potassium hydroxide (4 mL) was added to a solution of **9** (0.5 g, 1.85 mmol) in ethanol (2 mL). After stirring for 50 h, t.l.c. (ethyl acetate–hexane, 1:2) showed the absence of **9**. The reaction mixture was then extracted with ether (2 × 3 mL), the aqueous layer was acidified (Congo Red) with 10% hydrochloric acid, and the resulting solid was collected, washed with cold water, and recrystallised from ethanol or ether, to give **12** (400 mg, 85%), m.p. 173–175°, $[\alpha]_D^{20}$ −177.5° (*c* 0.1, chloroform); λ_{max}^{EtOH} 243 nm (ε 26,000); ν_{max}^{KBr} 3400–3200, 2990, 2920, 2850, 2650, 2590, 1660, 1620, 1435, 1375, 1365, 1320, 1300, 1260, 1235, 1215, 1190, 1175, 1150, 1125, 1080, 1050, 1030, 990,

960, 945, 875, 850, 835, 805, 780, 765, 740, and 660 cm^{-1}. ^{1}H-N.m.r. data (60 MHz, $CDCl_3$): δ 11.20 (bs, 1 H, COOH), 4.80 (m, 1 H, H-8), 4,45 (d, 1 H, *J* 6 Hz, H-4), 3.90 (m, 2 H, H-7,7'), 3.25 (dq, 1 H, *J* 16 and 2 Hz, H-3'*endo*), 2.80 (dq, 1 H, *J* 16 and 2 Hz, H-3'*exo*), 2.14 (t, 3 H, *J* 2 Hz, Me-C=), 1.41, and 1.30 (2 s, 6 H, Me_2C).

Anal. Calc. for $C_{13}H_{16}O_6$: C, 56.24; H, 6.29. Found: C, 56.26; H, 6.30.

*(4*R*,5*S*,8*R*)-2,2-Dimethyloxolano[4,3-*d*][1,3]dioxolane-5-spiro-2'-(4-acetyl-5-methyl-2,3-dihydrofuran)* (**11**). — The mixture of **5**–**7** (2.7 g), CCl_4 (25 mL), and trifluoroacetic acid (0.5 mL) was boiled under reflux (45 min) and then washed with saturated, aqueous Na_2CO_3, dried (Na_2SO_4), and concentrated. The residue was purified by column chromatography (ethyl acetate–hexane, 1:4), to give syrupy **11** (1.05 g, 42%), $[\alpha]_D^{20}$ −157° (*c* 1, chloroform), R_F 0.42 (ethyl acetate–hexane, 1:2); λ_{max}^{EtOH} 265 nm (ε 26,000); ν_{max}^{film} 2990–2940, 2865, 2845, 1745, 1740, 1670, 1630, 1600, 1450, 1420, 1380, 1360, 1260, 1210, 1180, 1150, 1130, 1100, 1050, 1030, 1000, 960, 920, 880, 810, 785, 750, and 690 cm^{-1}. ^{1}H-N.m.r. data (60 MHz, CCl_4): δ 4.70 (m, 1 H, H-8), 4.40 (d, 1 H, *J* 5 Hz, H-4), 3.76 (m, 2 H, H-7,7'), 3.10 (dq, 1 H, *J* 15 and 2 Hz, H-3'*endo*), 2.70 (dq, 1 H, *J* 15 and 2 Hz, H-3'*exo*), 2.00 (s, 6 H, MeCO and Me-C=), 1.32, and 1.20 (2 s, 6 H, Me_2C).

Anal. Calc. for $C_{13}H_{18}O_5$: C, 61.41; H, 7.13. Found: C, 61.32; H, 7.01.

The 2,4-dinitrophenylhydrazone of **11** had m.p. 182° (from ethanol).

Anal. Calc. for $C_{19}H_{22}N_4O_8$: C, 52.54; H, 5.10; N, 12.89. Found: C, 52.54; H, 4.80; N, 12.88.

To a solution of **11** (100 mg) in 1,4-dioxane (5 mL) were added aqueous 10% sodium hydroxide (1 mL) and then a solution of iodine (1 g) and potassium iodide (2 g) in water (8 mL), dropwise, until the red colour persisted after 10 min at 60°. Aqueous 10% sodium hydroxide was then added to eliminate the excess of iodine. After removal of iodoform, the filtrate was neutralised with 10% hydrochloric acid and extracted with ether (2 × 10 mL). The combined extracts were washed with aqueous Na_2SO_3, dried, and concentrated, to give **12** (30 mg, 30%) (see above).

*(4*R*,5*S*)-5-(2,3-*O*-Isopropylidene-α-*D*-erythrofuranosyl)-4-methoxycarbonyl-3-methylcyclohex-2-en-1-one* (**15**). — A mixture of **1** (1 g, 5.78 mmol), methyl acetoacetate (1.35 g, 11.6 mmol), and piperidine (0.2 mL) was kept at room temperature for at least 4 weeks. Crystallisation occurred slowly. The product was purified by column chromatography (ethyl acetate–hexane, 1:3) on silica gel (100 g), to give **15** as white needles (1.6 g, 89.3%), m.p. 178–180° (from ethanol), $[\alpha]_D^{20}$ +184° (*c* 0.1, chloroform), R_F 0.2 (ethyl acetate–hexane, 1:1); λ_{max}^{EtOH} 235 nm (ε 17,800); ν_{max}^{KBr} 2980, 2955, 2920, 2845, 1725, 1710, 1440, 1380, 1265, 1210, 1170, 1100, 1080, 1060, 1045, 1015, 995, 945, 900, and 855 cm^{-1}. N.m.r. data: ^{1}H (200 MHz, $CDCl_3$), δ 5.905 (bs, 1 H, H-2), 4.688 (dd, 1 H, *J* 6.25 and 3.5 Hz, H-3'), 4.534 (dd, 1 H, *J* 6.25 and 3.5 Hz, H-2'), 3.942 (d, 1 H, *J* 10.5 Hz, H-4'*endo*), 3.652 (s, 3 H, MeO), 3.447 (bd, 1 H, *J* 4.0 Hz, H-4), 3.373 (dd, 1 H, *J* 10.5 and 3.5 Hz, H-4'*exo*), 3.340 (m, 1 H, H-1'), 2.727 (m, 1 H, H-5), 2.717 (m, 1 H, *J* 11.5 Hz, H-6 *cis* to COOMe), 2.433 (m, 1 H, *J* 11.5 Hz, H-6 *trans* to COOMe), 1.976 (d, 3 H,

J 1 Hz, Me-C=). 1.361 (s, 3 H, *endo*-Me of CMe_2), and 1.228 (s, 3 H, *exo*-Me of CMe_2); ^{13}C ($CDCl_3$), δ 197.7 (C-1), 170.8 (C=O of ester), 156.7 (C-3), 128.4 (C-2), 112.2 (O-C-O), 82.8, 80.9, 80.0, 73.0 (C-2′,3′,1′,4′), 52.1 (OMe), 47.4 (C-4), 36.5 (C-5), 34.9 (C-6), 26.0, 24.7 (Me of Me_2C), and 23.5 (Me on C-3). Mass spectrum: *m/z* 310 (M^+), 295 ($M^+ - Me$), 279 ($M^+ - OMe$), and 252 ($M^+ - CO_2Me + H$).

Anal. Calc. for $C_{16}H_{22}O_6$: C, 61.98; H, 7.15. Found: C, 61.80; H, 7.35.

ACKNOWLEDGMENTS

The authors thank Dr. W. E. Hull (Bruker Analytische Messtechnik GMBH) for recording the 200-MHz n.m.r. spectra and for helpful discussions.

REFERENCES

1 F. J. LOPEZ APARICIO, M. YRUELA ANTIÑOLO, AND F. GARCIA GONZALEZ, *An. R. Soc. Esp. Fis. Quim., Ser. B*, 54 (1953) 705–714; H. ZINNER, E. WITTEMBURG, AND G. REMBARZ, *Chem. Ber.*, 92 (1959) 1614–1617; N. K. KOCHETKOV AND B. I. DMITRIEV, *Chem. Ind. (London)*, (1962) 2147–2148; *Izv. Akad. Nauk SSSR, Ser. Khim.*, (1962) 1262–1263; F. MICHEEL AND W. MOELLER, *Justus Liebigs Ann. Chem.*, 670 (1963) 63–68; F. ALONSO CERMEÑO, A. M. GONZALEZ NOGAL, AND F. J. LOPEZ APARICIO, *An. R. Soc. Esp. Fis. Quim., Ser. B*, 68 (1972) 285–292; F. J. LOPEZ APARICIO, M. GOMEZ GUILLEN, AND I. IZQUIERDO CUBERO, *ibid.*, 72 (1976) 938–945; 73 (1977) 1168–1176.

2 F. J. LOPEZ APARICIO, F. J. LOPEZ HERRERA, AND J. SANCHEZ BALLESTEROS, *Carbohydr. Res.*, 69 (1979) 55–70; F. J. LOPEZ APARICIO AND F. J. LOPEZ HERRERA, *An. R. Soc. Esp. Fis. Quim., Ser. B*, 72 (1976) 931–937; F. J. LOPEZ APARICIO, I. IZQUIERDO CUBERO, AND M. D. PORTAL OLEA, *Carbohydr. Res.*, 115 (1983) 250–253.

3 F. J. LOPEZ HERRERA, *Tetrahedron Lett.*, (1980) 4963–4966.

4 A. B. FOSTER AND W. G. OVEREND, *J. Chem. Soc.*, (1951) 680–684; F. J. LOPEZ HERRERA, C. GOMEZ PEREZ, AND M. VALPUESTA FERNANDEZ, *An. Quim., Ser. C*, in press.

5 H. OHRUI AND S. EMOTO, *J. Org. Chem.*, 42 (1977) 1951–1957; F. J. LOPEZ HERRERA AND C. URAGA BAELO, submitted to *Carbohydr. Res.*

6 H. OHRUI, G. H. JONES, J. G. MOFFATT, M. L. MADDOX, A. T. CHRISTENSEN, AND S. K. BYRAM, *J. Am. Chem. Soc.*, 97 (1975) 4602–4613.

7 G. JONES, *Org. React*, 15 (1967) 249–254.