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Regioselective glycosylation of 4,6-*O*-benzylidenated glucopyranosides

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Abstract

Regioselective glycosylation with allyl 4,6-*O*-benzylidene-α,β-D-glucopyranoside or methyl 4,6-*O*-benzylidene-α,β-D-glucopyranoside as the acceptor was investigated. It was found that the regioselectivity depends upon donor size and anomeric configuration of the acceptor, i.e., with a monosaccharide donor and an α-form acceptor, the (1→3)-linked product was obtained predominantly or exclusively, while with disaccharide or trisaccharide donors and either an α or β form acceptor, the (1→2)-linked oligosaccharides were the only products.

Keywords: Glucose oligosaccharides; Trichloroacetimidates; Regioselective glycosylation

1. Introduction

Regioselective coupling is an effective and concise method for the synthesis of oligosaccharides as it can simplify the synthetic route substantially and avoid a tedious protection–deprotection procedure. Just like stereoselective formation of the glycosidic linkage, the results of regioselective coupling are influenced by many factors.[1] Recently, a series of work on regioselective coupling has been carried out in our group, resulting in a variety of branched mannose, rhamnose, and glucose oligosaccharides.[2]

β-(1→3)-Linked glucans occur in some biologically important natural products, such as schizophyllan, sclerоglucan and lentinan with antitumor activity,[3] and the β-(1→2)-glucosyl linkage occurs in the capsular polysaccharide of *Streptococcus peumoniae* type 37[4a] and in the exopolysaccharide of *Pediococus domnosus*.[4b] 4,6-*O*-Benzylidenated glucopyranosides are good acceptors since their 3-*O*- or 2-*O*-selective coupling with appropriate donors can afford (1→3)- or (1→2)-linked oligosaccharides, based on which useful fragments of natural polysaccharides can be synthesized. However, there is a very subtle distinction between the 2-OH and the 3-OH of the acceptors, and the activity of the 3-OH is little bit greater than that of the 2-OH when fully benzylated glucosyl trichloroacetimidate was used as the donor.[5] We present herein 3-*O*- or 2-*O*-regioselective glycosylation of 4,6-*O*-benzylidenated glucosides with fully benzoylated glycosyl trichloroacetimidates as donors.

2. Results and discussion

As shown in Scheme 1, glycosylation of methyl 4,6-*O*-benzylidene-α-D-glucopyranoside (**2**) with 2,3,4,6-tetra-*O*-benzoyl-α-D-glucopyranosyl trichloroacetimidate (**1**) afforded a mixture of β-(1→3)-linked disaccharide **3** (53%) and β-(1→2)-linked disaccharide **4** (24%), and no α-linked product was detected. Compounds **3** and **4** were isolated and characterized by their acetylation to give the corresponding 2-acetate and 3-acetate, respectively. The former showed H-2 at δ 4.77 ppm with $J_{1,2} = 4.0$, $J_{2,3} = 9.6$ Hz, and the latter showed H-3 at δ 5.46 ppm with $J_{2,3} = J_{3,4} = 9.6$ Hz in their ^{1}H NMR spectra. It was interesting to find that coupling of **1** with the allyl glucoside **5** instead of **2**, gave exclusive β-(1→3)-linked disaccharide **6** (75%), disclosing that allyl, instead of methyl, as the aglycon moiety of the acceptor led to 3-*O*-glycosylation. It was also found

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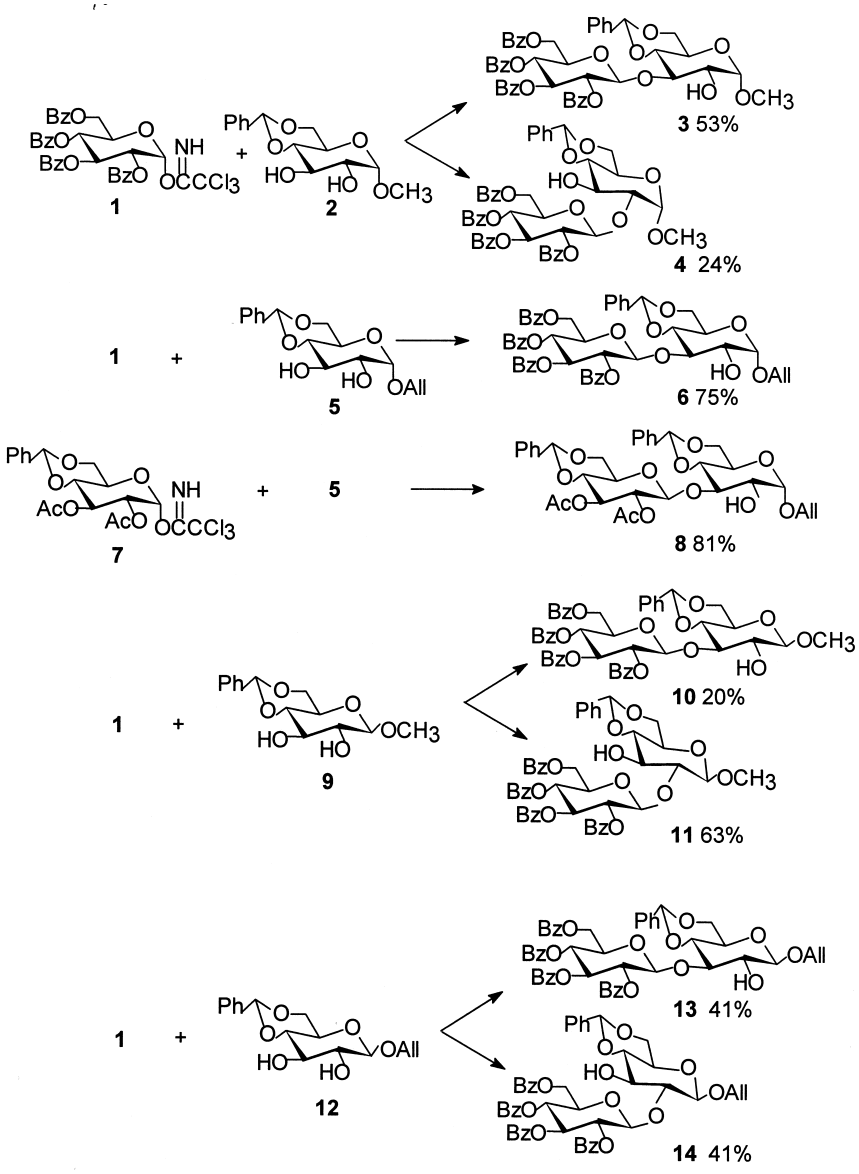
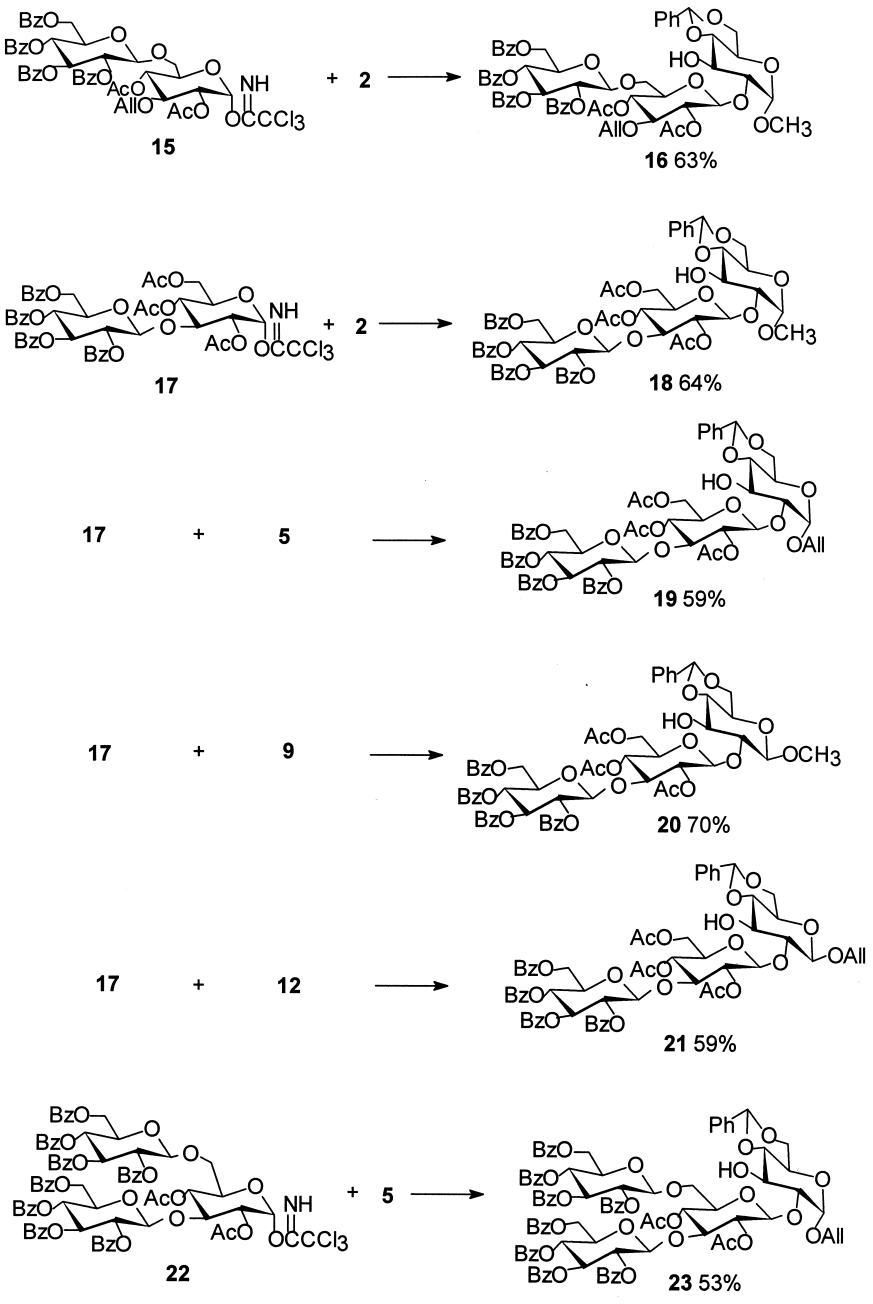
that condensation of **5** with the donor, 2,3-di-*O*-acetyl-4,6-*O*-benzylidene-α-D-glucopyranosyl trichloroacetimidate (**7**), yielded solely the β-(1→3)-linked disaccharide **8** (81%). To examine the effect of anomeric configuration in the acceptor, methyl 4,6-*O*-benzylidene-β-D-glucopyranoside (**9**) and allyl 4,6-*O*-benzylidene-β-D-glucopyranoside (**12**) were used as the acceptors for coupling with **1**. Again, the regioselectivity was established by acetylation. In the ^{1}H NMR spectra of the acetylated compounds, H-2 was found by irradiation of H-1. For the 3-*O*-glycosylation, H-2 appeared at $\delta \sim 5.0$ ppm, whereas for the 2-*O*-glycosylation, H-2 appeared at δ 3.58–3.83 ppm. It was found that the regioselectivity was changed substantially along with the configuration alteration, i.e., β-glucoside **9** inversely gave (1→2)-linked **11** (63%) as the major product and (1→3)-linked **10** (20%) as the minor one. Meanwhile, β-glucoside **12** afforded (1→2)-linked **14** and (1→3)-linked **13** in almost equivalent amounts. However, glycosylation of the acceptor **2** or **5** or their β anomer **9** or **12** with β-(1→3)-linked disaccharide **17** or β-(1→6)-linked disaccharide **15** or 3,6-branched trisaccharide **22**, always furnished (1→2)-linked oligosaccharides, indicating that large size donors intended to give (1→2)-regioselectivity (Scheme 2).

Vasella's group[5] explored the regioselectivity–structure relationship. They found that the glycosylation regioselectivity depends upon the relative strength of the intramolecular H-bonds of the acceptors when the donors were monosaccharides. Fraser-Reid and coworkers[6] found that a 2-*O*-benzoyl group in the donor gave more 2-linked product compared to the 2-*O*-ben-



Scheme 1.



Scheme 2.

zyl group when the acceptors were methyl 4,6-*O*-benzylidene-α,β-D-glucopyranosides. In our research, di- or trisaccharide donors exclusively gave 2-*O*-glycosylation products, and the β-form of the acceptor tended to give 2-*O*-glycosylation. We hypothesized that the large-size donors had a serious repulsion with the benzylidene group of the acceptor, making 3-*O* less reactive than 2-*O*, and the β-form of the acceptor had less steric hindrance between the donor and aglycon, leading to more of the (1→2)-linkage.

In summary, the regioselectivity of glycosylation of a 4,6-*O*-benzylidene glucopyranoside depends upon donor size and anomeric configuration of acceptor. With a monosaccharide donor and an α-form acceptor, (1→3)-linked product was obtained predominantly or exclusively, while with di- or trisaccharide as the donors, (1→2)-linked oligosaccharides were the only products.

3. Experimental

3.1. General methods

Optical rotations were determined at 25 °C with a Perkin–Elmer Model 241-Mc automatic polarimeter.

^{1}H, ^{13}C NMR were recorded with Bruker ARX 400 spectrometers (400 MHz for ^{1}H, 100 MHz for ^{13}C) at 25 °C for solutions in $CDCl_3$ or D_2O as indicated. Thin-layer chromatography (TLC) was performed on silica gel HF_{254} with detection by charring with 30% (v/v) H_2SO_4 in MeOH or in some cases by a UV lamp. Column chromatography was conducted by elution of a column (8×240, 18×300, 35×400 mm) of silica gel (100–200 mesh) with EtOAc–petroleum ether (bp 60–90 °C) as the eluent. Solutions were concentrated at < 60 °C under reduced pressure.

3.2. Methyl 2,3,4,6-tetra-*O*-benzoyl-β-D-glucopyranosyl-(1→3)-4,6-*O*-benzylidene-α-D-glucopyranoside (3)

Compounds **2** (150 mg, 0.20 mmol) and **1** (60 mg, 0.21 mmol) were dried together under high vacuum for 2 h, then dissolved in anhyd CH_2Cl_2 (5 mL). TMSOTf (8 μL) was added dropwise at −20 °C with N_2 protection. The reaction mixture was stirred for 3 h, during which time the temperature was gradually raised to ambient temperature. Then the mixture was neutralized with Et_3N. Concentration of the reaction mixture, followed by purification on a silica gel column with 2:1 petroleum ether–EtOAc as the eluent, gave two disaccharides with R_f 0.45 and 0.60 on TLC (2:1 petroleum ether–EtOAc), respectively. The disaccharide with R_f 0.45 was acetylated in pyridine (2 mL) with Ac_2O (0.5 mL) for 3 h, then concentrated to dryness. The residue was purified by flash chromatography (3:1 petroleum ether–EtOAc) to give the 2-acetate of **3** (95 mg, 53% for two steps) as a syrup: $[\alpha]_D + 17.0°$ (*c* 1.0, $CHCl_3$); ^{1}H NMR (400 MHz, $CDCl_3$): δ 7.93–7.25 (m, 25 H, Ph*H*), 5.85 (dd, 1 H, $J_{3',4'} = J_{4',5'} = 9.6$ Hz, H-4′), 5.65 (dd, 1 H, $J_{3',4'} = J_{2',3'} = 9.6$ Hz, H-3′), 5.600 (s, 1 H, PhC*H*), 5.50 (dd, 1 H, $J_{1',2'}$ 8.0, $J_{2',3'}$ 9.6 Hz, H-2′), 5.07 (d, 1 H, $J_{1',2'}$ 8.0 Hz, H-1′), 4.85 (d, 1 H, $J_{1,2}$ 4.0 Hz, H-1), 4.77 (dd, 1 H, $J_{2,3}$ 9.6, $J_{1,2}$ 4.0 Hz, H-2), 4.47 (dd, 1 H, $J_{6'a,6'b}$ 12.0, $J_{5',6'a}$ 3.6 Hz, H-6′a), 4.30–4.24 (m, 3 H), 3.91–3.73 (m, 4 H), 3.32 (s, 3 H, CH_3O), 1.77 (s, 3 H, CH_3CO). Anal. Calcd for $C_{50}H_{46}O_{16}$: C, 66.51; H, 5.14. Found: C, 66.79; H, 5.01.

3.3. Methyl 2,3,4,6-tetra-*O*-benzoyl-β-D-glucopyranosyl-(1→2)-4,6-*O*-benzylidene-α-D-glucopyranoside (4)

The disaccharide with R_f 0.60 in Section 3.2, above, was acetylated with Ac_2O in pyridine to give the 3-acetate of **4** (45 mg, 24% for two steps): $[\alpha]_D + 13.2°$ (*c* 1.0, $CHCl_3$); ^{1}H NMR (400 MHz, $CDCl_3$): δ 8.03–7.25 (m, 25 H, Ph*H*), 5.93 (dd, 1 H, $J_{3',4'} = J_{4',5'} = 9.6$ Hz, H-4′), 5.69 (dd, 1 H, $J_{3',4'} = J_{2',3'} = 9.6$ Hz, H-3′), 5.55 (dd, 1 H, $J_{1',2'}$ 7.8, $J_{2',3'}$ 9.6 Hz, H-2′), 5.46 (dd, 1 H, $J_{3,4} = J_{2,3} = 9.6$ Hz, H-3), 5.41 (s, 1 H, PhC*H*), 5.01 (d, 1 H, $J_{1,2}$ 3.2 Hz, H-1), 4.99 (d, 1 H, $J_{1',2'}$ 7.8 Hz, H-1′), 4.77–3.85 (m, 5 H), 3.74 (dd, $J_{1,2}$ 3.2, $J_{2,3}$ 9.6 Hz, H-2), 3.71–3.46 (m, 2 H), 3.37 (s, 3 H, CH_3O), 1.70 (s, CH_3CO). Anal. Calcd for $C_{50}H_{46}O_{16}$: C, 66.51; H, 5.14. Found: C, 66.27; H, 5.22.

3.4. Allyl 2,3,4,6-tetra-*O*-benzoyl-β-D-glucopyranosyl-(1→3)-4,6-*O*-benzylidene-α-D-glucopyranoside (6)

The 2-acetate of **6** (138 mg, 75% for two steps) was obtained as a syrup by coupling of **1** (150 mg, 0.20 mmol) with **5** (62 mg, 0.20 mmol), followed by acetylation under the same conditions as described for the preparation of the 2-acetate of **3**: $[\alpha]_D + 15.3°$ (*c* 1.0, $CHCl_3$); ^{1}H NMR (400 MHz, $CDCl_3$): δ 7.95–7.26 (m, 25 H, Ph*H*), 5.82 (dd, 1 H, $J_{3',4'} = J_{4',5'} = 9.6$ Hz, H-4′), 5.81–5.72 (m, 1 H, –C*H*=), 5.66 (dd, 1 H, $J_{3',4'} = J_{2',3'} = 9.6$ Hz, H-3′), 5.60 (s, 1 H, PhC*H*), 5.50 (dd, 1 H, $J_{1',2'}$ 8.0, $J_{2',3'}$ 9.6 Hz, H-2′), 5.22–5.13 (m, 2 H, =CH_2), 5.09 (d, 1 H, $J_{1',2'}$ 8.0 Hz, H-1′), 5.00 (d, 1 H, $J_{1,2}$ 3.6 Hz, H-1), 4.76 (dd, 1 H, $J_{1,2}$ 4.0, $J_{2,3}$ 9.6 Hz, H-2), 4.47 (dd, 1 H, $J_{6'a,6'b}$ 12.4, $J_{5',6'a}$ 3.2 Hz, H-6′a), 4.34–4.23 (m, 3 H), 4.10–3.89 (m, 4 H), 3.79–3.74 (m, 2 H), 1.74 (s, 3 H, CH_3CO). Anal. Calcd for $C_{52}H_{48}O_{16}$: C, 67.27; H, 5.21. Found: C, 67.43; H, 5.19.

3.5. Allyl 2,3-di-*O*-acetyl-4,6-*O*-benzylidene-β-D-glucopyranosyl-(1→3)-4,6-*O*-benzylidene-α-D-glucopyranoside (8)

The 2-acetate of **8** (110 mg, 81% for two steps) was obtained as a syrup by coupling of **7** (100 mg, 0.20 mmol) with **5** (62 mg, 0.20 mmol), followed by acetylation under the same conditions as described for the preparation of the 2-acetate of **3**: $[\alpha]_D + 15.3°$ (*c* 1.0, $CHCl_3$); ^{1}H NMR (400 MHz, $CDCl_3$): δ 7.51–7.34 (m, 10 H, Ph*H*), 5.91–5.82 (m, 1 H, –C*H*=), 5.57 (s, 1 H, PhC*H*), 5.34 (s, 1 H, PhC*H*), 5.33–5.21 (m, 2 H, =CH_2), 5.21 (dd, 1 H, $J_{3',4'} = J_{2',3'} = 9.6$ Hz, H-3′), 5.05 (d, 1 H, $J_{1,2}$ 4.0 Hz, H-1), 5.01 (dd, 1 H, $J_{1',2'}$ 7.8, $J_{2',3'}$ 9.6 Hz, H-2′), 4.88 (d, 1 H, $J_{1',2'}$ 7.8 Hz, H-1′), 4.86 (dd, $J_{1,2}$ 4.0, $J_{2,3}$ 9.6 Hz, H-2), 4.32–4.16 (m, 4 H), 4.02–3.89 (m, 2 H), 3.79–3.63 (m, 4 H), 3.49–3.42 (m, 1 H), 2.16 (s, 3 H, CH_3CO), 2.04 (s, 6 H, 2CH_3CO). Anal. Calcd for $C_{35}H_{40}O_{14}$: C, 61.40; H, 5.89. Found: C, 61.31; H, 5.97.

3.6. Methyl 2,3,4,6-tetra-*O*-benzoyl-β-D-glucopyranosyl-(1→3)-4,6-*O*-benzylidene-β-D-glucopyranoside (10)

The 2-acetate of **10** (115 mg, 63% for two steps) was obtained as a syrup by coupling of **1** (150 mg, 0.20 mmol) with **9** (60 mg, 0.21 mmol), followed by silica gel separation and acetylation under the same conditions as described for the preparation of the 2-acetate of **3**: $[\alpha]_D + 13.5°$ (*c* 1.0, $CHCl_3$); ^{1}H NMR (400 MHz, $CDCl_3$): δ 7.92–7.26 (m, 25 H, Ph*H*), 5.79 (dd, 1 H, $J_{3',4'} = J_{4',5'} = 9.6$ Hz, H-4′), 5.63 (dd, 1 H, $J_{3',4'} = J_{2',3'}$

9.6 Hz, H-3′), 5.58 (s, 1 H, PhC*H*), 5.46 (dd, 1 H, $J_{1',2'}$ 8.0, $J_{2',3'}$ 9.6 Hz, H-2′), 5.05 (d, 1 H, $J_{1',2'}$ 8.0 Hz, H-1′), 4.98 (dd, 1 H, $J_{1,2}$ 8.0, $J_{2,3}$ 8.8 Hz, H-2), 4.45–4.33 (m, 2 H), 4.30 (d, 1 H, $J_{1,2}$ 8.0 Hz, H-1), 4.24–4.20 (m, 1 H), 4.02–3.97 (m, 1 H), 3.84–3.77 (m, 3 H), 3.47–3.42 (m, 1 H), 3.37 (s, 3 H, CH_3O), 1.73 (s, 3 H, CH_3CO). Anal. Calcd for $C_{50}H_{46}O_{16}$: C, 66.51; H, 5.14. Found: C, 66.32; H, 5.17.

3.7. Methyl 2,3,4,6-tetra-*O*-benzoyl-β-D-glucopyranosyl-(1→2)-4,6-*O*-benzylidene-β-D-glucopyranoside (11)

The 3-acetate of **11** (35 mg, 20%, two steps) was prepared as a syrup under the same conditions as described for the preparation of the 3-acetate of **4**: $[\alpha]_D + 16.8°$ (*c* 1.0, $CHCl_3$); ^{1}H NMR (400 MHz, $CDCl_3$): δ 7.92–7.24 (m, 25 H, Ph*H*), 5.85 (dd, 1 H, $J_{3',4'} = J_{4',5'} = 9.6$ Hz, H-4′), 5.72 (dd, 1 H, $J_{3',4'} = J_{2',3'} =$ 9.6 Hz, H-3′), 5.48 (dd, 1 H, $J_{1',2'}$ 8.0, $J_{2',3'}$ 9.6 Hz, H-2′), 5.37 (s, 1 H, PhC*H*), 5.25 (d, 1 H, $J_{1',2'}$ 8.0 Hz, H-1′), 5.19 (dd, 1 H, $J_{3,4} = J_{2,3} = 9.6$ Hz, H-3), 4.67 (dd, 1 H, $J_{6'a,6'b}$ 12.4, $J_{5',6'a}$ 3.2 Hz, H-6′a), 4.57 (d, 1 H, $J_{1,2}$ 8.0 Hz, H-1), 4.48 (dd, 1 H, $J_{6'a,6'b}$ 12.4, $J_{5',6'b}$ 3.2 Hz, H-6′b), 4.28 (dd, 1 H, $J_{6a,6b}$ 12.0, $J_{5,6a}$ 3.2 Hz, H-6a), 4.18 (dd, 1 H, $J_{6a,6b}$ 12.0, $J_{5,6b}$ 3.2 Hz, H-6b), 3.76 (dd, 1 H, $J_{1,2}$ 8.0, $J_{2,3}$ 9.6 Hz, H-2), 3.69–3.55 (m, 2 H), 3.51 (s, 3 H, CH_3O), 3.79–3.45 (m, 1 H), 1.73 (s, 3 H, CH_3CO). Anal. Calcd for $C_{50}H_{46}O_{16}$: C, 66.51; H, 5.14. Found: C, 66.61; H, 5.20.

3.8. Allyl 2,3,4,6-tetra-*O*-benzoyl-β-D-glucopyranosyl-(1→3)-4,6-*O*-benzylidene-β-D-glucopyranoside (13)

The 2-acetate of **13** (77 mg, 41% for two steps) was obtained as a syrup by coupling of **1** (150 mg, 0.20 mmol) with **12** (62 mg, 0.20 mmol), followed by silica gel separation and acetylation under the same conditions as described for the preparation of the 2-acetate of **3**: $[\alpha]_D + 8.0°$ (*c* 2.0, $CHCl_3$); ^{1}H NMR (400 MHz, $CDCl_3$): δ 7.95–7.25 (m, 25 H, Ph*H*), 5.81 (dd, 1 H, $J_{3',4'} = J_{4',5'} = 9.6$ Hz, H-4′), 5.76–5.70 (m, 1 H, –C*H*=), 5.64 (dd, 1 H, $J_{3',4'} = J_{2',3'} = 9.6$ Hz, H-3′), 5.59 (s, 1 H, PhC*H*), 5.48 (dd, 1 H, $J_{1',2'}$ 8.0, $J_{2',3'}$ 9.6 Hz, H-2′), 5.20–5.09 (m, 2 H, =CH_2), 5.05 (d, 1 H, $J_{1',2'}$ 8.0 Hz, H-1′), 5.03 (dd, 1 H, $J_{1,2}$ 8.0, $J_{2,3}$ 8.8 Hz, H-2), 4.47–4.43 (m, 1 H), 4.43 (d, 1 H, $J_{1,2}$ 8.0 Hz, H-1), 4.33 (m, 1 H), 4.26–4.22 (m, 2 H), 4.04–3.95 (m, 2 H), 3.91–3.78 (m, 3 H), 3.47–3.39 (m, 1 H), 1.73 (s, 3 H, CH_3CO). Anal. Calcd for $C_{52}H_{48}O_{16}$: C, 67.27; H, 5.21. Found: C, 66.97; H, 5.20.

3.9. Allyl 2,3,4,6-tetra-*O*-benzoyl-β-D-glucopyranosyl-(1→2)-4,6-*O*-benzylidene-β-D-glucopyranoside (14)

The 3-acetate of **14** (75 mg, 41%, two steps) was prepared as a syrup under the same conditions as described for the preparation of the 3-acetate of **4**: $[\alpha]_D + 6.5°$ (*c* 1.0, $CHCl_3$); ^{1}H NMR (400 MHz, $CDCl_3$): δ 8.04–7.25 (m, 25 H, Ph*H*), 5.95–5.84 (m, 1 H, C*H*=), 5.86 (dd, 1 H, $J_{3',4'} = J_{4',5'} = 9.6$ Hz, H-4′), 5.75 (dd, 1 H, $J_{3',4'} = J_{2',3'} = 9.6$ Hz, H-3′), 5.49 (dd, 1 H, $J_{1',2'}$ 8.0, $J_{2',3'}$ 9.6 Hz, H-2′), 5.38 (s, 1 H, PhC*H*), 5.36–5.31 (m, 1 H, =CH_{2a}), 5.28 (d, 1 H, $J_{1',2'}$ 8.0 Hz, H-1′), 5.21 (dd, 1 H, $J_{3,4} = J_{2,3} = 9.2$ Hz, H-3), 5.19–5.15 (m, 1 H, =CH_{2b}), 4.72 (d, 1 H, $J_{1,2}$ 7.8 Hz, H-1), 4.64 (dd, 1 H, $J_{6'a,6'b}$ 12.4, $J_{5',6'a}$ 3.2 Hz, H-6′a), 4.47–4.13 (m, 5 H), 3.83 (dd, 1 H, $J_{1,2}$ 8.0, $J_{2,3}$ 9.2 Hz, H-2), 3.68–3.46 (m, 3 H), 1.76 (s, 3 H, CH_3CO). Anal. Calcd for $C_{52}H_{48}O_{16}$: C, 67.27; H, 5.21. Found: C, 67.37; H, 5.31.

3.10. Methyl 2,3,4,6-tetra-*O*-benzoyl-β-D-glucopyranosyl-(1→6)-2,4-di-*O*-acetyl-3-*O*-allyl-β-D-glucopyranosyl-(1→2)-4,6-*O*-benzylidene-α-D-glucopyranoside (16)

2,3,4,6-Tetra-*O*-benzoyl-β-D-glucopyranosyl-(1→6)-2,4-di-*O*-acetyl-3-*O*-allyl-α-D-glucopyranosyl trichloroacetimidate (**15**, 100 mg, 0.1 mmol) and methyl 4,6-*O*-benzylidene-α-D-glucopyranoside (**2**, 30 mg, 0.11 mmol) were dried together under high vacuum for 2 h, then dissolved in anhyd CH_2Cl_2 (5 mL). TMSOTf (8 μL) was added dropwise at −20 °C with N_2 protection. The reaction mixture was stirred for 3 h, during which time the temperature was gradually raised to ambient temperature. Then the mixture was neutralized with Et_3N. Concentration of the reaction mixture, followed by purification on a silica gel column with 2:1 petroleum ether–EtOAc as the eluent, gave the trisaccharide (72 mg, 63%). The trisaccharide was acetylated in pyridine (2 mL) with Ac_2O (0.5 mL), then concentrated to dryness. The residue was purified by flash chromatography (2:1 petroleum ether–EtOAc) to give the 3-acetate of **16** (70 mg, 94%) as a syrup: $[\alpha]_D + 12.0°$ (*c* 1.0, $CHCl_3$); ^{1}H NMR (400 MHz, $CDCl_3$): δ 8.06–7.25 (m, 25 H, Ph*H*), 5.88 (dd, 1 H, $J_{3'',4''} = J_{4'',5''} = 9.6$ Hz, H-4″), 5.72–5.68 (m, 1 H, –C*H*=), 5.68 (dd, 1 H, $J_{3'',4''} = J_{2'',3''} = 9.6$ Hz, H-3″), 5.57–5.47 (m, 3 H, H-2″, H-3, PhC*H*), 5.22–5.15 (m, 2 H, CH_2=), 5.01 (d, 1 H, $J_{1'',2''}$ 8.0 Hz, H-1″), 4.86 (dd, 1 H, $J_{4',5'} = J_{4',3'}$ 9.6 Hz, H-4′), 4.80 (d, 1 H, $J_{1,2}$ 4.0 Hz, H-1), 4.78 (dd, 1 H, $J_{2',3'}$ 9.6, $J_{1',2'}$ 8.0 Hz, H-2′), 4.65–4.48 (m, 2 H), 4.45 (dd, 1 H $J_{1',2'}$ 8.0 Hz, H-1′), 4.30–4.12 (m, 2 H), 3.96–3.75 (m, 4 H), 3.71 (dd, 1 H, $J_{2,3}$ 9.6, $J_{1,2}$ 4.0 Hz, H-2), 3.67 (dd,1 H, $J_{3,4} = J_{4,5} = 9.6$ Hz, H-4), 3.65–3.63 (m, 1 H), 3.43 (dd, 1 H, $J_{3',4'} = J_{2',3'} = 9.6$ Hz, H-3′), 3.36 (s, 3 H, CH_3O), 2.09 (s, 3 H, CH_3CO), 2.07 (s, 3 H, CH_3CO), 1.99 (s, 3 H, CH_3CO). Anal. Calcd for $C_{63}H_{64}O_{23}$: C, 63.63; H, 5.42. Found: C, 64.01; H, 5.50.

3.11. Methyl 2,3,4,6-tetra-*O*-benzoyl-β-D-glucopyranosyl-(1→3)-2,4,6-tri-*O*-acetyl-β-D-glucopyranosyl-(1→2)-4,6-*O*-benzylidene-α-D-glucopyranoside (18)

The 3-acetate of **18** (111 mg, 64% for two steps) was obtained as a syrup by coupling of 2,3,4,6-tetra-*O*-benzoyl-β-D-glucopyranosyl-(1→3)-2,4,6-tri-*O*-acetyl-α-D-glucopyranosyl trichloroacetimidate (**17**, 150 mg, 0.15 mmol) with **2** (40 mg, 0.15 mmol) followed by acetylation under the same conditions as described for the preparation of the 3-acetate of **16**: $[\alpha]_D + 21.4°$ (*c* 0.5, $CHCl_3$); ^1H NMR (400 MHz, $CDCl_3$): δ 8.03–7.26 (m, 25 H, Ph*H*), 5.90 (dd, 1 H, $J_{3'',4''} = J_{4'',5''} = 9.6$ Hz, H-4″), 5.68 (dd, 1 H, $J_{3'',4''} = J_{2'',3''} = 9.6$ Hz, H-3″), 5.43 (s, 1 H, PhC*H*), 5.43–5.38 (m, 2 H, H-4′, H-2″), 5.03 (dd, 1 H, $J_{3,4} = J_{2,3} = 9.6$ Hz, H-3), 4.92 (dd, 1 H, $J_{1',2'}$ 8.0, $J_{2',3'}$ 9.6 Hz, H-2′), 4.89 (d, 1 H, $J_{1'',2''}$ 8.0 Hz, H-1″), 4.74 (d, 1 H, $J_{1,2}$ 3.6 Hz, H-1), 4.61–4.50 (m, 2 H), 4.47 (d, 1 H, $J_{1',2'}$ 8.0 Hz, H-1′), 4.38–4.07 (m, 4 H), 3.97–3.69 (m, 3 H), 3.62 (dd, 1 H, $J_{1,2}$ 4.0, $J_{2,3}$ 9.6 Hz, H-2), 3.54–3.46 (m, 2 H), 3.32 (s, 3 H, CH_3O), 2.08, 2.06, 1.97, 1.90 (4 s, 12 H, 4 CH_3CO). Anal. Calcd for $C_{62}H_{62}O_{24}$: C, 62.52; H, 5.25. Found: C, 62.27; H, 5.31.

3.12. Allyl 2,3,4,6-tetra-*O*-benzoyl-β-D-glucopyranosyl-(1→3)-2,4,6-tri-*O*-acetyl-β-D-glucopyranosyl-(1→2)-4,6-*O*-benzylidene-α-D-glucopyranoside (19)

The 3-acetate of **19** (105 mg, 59% for two steps) was obtained as a syrup by coupling of **17** (150 mg, 0.15 mmol) with **5** (45 mg, 0.15 mmol), followed by acetylation under the same conditions as described for the preparation of the 3-acetate of **16**: $[\alpha]_D + 8.2°$ (*c* 1.0, $CHCl_3$); ^1H NMR (400 MHz, $CDCl_3$): δ 8.04–7.29 (m, 25 H, Ph*H*), 5.92 (dd, 1 H, $J_{3'',4''} = J_{4'',5''} = 9.6$ Hz, H-4″), 5.85 (m, 1 H, –C*H*=), 5.70 (dd, 1 H, $J_{3'',4''} = J_{2'',3''} = 9.6$ Hz, H-3″), 544 (s, 1 H, PhC*H*), 5.43 (dd, 1 H, $J_{1'',2''}$ 8.0, $J_{2'',3''}$ 9.6 Hz, H-2″), 5.32–5.15 (m, 2 H, CH_2=), 5.04 (dd, 1 H, $J_{3',4'} = J_{4',5'} = 9.6$ Hz, H-4′), 5.02 (d, 1 H, $J_{1'',2''}$ 4.0 Hz, H-1″), 4.95–4.90 (m, 3 H, H-2′, H-3, H-1), 4.65–4.54 (m, 2 H), 4.50 (d, 1 H, $J_{1,2}$ 8.0 Hz, H-1′), 4.30–3.95 (m, 7 H), 3.72–3.69 (m, 1 H), 3.66 (dd, 1 H, $J_{1,2}$ 4.0, $J_{2,3} = 9.6$ Hz, H-2), 3.59–3.50 (m, 2 H), 2.09, 2.09, 1.99, 1.91 (3 s, 12 H, 4 CH_3CO). Anal. Calcd for $C_{64}H_{64}O_{24}$: C, 63.15; H, 5.30. Found: C, 63.35; H, 5.30.

3.13. Methyl 2,3,4,6-tetra-*O*-benzoyl-β-D-glucopyranosyl-(1→3)-2,4,6-tri-*O*-acetyl-β-D-glucopyranosyl-(1→2)-4,6-*O*-benzylidene-β-D-glucopyranoside (20)

The 3-acetate of **20** (121 mg, 70% for two steps) was prepared as a syrup by coupling of **17** (150 mg, 0.15 mmol) with **9** (40 mg, 0.15 mmol), followed by acetylation under the same conditions as described for the preparation of the 3-acetate of **16**: $[\alpha]_D - 15.3°$ (*c* 1.0, $CHCl_3$); ^1H NMR (400 MHz, $CDCl_3$): δ 8.02–7.26 (m, 25 H, Ph*H*), 5.90 (dd, 1 H, $J_{3'',4''} = J_{4'',5''} = 9.6$ Hz, H-4″), 5.65 (dd, 1 H, $J_{3'',4''} = J_{2'',3''} = 9.6$ Hz, H-3″), 5.44 (s, 1 H, PhC*H*), 5.42 (dd, 1 H, $J_{1'',2''}$ 8.0, $J_{2'',3''}$ 9.6 Hz, H-2″), 5.09 (dd, 1 H, $J_{3',4'} = J_{4',5'} = 9.6$ Hz, H-4′), 5.00 (dd, $J_{1',2'}$ 8.0, $J_{2',3'}$ 9.6 Hz, H-2′), 4.98 (d, 1 H, $J_{1'',2''}$ 8.0 Hz, H-1″), 4.89 (dd, 1 H, $J_{3,4} = J_{2,3} = 9.6$ Hz, H-3), 4.70 (d, 1 H, $J_{1',2'}$ 8.0 Hz, H-1′), 4.67–4.50 (m, 2 H), 4.34 (d, 1 H, $J_{1,2}$ 3.2 Hz, H-1), 4.33–4.29 (m, 1 H), 4.28–4.11 (m, 2 H), 3.93–3.91 (m, 1 H), 3.68–3.66 (m, 1 H), 3.64 (dd, $J_{1,2}$ 8.0, $J_{2,3}$ 9.6 Hz, H-2), 3.64–3.62 (m, 1 H), 3.59–3.54 (m, 1 H), 3.47 (s, 3 H, CH_3O), 3.41–3.34 (m, 1 H), 2.06, 2.04, 1.96, 1.95 (4 s, 12 H, 4 CH_3CO). Anal. Calcd for $C_{62}H_{62}O_{24}$: C, 62.52; H, 5.25. Found: C, 62.48; H, 5.41.

3.14. Allyl 2,3,4,6-tetra-*O*-benzoyl-β-D-glucopyranosyl-(1→3)-2,4,6-tri-*O*-acetyl-β-D-glucopyranosyl-(1→2)-4,6-*O*-benzylidene-β-D-glucopyranoside (21)

The 3-acetate of **21** (105 mg, 59% for two steps) was obtained as a syrup by coupling of **17** (150 mg, 0.15 mmol) with **12** (45 mg, 0.15 mmol), followed by acetylation under the same conditions as described for the preparation of the 3-acetate of **16**: $[\alpha]_D - 25.5°$ (*c* 1.0, $CHCl_3$); ^1H NMR (400 MHz, $CDCl_3$): δ 7.95–7.18 (m, 25 H, Ph*H*), 5.82 (dd, 1 H, $J_{3'',4''} = J_{4'',5''} = 9.6$ Hz, H-4″), 5.80 (m, 1 H, –C*H*=), 5.60 (dd, 1 H, $J_{3'',4''} = J_{2'',3''} = 9.6$ Hz, H-3″), 5.36 (s, 1 H, PhC*H*), 5.34 (dd, 1 H, $J_{1'',2''}$ 8.0, $J_{2'',3''}$ 9.6 Hz, H-2″), 5.25–5.07 (m, 2 H, CH_2=), 5.02–4.98 (m, 2 H, H-4′ H-3), 4.87 (d, 1 H, $J_{1'',2''}$ 8.0 Hz, H-1″), 4.83 (dd, 1 H, $J_{1',2'}$ 8.0, $J_{2',3'}$ 9.2 Hz, H-2′), 4.61 (d, 1 H, $J_{1',2'}$ 8.0 Hz, H-1′), 4.56–4.46 (m, 2 H), 4.43 (d, 1 H, $J_{1,2}$ 8.0 Hz, H-1), 4.24–4.20 (m, 2 H), 4.08–4.01 (m, 4 H), 3.85 (dd, 1 H, $J_{3',4'} = J_{2',3'} = 9.6$ Hz, H-3′), 3.64–3.59 (m, 2 H), 3.58 (dd, 1 H, $J_{1,2}$ 8.0, $J_{2,3}$ 9.6 Hz, H-2), 3.51–3.45 (m, 1 H), 3.38–3.29 (m, 1 H), 2.00, 1.98, 1.88, 1.86 (4 s, 12 H, 4 CH_3CO). Anal. Calcd for $C_{64}H_{64}O_{24}$: C, 63.15; H, 5.30. Found: C, 63.31; H, 5.17.

3.15. Allyl 2,3,4,6-tetra-*O*-benzoyl-β-D-glucopyranosyl-(1→3)-[2,3,4,6-tetra-*O*-benzoyl-β-D-glucopyranosyl-(1→6)]-2,4-di-*O*-acetyl-β-D-glucopyranosyl-(1→2)-4,6-*O*-benzylidene-α-D-glucopyranoside (23)

The 3-acetate of **23** (135 mg, 53% for two steps) was obtained as a syrup by coupling of **22** (235 mg, 0.15 mmol) with **5** (45 mg, 0.15 mmol), followed by acetylation under the same conditions as described for the preparation of the 3-acetate of **16**: $[\alpha]_D + 21.3°$ (*c* 1.0, $CHCl_3$); ^1H NMR (400 MHz, $CDCl_3$): δ 8.01–7.32 (m, 45 H, 9 Ph*H*), 5.88 (t, 1 H, *J* 9.6 Hz), 5.86 (t, 1 H, *J* 9.6 Hz), 5.82–5.75 (m, 1 H, =C*H*–), 5.68–5.6 (m, 2 H), 5.49 (s, 1 H, PhC*H*), 5.48–5.45 (m, 2 H), 5.37 (t, 1 H, *J* 9.6 Hz), 5.22–5.02 (m, 2 H), 5.01 (d, 1 H, *J* 8.0 Hz,

H-1), 4.88 (d, 1 H, *J* 3.6 Hz, H-1), 4.84 (d, 1 H, *J* 7.6 Hz, H-1), 4.79–4.70 (m, 2 H), 4.66–4.56 (m, 2 H), 4.49–4.44 (m, 2 H), 4.37 (d, 1 H, *J* 8.0 Hz, H-1), 4.18–4.09 (m, 3 H), 4.04–3.98 (m, 1 H), 3.94–3.88 (m, 2 H), 3.85–3.72 (m, 4 H), 3.68 (dd, 1 H, $J_{1,2}$ 2.8, $J_{2,3}$ 10.4 Hz, H-2), 3.62–3.54 (m, 2 H), 2.04, 1.90, 1.85 (3 s, 9 H, CH_3CO). Anal. Calcd for $C_{96}H_{88}O_{32}$: C, 65.75; H, 5.06. Found: C, 66.05; H, 4.98.

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