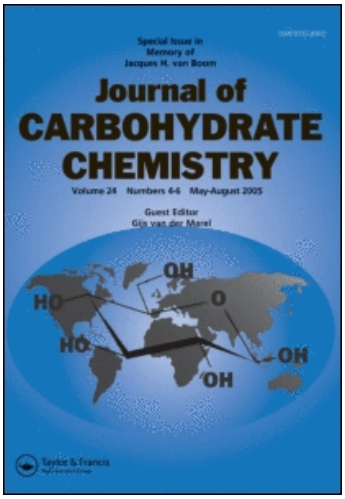

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On Resin Modification of Monosaccharides

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On Resin Modification of Monosaccharides

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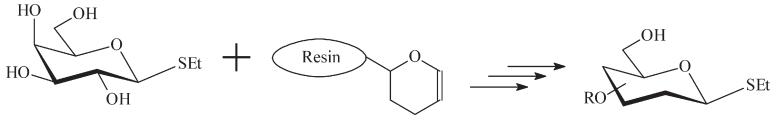
Ellman's dihydropyran resin was used for selective protection of monosaccharide thioglycosides and glycosides. Following on-resin acylation and subsequent cleavage of the polymer-bound intermediates, product components having selectively unblocked hydroxyl functions could be obtained.



Keywords Solid supported reactions, Selective protection, Acetals, (Thio)glycosides

INTRODUCTION

In solid phase or solid supported chemistry the linker chosen to attach the first residue to the support has influence on the synthetic strategy, since the chemical nature of this linkage determines all other reactions performed in subsequent synthetic steps. The bond between linker and support is usually stable enough to survive several further modifications, but the chemical properties of the linkage between the linker and attached chemical entity need to be

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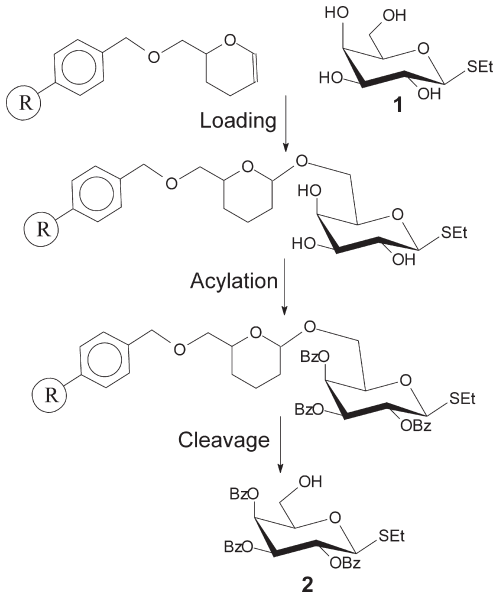
taken into account during synthesis. Linkers in solid phase carbohydrate chemistry can be considered as modified hydroxyl protecting groups, and thus products can be released from the resin corresponding to cleavage of protecting groups. Several linker systems have been investigated in solid phase carbohydrate chemistry, and they can be categorized by reaction conditions used to cleave the final product from the resin. These linkers have been reviewed for solid phase organic chemistry[1,2] and especially solid phase carbohydrate chemistry. [3,4]

Acid labile linkers are well known in solid phase peptide chemistry, but rarely used in the case of carbohydrate chemistry since these compounds are rather acid sensitive themselves. Rink linker has been used to link the carboxyl function of a uronic acid to solid support and the product cleaved with diluted TFA.[5] A tris-alkoxy-benzylamine linker was applied to couple the amino function of glucosamine to a resin and at the end of the synthesis cleaved with TFA after acetylating the secondary amine.[6] The anomeric hydroxyl function of lactose was linked to Wang resin with a *p*-alkyloxybenzyl-type linker and cleaved later with trityl-tetrafluoroborate.[7] The use of the Wang aldehyde linker creating an acetal linkage was introduced to prepare differentially protected monosaccharides, cleaving the products with diluted TFA from the resin.[8] A dihydropyranyl-type linker was examined by loading carbohydrates to Wang resin and cleaving them without any modification to recover the carbohydrate moiety.[9] Benzylated glucal was used as a linker to bind alcohols to the Merrifield resin and cleave them under mild acidic conditions.[10] For the work presented here Ellman's[11] linker was chosen to attach monosaccharides to the resin, derivatize them, and subsequently cleave the derivatized product. The selectivity of the loading was examined for a series of different pyranoses.

RESULTS AND DISCUSSION

In this study, a monosaccharide unit was linked via a hydroxyl group to Ellman's dihydropyran resin followed by acylation of the remaining free hydroxyl functions and cleavage of the product from the resin (Sch. 1). For initial experiments, monosaccharides were selected where the anomeric positions were protected (thioglycosides) or blocked (methyl glycosides). These compounds had sufficient solubility in the solvent mixture used to perform the loading.

Experiments with unprotected monosaccharides (glucose, galactose) were performed as well, but due to their low solubility in the solvent systems only traces of products were isolated after cleavage (data not shown). During loading an acetal linkage was formed catalyzed by pyridinium *p*-toluenesulfonate (P*p*Ts). The loading efficiency was determined by the following equation: $M_2 - M_1/M_w \times M_1$, wherein M_2 is the weight of the resin after loading in g, M_1 is the weight of the resin before loading in g, and M_w is the molecular weight of

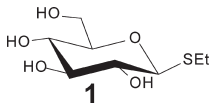
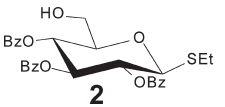
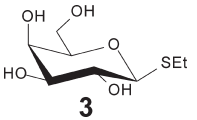
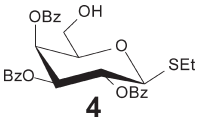
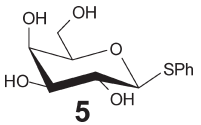
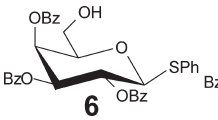
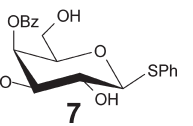
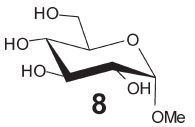
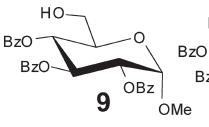
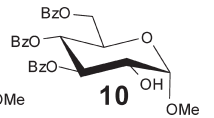
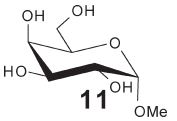
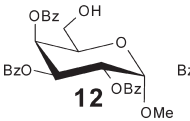
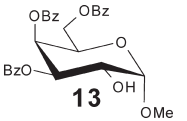


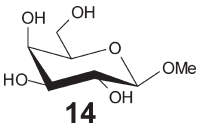
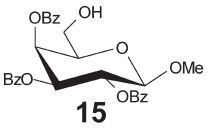
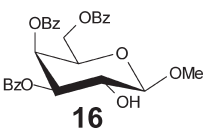
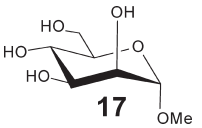
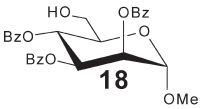
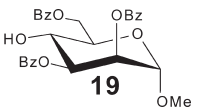
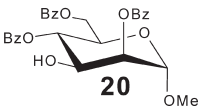
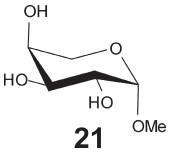
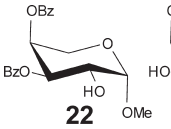
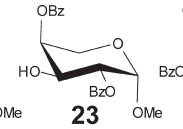
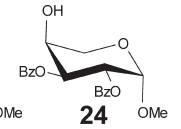
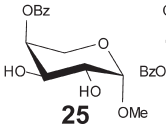
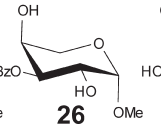
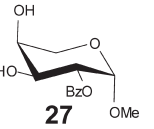
Scheme 1: General scheme.

the compound loaded to the resin in g/mol. The average loading was between 0.8 and 1.1 mmol/g. According to the manufacturer, the loading of the linker is 1.1 mmol/g. After the monosaccharide was loaded on the resin, the remaining free hydroxyl functions were protected by standard benzoylation. This facilitated the isolation of the products after cleavage by transacetylization with *p*-toluenesulfonic acid and methanol and enabled to determine which hydroxyl function had been attached to the resin. The results are summarized in Table 1.

In the case of hexopyranoses (entries 1–7), the reaction took place predominantly at the 6-position and only traces of side products could be isolated. β-Thioethylglycosides (gluco **1** and galacto **3**, respectively) gave the expected 6-OH derivatives (**2** and **4**) in high yields without any side products. The 2,6-diol **7** was isolated in traces besides the mayor 6-OH product **6** in the case of β-thiophenyl galactopyranose (**5**) having a bulky aglycon, probably as a result of steric hindrance during acylation (entry 3). Increasing the nucleophilicity of a secondary hydroxyl function enabled a coupling of this group to the resin in considerable amounts, raising the presence of the side products to 20% to 25% (entry 4: **8** → **9** and **10**, and entry 5: **11** → **12** and **13**). The higher reactivity of a hydroxyl function at position 2 of methyl α-D-glucopyranoside (**8**) and galactopyranoside (**11**) due to the hydrogen bond with the anomeric oxygen is well known explaining the difference between entry 5 and 6. The 2-OH side product also appeared in the case of methyl β-D-

Table 1: On-resin modification of monosaccharides.

Entry	Starting monosaccharide	Isolated compound(s)	Comments
1	 **1**	 **2**	
2	 **3**	 **4**	
3	 **5**	 **6**  **7**	Only ~10% of diol **7** was isolated due to incomplete benzoylation
4	 **8**	 **9**  **10**	Ratio of **9**:**10** 80%:20%
5	 **11**	 **12**  **13**	Ratio of **12**:**13** 77%:23%

6	 **14**	 **15**  **16**	Only ~5% of 2-OH was isolated
7	 **17**	 **18**  **19**  **20**	The mixture of 3-OH and 4-OH was isolated in very low yield (≤5%)
8	 **21**	 **22**  **23**  **24**  **25**  **26**  **27**	Ratio of the prepared derivatives: **22**:20%; **23**:20%; **24**:15% **25**:15%; **26**:10%; **27**:20%

galactopyranoside (**14** → **15** and **16**) but in far lower percentage. Using methyl α-D-mannopyranoside (**17**, entry 7) as a starting compound, small amounts of side products were isolated (**19** and **20**) in low yields besides the main product (**18**). Apparently, loading in minor amounts happened on the 3- and 4-hydroxy position of this mannoside.

Methyl β-L-arabinopyranoside (**21**) as a starting compound resulted in the formation of all possible derivatives (entry 8). If the acylation would have been complete, only the three monohydroxyl derivatives (**22**, **23**, and **24**) could be obtained. Due to steric hindrance of the resin as protecting group, the benzoylation was not complete and all possible dihydroxyl derivatives (**25**, **26**, and **27**) could be isolated as well. With three steps and only one chromatography, a small arabinopyranoside library was generated.

In summary, Ellman's dihydropyran resin was used as support for monosaccharides. When a primary hydroxyl was present, the reaction occurred exclusively (compounds **1**, **3**, and **5**) or almost exclusively (compounds **14** and **17**) at this site. When in addition to the primary hydroxyl group a secondary with enhanced reactivity was present, both groups reacted with the resin in the favor of the primary hydroxyl (compounds **8** and **11**). In the presence of only secondary hydroxyls, coupling to the resin could occur at either of them, giving access to monosaccharide libraries.

EXPERIMENTAL

General

Commercially available starting materials were used without further purification. 3,4-Dihydro-2H-pyran-2-yl-methoxymethyl polystyrene resin was purchased from Novabiochem (Darmstadt, Germany). Solvents were dried according to standard methods. NMR spectra were recorded on a Bruker AMX-400 (100.62 MHz for ^{13}C) or DRX-500 (125.83 MHz for ^{13}C) spectrometer in DMSO-d6 as a solvent. All chemical shifts are quoted in ppm downfield from the characteristic signals of the used solvent (1H: 2.50 ppm, 13C: 39.43 ppm). Kieselgel 60 (E. Merck, Darmstadt, Germany) was used for column chromatography. MALDI-TOF measurements were carried out on a Bruker Biflex III mass spectrometer. 2,5-Dihydroxybenzoic acid was used as matrix and 100 to 200 laser shots were applied for each spectrum.

General Descriptions of Reaction Conditions

Loading

The resin (200 mg) was preswelled in a mixture of DMF (2 mL) and DCE (2 mL) for 30 min. The resin was drained and the monosaccharide (3 eq. per

loading site) in a mixture of DMF (2 mL) and DCE (2 mL) was added followed by the addition of P*p*Ts (pyridinium *p*-toluenesulfonate, 1.5 eq.). The mixture was stirred under N_2 overnight and the reaction was stopped by adding pyridine (200 μL). The resin was drained and washed with DCM (2 × 3 mL), DMF (3 × 3 mL), and DCM (5 × 3 mL).

Acylation

The resin was preswelled in DCM (2 mL). Pyridine (0.8 mL) was added to the mixture followed by BzCl (0.4 mL) in DCM (2 mL). The mixture was shaken for 2 h, the resin was drained, and the acylation repeated using the same amounts of reagents for an additional 2 h. Finally, the resin was drained and washed with DCM (2 × 3 mL), DMF (5 × 3 mL), and DCM (5 × 3 mL).

Cleavage

pTsOH (100 mg) in a mixture of DCM (3 mL) and MeOH (1 mL) was added to the resin (preswelled in DCM) and the mixture was shaken for 30 min. The resin was filtered off and washed with DCM (5 × 3 mL). The filtrates were combined and washed with aq. $NaHCO_3$ (2 × 5 mL) and water (2 × 5 mL), dried, filtered, and concentrated. Column chromatography (hexane:EtOAc, 1:1) of the residue afforded the derivatized monosaccharides.

Spectroscopic Data of Compounds

*Ethyl 2,3,4-tri-O-benzoyl-1-thio-β-D-galactopyranoside (**4**)*[12]

^{1}H NMR: $\delta = 7.95–7.30$ (m, 15H, aromatic), 5.98 (dd, 1H, $J_{3,4}$ 3.30 Hz, $J_{4,5}$ <1 Hz, H-4), 5.93 (dd, 1H, $J_{2,3}$ 9.66 Hz, H-3), 5.73 (dd, 1H, $J_{1,2}$ 9.92 Hz, H-2), 5.37 (d, 1H, H-1), 5.20 (dd, 1H, $J_{6,OH}$ 4.57 Hz, and 6.10 Hz, 6-OH), 4.30 (m, 1H, H-5), 3.75 and 3.63 (2 m, each 1H, H-6), 2.91 (m, 2H, -CH_2CH$_3$), 1.41 (t, 3H, -CH$_2$CH_3).

^{13}C NMR: $\delta = 82.87$ (C-1), 77.61 (C-5), 73.77 (C-3), 69.52 (C-4), 69.46 (C-2), 59.86 (C-6), 24.48 (-*C*H$_2$CH$_3$), 16.46 (-CH$_2$*C*H$_3$).

MALDI-TOF: Calcd. for $C_{29}H_{28}O_8S$: 536. Found: 559 $[M + Na]^+$, 575 $[M + K]^+$.

*Ethyl 2,3,4-tri-O-benzoyl-1-thio-β-D-glucopyranoside (**2**)*[13]

^{1}H NMR: $\delta = 7.80–7.30$ (m, 15H, aromatic), 5.93 (pt, 1H, $J_{2,3}$ 9.45 Hz, $J_{3,4}$ 9.77 Hz, H-3), 5.46 (pt, 1H, $J_{4,5}$ 9.77 Hz, H-4), 5.34 (dd, 1H, $J_{1,2}$ 10.09 Hz, H-2), 5.23 (d, 1H, H-1), 4.90 (bs, 1H, 6-OH), 4.10 (m, 1H, H-5), 3.62 and 3.55 (2 m, each 1H, J_{gem} 12.29 Hz, H-6), 2.75 (m, 2H, -CH_2CH$_3$), 1.24 (t, 3H, -CH$_2$CH_3).

^{13}C NMR: $\delta = 82.14$ (C-1), 78.23 (C-5), 74.88 (C-3), 71.13 (C-2), 69.66 (C-4), 60.64 (C-6), 23.74 (-*C*H$_2$CH$_3$), 15.30 (-CH$_2$*C*H$_3$).

MALDI-TOF: Calcd. for $C_{29}H_{28}O_8S$: 536. Found: 559 $[M+Na]^+$, 575 $[M+K]^+$.

*Phenyl 2,3,4-tri-O-benzoyl-1-thio-β-D-galactopyranoside (**6**)*[14]

^{1}H NMR: $\delta = 7.92-7.30$ (m, 20 H, aromatic), 5.78 (dd, 1H, $J_{3,4} \sim 3$ Hz, $J_{4,5} < 1$ Hz, H-4), 5.77 (dd, 1H, $J_{1,2}$ 9.91 Hz, $J_{2,3}$ 7.63 Hz, H-2), 5.49 (m, 2H, H-3 and H-1), 5.08 (dd, 1H, $J_{6,OH}$ 5.05 Hz, and 6.31 Hz, 6-OH), 4.33 (pt, 1H, $J_{5,6}$ 6.63 Hz, H-5), 3.62 and 3.47 (2 m, each 1H, H-6).

^{13}C NMR: $\delta = 83.75$ (C-1), 77.62 (C-5), 73.45 (C-2), 68.69 (C-4), 68.23 (C-3), 59.38 (C-6).

MALDI-TOF: Calcd. for $C_{33}H_{28}O_8S$: 584. Found: 607 $[M+Na]^+$, 623 $[M+K]^+$.

*Phenyl 3,4-di-O-benzoyl-1-thio-β-D-galactopyranoside (**7**)*

^{1}H NMR: $\delta = 7.95-7.30$ (m, 15H, aromatic), 5.75 (d, 1H, $J_{2,OH}$ 6.31 Hz, 2-OH), 5.67 (dd, 1H, $J_{3,4}$ 3.15 Hz, $J_{4,5} < 1$ Hz, H-4), 5.03 (dd, 1H, $J_{2,3}$ 9.46 Hz, H-3), 4.96 (d, 1H, $J_{1,2}$ 9.45 Hz, H-1), 4.92 (dd, 1H, $J_{6,OH}$ 4.73 Hz, and 6.30 Hz, 6-OH), 4.13 (pt, 1H, H-5), 3.77 (ddd, 1H, H-2), 3.54 and 3.39 (2 m, each 1H, H-6).

^{13}C NMR: $\delta = 84.44$ (C-1), 76.74 (C-5), 76.28 (C-3), 69.47 (C-4), 67.05 (C-2), 60.13 (C-6).

MALDI-TOF: Calcd. for $C_{26}H_{24}O_7S$: 480. Found: 503 $[M+Na]^+$, 519 $[M+K]^+$.

*Methyl 2,3,4-tri-O-benzoyl-α-D-glucopyranoside (**9**)*[15]

^{1}H NMR: $\delta = 8.00-7.40$ (m, 15H, aromatic), 5.93 (dd, 1H, $J_{2,3}$ 10.41 Hz, $J_{3,4}$ 9.77 Hz, H-3), 5.54 (dd, 1H, $J_{4,5}$ 10.09 Hz, H-4), 5.31 (dd, 1H, $J_{1,2}$ 3.79 Hz, H-2), 5.22 (d, 1H, H-1), 4.96 (pt, 1H, $J_{6,OH}$ 5.68 Hz, 6-OH), 4.05 (m, 1H, H-5), 3.65 and 3.52 (2 m, each 1H, J_{gem} 11.10 Hz, H-6), 3.45 (s, 3H, OMe).

^{13}C NMR: $\delta = 96.15$ (C-1), 71.55 (C-2), 70.95 (C-3), 70.08 (C-5), 69.10 (C-4), 58.01 (C-6), 55.09 (OMe).

MALDI-TOF: Calcd. for $C_{28}H_{26}O_9$: 506. Found: 529 $[M+Na]^+$, 545 $[M+K]^+$.

*Methyl 3,4,6-tri-O-benzoyl-α-D-glucopyranoside (**10**)*[16]

^{1}H NMR: $\delta = 8.00-7.40$ (m, 15H, aromatic), 5.61 (pt, 1H, $J_{2,3}$ 9.77 Hz, $J_{3,4}$ 9.77 Hz, H-3), 5.53 (d, 1H, $J_{2,OH}$ 5.80 Hz, 2-OH), 5.40 (pt, 1H, $J_{4,5}$ 9.80 Hz, H-4), 4.89 (d, 1H, $J_{1,2}$ 3.46 Hz, H-1), 4.48 and 4.40 (2 m, each 1H, J_{gem} 11.03 Hz, H-6), 4.29 (m, 1H, H-5), 3.91 (m, 1H, H-2), 3.45 (s, 3H, OMe).

^{13}C NMR: $\delta = 99.54$ (C-1), 73.49 (C-3), 69.66 (C-2), 69.64 (C-4), 67.09 (C-5), 60.92 (C-6), 55.09 (OMe).

MALDI-TOF: Calcd. for $C_{28}H_{26}O_9$: 506. Found: 529 $[M+Na]^+$, 545 $[M+K]^+$.

*Methyl 2,3,4-tri-O-benzoyl-α-D-galactopyranoside (**12**)*[17]

^{1}H NMR: $\delta = 8.05-7.35$ (m, 15H, aromatic), 5.86 (dd, 1H, $J_{3,4}$ 3.50 Hz, $J_{4,5} < 1$ Hz, H-4), 5.78 (dd, 1H, $J_{2,3}$ 10.72 Hz, H-3), 5.59 (dd, 1H, $J_{1,2}$ 3.47 Hz, H-2), 5.26 (d, 1H, H-1), 4.97 (dd, 1H, $J_{6,OH}$ 4.73 Hz, and 6.31 Hz, 6-OH), 4.21 (pt, 1H, $J_{5,6}$ 6.94 Hz, H-5), 3.59 and 3.52 (2 m, each 1H, H-6), 3.49 (s, 3H, OMe).

^{13}C NMR: $\delta = 97.06$ (C-1), 69.63 (C-5), 69.50 (C-4), 69.28 and 69.28 (C-2 and C-3), 59.57 (C-6), 55.34 (OMe).

MALDI-TOF: Calcd. for $C_{28}H_{26}O_9$: 506. Found: 529 $[M + Na]^+$, 545 $[M + K]^+$.

*Methyl 3,4,6-tri-O-benzoyl-α-D-galactopyranoside (**13**)*[18]

^{1}H NMR: $\delta = 8.05-7.35$ (m, 15H, aromatic), 5.79 (dd, 1H, H-4), 5.44 (dd, 1H, $J_{2,3}$ 10.41 Hz, $J_{3,4}$ 3.47 Hz, H-3), 5.37 (d, 1H, $J_{2,OH}$ 7.26 Hz, 2-OH), 4.96 (d, 1H, $J_{1,2}$ 3.15 Hz, H-1), 4.51 (dd, 1H, $J_{5,6}$ 6.93 Hz, and 5.68 Hz, H-5), 4.42 and 4.35 (2 dd, each 1H, J_{gem} 11.03 Hz, H-6), 4.18 (m, 1H, H-2), 3.49 (s, 3H, OMe).

^{13}C NMR: $\delta = 100.31$ (C-1), 71.43 (C-3), 69.50 (C-4), 66.79 (C-2), 66.52 (C-5), 64.30 (C-6), 55.34 (OMe).

MALDI-TOF: Calcd. for $C_{28}H_{26}O_9$: 506. Found: 529 $[M + Na]^+$, 545 $[M + K]^+$.

*Methyl 2,3,4-tri-O-benzoyl-β-D-galactopyranoside (**15**)*[19]

^{1}H NMR: $\delta = 8.00-7.40$ (m, 15H, aromatic), 5.79 (dd, 1H, $J_{3,4}$ 3.47 Hz, $J_{4,5} < 1$ Hz, H-4), 5.72 (dd, 1H, $J_{2,3}$ 10.40 Hz, H-3), 5.48 (dd, 1H, $J_{1,2}$ 8.20 Hz, H-2), 5.03 (dd, 1H, $J_{6,OH}$ 4.42 Hz, and 6.31 Hz, 6-OH), 4.97 (d, 1H, H-1), 4.21 (pt, 1H, $J_{5,6}$ 6.93 Hz, H-5), 3.62 and 3.51 (2 m, each 1H, H-6), 3.47 (s, 3H, OMe).

^{13}C NMR: $\delta = 101.09$ (C-1), 73.35 (C-5), 72.35 (C-3), 70.38 (C-2), 68.69 (C-4), 59.32 (C-6), 56.69 (OMe).

MALDI-TOF: Calcd. for $C_{28}H_{26}O_9$: 506. Found: 529 $[M + Na]^+$, 545 $[M + K]^+$.

*Methyl 3,4,6-tri-O-benzoyl-β-D-galactopyranoside (**16**)*[20]

^{1}H NMR: $\delta = 8.00-7.35$ (m, 15H, aromatic), 5.62 (m, 2H, H-4 and 2-OH), 5.25 (dd, 1H, $J_{2,3}$ 9.92 Hz, $J_{3,4}$ 3.56 Hz, H-3), 4.46 (d, 1H, $J_{1,2}$ 7.89 Hz, H-1), 4.38 (m, 1H, H-5), 4.37 and 4.26 (2 m, each 1H, H-6), 3.68 (ddd, 1H, H-2), 3.42 (s, 3H, OMe).

MALDI-TOF: Calcd. for $C_{28}H_{26}O_9$: 506. Found: 529 $[M + Na]^+$, 545 $[M + K]^+$.

*Methyl 2,3,4-tri-O-benzoyl-α-D-mannopyranoside (**18**)*[21]

^{1}H NMR: $\delta = 8.00-7.20$ (m, 15H, aromatic), 5.60 (dd, 1H, $J_{3,4}$ 9.92 Hz, $J_{4,5}$ 10.17 Hz, H-4), 5.44 (dd, 1H, $J_{2,3}$ 3.31 Hz, H-3), 5.39 (dd, 1H, $J_{1,2}$ 1.52 Hz, H-2),

4.85 (d, 1H, H-1), 4.83 (dd, 1H, $J_{6,OH}$ 5.34 Hz, and 6.36 Hz, 6-OH), 3.86 (m, 1H, H-5), 3.44 (m, 2H, H-6), 3.43 (s, 3H, OMe).

^{13}C NMR: $\delta = 98.04$ (C-1), 71.21 (C-5), 71.00 (C-3), 70.33 (C-2), 66.80 (C-4), 60.34 (C-6), 55.13 (OMe).

MALDI-TOF: Calcd. for $C_{28}H_{26}O_9$: 506. Found: 528 $[M + Na]^+$, 544 $[M + K]^+$.

*Methyl 2,3,6-tri-O-benzoyl-α-D-mannopyranoside (**19**).*[22]

^{1}H NMR: $\delta = 8.10-7.30$ (m, 15H, aromatic), 5.81 (d, 1H, $J_{4,OH}$ 6.36 Hz, 4-OH), 5.49 (dd, 1H, $J_{1,2}$ 1.78 Hz, $J_{2,3}$ 3.31 Hz, H-2), 5.36 (dd, 1H, $J_{3,4}$ 9.91 Hz, H-3), 4.97 (d, 1H, H-1), 4.71 (m, 2H, J_{gem} 11.03 Hz, H-6), 4.20 (m, 1H, H-4), 4.01 (m, 1H, H-5), 3.44 (s, 3H, OMe).

^{13}C NMR: $\delta = 98.86$ (C-1), 73.35 (C-3), 71.34 (C-5), 70.69 (C-2), 66.06 (C-6), 64.65 (C-4), 54.24 (OMe).

MALDI-TOF: Calcd. for $C_{28}H_{26}O_9$: 506. Found: 528 $[M + Na]^+$, 544 $[M + K]^+$.

*Methyl 2,4,6-tri-O-benzoyl-α-D-mannopyranoside (**20**)*[23]

^{1}H NMR: $\delta = 8.10-7.30$ (m, 15H, aromatic), 5.69 (d, 1H, $J_{3,OH}$ 5.85 Hz, 3-OH), 5.64 (pt, 1H, $J_{3,4}$ 9.92 Hz, $J_{4,5}$ 9.92 Hz, H-4), 5.30 (dd, 1H, $J_{1,2}$ 1.53 Hz, $J_{2,3}$ 3.30 Hz, H-2), 4.93 (d, 1H, H-1), 4.43 and 4.55 (2 dd, each 1H, J_{gem} 11.20 Hz, H-6), 4.45 (m, 1H, H-5), 4.23 (m, 1H, H-3), 3.44 (s, 3H, OMe).

^{13}C NMR: $\delta = 98.61$ (C-1), 73.27 (C-2), 70.07 (C-4), 67.41 (C-5), 64.65 (C-3), 64.12 (C-6), 54.26 (OMe).

MALDI-TOF: Calcd. for $C_{28}H_{26}O_9$: 506. Found: 528 $[M + Na]^+$, 544 $[M + K]^+$.

*Methyl 3,4-di-O-benzoyl-β-L-arabinopyranoside (**22**)*[24]

^{1}H NMR: $\delta = 8.00-7.45$ (m, 10H, aromatic), 5.56 (m, 1H, H-4), 5.36 (dd, 1H, $J_{2,3}$ 10.41 Hz, $J_{3,4}$ 3.47 Hz, H-3), 5.31 (d, 1H, $J_{2,OH}$ 7.25 Hz, 2-OH), 4.85 (d, 1H, $J_{1,2}$ 3.56 Hz, H-1), 4.13 (m, 1H, H-2), 4.00 and 3.76 (2 dd, each 1H, J_{gem} 13.24 Hz, H-5), 3.38 (s, 3H, OMe).

^{13}C NMR: $\delta = 100.26$ (C-1), 70.49 (C-3), 69.60 (C-4), 66.05 (C-2), 59.91 (C-5), 55.00 (OMe).

*Methyl 2,4-di-O-benzoyl-β-L-arabinopyranoside (**23**)*[25]

^{1}H NMR: $\delta = 8.10-7.55$ (m, 10H, aromatic), 5.59 (d, 1H, $J_{3,OH}$ 5.99 Hz, 3-OH), 5.39 (m, 1H, H-4), 5.22 (dd, 1H, $J_{1,2}$ 3.46 Hz, $J_{2,3}$ 10.08 Hz, H-2), 5.04 (d, 1H, H-1), 4.27 (m, 1H, H-3), 3.95 and 3.75 (2 dd, each 1H, J_{gem} 12.26 Hz, H-5), 3.33 (s, 3H, OMe).

^{13}C NMR: $\delta = 97.93$ (C-1), 73.61 (C-4), 72.89 (C-2), 65.26 (C-3), 62.21 (C-5), 55.95 (OMe).

*Methyl 2,3-di-O-benzoyl-β-L-arabinopyranoside (**24**)*[26]

^{1}H NMR: $\delta = 8.00-7.45$ (m, 10H, aromatic), 5.56 (d, 1H, $J_{4,OH} \sim 3$ Hz, 4-OH), 5.54 (dd, 1H, $J_{1,2}$ 3.30 Hz, $J_{2,3}$ 7.25 Hz, H-2), 5.48 (dd, 1H, $J_{3,4}$ 3.47 Hz, H-3), 5.05 (d, 1H, H-1), 4.18 (m, 1H, H-4), 3.86 and 3.64 (2 dd, each 1H, J_{gem} 12.30 Hz, H-5), 3.35 (s, 3H, OMe).

^{13}C NMR: $\delta = 97.00$ (C-1), 70.00 (C-3), 69.00 (C-2), 66.30 (C-4), 63.15 (C-5), 54.75 (OMe).

*Methyl 4-O-benzoyl-β-L-arabinopyranoside (**25**)*[24]

^{1}H NMR: $\delta = 8.00-7.50$ (m, 5H, aromatic), 5.24 (m, 1H, 4-H), 5.12 (d, 1H, $J_{3,OH}$ 5.36 Hz, 3-OH), 4.90 (d, 1H, $J_{2,OH}$ 6.31 Hz, 2-OH), 4.67 (d, 1H, $J_{1,2}$ 3.15 Hz, H-1), 3.85–3.58 (m, 4 H, H-2, H-3 and H-5), 3.13 (s, 3H, OMe).

^{13}C NMR: $\delta = 101.38$ (C-1), 73.71 (C-4), 70.00 (C-2), 67.87 (C-3), 61.23 (C-5), 55.91 (OMe).

*Methyl 3-O-benzoyl-β-L-arabinopyranoside (**26**)*[24]

^{1}H NMR: $\delta = 8.15-7.50$ (m, 5H, aromatic), 5.14 (d, 1H, $J_{4,OH}$ 4.73 Hz, 4-OH), 5.04 (dd, 1H, $J_{2,3}$ 10.03 Hz, $J_{3,4}$ 2.21 Hz, H-3), 4.99 (d, 1H, $J_{2,OH}$ 7.25 Hz, 2-OH), 4.67 (d, 1H, $J_{1,2}$ 3.46 Hz, H-1), 4.01 (m, 2H, H-2 and H-4), 3.74 and 3.52 (2 dd, each 1H, J_{gem} 12.35 Hz, H-5), 3.37 (s, 3H, OMe).

^{13}C NMR: $\delta = 101.43$ (C-1), 74.15 (C-3), 67.00 (C-2 and C-4), 64.35 (C-5), 55.70 (OMe).

*Methyl 2-O-benzoyl-β-L-arabinopyranoside (**27**)*[27]

^{1}H NMR: $\delta = 8.10-7.50$ (m, 5H, aromatic), 5.08 (dd, 1H, $J_{1,2}$ 3.47 Hz, $J_{2,3}$ 10.09 Hz, H-2), 5.06 (d, 1H, $J_{3,OH}$ 6.62 Hz, 3-OH), 4.91 (d, 1H, $J_{4,OH}$ 3.78 Hz, 4-OH), 4.86 (d, 1H, H-1), 3.93 (ddd, 1H, H-3), 3.84 (m, 1H, H-4), 3.72 and 3.54 (2 dd, each 1H, J_{gem} 12.30 Hz, H-5), 3.30 (s, 3H, OMe).

^{13}C NMR: $\delta = 98.15$ (C-1), 72.88 (C-2), 69.59 (C-4), 67.19 (C-3), 64.24 (C-5), 55.80 (OMe).

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