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# A comparative analysis of mono- and disaccharide benzyl fucopyranosides

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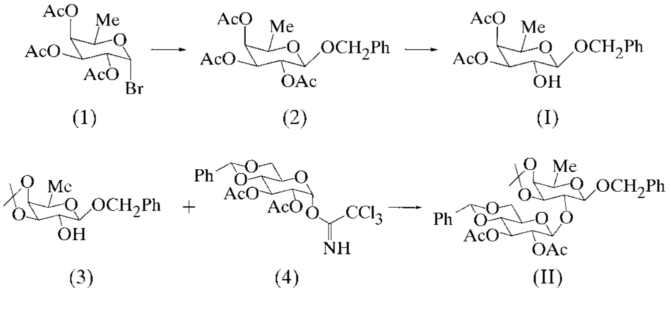
The syntheses and X-ray analyses of two fucopyranosides, the monosaccharide benzyl 3,4-di-*O*-acetyl-2-hydroxy-β-D-fucopyranoside, $C_{17}H_{22}O_7$, and the disaccharide 1-benzyl *O*-(2,3-di-*O*-acetyl-4,6-*O*-benzylidene-β-D-glucopyranosyl)-(1→2)-3,4-*O*-isopropylidene-β-D-fucopyranoside, $C_{33}H_{40}O_{12}$, are described. The different substituents induce small conformational changes on the fucopyranoside ring. However, the conformation of the benzyl group varies from (+)*gauche* for the monosaccharide to synperiplanar for the disaccharide.

## Comment

Fucose is an important deoxysugar found recently as a constituent unit of glycoresins from the genus *Ipomea* (Bah & Pereda-Miranda, 1997). These glycoresins, called tricolorins, have attracted much interest from biological and chemical points of view. As part of a strategy directed towards the synthesis of analogues of the corresponding glycosides, the syntheses and X-ray analyses of benzyl fucopyranoside, (I) (Fig. 1), and the closely related benzyl disaccharide, (II) (Fig. 2), have been performed and the results are presented here.



In both compounds, the pyranoside rings have a $^4C_1$ chair conformation, with all substituents oriented in equatorial positions, except for the substituent at position C4 of the glucopyranoside moiety, which exhibits an axial orientation. For compound (II), the equatorial orientation at position 3 in the fucopyranoside ring is frustrated by the formation of a five-membered ring. Therefore, a biaxial conformation is observed, with an angle of 53.9 (2)° between the C3—O3 bond and the Cremer–Pople plane, calculated according to Cremer & Pople (1975) and defined, in both compounds, by the atoms C1–C5 and O5.

The isopropylidene group also produces the significant deviation from the ideal $^4C_1$ chair conformation observed in the fucopyranoside ring of compound (II), as can be seen when comparing the puckering parameters (Cremer & Pople, 1975) of both fucopyranoside rings [$Q$ = 0.572 (2) Å, $\theta$ = 176.9 (2)° and $\varphi$ = 186 (3)° for (I), and $Q$ = 0.556 (3) Å, $\theta$ = 159.9 (3)° and $\varphi$ = 220.9 (8)° for (II)]. In compound (II), the effect of the benzylidene group on the glucopyranosil

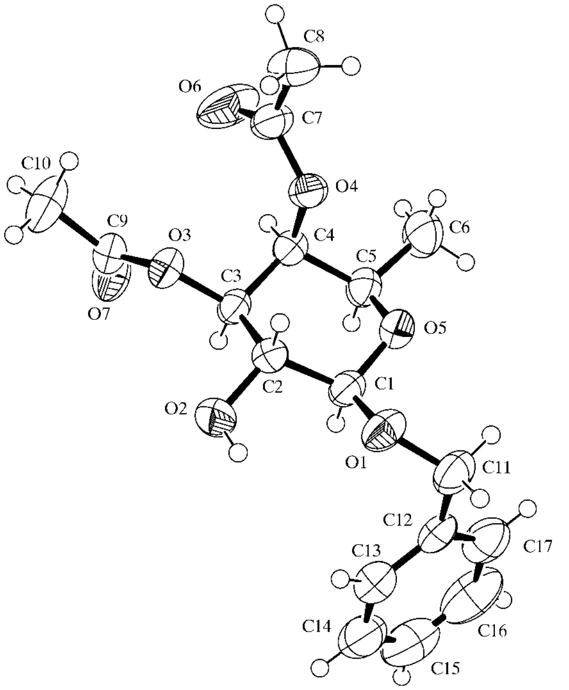


**Figure 1**
A view of the molecular structure of (I), showing 50% displacement ellipsoids and the atom-numbering scheme. H atoms are drawn as small spheres of arbitrary radii.

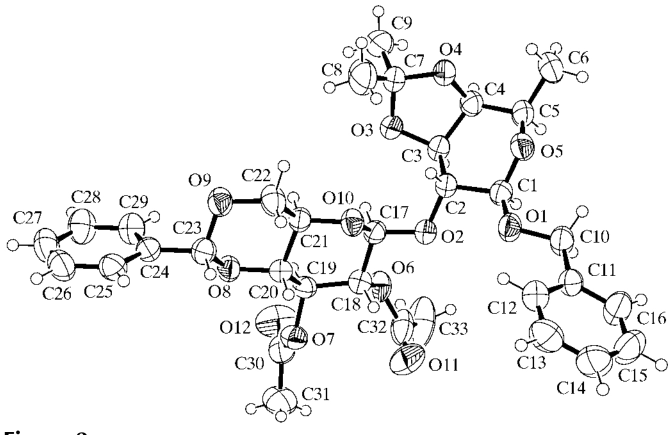


**Figure 2**
A view of the molecular structure of (II), showing 50% displacement ellipsoids and the atom-numbering scheme. H atoms are drawn as small spheres of arbitrary radii.

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conformation is smaller, and the ring defined by atoms O10 and C17–C21 is very close to the ideal $^4C_1$ chair conformation [$Q$ = 0.597 (3) Å, $\theta$ = 170.7 (3)° and $\varphi$ = 156.0 (16)°].

The angle between the glycosidic bond and the normal to the Cremer–Pople plane, calculated for both fucopyranoside rings, is 68.7 (1)° for (I) and 76.0 (2)° for (II). Due to the exoanomeric effect, the substituent on C1, in this case the benzyl group, should prefer a (+)*gauche* conformation (Jeffrey, 1990). This is the case in (I), as can be seen in the C12—C11—O1—C1 torsion angle, but not in (II), which shows a clear synperiplanar conformation, with atoms C1, O1, C10 and C11 in almost the same plane [largest deviation from the least-squares plane is 0.023 (1) Å for atom O1]. It is also noticeable that, for (I), the C5—O5, C1—O5 and C1—O1 bond distances (Table 1) are closer to the standard values for an axial glycosidic bond (1.434, 1.419 and 1.398 Å, respectively) than for an equatorial one (1.426, 1.428 and 1.385 Å, respectively) (Jeffrey & Taylor, 1980; Jeffrey, 1990). In (II), these bond distances (Table 3) do not correspond clearly to equatorial or axial cases.

In the disaccharide, (II), atoms O5, C1, C2, O2, C17, C18 and C19 are almost coplanar [largest deviation from the least squares plane is −0.109 (2) Å for C19]. Therefore, three atoms of each saccharide lie in the plane defined by the glycosidic linkage. For each pyranoside, the rest of the atoms lie on one side of this plane, the two rings being on opposite sides of the plane. For this reason, the O10—C17—O2—C2 torsion angle is almost equal to C3—C2—O2—C17. This conformation could be partly due to the weak hydrogen bond joining C17 in the glucopyranoside ring and O3 in the fucopyranoside moiety (Table 4).

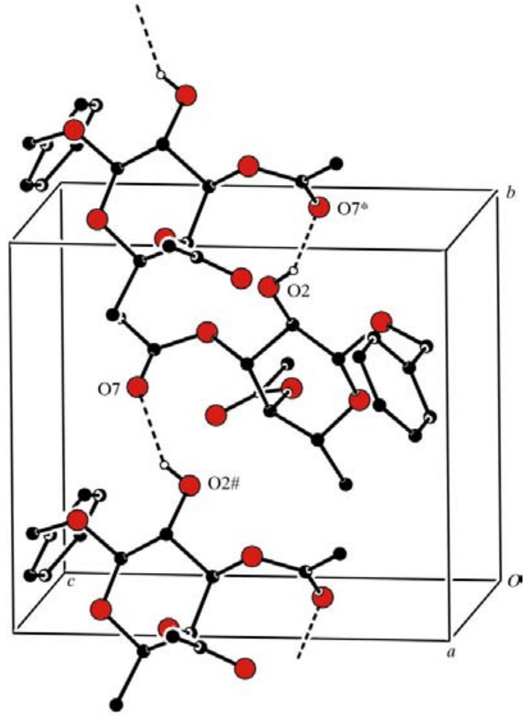

**Figure 3**
A drawing of the unit cell of (I), viewed along the *a* axis. Dashed lines indicate hydrogen bonds. Atom O7* is at symmetry position ($2 - x, y + \frac{1}{2}, 1 - z$) and atom O2# is at symmetry position ($2 - x, y - \frac{1}{2}, 1 - z$).

An O—H···O hydrogen bond is observed in (I) between the hydroxy group and one of the acetate O atoms (Table 2). Due to this intermolecular interaction, the molecules form chains along the *b* direction (Fig. 3). There are also weak C—H···O interactions involving the benzyl group as donor and the pyranoside group as acceptor, which join the chains along the *a* direction. For compound (II), there are no strong hydrogen-bond interactions, due to the absence of hydroxyl groups. The only significant intermolecular interaction is a weak C—H···O hydrogen bond (Table 4) joining the molecules in the *a* direction.

## Experimental

Compound (I) (see *Scheme*) was prepared using fucose (Lerner, 1993) as the starting material, which was peracetylated with acetic anhydride. Bromination of the anomeric C atom was performed using hydrobromic acid (30 wt%) in acetic acid to produce intermediate (1), which was subsequently reacted with benzyl alcohol under Koenigs–Knorr conditions to yield glycoside (2) (Igarashi, 1977). Deacetylation with sodium methoxide solution afforded a compound which was treated with two equivalents of acetic anhydride to produce (I). Spectroscopic analysis for (I), $^1$H NMR ($CDCl_3$, 300 MHz, $\delta$, p.p.m.): 1.3 (*d*, 3H), 2.0 and 2.2 (both *s*, 3H), 3.8 (*m*, 1H), 3.9 (*dd*, 1H), 4.4 (*d*, 1H), 4.6 (*d*, 1H), 4.95 (*dd*, 1H), 5.0 (*d*, 1H), 5.22 (*dd*, 1H), 7.4 (*m*, 5H). Compound (II) (see *Scheme*) was prepared under Fischer *O*-glycoside coupling-reaction conditions, by the reaction between fucose and benzyl alcohol under a controlled stream of HCl gas to produce benzyl fucose (Searle *et al.*, 1996). Acetonide formation was performed under standard conditions (acetone and 2,2-dimethoxypropane, with *p*-toluenesulfonic acid as catalyst), to afford the intermediate glycosyl acceptor, (3), which was coupled with 2,3-di-*O*-acetyl-4,6-*O*-benzylideneglucopyranosyl trichloroacetimidate, (4) (Larson & Heathcock, 1997), under silver triflate catalysis to generate the desired disaccharide, (II), in 50% yield. Spectroscopic analysis for (II), $^1$H NMR ($CDCl_3$, 300 MHz, $\delta$, p.p.m.): 1.3 (*s*, 3H), 1.4 (*d*, 3H), 1.5 (*s*, 3H), 2.0, 2.1 (*s*, 6H), 3.4 (*m*, 1H), 3.7 (*m*, 4H), 3.9 (*dd*, 1H), 4.0 (*m*, 2H), 4.3 (*d*, 1H), 4.6 (*d*, 1H), 4.9 (*t*, 2H), 5.0 (*t*, 1H), 5.4 (*s*, 1H), 7.3 (*m*, 10H).

### Compound (I)

*Crystal data*

$C_{17}H_{22}O_7$
$M_r$ = 338.36
Monoclinic, $P2_1$
$a$ = 8.735 (2) Å
$b$ = 9.526 (2) Å
$c$ = 10.605 (3) Å
$\beta$ = 91.00 (2)°
$V$ = 882.4 (5) Å$^3$
$Z$ = 2
$D_x$ = 1.273 Mg m$^{-3}$
Mo $K\alpha$ radiation
Cell parameters from 15 reflections
$\theta$ = 11.2–12.6°
$\mu$ = 0.10 mm$^{-1}$
$T$ = 293 (2) K
Prism, colourless
0.85 × 0.70 × 0.32 mm

*Data collection*

Enraf–Nonius CAD-4 diffractometer
Non-profiled $\omega/2\theta$ scans
Absorption correction: $\psi$ scan (North *et al.*, 1968)
$T_{\min}$ = 0.890, $T_{\max}$ = 0.965
2982 measured reflections
2820 independent reflections
2457 reflections with $I > 2\sigma(I)$
$R_{\rm int}$ = 0.017
$\theta_{\max}$ = 30.4°
$h = 0 \rightarrow 12$
$k = -13 \rightarrow 0$
$l = -15 \rightarrow 15$
3 standard reflections
frequency: 60 min
intensity decay: none

*Refinement*

Refinement on $F^2$
$R(F) = 0.040$
$wR(F^2) = 0.130$
$S = 1.09$
2820 reflections
221 parameters
H-atom parameters constrained
$w = 1/[\sigma^2(F_o^2) + (0.0964P)^2 + 0.0099P]$ where $P = (F_o^2 + 2F_c^2)/3$
$(\Delta/\sigma)_{\max} = 0.004$
$\Delta\rho_{\max} = 0.23$ e Å$^{-3}$
$\Delta\rho_{\min} = -0.16$ e Å$^{-3}$

**Table 1**
Selected geometric parameters (Å, °) for (I).

| | | | |
|---|---|---|---|
| C1—O1 | 1.394 (2) | C5—O5 | 1.434 (2) |
| C1—O5 | 1.411 (2) | | |
| | | | |
| O1—C1—O5 | 108.78 (13) | O5—C5—C4 | 109.90 (14) |
| O1—C1—C2 | 106.60 (14) | C1—O1—C11 | 114.44 (16) |
| O5—C1—C2 | 111.65 (12) | C1—O5—C5 | 111.84 (12) |
| | | | |
| O5—C1—C2—C3 | 57.13 (16) | C3—C4—C5—O5 | −55.72 (17) |
| C2—C3—C4—C5 | 53.06 (17) | C12—C11—O1—C1 | −62.4 (3) |

**Table 2**
Hydrogen-bonding geometry (Å, °) for (I).

| *D*—H···*A* | *D*—H | H···*A* | *D*···*A* | *D*—H···*A* |
|---|---|---|---|---|
| O2—H2*A*···O7$^{\rm i}$ | 0.82 | 2.14 | 2.878 (2) | 150 |
| C15—H15···O5$^{\rm ii}$ | 0.93 | 2.57 | 3.447 (3) | 158 |

Symmetry codes: (i) $2 - x, \frac{1}{2} + y, 1 - z$; (ii) $1 + x, y, z$.

## Compound (II)

*Crystal data*

$C_{33}H_{40}O_{12}$
$M_r = 628.65$
Orthorhombic, $P2_12_12_1$
$a = 8.901$ (1) Å
$b = 14.261$ (1) Å
$c = 25.583$ (1) Å
$V = 3247.4$ (4) Å$^3$
$Z = 4$
$D_x = 1.286$ Mg m$^{-3}$
Mo $K\alpha$ radiation
Cell parameters from 25 reflections
$\theta = 11.9$–$20.9°$
$\mu = 0.10$ mm$^{-1}$
$T = 293$ (2) K
Prism, colourless
0.65 × 0.50 × 0.32 mm

*Data collection*

Enraf–Nonius CAD-4 diffractometer
Non-profiled $\omega/2\theta$ scans
Absorption correction: $\psi$ scan (North *et al.*, 1968)
$T_{\min} = 0.905$, $T_{\max} = 0.965$
5471 measured reflections
5471 independent reflections
2832 reflections with $I > 2\sigma(I)$
$\theta_{\max} = 30.4°$
$h = -12 \rightarrow 0$
$k = -20 \rightarrow 0$
$l = 0 \rightarrow 36$
3 standard reflections
frequency: 60 min
intensity decay: none

*Refinement*

Refinement on $F^2$
$R(F) = 0.041$
$wR(F^2) = 0.138$
$S = 0.89$
5471 reflections
411 parameters
H-atom parameters constrained
$w = 1/[\sigma^2(F_o^2) + (0.0882P)^2]$ where $P = (F_o^2 + 2F_c^2)/3$
$(\Delta/\sigma)_{\max} = 0.022$
$\Delta\rho_{\max} = 0.21$ e Å$^{-3}$
$\Delta\rho_{\min} = -0.19$ e Å$^{-3}$

**Table 3**
Selected geometric parameters (Å, °) for (II).

| | | | |
|---|---|---|---|
| C1—O1 | 1.390 (3) | C17—O10 | 1.419 (3) |
| C1—O5 | 1.418 (3) | C17—C18 | 1.513 (4) |
| C2—O2 | 1.432 (3) | C18—C19 | 1.536 (3) |
| C5—O5 | 1.424 (3) | C19—C20 | 1.504 (4) |
| C17—O2 | 1.396 (3) | C20—C21 | 1.522 (3) |
| | | | |
| O1—C1—O5 | 108.0 (2) | O10—C17—C18 | 109.1 (2) |
| O1—C1—C2 | 109.6 (2) | O10—C21—C22 | 110.8 (2) |
| O5—C1—C2 | 108.0 (2) | C1—O1—C10 | 111.29 (19) |
| O5—C5—C4 | 111.2 (2) | C17—O2—C2 | 114.62 (18) |
| O2—C17—O10 | 108.6 (2) | C1—O5—C5 | 111.3 (2) |
| O2—C17—C18 | 108.3 (2) | C17—O10—C21 | 109.07 (19) |
| | | | |
| O5—C1—C2—C3 | 61.6 (3) | O10—C17—O2—C2 | −64.5 (3) |
| C1—C2—C3—C4 | −44.8 (3) | C3—C2—O2—C17 | −65.9 (3) |
| C2—C3—C4—C5 | 36.2 (3) | C2—C1—O5—C5 | −72.1 (3) |
| C3—C4—C5—O5 | −42.4 (3) | C4—C5—O5—C1 | 61.2 (3) |
| C17—C18—C19—C20 | −48.9 (3) | C18—C17—O10—C21 | −65.6 (3) |
| C18—C19—C20—C21 | 51.1 (3) | C20—C21—O10—C17 | 69.5 (3) |
| C19—C20—C21—O10 | −61.8 (3) | | |

**Table 4**
Hydrogen-bonding geometry (Å, °) for (II).

| *D*—H···*A* | *D*—H | H···*A* | *D*···*A* | *D*—H···*A* |
|---|---|---|---|---|
| C17—H17···O3 | 0.98 | 2.35 | 2.995 (3) | 123 |
| C22—H22*A*···O12$^{\rm i}$ | 0.97 | 2.59 | 3.095 (4) | 113 |

Symmetry code: (i) $1 + x, y, z$.

The absolute configurations of these two light-atom structures were not determined by the present X-ray analyses but were already known from the known configurations of the starting materials. H atoms were placed in calculated positions, with C—H distances in the range 0.93–0.98 Å and an O—H distance of 0.82 Å, and their isotropic displacement parameters were fixed at 1.2 or 1.5 times the $U_{\rm eq}$ of the bonded atom.

For both compounds, data collection: *CAD*-4 *EXPRESS* (Enraf–Nonius, 1994); cell refinement: *CAD*-4 *EXPRESS*; data reduction: *XCAD*4 (Harms & Wocadlo, 1995); program(s) used to solve structure: *SHELXS*97 (Sheldrick, 1997); program(s) used to refine structure: *SHELXL*97 (Sheldrick, 1997); molecular graphics: *ORTEP*-3 *for Windows* (Farrugia, 1997) and *PLATON* (Spek, 1998); software used to prepare material for publication: *WinGX* (Farrugia, 1999).

Supplementary data for this paper are available from the IUCr electronic archives (Reference: FG1655). Services for accessing these data are described at the back of the journal.

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