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Note

Synthesis of new heterocyclic derivatives of α,α-trehalose

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Abstract—Several novel N-1, N-2, and *S*-5 tetrazole and 1,3,4-oxadiazole derivatives of α,α-trehalose disubstituted at C-6,6′, with potential synthetic and pharmacological interest were prepared from commercial tetrazoles and 1,3,4-oxadiazoles in reaction with hexa-*O*-benzyl-6,6′-di-*O*-triflyl-α,α-trehalose.

Keywords: α,α-Trehalose; Alkylation; Tetrazole; 1,3,4-Oxadiazole

Most pharmaceuticals and biologically active agrochemicals are heterocyclic derivatives, as are numerous additives used in industries such as in cosmetics, reprography, information storage, and plastics.[1–5] Knowing the broad spectrum of biological activities and the significant applications of heterocyclic ring systems, we have focused our interest on improving the synthesis of tetrazole and oxadiazole compounds linked to monosaccharides[6–10] and disaccharides.[11] In continuation of this study, we now focus on the synthesis of tetrazole and 1,3,4-oxadiazole derivatives of α,α-trehalose. Among the methods of synthesis of substituted tetrazoles developed in the last few years, a simple and effective one involves the alkylation of tetrazole and oxadiazoles.[7,8,10,11,13] A convenient electrophilic derivative of α,α-trehalose for this purpose is the 6,6′-di-*O*-triflyl derivative **1** which was easily prepared from 2,2′,3,3′,4,4′-hexabenzyl-α,α-trehalose.[12] Reaction of commercial tetrazoles (**2**, **3**, or **4**) or 1,3,4-oxadiazoles (**5** or **6**) with **1** in acetone and K_2CO_3 gave the respective derivatives **2a**–**b**, **3a**–**b**, **4a**, **5a**, or **6a** (Scheme 1).

The reaction of heterocyclic thiols **4**, **5**, **6** with **1** gave products **4a**, **5a**, and **6a** in relatively good and similar yields (either 76% or 77%). These results suggest that nucleophilic substitution at C-6,6′ of **1** is not affected by either the heterocyclic ring or the substitution in the ring. On the other hand, the reaction of either tetrazole **2** or **3** with **1** yielded the regioisomers N-2, N-2 and N-1, N-2 in different yields and ratios. While the alkylation of 5-phenyltetrazole (**3**) furnished the mixture of N-2, N-2 and N-1, N-2 isomers, **3a** and **3b**, in 2.5:1 ratio (overall yield 81%), the reaction of unsubstituted tetrazole **2** led to a mixture of N-2, N-2 and N-1, N-2 products, **2a** and **2b**, in 1:1.7 ratio (overall yield 68%).

The alkylation of 5-substituted tetrazole derivatives, as **3**, is known to lead to mixtures of N-1 and N-2 substituted products, the regioselectivity being dependent on the reaction conditions and the nature of the C- and N-substituents.[3] To the best of our knowledge, the alkylation of 5-substituted tetrazoles in the presence of base gives the N-2 isomers predominantly.[3,7,8,10,11,14,15] Alkylated bis-tetrazole derivatives were obtained as N-2, N-2 and N-1, N-2 isomers with the predominance of the symmetrical product.[11,13,15] Thus, the ratio of products formed by the alkylation of **3** with the carbohydrate derivative **1** is in agreement with the literature data.

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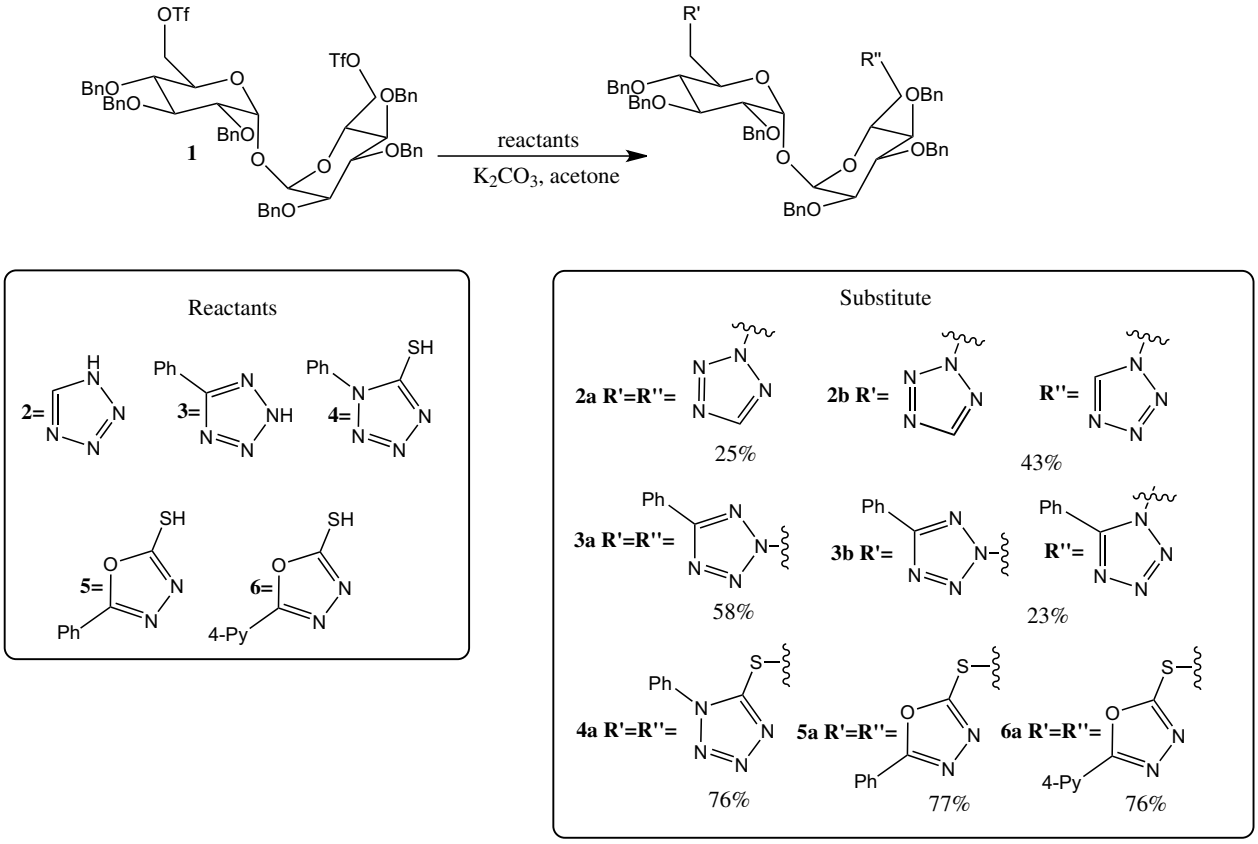

Scheme 1.

The synthesis of di-N-alkylated bis-tetrazoles derivatives unsubstituted at position 5 has not been found in the literature. This kind of compound has been obtained by our research group and the unsymmetrical N-1, N-2 substituted tetrazoles have been obtained as main products.[11] Similarly, the alkylation of 5-unsubstituted tetrazole **2** with the carbohydrate derivative **1** led to a mixture of the symmetrical compound N-2, N-2 substituted **2a** and the unsymmetrical N-1, N-2 isomer with the predominance of **2b**.

The structures of the compounds **2a**, **2b**, **3a**, **3b**, **4a**, **5a**, and **6a** were determined by the assignment of ^{1}H and ^{13}C NMR spectra involving COSY, HMQC, and HMBC experiments. Product purity was confirmed by elemental analysis. The structure of the isomeric N-2, N-2 and N-1, N-2 derivatives (**2a**/**2b** and **3a**/**3b**) is readily distinguishable by their ^{1}H and ^{13}C NMR. It is well established that the ^{13}C carbon atom of the tetrazole ring in N-1 substituted derivatives is more shielded by ca. 10 ppm relative to their corresponding N-2 substituted isomer.[16] The ^{13}C NMR chemical shift of the tetrazole carbon atom appears at ca. 154.0 and 164.0 in 1,5- and 2,5-disubstituted tetrazoles, respectively.[8,11,13,16] The ^{13}C chemical shift of 5-unsubstituted N-1and N-2 substituted tetrazoles appears at ca. 143 and 153, respectively.[10,11] The symmetrical N-2, N-2 substituted compounds thus gave rise to a single resonance at either ca. 164 or 154 ppm (5-substituted and 5-unsubstituted, respectively), while both signals were apparent in N-1, N-2 substituted compounds. For example, **2a** has a single peak at 153.0 ppm, while **2b** has two peaks at 153.0 and 143.0 ppm. The main difference between the ^{1}H NMR spectra of the isomers is the signal doubling in the case of N-1, N-2 derivatives **2b** and **3b**. The position of the sugar unit at N-1 in the compounds was confirmed by the cross-peak between the C-6 methylene protons and C-5 of the tetrazole ring in HMBC spectra. Such cross-peak resulted from *J* coupling of these atoms through three bonds. No cross-peak between C-6 of the carbohydrate moiety and C-5 of the N-2 substituted tetrazole rings was observed in HMBC spectra.

1. Experimental

1.1. General methods

Melting points were determined in a Mettler FP80HT apparatus and are uncorrected. Optical rotation was determined in a Perkin–Elmer 341 Polarimeter at 20 °C. NMR spectra were recorded in either Bruker Avance DRX-200 or DRX-400 spectrometers. Chemical shifts are reported in δ units downfield from TMS and *J* values are given in Hz. Elemental analyses were carried

out in a Perkin–Elmer 2400 CHN apparatus. IR spectra were obtained in a Perkin–Elmer Spectrum One sP-IR Spectrometer. Column chromatography was performed with Silica Gel 60, 70–230 mesh (E. Merck). The term 'standard work-up' means that the organic layer was dried over anhyd Na_2SO_4, filtered, and the solvent was removed under diminished pressure.

1.2. 2,3,4-Tri-*O*-benzyl-6-*O*-trifluoromethylsulfonyl-α-D-glucopyranosyl 2,3,4-tri-*O*-benzyl-6-*O*-trifluoromethylsulfonyl-α-D-glucopyranoside (1)[12]

To an ice-cold soln of dry CH_2Cl_2 (12 mL) and pyridine (0.40 mL, 4.9 mmol) was added triflic anhydride drop by drop (1.03 mL, 6.12 mmol). After 10 min, the ice bath was removed and a soln of 2,3,4-tri-*O*-benzyl-α-D-glucopyranosyl 2,3,4-tri-*O*-benzyl-α-D-glucopyranoside (1.08 g, 1.22 mmol[12]) in anhyd CH_2Cl_2 (13 mL) was added. The reaction mixture was stirred for 2 h at room temperature, and then water was added. The reaction mixture was extracted with CH_2Cl_2 (3×20 mL), and the combined organic extracts were submitted to standard work-up to give 1.25 g of product **1** (1.09 mmol, 90%) as an oil; R_f 0.80 (1:4 EtOAc–hexane); IR: *v* 3066, 3030, 2919, 2860, 1454, 1411, 1357, 1244, 1206, 1142, 1093, 1070, 986, 928, 734, 697 cm^{-1}; ^1H NMR (400 MHz, $CDCl_3$): δ ppm 7.37–7.23 (m, 30H, C_6H_5), 5.15 (d, 2H, J_{1-2} 3.6, H-1), 5,04 (d, 2H, J_{gem} 11.0, ØCH_2), 4.91 (d, 2H, J_{gem} 10.8, ØCH_2), 4.89 (d, 2H, J_{gem} 11.0, ØCH_2), 4.76 (d, 2H, J_{gem} 11.8, ØCH_2), 4.61 (d, 2H, J_{gem} 11.8, ØCH_2), 4.54 (d, 2H, J_{gem} 10.9, ØCH_2), 4.20–4.14 (m, 4H, H-5, H-6), 4.07 (d, 2H, J_{6-6} 9.2, H-6), 4.02 (t, 2H, J_{3-4} 9.2, H-3), 3.57 (dd, 2H, J_{2-3} 9.6, H-2), 3.49 (t, 2H, J_{4-5} 9.4, H-4); ^{13}C NMR (50 MHz, $CDCl_3$): δ ppm 138.4, 137.8, 137.6 (6C-*ipso*), 129.4, 128.7, 128.6, 128.5, 128.3, 128.2, 127.9, 127.8, 127.3 (30C_6H_5), 118.6 (q, J_{C-F} 317.6, 2 CF_3), 94.6 (2 C-1), 81.6 (2 C-3), 79.4 (2 C-2), 77.1 (2C-4), 75.7, 75.3 (4 ØH$_2$), 74.4 (2 C-6), 73.4 (2ØCH_2), 68.7 (2 C-5); Anal. Calcd for $C_{56}H_{56}F_6O_{15}S_2$: C, 58.63; H, 4.92. Found: C, 58.86; H, 5.20.

1.3. General tetrazole and 1,3,4-oxadiazole alkylation procedure[7,8,10,11,13,14]

To a stirred soln of either tetrazole (**2**, **3**, or **4**) or oxadiazole (**5** or **6**) (0.52 mmol) and anhyd K_2CO_3 (5.23 mmol) in dry acetone (7 mL) was added triflate **1** (0.17 mmol). The soln was stirred overnight. After complete conversion to the corresponding product, as indicated by TLC, the solvent was removed under diminished pressure. The residue was diluted with CH_2Cl_2 (30 mL) and washed with water (3×20 mL). The organic phase was submitted to standard work-up and the product was purified by column chromatography (hexane→EtOAc–hexane) to give the respective alkylated tetrazoles and 1,3,4-oxadiazoles.

1.3.1. 2,3,4-Tri-*O*-benzyl-6-deoxy-6-*N*-(tetrazol-2-yl)-α-D-glucopyranosyl 2,3,4-tri-*O*-benzyl-6-deoxy-6-*N*-(tetrazol-2-yl)-α-D-glucopyranoside (2a).

42 mg (25%); oil; $[\alpha]_D^{20}$ +110 (*c* 0.9, $CHCl_3$); R_f 0.60 (1:1 EtOAc–hexane); IR: *v* 3031, 2920, 1728, 1453, 1361, 1281, 1066, 988, 734, 695 cm^{-1}; ^1H NMR (400 MHz, $CDCl_3$): δ ppm 8.44 (s, 1H, H-5′), 7.35–7.22 (m, 30H, C_6H_5), 5.04 (d, 2H, J_{1-2} 3.9, H-1), 5,02 (d, 2H, J_{gem} 11.8, ØCH_2), 4.98 (d, 2H, J_{gem} 10.8, ØCH_2), 4.88 (d, 2H, J_{gem} 10.9, ØCH_2), 4.82 (d, 2H, J_{gem} 10.8, ØCH_2), 4.65 (s, 4H, ØCH_2), 4.59 (dd, 2H, J_{5-6} 4.9, J_{6-6} 14,4, H-6), 4.47–4.40 (m, 4H, H-5, H-6), 4.08 (t, 2H, J_{2-3} 9.2, H-3), 3.41 (dd, 2H, J_{1-2} 3.9, J_{2-3} 9.2, H-2), 3.36 (t, 2H, J_{3-4} 9.4, H-4); ^{13}C NMR (50 MHz, $CDCl_3$): δ ppm 152.9 (C-5′), 138.5, 138.3, 138.0 (6C-*ipso*), 128.7, 128.3, 128.2, 128.1, 127.9, 127,5 (30C_6H_5), 93.9 (2C-1), 81.8 (2C-3), 79.4 (2C-2), 78.1 (2C-4), 75.8, 75.2, 73.3 (6ØCH_2), 68.9 (2C-5), 52.7 (2C-6); Anal. Calcd for $C_{56}H_{58}N_8O_9$: C, 68.14; H, 5.92; N,11.35. Found: C, 67.92; H, 5.59; N, 11.14.

1.3.2. 2,3,4-Tri-*O*-benzyl-6-deoxy-6-*N*-(tetrazol-1-yl)-α-D-glucopyranosyl 2,3,4-tri-*O*-benzyl-6-deoxy-6-*N*-(tetrazol-2-yl)-α-D-glucopyranoside (2b).

73 mg (43%); oil; $[\alpha]_D^{20}$ +73 (*c* 0.7, $CHCl_3$); R_f 0.10 (1:1 EtOAc–hexane); IR: *v* 3031, 2923, 1729, 1453, 1362, 1281, 1066, 988, 734, 695 cm^{-1}; ^1H NMR (400 MHz, $CDCl_3$): δ ppm 8.46 (s, 1H, H-5′), 8.38 (s, 1H, H-5″), 7.36–7.23 (m, 30H, C_6H_5), 5.06 (d, 1H, $J_{1-2} = 3.4$, H-1), 5.02–4.95 (m, 3H, H-1, ØCH_2), 4.92–4.84 (m, 4H, ØCH_2), 4.74–4.60 (m, 6H, H-6, ØCH_2), 4.50–4.40 (m, 4H, H-5, H-6, ØCH_2), 4.24 (2t, 1H, J_{4-5} 10.0, H-5), 4.09–4.01 (2t, 2H, J_{2-3} 9.3, H-3), 3.98–3.93 (dd, 1H, J_{5-6} 2.9, J_{6-6} 14.5, H-6), 3.41–3.34 (m, 3H, H-2, H-4), 2.98 (t, 1H, J_{3-4} 9.8, H-4); ^{13}C NMR (100 MHz, $CDCl_3$): δ ppm 153.0 (C-5′), 143.0 (C-5″), 138.4, 138.3, 138.1, 138.0, 137.9 (6C-*ipso*), 128.8, 128.7, 128.6, 128.5, 128.4, 128.3, 128.2, 128.1, 128.0, 127.9, 127.5, 127.4 (30C_6H_5), 94.4, 94.2 (2C-1), 81.9, 81.5 (2C-3), 79.5 (2C-2), 78.1, 77.4 (2C-4), 75.8, 75.8, 75.4, 75.3, 73.6, 73.5 (6ØCH_2), 69.1, 68.9 (2C-5), 52.6, 47.9 (2C-6); Anal. Calcd for $C_{56}H_{58}N_8O_9$: C, 68.14; H, 5.92; N,11.35. Found: C, 67.97; H, 5.63; N, 11.21.

1.3.3. 2,3,4-Tri-*O*-benzyl-6-deoxy-6-*N*-(5-phenyltetrazol-2-yl)-α-D-glucopyranosyl 2,3,4-tri-*O*-benzyl-6-deoxy-6-*N*-(5-phenyltetrazol-2-yl)-α-D-glucopyranoside (3a).

115 mg (58%); oil; $[\alpha]_D^{20}$ +107 (*c* 1.05, $CHCl_3$); R_f 0.40 (1:4 EtOAc–hexane); IR: *v* 3031, 2922, 1729, 1450, 1361, 1207, 1067, 989, 731, 692 cm^{-1}; ^1H NMR (400 MHz, $CDCl_3$): δ ppm 8.09–7.20 (m, 40H, C_6H_5), 5.09 (d, 2H, J_{1-2} 3.6, H-1), 5.01 (d, 4H, J_{gem} 10.7, ØCH_2), 4.92 (d, 2H, J_{gem} 12.8, ØCH_2), 4.89 (d, 2H, J_{gem} 10.8, ØCH_2), 4.69–4.43 (m, 10H, H-5, H-6, ØCH_2), 4.10 (t, 2H, J_{2-3} 9.2, H-3), 3.47–3.41 (m, 4H, H-2, H-4); ^{13}C NMR (50 MHz, $CDCl_3$): δ ppm 165.2 (C-5′),138.5, 138.4,

137.9 (6C-*ipso*), 130.4, 129.0, 128.7, 128.6, 128.3, 128.2, 128.1, 127.9, 127.5 (38C_6H_5), 127.4 (2C-*ipso*), 127.0 (2C_6H_5), 93.8 (2C-1), 81.8 (2C-3), 79.5 (2C-4), 78.2 (2C-2), 75.8, 75.3, 73.3 (6ØCH_2), 68.9 (2C-5), 52.9 (2C-6); Anal. Calcd for $C_{68}H_{66}N_8O_9$: C, 71.69; H, 5.84; N, 9.84. Found: C,71.02; H,5.84; N, 9.84.

1.3.4. 2,3,4-Tri-*O*-benzyl-6-deoxy-6-*N*-(5-phenyltetrazol-1-yl)-α-D-glucopyranosyl 2,3,4-tri-*O*-benzyl-6-deoxy-6-*N*-(5-phenyltetrazol-2-yl)-α-D-glucopyranoside (3b). 46 mg (23%); oil; $[\alpha]_D^{20}$ +114 (*c* 0.8, $CHCl_3$); R_f 0.13 (1:4 EtOAc–hexane); IR: *v* 3031, 2923, 1730, 1451, 1361, 1208, 1067, 989, 731, 693 cm^{-1}; ^1H NMR (400 MHz, $CDCl_3$): δ ppm 8.04–7.09 (m, 40H, C_6H_5), 5.03–4.99 (m, 4H, H-1, ØCH_2), 4.95–4.87 (m, 6H, ØCH_2), 4.69–4.37 (m, 10H, H-5, H-6, ØCH_2), 4.20 (dd, 1H, J_{5-6} 4.8, J_{6-6} 14.6, H-6), 4.11 (t, 2H, J_{2-3} 9.2, H-3), 3.99 (dd, 1H, J_{5-6} 3.4, J_{6-6} 14.6, H-6), 3.61 (t, 1H, J_{3-4} 9.8, H-4), 3.46–3.40 (m, 3H, H-2, H-4); ^{13}C NMR (100 MHz, $CDCl_3$): δ ppm 165.0 (C-5′), 155.8 (C-5″), 138.4, 138.3, 138.2, 138.1, 137.8, 137.7 (6C-*ipso*), 131.0, 130.4, 129.3, 128.9, 128.9, 128.7, 128.6, 128.5, 128.4, 128.3, 128.2, 128.1, 128.0, 127.9, 127.8, 127.6, 127.3, 127.1, 126.9 (40C_6H_5), 124.2, 124.1 (2C-*ipso*), 93.7, 93.6 (2C-1), 81.7, 81.6 (2C-3), 79.1, 77.9 (2C-2, 2C-4), 75.7, 75.5, 75.1, 73.3, 72.9 (6ØCH$_2$), 68.9 (2C-5), 52.6, 46.8 (2C-6); Anal. Calcd for $C_{68}H_{66}N_8O_9$: C, 71.69; H, 5.84; N, 9.84. Found: C, 72.19; H, 5.24; N, 9.71.

1.3.5. 2,3,4-Tri-*O*-benzyl-6-deoxy-6-*S*-(1-phenyltetrazol-5-thiolyl)-α-D-glucopyranosyl 2,3,4-tri-*O*-benzyl-6-deoxy-6-*S*-(1-phenyltetrazol-5-thiolyl)-α-D-glucopyranoside (4a). 159 mg (76%); oil; $[\alpha]_D^{20}$ +59 (*c* 0.6, $CHCl_3$); R_f 0.14 (1:4 EtOAc–hexane); IR: *v* 3030, 2919, 1727, 1597, 1498, 1453, 1387, 1275, 1208, 1063, 987, 734, 694 cm^{-1}; ^1H NMR (400 MHz, $CDCl_3$): δ ppm 7.50–7.19 (m, 40H, C_6H_5), 5.02 (d, 2H, J_{1-2} 3.3, H-1), 4.97 (d, 2H, J_{gem} 10.8, ØCH_2), 4.88 (d, 2H, J_{gem} 11.0, ØCH_2), 4.85 (d, 2H, J_{gem} 11.1, ØCH_2), 4.65–4.57 (m, 6H, ØCH_2), 4.34 (dt, 2H, J_{4-5} 9.3, J_{5-6} 5.2, H-5), 4.05 (t, 2H, J_{2-3} 9.2, H-3), 3.68–3.57 (m, 4H, H-6), 3.48–3.41 (m, 4H, H-2, H-4); ^{13}C NMR (50 MHz, $CDCl_3$): δ ppm 154.2 (C-5′), 138.5, 137.8, 133.7 (6 C-*ipso*), 130.2, 129.9, 128.6, 128.5, 128.4, 128.0, 127.9, 127.4, 123.9 (40C_6H_5), 121.3 (2C-*ipso*), 93.5 (2C-1), 81.4 (2C-3), 79.8, 79.2 (2C-2, 2C-4), 75.7, 75.3, 73.2 (6ØCH$_2$), 69.5 (2C-5), 35.6 (2C-6); Anal. Calcd for $C_{68}H_{66}N_8O_9S_2$: C, 67.87; H, 5.53; N, 9.31. Found: C, 67.85; H, 5.56; N, 9.40.

1.3.6. 2,3,4-Tri-*O*-benzyl-6-deoxy-6-*S*-(5-phenyl-1,3,4-oxadiazol-2-thiolyl)-α-D-glucopyranosyl 2,3,4-tri-*O*-benzyl-6-deoxy-6-*S*-(5-phenyl-1,3,4-oxadiazol-2-thiolyl)-α-D-glucopyranoside (5a). 162 mg (77%); oil; $[\alpha]_D^{20}$ +86 (*c* 1.25, $CHCl_3$); R_f 0.21 (1:4 EtOAc–hexane); IR: *v* 3030, 2918, 1727, 1597, 1498, 1453, 1387, 1359, 1273, 1243, 1063, 988, 734, 694 cm^{-1}; ^1H NMR (400 MHz, $CDCl_3$): δ ppm 7.95–7.92 (m, 4H, C_6H_5), 7.51–7.17 (m, 36H, C_6H_5), 5.18 (d, 2H, J_{1-2} = 3.4, H-1), 4.99 (d, 2H, J_{gem} 10.9, ØCH_2), 4.92 (d, 2H, J_{gem} 10.9, ØCH_2), 4.87 (d, 2H, J_{gem} 10.9, ØCH_2), 4.75 (s, 4H, ØCH_2), 4.65 (d, 2H, J_{gem} 10.9, ØCH_2), 4.37 (ddd, 2H, J_{4-5} 9.7, J_{5-6} 6.3, J_{5-6} 3.2, H-5), 4.10 (t, 2H, J_{2-3} 9.3, H-3), 3.60 (dd, 2H, J_{1-2} 3.4, H-2), 3.55–3.37 (m, 6H, H-4, H-6); ^{13}C NMR (50 MHz, $CDCl_3$): δ ppm 165.8, 164.3 (C-2′, C-5′),138.6, 137.9 (6 C-*ipso*), 131.7, 129.1, 128.6, 128.5, 128.4, 128.0, 127.7, 127.4, 126.7 (40C_6H_5), 123.7 (2C-*ipso*), 93.3 (2C-1), 81.5 (2C-3), 80.0 (2C-4), 79.4 (2C-2), 75.7, 75.3, 73.3 (6ØCH$_2$), 69.7 (2C-5), 34.8 (2C-6); Anal. Calcd for $C_{70}H_{66}N_4O_{11}S_2$: C, 69.86; H, 5.53; N, 4.66. Found: C, 69.30; H, 5.41; N, 4.65.

1.3.7. 2,3,4-Tri-*O*-benzyl-6-deoxy-6-*S*-[5-pyridin-4-yl-1,3,4-oxadiazol-2-thiolyl]-α-D-glucopyranosyl 2,3,4-tri-*O*-benzyl-6-deoxy-6-*S*-[5-pyridin-4-yl-1,3,4-oxadiazol-2-thiolyl]-α-D-glucopyranoside (6a). 160 mg (76%); oil; $[\alpha]_D^{20}$ +80 (*c* 1.65, $CHCl_3$); R_f 0.43 (1:1 EtOAc–hexane); IR: *v* 3030, 2925, 1727, 1608, 1454, 1413, 1267, 1062, 988, 828, 734, 695 cm^{-1}; ^1H NMR (400 MHz, $CDCl_3$): δ ppm 8.77 (d, 4H, J_{o-m} 2.4, C_5H_4), 7.79 (d, 4H, J_{o-m} 2.4, C_5H_4) 7.34–7.16 (m, 30H, C_6H_5), 5.18 (d, 2H, J_{1-2} 3.4, H-1), 4.98 (d, 2H, J_{gem} 10.8, ØCH_2), 4.94 (d, 2H, J_{gem} 11.0, ØCH_2), 4.87 (d, 2H, J_{gem} 10.8, ØCH_2), 4.74 (sl, 4H, ØCH_2), 4.65 (d, 2H, J_{gem} 11.0, ØCH_2), 4.38 (ddd, 2H, J_{4-5} 9.7, J_{5-6} 6.4, J_{5-6} 3.2, H-5), 4.11 (t, 2H, J_{3-4} 9.1, H-3), 3.60 (dd, 2H, J_{2-3} 9.1, H-2), 3.57 (dd, 2H, J_{6-6} 13.1, H-6), 3.45 (t, 2H, J_{4-5} 9.7, H-4), 3.38 (ddd, 2H, J_{5-6} 6.4, J_{5-6} 3.2, J_{6-6} 13.1, H-6); ^{13}C NMR (50 MHz, $CDCl_3$): δ ppm 165.9, 163.8 (C-2′, C-5′), 150.7 (4C_6H_5), 138.4, 137.8 (6C-*ipso*), 130.8, 128.6, 128.5, 128.4, 128.3, 127.9, 127.8, 127.7, 127.2, 120.1 (36C_6H_5), 93.3 (2C-1), 81.4 (2C-3), 79.9 (2C-4), 79.3 (2C-2), 75.7, 75.3, 73.2 (6ØCH$_2$), 69.7 (2C-5), 34.7 (2C-6); Anal. Calcd for $C_{68}H_{64}N_6O_{11}S_2$: C, 67.76; H, 5.35; N, 6.97. Found: C, 67.16; H, 4.81; N, 6.41.

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