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Carbohydrate Research 260 (1994) 137–144

CARBOHYDRATE RESEARCH

Note

Synthesis of acylated tri- and tetra-saccharides with one thioureylene group

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(Received May 17th, 1993; accepted in revised form January 27th, 1994)

Monosaccharides joined by urea or thiourea groups, non-ionic isosteric bridges of phosphates, have been studied [1]. These bridges are present in a few natural products such as glycocinnamoylspermidines [2,3], a family of broad spectrum antibiotics. Jochims and Seeliger [4] described the first thiourea derivative in which both nitrogen atoms are joined to non-anomeric carbon atoms. Recently, we reported the preparation of disaccharide compounds in which the thioureylene (NH–CS–NH) group links aldopyranose frameworks, through the reaction of the free amino group of an amino sugar with a sugar isothiocyanate [1]. At the same time, the isothiocyanates are valuable intermediates in the syntheses of heterocyclic compounds [5–7], and the previously known disaccharide isothiocyanates are limited to compounds having the NCS group in the anomeric [8] or in primary positions [9].

In this note we describe the preparation of the ethyl 2-deoxy-2-isothiocyanato-gentiobiosides **1** and **2**, the *p*-methylphenacylthiourea **3**, and the thioureylene-trisaccharides (**4** and **5**) and -tetrasaccharides (**6** and **7**) in which the thiourea group joins non-anomeric carbon atoms of mono- or di-saccharides.

Ethyl 3,4-di-*O*-acyl-2-deoxy-2-isothiocyanato-6-*O*-(2,3,4,6-tetra-*O*-acetyl-β-D-glucopyranosyl)-α-D-glucopyranosides (**1** and **2**) were prepared in high yield from ethyl 3,4-di-*O*-acyl-2-amino-2-deoxy-6-*O*-(2,3,4,6-tetra-*O*-acetyl-β-D-glucopyranosyl)-α-D-glucopyranoside hydrobromide [10] and thiophosgene in a basic medium [4,6].

The ethyl 2-deoxy-2-thioureidoglycoside **3** was prepared, as a spectroscopic model, from **2** and *p*-methylphenacylamine hydrochloride by a published method [7]. Treatment of **1** and **2** with 1,3,4,6-tetra-*O*-acetyl-2-amino-2-deoxy-β-D-glucopyranose hydrochloride [11] gave the thioureylene derivatives **4** and **5**. Similarly, **6**

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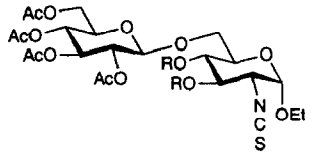
SSDI 0008-6215(94)00051-G



1 2

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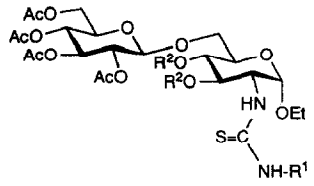

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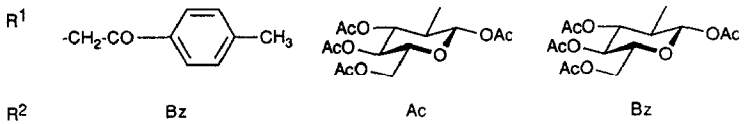

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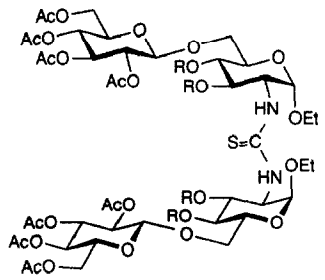

6 7

R Ac Bz

and **7** were obtained from **1** or **2** and ethyl 3,4-di-*O*-acyl-2-amino-2-deoxy-6-*O*-(2,3,4,6-tetra-*O*-acetyl-β-D-glucopyranosyl)-α-D-glucopyranoside hydrobromide [10].

The structures of **1–7** were assigned on the basis of analytical, IR, ^{1}H (see Experimental) and ^{13}C NMR (Table 1), and MS data. Thus, compounds **1** and **2** had an IR band (~ 2070 cm^{-1}) for the NCS group and compounds **3–7** a band (1225 cm^{-1}) for the C=S group [12]. Compounds **1** and **2** had a ^{13}C NMR resonance at 138.9–139.6 ppm for the NCS group. There are no precedents for the ^{13}C NMR data of 2-deoxy-2-isothiocyanato sugars, but the δ NCS value is in agreement with those reported for glycosyl isothiocyanates [8,13] and 6-deoxy-6-

Table 1
Selected ^{13}C NMR chemical shifts (δ in ppm) for solutions of **1–7** in $CDCl_3$

	C=S	Ring [a]	C-1	C-2	C-3	C-4	C-5	C-6
1 [b]	138.9	A	96.1	58.7	71.1	68.1 [d]	68.3 [d]	67.2
		B	100.6	70.8	72.5	68.2 [d]	71.7	61.7
2 [b]	139.6	A	96.5	59.1	71.3	68.5 [d]	68.7 [d]	67.4
		B	100.7	70.9	72.5	68.1 [d]	71.6	61.7
3 [b]	181.9	A	96.4	57.0	71.6 [d]	69.0	69.2	68.4
		B	100.8	71.0	72.6	68.2	71.8 [d]	61.7
4 [b]	183.8	A	95.9	57.0	71.1 [e]	68.5 [d]	68.6 [d]	68.4
		B	100.7	70.9 [e]	72.5	68.1	71.7	61.7
		C	92.7	57.5	72.7 [f]	67.5	72.7 [f]	61.5
5 [b]	183.8	A	95.9	57.4	71.6 [e]	68.8 [d]	68.9 [d]	68.3
		B	100.7	70.9	72.6	68.1	71.6 [e]	61.7
		C	92.4	58.2	72.7 [f]	67.3	72.6 [f]	61.4
6 [c]	183.0	A	96.2	56.7	71.3	68.5	68.5	68.5
		B	100.8	70.8	72.5	68.1	71.7	61.6
7 [b]	182.9	A	96.2	56.8	71.6	68.9 [d]	69.2 [d]	68.6
		B	100.8	70.9	72.6	68.1	71.6	61.7

[a] Rings A, B, and C refer to the gluco residue joined to N, the 2,3,4,6-tetra-*O*-acetyl-β-D-glucosyl group, and the gluco residue joined to N′, respectively. [b] At 50.3 MHz. [c] At 125.7 MHz. [d,e,f] Assignments may be interchanged.

isothiocyanato sugars [14]. Compounds **3–7** showed a resonance at ~ 182.5 ppm for the C=S group. Additionally, **3** showed an IR band at 1690 cm^{-1} (CO), two ^1H NMR resonances at ~ 4.90 and 4.81 ppm (CH_2), and ^{13}C NMR resonances at 193.1 (CO) and 51.3 ppm (CH_2) for the phenacyl group. The anomeric configurations of each sugar ring were evident from $J_{1,2}$ and $\delta_{C\text{-}1}$ values [15,16] (see Experimental and Table 1). The assignments of NMR resonances were supported by homonuclear (COSY) 2D correlated experiments performed on **3–6**, one heteronuclear 2D correlated and DEPT experiment (on **6**), APT [17] spectra, and literature data on glucodisaccharides [10,13].

The FAB-mass spectra of isothiocyanates **1** and **2** contained the pseudomolecular peak $[M + Na]^+$. The HREI-mass spectra of both of them showed two peaks assigned to $[M - EtO^{\cdot}]^+$ and $[M - NCS^{\cdot}]^+$, and the characteristic ion at m/z 331 ($C_{14}H_{19}O_9^+$) reported for acetylated glycohexopyranoses [15]. Compounds **3–7** gave, in the FAB-mass spectrum, pseudomolecular peaks $[M + Na]^+$ and $[M + H]^+$.

The 1,3-disubstituted alkylthioureas can exist in solution as three conformational isomers by rotation of the C–N bonds (*ZZ*, *ZE*, and *EZ*), although the *EZ* isomer has not been detected [18]. The thioureylenedisaccharides [1] and the monosaccharide thioacetamides [19] in chloroform solutions at room temperature exist in the *ZZ* conformation. It has been observed that, in the case of several conformational isomers, a very useful parameter for the identification of this rotamer is the chemical shift of the sugar proton directly joined to the carbon carrying the substituent. The chemical shift for the resonances of H-2 and/or H-2′ of compounds **3–7** are in the range 4.73–5.10 ppm, close to that for the resonances of the same protons of *ZZ*-thioureylenedisaccharides and *Z*-monosaccharide

thioacetamides. On the other hand, the high values of the coupling constants $J_{2,NH}$ (8.5–9.2 Hz) agree with an antiperiplanar disposition between these protons. For these reasons, we propose a *ZZ-anti,anti* assignment (Fig. 1) for the major conformer of **3–7** in $CDCl_3$ solution at room temperature. The $^3J_{H,H}$ values of the sugar protons show that the $^4C_1$ conformation for each sugar ring preponderates in the same solutions.

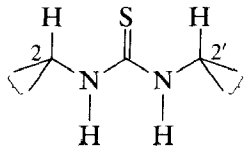

Fig. 1.

The methoxide deacylation of **4–7** was not attempted, because the thioureylene group produces unstable anions under these conditions [20].

1. Experimental

General methods.—Melting points are uncorrected. Optical rotations were measured at 22 ± 1°C for solutions in CH_2Cl_2. UV spectra were obtained for solutions in CH_2Cl_2. FTIR spectra were recorded for KBr discs. ^{1}H NMR spectra (200 and 500 MHz) were recorded for solutions in $CDCl_3$ (J values are given in Hz). Assignments were confirmed by decoupling, H–D exchange, and homonuclear 2D COSY experiments. ^{13}C NMR spectra were recorded at 50.3 and 125.7 MHz. Proton-decoupled attached proton test (APT [17]), DEPT, and heteronuclear 2D correlated spectra were obtained in order to assist in carbon resonance assignments. EI-mass spectra (70 eV) were measured with a Kratos MS-80RFA instrument, with an ionising current of 100 μA, an accelerating voltage of 4 kV, and a resolution of 1000 (10% valley definition). The elemental composition of the ions was determined with a resolution of 10000 (10% valley definition). The FAB-mass spectra were recorded with the same instrument. Ions were produced by a beam of Xe atoms (6–7 keV), using a matrix consisting of thioglycerol and NaI as salt. $(CsI)_{37}Cs$ was used as reference, and the positive ions were extracted and accelerated over a potential of 10 kV. TLC was performed on Silica Gel HF_{254} (Merck), with detection by UV light or charring with H_2SO_4. Silica Gel 60 (Merck, 230 mesh) was used for preparative chromatography.

*Ethyl 3,4-di-*O*-acetyl-* (**1**) *and ethyl 3,4-di-*O*-benzoyl-2-deoxy-2-isothiocyanato-6-*O*-(2,3,4,6-tetra-*O*-acetyl-β-*D*-glucopyranosyl)-α-*D*-glucopyranoside* (**2**).—To a heterogeneous mixture of ethyl 3,4-di-*O*-acetyl-2-amino- or ethyl 2-amino-3,4-di-*O*-benzoyl-2-deoxy-6-*O*-(2,3,4,6-tetra-*O*-acetyl-β-D-glucopyranosyl)-α-D-glucopyranoside hydrobromide [10] (1.46 mmol) in $CHCl_3$ (20 mL for **1** and 15 mL for **2**) and $CaCO_3$ (0.44 g, 4.38 mmol) in water (20 mL for **1** and 15 mL for **2**) was added thiophosgene (0.2 mL). The mixture was stirred vigorously (40 min for **1** and 8 h for **2**) and then filtered; the organic layer was separated, washed with water (20

mL), dried ($CaCl_2$), and concentrated to dryness, and the residue was crystallised from ether.

Compound **1** (0.75 g, 78%) had: mp 151°C; $[\alpha]_D^{22}$ +90.6° (*c* 0.6, CH_2Cl_2); $\lambda_{max}^{CH_2Cl_2}$ 302 and 256 nm (ϵ_{mM} 0.8 and 0.9); ν_{max} 2978 (CH aliphatic), 2074 (NCS), 1742 (C=O acetate), 1460, 1368 (CH aliphatic), and 1231 cm^{-1} (C–O–C). ^1H NMR data (200 MHz): δ 5.46 (dd, 1 H, $J_{2,3}$ 10.4, $J_{3,4}$ 9.4 Hz, H-3), 5.20 (t, 1 H, $J_{2',3'} = J_{3',4'} = 9.1$ Hz, H-3'), 5.07 (t, 1 H, $J_{4',5'}$ 9.1 Hz, H-4'), 5.01 (dd, 1 H, $J_{1',2'}$ 7.8 Hz, H-2'), 4.96 (d, 1 H, $J_{1,2}$ 3.3 Hz, H-1), 4.88 (t, 1 H, $J_{4,5}$ 9.4 Hz, H-4), 4.50 (d, 1 H, H-1') 4.26 (dd, 1 H, $J_{5',6'a}$ 4.5, $J_{6'a,6'b}$ 12.3 Hz, H-6'a), 4.13 (dd, 1 H, $J_{5',6'b}$ 2.4 Hz, H-6'b), 4.03–3.91 (m, 1 H, H-5), 3.95 (dd, 1 H, $J_{5,6a}$ 1.9, $J_{6a,6b}$ 10.8 Hz, H-6a), 3.82–3.50 (m, 4 H, H-2,5', CH_3CH_2), 3.48 (dd, 1 H, $J_{5,6b}$ 4.8 Hz, H-6b), 2.08, 2.07, 2.06, 2.03, 2.02, 2.00 (6 s, each 3 H, 6 Ac), and 1.28 (t, 3 H, *J* 7.0 Hz, CH_3CH_2). The ^{13}C NMR data are given in Table 1. FAB-mass spectrum: *m/z* 686 (10%, $[M + Na]^+$); EI-mass spectrum: *m/z* 618.1457 (1%, $M^+ - EtO^\cdot$), 605 (1%, $M^+ - NCS^\cdot$), 558 (1%, 618 – AcOH), 498 (1%, 618 – 2 AcOH), 545 (1%, 605 – AcOH), 592 (1%, M^+ – BzOH – HCO_2Et), and 331 (50%, $C_{14}H_{19}O_9^+$). Anal. Calcd for $C_{27}H_{37}NO_{16}S$: C, 48.86; H, 5.62; N, 2.11. Found: C, 48.65; H, 5.56; N, 1.95.

Compound **2** (1.09 g, 95%) had: mp 125°C; $[\alpha]_D^{22}$ +48.3° (*c* 0.9, CH_2Cl_2); $\lambda_{max}^{CH_2Cl_2}$ 230 nm (ϵ_{mM} 13.0); ν_{max} 3060 (CH aromatic), 2961 (CH aliphatic), 2050 (NCS), 1755, 1746 (C=O acetate and benzoate), 1452 (CH aromatic), 1377 (CH aliphatic), 1227 (C–O–C), and 714 cm^{-1} (CH aromatic). ^1H NMR data (200 MHz): δ 8.00–7.20 (m, 10 H, 2 Ph), 5.94 (t, 1 H, $J_{2,3} = J_{3,4} = 9.9$ Hz, H-3), 5.31 (t, 1 H, $J_{4,5}$ 9.9 Hz, H-4), 5.21 (t, 1 H, $J_{2',3'} = J_{3',4'} = 9.0$ Hz, H-3'), 5.10 (d, 1 H, $J_{1,2}$ 3.2 Hz, H-1), 5.05 (t, 1 H, $J_{4',5'}$ 9.0 Hz, H-4'), 5.03 (dd, 1 H, $J_{1',2'}$ 7.8 Hz, H-2') 4.51 (d, 1 H, H-1'), 4.26–4.18 (m, 2 H, H-5,6'a), 4.10–3.84 (m, 3 H, H-2,6a,6'b), 4.10–3.55 (m, 4 H, H-5',6b, and CH_3CH_2), 2.12 (s, 3 H, Ac), 2.02 (s, 9 H, 3 Ac), and 1.39 (t, 3 H, *J* 7.0 Hz, CH_3CH_2). The ^{13}C NMR data are given in Table 1. FAB-mass spectrum: *m/z* 810 (38%, $[M + Na]^+$); EI-mass spectrum: *m/z* 742.1685 (1%, $M^+ - EtO'$), 729.2378 (1%, $M^+ - NCS^\cdot$), 727 (1%, $M^+ - AcOH$), 665 (1%, $M^+ - BzOH$), and 331 (40%, $C_{14}H_{19}O_9^+$). Anal. Calcd for $C_{37}H_{41}NO_{16}S$: C, 56.41; H, 5.24; N, 1.77. Found: C, 56.24; H, 5.34; N, 2.01.

Ethyl 3,4-di-O-benzoyl-2-deoxy-2-[3-(p-methylphenacyl)thioureido]-6-O-(2,3,4,6-tetra-O-acetyl-β-D-glucopyranosyl)-α-D-glucopyranoside (**3**).—A solution of *p*-methylphenacylamine hydrochloride (0.03 g, 0.16 mmol) in water (2 mL) was neutralised with $NaHCO_3$ (0.02 g, 0.16 mmol) and added to a solution of **2** (0.125 g, 0.16 mmol) in acetone (2 mL) under Ar. The resulting solution was kept at room temperature for 4 days. The solvent was evaporated under diminished pressure, and the residue crystallised from EtOH to give a white product (0.078 g, 52%) which had mp 120°; $[\alpha]_D^{22}$ +12.9° (*c* 0.8, CH_2Cl_2); $\lambda_{max}^{CH_2Cl_2}$ 232 nm (ϵ_{mM} 19.0); ν_{max} 3362 (NH), 1757 (C=O acetate), 1728 (C=O benzoate), 1690 (C=O ketone), 1605, 1535 (C=C aromatic), 1229, 1240 (C–O–C), 1229 (C=S), and 712 cm^{-1} (CH aromatic). ^1H NMR data (500 MHz): δ 7.93–7.20 (m, 14 H, H aromatics), 6.96 (bs, 1 H, $NHCH_2$), 6.32 (d, 1 H, $J_{2,NH}$ 9.1 Hz, NH-C-2), 5.75 (t, 1 H, $J_{2,3} = J_{3,4} = 9.7$ Hz, H-3), 5.43 (t, 1 H, $J_{4,5}$ 9.7 Hz, H-4), 5.20 (t, 1 H, $J_{2',3'} = J_{3',4'} = 9.5$ Hz, H-3'), 5.13 (d, 1 H, $J_{1,2}$ 2.9 Hz, H-1), 5.10–4.98 (m, 2 H, H-2, CH_aH of phenacyl), 5.05 (t,

1 H, $J_{4',5'}$ 9.5 Hz, H-4'), 5.01 (dd, 1 H, $J_{1',2'}$ 8.0 Hz, H-2'), 4.81 (d, 1 H, $^2J_{H,H}$ 19.8 Hz, CHH_b of phenacyl), 4.58 (d, 1 H, H-1'), 4.23 (dd, 1 H, $J_{5',6'a}$ 4.8, $J_{6'a,6'b}$ 12.3 Hz, H-6'a), 4.21–4.14 (m, 1 H, H-5), 4.04 (dd, 1 H, $J_{5',6'b}$ 2.3 Hz, H-6'b), 4.01 (dd, 1 H, $J_{5,6a}$ 2.0, $J_{6a,6b}$ 11.0 Hz, H-6a), 3.84–3.80 and 3.56–3.50 (2 dq, each 1 H, $^2J_{H,H}$ 9.8, $^3J_{H,H}$ 7.0 Hz, CH_3CH_2), 3.72–3.64 (m, 2 H, H-5',6b), 2.40 (s, 3 H, CH_3 of *p*-Me-phenacyl), 2.02, 2.01, 2.00, 1.99 (4 s, each 3 H, 4 Ac), 1.26 (t, 3 H, CH_3CH_2); ^{13}C NMR (50.3 MHz): Table 1; the signals for the *p*-Me-phenacyl group were 193.1 (C=O), 145.0–127.9 (Ph), 51.3 (CH_2), 21.7 (Me). FAB-mass spectrum: *m/z* 959 (100%, $[M + Na]^+$), 937 (40%, $[M + H]^+$). Anal. Calcd for $C_{46}H_{53}N_2O_{17}S$: C, 58.90; H, 5.69; N, 2.98; S, 3.41. Found: C, 58.87; H, 5.60; N, 3.21; S, 3.35.

General procedure for the preparation of compounds **4–7**.—To a solution of the corresponding 2-deoxy-2-isothiocyanato sugar (0.38 mmol) in dry pyridine (10 mL) was added the corresponding amino sugar hydrohalide (0.38 mmol). The solution was kept at *c*°C for *t* days, then poured into ice–water, and the resulting solid was filtered off. Column chromatography (EtOAc–hexane) of this residue gave **4–7** as amorphous solids.

N-*[Ethyl 3,4-di*-O-*acetyl-2-deoxy-6*-O-*(2,3,4,6-tetra*-O-*acetyl-β*-D-*glucopyranosyl)-α*-D-*glucopyranosid-2-yl]*-N'-*(1,3,4,6-tetra*-O-*acetyl-2-deoxy-β*-D-*glucopyranos-2-yl)-thiourea* (**4**; 0.13 g, 34%); from compound **1** and 1,3,4,6-tetra-*O*-acetyl-2-amino-2-deoxy-*β*-D-glucopyranose hydrochloride [11]; *c* = 40°C; *t* = 8 days; $[\alpha]_D^{22}$ + 59.4° (*c* 0.4, CH_2Cl_2); $\lambda_{max}^{CH_2Cl_2}$ 253 nm (ϵ_{mM} 16.6); ν_{max} 3356 (NH), 1759 (C=O acetate), 1225 (C–O–C and C=S). ^{1}H NMR data (500 MHz) *: δ 6.18 (bs, 1 H, NH), 6.07 (bs, 1 H, N'H), 5.70 (d, 1 H, $J_{1',2'}$ 7.5 Hz, H-1'), 5.24 (t, 2 H, $J_{2,3} = J_{3,4} = J_{2',3'} = J_{3',4'}$ = 9.5 Hz, H-3,3'), 5.21 (t, 1 H, $J_{2'',3''} = J_{3'',4''}$ = 9.6 Hz, H-3''), 5.14 (t, 1 H, $J_{4',5'}$ 9.5 Hz, H-4'), 5.09 (t, 1 H, $J_{4'',5''}$ 9.6 Hz, H-4''), 5.06–4.90 (m, 2 H, H-1,2'), 5.00 (dd, 1 H, $J_{1'',2''}$ 8.0 Hz, H-2''), 4.96 (t, 1 H, $J_{4,5}$ 9.5 Hz, H-4), 4.75 (bs, 1 H, H-2), 4.55 (d, 1 H, H-1''), 4.27 (m, 2 H, H-6'a,6''a), 4.14 (dd, 2 H, $J_{5',6'b} = J_{5'',6''b}$ = 2.5, $J_{6'a,6'b} = J_{6''a,6''b}$ = 12.5 Hz, H-6'b,6''b), 3.94 (m, 1 H, H-5), 3.90 (dd, 1 H, $J_{5,6a}$ 1.9, $J_{6a,6b}$ 10.9 Hz, H-6a), 3.81 (ddd, 1 H, $J_{5',6'a}$ 4.5 Hz, H-5'), 3.69 (ddd, 1 H, $J_{5'',6''a}$ 4.6 Hz, H-5''), 3.60–3.36 (m, 2 H, CH_3CH_2), 3.55 (dd, 1 H, $J_{5,6b}$ 6.9 Hz, H-6b), 2.12 (s, 3 H, Ac), 2.10, 2.03, 2.02 (3 s, each 6 H, 6 Ac), 2.06 (s, 9 H, 3 Ac), 1.22 (t, 3 H, *J* 7.0 Hz, CH_3CH_2). The ^{13}C NMR data are given in Table 1. FAB-mass spectrum: *m/z* 1033 (100%, $[M + Na]^+$), 1011 (10%, $[M + H]^+$). Anal. Calcd for $C_{41}H_{58}N_2O_{25}S$: C, 48.70; H, 5.78; N, 2.77. Found: C, 48.50; H, 5.83; N, 2.81.

N-*[Ethyl 3,4-di*-O-*benzoyl-2-deoxy-6*-O-*(2,3,4,6-tetra*-O-*acetyl-β*-D-*glucopyranosyl)-α*-D-*glucopyranosid-2-yl]*-N'-*(1,3,4,6-tetra*-O-*acetyl-2-deoxy-β*-D-*glucopyranos-2-yl)thiourea* (**5**; 0.70 g, 40%); from compound **2** and 1,3,4,6-tetra-*O*-acetyl-2-amino-2-deoxy-*β*-D-glucopyranose hydrochloride [11]; *c* = 40°C; *t* = 8 days; $[\alpha]_D^{22}$ + 5.2° (*c* 1.0, CH_2Cl_2); $\lambda_{max}^{CH_2Cl_2}$ 253 and 228 nm (ϵ_{mM} 13.1 and 19.7); ν_{max} 3352 (NH), 1755 (C=O), 1587, 1547 (C=C aromatic), 1225 (C–O–C and C=S), and 712 cm^{-1} (CH aromatic). ^{1}H NMR data (500 MHz)*: δ 7.98–7.25 (m, 10 H, 2 Ph), 6.40 (m, 1 H,

* For **4** and **5**, the protons of rings B and C (see footnote [a] of Table 1) are named as H'' and H', respectively.

NH), 6.11 (d, 1 H, $J_{2,N'H}$ 8.5 Hz, N'H), 5.70–5.60 (m, 2 H, H-1',3), 5.42 (t, 1 H, $J_{3,4} = J_{4,5} = 9.7$ Hz, H-4), 5.19 (t, 1 H, $J_{2'',3''} = J_{3'',4''} = 9.5$ Hz, H-3''), 5.15–4.95 (m, 1 H, H-2'), 5.12 (m, 2 H, H-3',4'), 5.05 (t, 1 H, $J_{4'',5''}$ 9.5 Hz, H-4''), 5.04–4.95 (m, 2 H, H-1,2), 5.01 (dd, 1 H, H-2''), 4.56 (d, 1 H, $J_{1'',2''}$ 7.9 Hz, H-1''), 4.27 (m, 1 H, H-6'a), 4.23 (dd, 1 H, $J_{5'',6''a}$ 4.5, $J_{6''a,6''b}$ 12.5 Hz, H-6''a), 4.17 (m, 1 H, H-5), 4.16 (dd, 1 H, $J_{5',6'b}$ 2.0, $J_{6'a,6'b}$ 12.5 Hz, H-6'b), 4.04 (dd, 1 H, $J_{5'',6''b}$ 2.3 Hz, H-6''b), 4.00 (dd, 1 H, $J_{5,6a}$ 1.0, $J_{6a,6b}$ 11.0 Hz, H-6a), 3.82 (m, 1 H, H-5'), 3.73–3.41 (m, 2 H, CH_3CH_2), 3.67 (m, 2 H, H-5'',6b), 2.08, 2.06 (2 s, each 3 H, 2 Ac), 2.02, 2.01, 1.97 (3 s, each 6 H, 6 Ac), 1.26 (t, 3 H, J 7.0 Hz, CH_3CH_2). The ^{13}C NMR data are given in Table 1. FAB-mass spectrum: m/z 1158 (100%, $[M + Na]^+$), 1136 (15%, $[M + H]^+$). Anal. Calcd for $C_{51}H_{62}N_2O_{25}S$: C, 53.96; H, 5.50; N, 2.46. Found: C, 54.15; H, 5.57; N, 2.50.

N,N'-*Bis[ethyl 3,4-di*-O-*acetyl-2-deoxy-6*-O-*(2,3,4,6-tetra*-O-*acetyl-β*-D-*glucopyranosyl)-α*-D-*glucopyranosid-2-yl]thiourea* (**6**; 0.38 g, 79%); from compound **1** and ethyl 3,4-di-*O*-acetyl-2-amino-2-deoxy-6-*O*-(2,3,4,6-tetra-*O*-acetyl-*β*-D-glucopyranosyl)-*α*-D-glucopyranoside hydrobromide [10]; $c = 20°C$; $t = 4$ days; crystallised from EtOH, **6** had mp 206–207°C; $[\alpha]_D^{22}$ +59.2° (*c* 0.8, $CHCl_2$); $\lambda_{max}^{CH_2Cl_2}$ 250 and 226 nm (ϵ_{mM} 17.3 and 12.2); ν_{max} 3312 (NH), 1751 (C=O acetate), 1225 (C–O–C and C=S). ^1H NMR data (500 MHz): δ 5.92 (bs, 2 H, 2 NH), 5.19 (t, 2 H, $J_{2,3} = J_{3,4} = 9.5$ Hz, 2 H-3), 5.17 (t, 2 H, $J_{2',3'} = J_{3',4'} = 9.8$ Hz, 2 H-3'), 5.05 (t, 2 H, $J_{4',5'}$ 9.8 Hz, 2 H-4'), 4.97 (dd, 2 H, $J_{1',2'}$ 8.0 Hz, 2 H-2'), 4.92 (t, 2 H, $J_{4,5}$ 9.5 Hz, 2 H-4), 4.89 (d, 2 H, $J_{1,2}$ 3.4 Hz, 2 H-1), 4.73 (bm, 2 H, 2 H-2), 4.53 (d, 2 H, 2 H-1'), 4.26 (dd, 2 H, $J_{5',6'a}$ 4.6, $J_{6'a,6'b}$ 12.4 Hz, 2 H-6'a), 4.09 (dd, 2 H, $J_{5',6'b}$ 1.9 Hz, 2 H-6'b), 3.90 (ddd, 2 H, $J_{5,6a}$ 1.5, $J_{6a,6b}$ 10.9 Hz, 2 H-5), 3.86 (dd, 2 H, $J_{5,6a}$ 6.8 Hz, 2 H-6a), 3.66 (ddd, 2 H, 2 H-5'), 3.52 (dd, 2 H, 2 H-6b), 3.70 and 3.43 (2 dq, each 2 H, $^2J_{H,H}$ 10.0, $^3J_{H,H}$ 7.0 Hz, 2 CH_3CH_2), 2.06, 2.01, 2.00, 1.97 (4 s, each 6 H, 8 Ac), 1.99 (s, 12 H, 4 Ac), 1.23 (t, 6 H, 2 CH_3CH_2). ^{13}C NMR data are given in Table 1. FAB-mass spectrum: m/z 1308 (100%, $[M + Na]^+$), 1286 (52%, $[M + H]^+$). Anal. Calcd for $C_{53}H_{76}N_2O_{32}S$: C, 49.52; H, 5.96; N, 2.17. Found: C, 49.36; H, 6.10; N, 2.20.

N,N'-*Bis[ethyl 3,4-di*-O-*benzoyl-2-deoxy-6*-O-*(2,3,4,6-tetra*-O-*acetyl-β*-D-*glucopyranosyl)-α*-D-*glucopyranosid-2-yl]thiourea* (**7**; 0.38 g, 66%); from compound **2** and ethyl 2-amino-3,4-di-*O*-benzoyl-2-deoxy-6-*O*-(2,3,4,6-tetra-*O*-acetyl-*β*-D-glucopyranosyl)-*α*-D-glucopyranoside hydrobromide [10]; $c = 20°C$; $t = 4$ days; crystallised from EtOH, **7** had mp 127–130°C; $[\alpha]_D^{22}$ +12.1° (*c* 0.9, CH_2Cl_2); $\lambda_{max}^{CH_2Cl_2}$ 230 nm (ϵ_{mM} 51.7); ν_{max} 3360 (NH), 1757 (C=O acetate), 1736 (C=O benzoate), 1535 (C=C aromatic), 1277, 1229 (C–O–C and C=S), and 712 (CH aromatic). ^1H NMR data (200 MHz): δ 7.91–7.27 (m, 20 H, 4 Ph), 6.05 (d, 2 H, $J_{2,NH}$ 9.2 Hz, 2 NH), 5.61 (t, 2 H, $J_{2,3} = J_{3,4} = 9.6$ Hz, 2 H-3), 5.31 (t, 2 H, $J_{4,5}$ 9.6 Hz, 2 H-4), 5.17 (t, 2 H, $J_{2',3'} = J_{3',4'} \approx 9.4$ Hz, 2 H-3'), 5.09–4.96 (bm, 2 H, 2 H-2), 5.01 (t, 2 H, $J_{4',5'}$ 9.4 Hz, 2 H-4'), 4.95 (dd, 2 H, $J_{1',2'}$ 7.9 Hz, 2 H-2'), 4.73 (d, 2 H, $J_{1,2}$ 3.4 Hz, 2 H-1), 4.52 (d, 2 H, 2 H-1'), 4.21 (dd, 2 H, $J_{5',6'a}$ 5.1, $J_{6'a,6'b}$ 12.5 Hz, 2 H-6'a), 4.11 (m, 2 H, 2 H-5), 4.01 (dd, 2 H, $J_{5',6'b}$ 2.5 Hz, 2 H-6'b), 3.94 (dd, 2 H, $J_{5,6a}$ 2.2, $J_{6a,6b}$ 12.2 Hz, 2 H-6a), 3.68–3.58 (m, 4 H, 2 H-5',6b), 3.72–3.40 (m, 4 H, 2 CH_3CH_2), 2.03, 2.01, 2.00, 1.99 (4 s, each 6 H, 8 Ac), 1.01 (t, 6 H, J 7.0, 2 CH_3CH_2). The ^{13}C NMR data

are given in Table 1. FAB-mass spectrum: m/z 1556 (100%, $[M + Na]^+$), 1534 (28%, $[M + H]^+$). Anal. Calcd for $C_{73}H_{84}N_2O_{32}S$: C, 57.17; H, 5.52; N, 1.82. Found: C, 56.84; H, 5.42; N, 1.60.

Acknowledgments

We thank the Dirección General de Investigación Científica y Técnica for financial support (grant number PB 91/0617), and the Spanish Ministry of Education and Science for the award of a scholarship (to T.C.).

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