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Three Solvent-Free Catalytic Approaches to the Acetal Functionalization of Carbohydrates and Their Applicability to One-Pot Generation of Orthogonally Protected Building Blocks

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Dedicated to the memory of Prof. Matteo Adinolfi.

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Abstract: Three alternative protocols were developed to carry out the selective installation of acetal groups on carbohydrates and polyols under mildly acidic, solvent-free conditions. One protocol is based on a diol/aldehyde condensation at room temperature, with an acetolysis process serving for the activation of the carbonyl component. A second approach is based on an orthoester-mediated activation of the carbonyl component at high temperature. The third protocol is instead entailing a transacetalation mechanism. Combination of these methods allows a wide set of acetal-protected building blocks to be accessed in short times under very simple experimental conditions working under air. The scope of the latter two approaches was also extended to unusual one-pot synthetic sequences leading to concomitant Fischer glycosidation/acetal protection of reducing sugars.

Keywords: acetals; benzylidenes; carbohydrates; polyols; solvent-free reactions

Introduction

Generation of acetal or ketal functionalities is an almost ubiquitous step in organic synthesis when polyol substrates, such as carbohydrates, have to be chemically manipulated. The reaction allows protection of either 1,2- or 1,3-diol motifs, and the selectivity is dependent on several factors such as nature of the polyol substrate, nature of the acetalating agent and experimental conditions applied.[1] Besides the broad application in the synthesis of highly functionalized targets, the usefulness of this reaction is further demonstrated by the increasing number of examples of sugar acetals employed as key building blocks in materials science.[2]

The acetal/ketal functionalization of polyols is more commonly performed through an acid-catalyzed transacetalation process committing the polyol substrate and the requisite dimethyl acetal/ketal. For this purpose, sulfonic acids in polar solvents are routinely employed,[1] but a large set of alternative acid catalysts such as HBF_4, $NaHSO_4$-SiO_2, H_2SO_4-SiO_2, $HClO_4$-SiO_2, tetrabutylammonium tribromide, $FeCl_3$, I_2, $In(OTf)_3$, $Cu(OTf)_2$ have also been reported.[3,4] Very recently, the feasible use of organic catalysts has been described, too.[5]

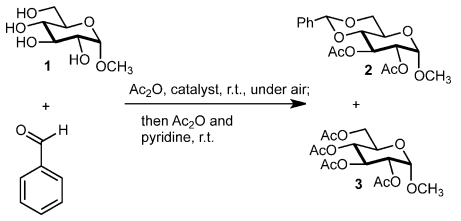
A more straightforward and atom-economical strategy for acetal/ketal synthesis entails an acid-catalyzed condensation of the polyol with the requisite aldehyde/ketone, but especially demanding experimental conditions are needed for the removal of water in order to shift the equilibrium towards the desired products, and much slower reactions are generally observed than with the transacetalation approaches.[2,6] Collectively, the reported protocols for polyol acetalization are suffering from one or more practical issues such as the use of sensitive or commercially unavailable promoters, use of sub-stoichiometric or stoichiometric amounts of acidic agents, adoption of strictly anhydrous conditions with the application of drying agents and inert atmosphere, need for an apparatus aimed at water removal, use of high-boiling solvents, application of vacuum conditions, use of ultrasonication, prolonged reaction times.

On pursuing our recent interest towards the development of experimentally simple solvent-free protocols for the regioselective manipulation of carbohydrates,[7] an effort was targeted to practical acetalation approaches employing experimentally simple procedures in the absence of solvents and under air. Herein we wish to report three alternative strategies aimed at the practical acetal functionalization of saccharide precursors and polyols.

Results and Discussion

Initially, we examined the potential of a sugar/aldehyde condensation triggered by the *O*-acetylation of the carbonyl component,[8] a mechanism which would prevent generation of water as the side product (acetic acid should be formed instead). In the first trials, the activation under air of a moderate excess of acetic anhydride (3 equiv.) with a catalytic amount of several acid promoters, in the presence of methyl α-glucopyranoside **1** and a moderate excess of benzaldehyde (3 equiv.), afforded in some cases 4,6-*O*-benzylidene products in interesting yields (significant examples in Table 1). Since the 4,6-*O*-benzylidenation was often accompanied by partial and unselective acetylation of saccharide carbinols, a short per-*O*-acetylation step was performed *in situ* so as to simplify the composition of the final mixtures, invariably containing benzylidene **2** and per-*O*-acetylated **3**.

Table 1. Optimization of the acetolysis-induced synthesis of benzylidenes[a]



Entry	Catalyst	Time [h]	Yield [%] of **2**
1	$Yb(OTf)_3$	4	60
2	$Cu(OTf)_2$	4	50
3	$Bi(OTf)_3$	4	10
4	CF_3SO_3H	4	55
5	CSA	36	70
6[b]	$Yb(OTf)_3$	2.5	77
7[b]	CF_3SO_3H	2.5	71

[a] *General conditions:* benzaldehyde (3 equiv.), Ac_2O (3 equiv.), catalyst (0.01 equiv.), room temperature; addition of pyridine (1.2 mL mmol^{-1}) and Ac_2O (3 equiv.).

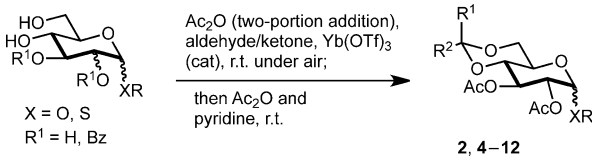
[b] Benzaldehyde (3 equiv.), Ac_2O (1.5 equiv.), catalyst (0.01 equiv.), room temperature; after 1.5 h, addition of further Ac_2O (1.5 equiv.); after total 2.5 h, per-*O*-acetylation as described above.

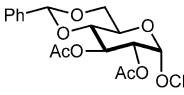
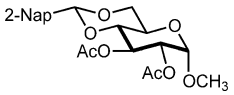
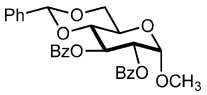
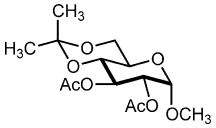
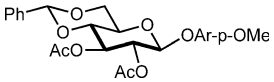
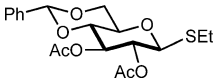
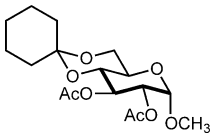
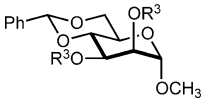
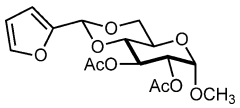
In this preliminary screening, $Yb(OTf)_3$,[9] $Cu(OTf)_2$, and triflic acid proved effective at room temperature within 4 h, with a loading as low as 1%, to afford benzylidene **2** as the main product (Table 1, entries 1, 2 and 4), whereas per-*O*-acetylation largely prevailed with $Bi(OTf)_3$ (Table 1, entry 3). Interestingly, a typical acetalation catalyst such as camphorsulfonic acid (CSA) led to a much slower reaction albeit in a high yield (Table 1, entry 5). A remarkable yield improvement was achieved through the portionwise addition of acetic anhydride, that minimized the undesired competitive acetylation at *O*-4 and *O*-6 (compare entries 6 and 7, with entries 1 and 4, respectively). The reaction was instead unproductive when **1** was added to a premixed mixture of all the other reagents. In addition, the reaction was very sluggish also when performed in the absence of acetic anhydride, thus evidencing the key role played by this latter reagent.

This acetalation approach is mechanistically interesting because the benzaldehyde carbonyl is apparently *O*-acetylated faster than saccharide carbinols with most acid catalysts (Table 1).[10] A critical role for this selectivity might be played by the insolubility of the sugar in the liquid medium, as suggested by the yield decrease observed on applying the $Yb(OTf)_3$-catalyzed procedure in the benzylidenation of glucosides less polar than **1** (Table 2, entries 2 and 3). The scope of this really simple procedure was then examined on **1** with alternative aldehydes and ketones (Table 2), and satisfying results were achieved in the synthesis of glucosides **6**–**8** (Table 2, entries 4–6). The isopropylidenated compound **9** was also prepared in a very good yield (Table 2, entry 7), but in this case the reaction was effective only on using 2,2-dimethoxypropane rather than acetone. On the other hand, the method failed in the attempted condensation with anisaldehyde and nonanal, or when assessed on alternative sugar substrates. For example, attempted protection of a β-thioglucoside tetraol afforded the corresponding benzylidene **10** in a low yield (Table 2, entry 8), whereas *galacto*-configured substrates exhibited a very poor reactivity (data not shown). In all these latter cases per-*O*-acetylation of the tetraol was the prevailing route. With methyl α-mannopyranoside (Table 2, entry 9), the method gave an approximately equimolar mixture of 4,6-*O*-benzylidene **11** (acetylated at O-2 and O-3) and dibenzylidene **12** (diastereoisomeric mixture).

In an attempt to extend the scope of the solvent-free strategies for acetal protection, alternative synthetic pathways were surveyed. The combination of orthoesters with carbonyl compounds under acid catalysis is occasionally employed under solvent-free conditions for the acetalation of diols,[11] but it is not applied to regioselective functionalization of polyols. This is likely due to the poor solubility of polar polyol

Table 2. Synthesis of sugar acetals/ketals *via* an acetolytic activation of the aldehyde/ketone[a]



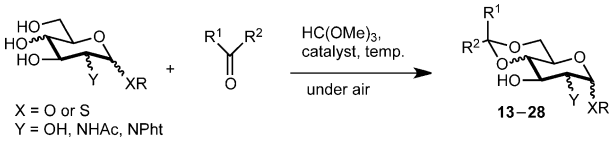
Entry	Product		Yield [%][b]	Entry	Product		Yield [%][b]
1		**2**	77	6[c]		**8**	82
2		**4**	41	7[d]		**9**	85
3		**5**	53	8		**10**	24
4		**6**	78	9		**11** R^3 = Ac **12** R^3 = CHPh	40[e] 40[e]
5		**7**	71				

[a] *General conditions:* aldehyde or ketone (3 equiv.), Ac_2O (1.5 equiv.), $Yb(OTf)_3$ (0.01 equiv.), room temperature; after 1.5 h, addition of further Ac_2O (1.5 equiv.); after total 2–4 h, addition of pyridine (1.2 mL mmol^{-1}) and Ac_2O (3 equiv.).
[b] Isolated yield unless otherwise stated.
[c] A third aliquot of Ac_2O (1.5 equiv.) was added prior to the *O*-acetylation step.
[d] 2,2-Dimethoxypropane was used as the reagent.
[e] Yield estimated by NMR analysis of the crude reaction mixture.

substrates in the reaction medium and the possible occurrence of competitive processes arising from direct interaction of the orthoester reagent with sugars (i.e., generation of sugar orthoesters).[5b,12] Notwithstanding, an extensive screening of conditions evidenced that the aldehyde-orthoester strategy can lead to especially good results in the absence of solvents (Table 3), adopting methyl orthoformate or orthobenzoate as the orthoesters, and a very low catalytic loading of CSA or $Yb(OTf)_3$ (0.01–0.03 equiv. in most cases). Due to the much lower cost of methyl orthoformate than the orthobenzoate counterpart, the former was preferentially assessed in the following applications. As to the acid, CSA was the preferred choice in most cases, although $Yb(OTf)_3$ was found to be the best serving catalyst with thioglycoside substrates (Table 3, entries 11–13, 15, 17, 21) and in the synthesis of nonylidene **16** (entries 8 and 9); on the other hand, its application in the benzylidenation of *O*-glycoside substrates caused partial anomerization (Table 3, entry 5). As shown in Table 3, high yields were generally achieved within a few hours at 70–90 °C, with a wide range of aldehydes and saccharide precursors. In most cases 1% catalyst was sufficient for a fast reaction; when necessary, the *in situ* addition of a further aliquot was performed to shorten reaction times. The method was found applicable at a 10-g scale (entry 4) and effective even in the presence of purportedly added water (entry 3). Notably, the best performing methods described in the literature for the generation of **13** *via* a condensation with benzaldehyde[2b,3f,5b,6b] gave comparable or slightly lower yields than under the solvent-free conditions herein reported (Table 3, entry 2), but required a higher catalyst loading and often much more prolonged reaction times.

A preliminary exposure of the aldehyde and orthoester to the catalyst in the absence of the polyol was occasionally found critical for yield improvement, owing to the minimized generation of undesired sugar orthoesters; this beneficial effect was especially evident in the synthesis of the *galacto*-products **21** and **22** (Table 3, entries 16 and 17). Application to mannosides once again was affected by the competitive double acetalation (data not shown), whereas the method served well with a 3-*O*-protected mannoside

Table 3. Solvent-free synthesis of sugar acetals mediated by orthoesters[a]



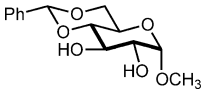
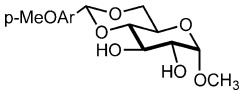
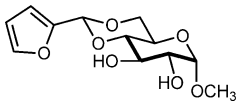
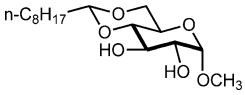
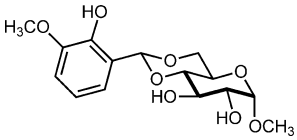
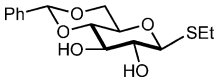
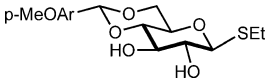
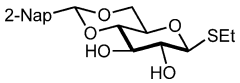
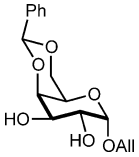
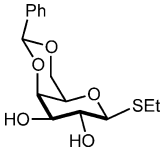
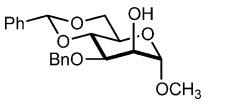
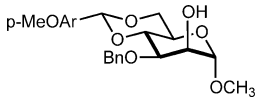
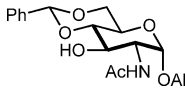
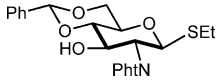
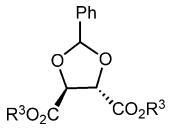
Entry	Catalyst (equiv.), time	Additional remarks	Product	Isolated yield [%]
1	CSA (0.01), 0.5 h		 **13**	79
2[b]	CSA (0.02), 1.5 h		**13**	92
3[b]	CSA (0.02), 1.5 h	0.1 equiv. H_2O added	**13**	90
4[b]	CSA (0.02), 1.5 h	10-g scale	**13**	85
5[b],[c]	$Yb(OTf)_3$ (0.02), 1.5 h		**13**	79 (anomeric mixture)
6	CSA (0.01), 1 h		 **14**	84
7	CSA (0.01), 2.5 h		 **15**	44
8[d]	$Yb(OTf)_3$ (0.02), 1 h		 **16**	59
9	$Yb(OTf)_3$ (0.01), 1.5 h	$PhC(OMe)_3$ in place of $HC(OMe)_3$	**16**	91
10	CSA (0.01), 1.5 h		 **17**	91
11[b]	$Yb(OTf)_3$ (0.02), 4 h		 **18**	75
12[d]	$Yb(OTf)_3$ (0.02), 4 h	under argon	**18**	82
13	$Yb(OTf)_3$ (0.01), 2 h		 **19**	90
14[e]	CSA (0.01), 4.5 h	gram-scale, 3 equiv. of $HC(OMe)_3$,	 **20**	69
15	$Yb(OTf)_3$ (0.01), 3.5 h		**20**	**73**
16[f]	CSA (0.05), 3 h	3 equiv. of $HC(OMe)_3$	 **21**	81
17[g]	$Yb(OTf)_3$ (0.03), 2 h	3 equiv. of $HC(OMe)_3$	 **22**	89
18	CSA (0.01), 3 h		 **23**	74

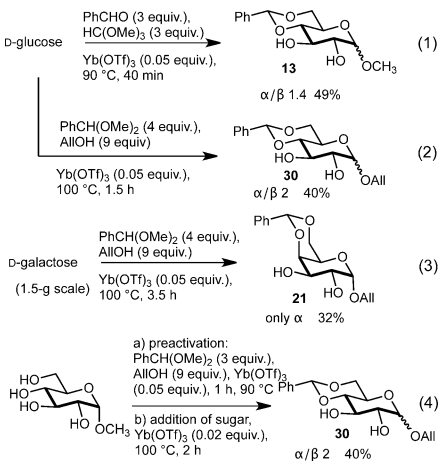
Table 3. (Continued)

Entry	Catalyst (equiv.), time	Additional remarks	Product	Isolated yield [%]
19	CSA (0.01), 1 h		 **24**	80
20[b]	CSA (0.02), 1.5 h		 **25**	67
21[b]	$Yb(OTf)_3$ (0.02), 2.5 h		 **26**	67
22	CSA (0.01), 3 h	diisopropyl tartrate as the substrate	 **27** $R^3 = i$-Pr **28** $R^3 = i$-Pr and/or Me	67 20

[a] *General conditions:* aldehyde (3 equiv.), $HC(OMe)_3$ (2 equiv.), CSA or $Yb(OTf)_3$ (0.01 equiv.), 90 °C. Further catalyst was added in some cases up to the final amount indicated in the Scheme (see footnotes below for details). Times are referred to the overall process (including the eventual pre-activation step, see below).
[b] The second aliquot of the catalyst was added after 1 hour.
[c] Product obtained as an anomeric mixture (α:β *ca.* 8).
[d] The overall amount of the catalyst added from the start.
[e] Aldehyde, orthoester and the catalyst kept at 90 °C for 1 h, then addition of the sugar.
[f] Aldehyde, orthoester and $Yb(OTf)_3$ (0.03 equiv.) kept at 90 °C for 1.5 h, then addition of the sugar and the second aliquot of the catalyst.
[g] Aldehyde, orthoester and the catalyst kept at 70 °C for 1.5 h, then addition of the sugar and the second aliquot of the catalyst.

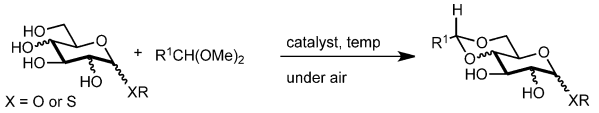
precursor (Table 3, entries 18 and 19), easily obtained in a single regioselective step from a mannoside precursor.[7b,13] Besides the effective installation of benzylidene protecting groups, the strategy worked remarkably well with alternative alkyl or aromatic aldehydes (Table 3, entries 6-10, 13, 14, and 19), even when applied to a sterically hindered di-substitued benzaldehyde such as *o*-vanillin (Table 3, entry 10). In a test experiment, the synthesis of **18** (Table 3, entry 11) was also performed under argon, and just a slight increase of yield was recorded (Table 3, entry 12) to confirm the tolerance of the method towards adventitious moisture. For a comparison purpose, the synthesis of (2-naphthyl)methylidene **20** (entries 14 and 15) was attempted through a standard protocol by exposing ethyl β-thioglucoside to 2-naphthaldehyde in DMF and in the presence of CSA (0.3–0.5 equiv.); under these conditions compound **20** was never obtained in yields exceeding 40% even after prolonged reaction times (48 h) at high temperature. Unlike the method in Table 2, this orthoster-based approach was unfruitful for the isopropylidene protection; indeed, neither acetone nor 2,2-dimethoxypropane were successfully activated by this reagent system.

Another result of this investigation lies in the extension of the solvent-free strategy to the transacetalation approach that is prevalently exploited to carry out the benzylidene functionalization of carbohydrates; indeed, exposure of the polyol to just a moderate excess of benzylidene dimethyl acetal and a very low loading of CSA (0.01–0.02 equiv.) at 90 °C proved effective within short times (0.5–3.5 h) on a variety of substrates (Table 4). Also in this case, the best performing methods described in the literature for the generation of **13** *via* a trans-acetalation mechanism[3e,h,5b,c,14] gave comparable or slightly lower yields

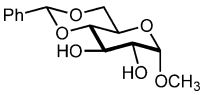
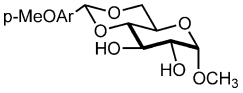
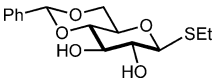
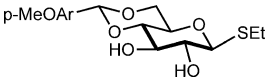
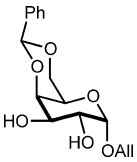
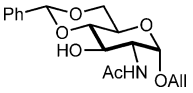
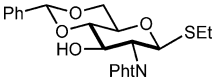
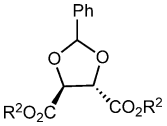
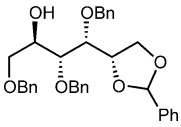


Scheme 1. One-pot Fischer glycosidation/acetalation of sugars under solvent-free conditions.

Table 4. Solvent-free synthesis of sugar acetals *via* a transacetalation process.[a]



13, **14**, **18**, **19**, **21**, **25**, **26**–**28**

Entry	Catalyst (equiv.)	Time [h]	Product	Isolated yield [%]
1	CSA (0.01)	1	 **13**	95
2	$Yb(OTf)_3$ (0.01)	1	**13**	65
3	CSA (0.01)	1	 **14**	80
4	CSA (0.01)	3	 **18**	76
5	CSA (0.01)	1	 **19**	85
6	CSA (0.03)	1	 **21**	78
7	CSA (0.01)	0.5	 **25**	78
8	CSA (0.01)	1.5	 **26**	83
9	CSA (0.01)	3.5	 **27** $R^2 = i$-Pr **28** $R^2 = i$-Pr and/or Me	65 20
10	CSA (0.02)	3.5	 **29**	58 (73)[b]

[a] *General conditions:* dimethyl acetal (2 equiv.), CSA or $Yb(OTf)_3$ (0.01–0.03 equiv.), 90 °C.
[b] Conversion.

than under the solvent-free conditions herein reported (Table 4, entry 1), requiring a higher catalyst loading.

The scope of some of the developed approaches was further extended to an unprecedented one-pot process leading to concomitant Fischer glycosidation and acetal protection of glucose and galactose in the reducing form, where $Yb(OTf)_3$ (0.05–0.07 equiv.) proved to be the best performing catalyst (Scheme 1); for example, 4,6-*O*-benzylidenated methyl glucoside **13** was directly accessed as an anomeric mixture upon a short exposure at 90 °C of glucose to benzaldehyde, trimethyl orthoformate and the catalyst (Scheme 1, reaction 1). Even more remarkable is the feasible installation of the allyl aglycone (synthetically more versatile than the methyl one) by simply performing the transacetalation reaction in the presence of excess allyl alcohol (Scheme 1, reactions 2 and 3). It is also worth noting that such conditions also allowed the *O*-1 methyl to be replaced with an allyl group along with the benzylidene installation (Scheme 1, reaction 4).

Conclusions

In conclusion, three alternative approaches were developed for the selective acetal functionalization of polyols. These procedures are differentiated by the

acetalation mechanism, but are endowed with multiple advantages such as a remarkable experimental simplicity, the avoided use of high-boiling solvents, the feasible applicability to a wide range of carbonyl precursors, reduced reaction times, very low catalyst loadings. Some of the protocols were also found compatible with an unprecedented Fischer glycosidation/acetal formation one-pot elaboration. Owing to these practical advantages, it is expected that such protocols will find wide application in synthetic organic chemistry.

Experimental Section

General Remarks

All acidic catalysts adopted in this investigation are commercially available and were used as supplied without any pre-treatment. The progress of reactions was monitored by TLC; after elution in the suitable eluent, the plates were soaked in 5% concentrated H_2SO_4 in ethanol and heated at 230 °C. NMR spectra were recorded in a 400 MHz device.

Synthesis of Sugar Acetals/Ketals Mediated by Acetic Anhydride

To a mixture of the polyol sugar (1 mmol), the aldehyde (or ketone) (3 mmol) and acetic anhydride (140 μL, 1.5 mmol), ytterbium(III) triflate (6.2 mg, 0.01 mmol) was added under air. The mixture was kept under stirring for 90 min at room temperature, after which a further aliquot of acetic anhydride (140 μL, 1.5 mmol) was added. When the starting sugar was totally consumed, pyridine (0.9 mL) and acetic anhydride (190 μL, 2.0 mmol) were added. On completion of the acetylation step (approx. one hour), the mixture was treated with methanol, and diluted with DCM. The organic phase was washed with water, and the aqueous phase was re-extracted with DCM. Combined organic phases were dried with anhydrous sodium sulfate, and concentrated under vacuum. The residue was purified by silica-gel flash chromatography to afford acetal derivatives in the yields indicated in Table 2.

Synthesis of Sugar Acetals Mediated by an Orthoester

To a mixture of the polyol sugar (1 mmol), the aldehyde (or ketone) (3 mmol) and the orthoester (220 μL, 2 mmol), ytterbium(III) triflate or camphorsulfonic acid (0.01 mmol) was added under air. The mixture was kept under stirring at 90 °C allowing distillation of the volatiles. When necessary a further aliquot of the catalyst was added (see Table 3 for times and amounts). The reaction was quenched with a few drops of pyridine and the mixture was concentrated under vacuum. The mixture was submitted to silica-gel flash chromatography (eluents: dichloromethane/methanol or hexane/ethyl acetate mixtures) for purification of acetal products. Unsubstituted benzylidene products obtained by this procedure were generally contaminated with variable amounts of benzoic acid which was removed washing a DCM solution of the benzylidene with 0.1 M aqueous NaOH, and water. The resulting organic phase was dried with sodium sulfate and concentrated under vacuum to yield the desired product in a pure form.

In the synthesis of *galacto*-benzylidenes **21** and **22**, best results were obtained by premixing the aldehyde (3 mmol), the orthoester (3 mmol) and ytterbium(III) triflate or camphorsulfonic acid (0.01 mmol) at 90 °C. The sugar was then added with the second aliquot of catalyst (see Table 3 for times and amounts)

Large-Scale Synthesis of 13 Mediated by Methyl Orthoformate

To a mixture of methyl glucoside **1** (10.0 g, 51.5 mmol), methyl orthoformate (11.3 mL. 103 mmol) and benzaldehyde (15.6 mL), camphorsulfonic acid (120 mg, 0.51 mmol) was added. The mixture was kept at 90 °C (oil bath) for 1 h allowing distillation of volatiles, then another aliquot of camphorsulfonic acid (120 mg, 0.51 mmol) was added. Upon completion of the reaction (TLC, approx. 90 min), the mixture was diluted with dichloromethane and washed with 0.1 M aqueous NaOH (to remove benzoic acid). The residue of the organic phase was then crystallized with ethyl acetate/hexane mixtures to obtain 8.20 g of **13**. The supernatant was concentrated and submitted to flash chromatography (eluent: dichloromethane and then dichloromethane/methanol 95:5) to obtain further 4.16 g of **13**; overall yield: 85%.

Synthesis of Sugar Acetals Based on a Transacetalation Mechanism

To a mixture of the polyol sugar (1 mmol) and dimethyl acetal (2 mmol), camphorsulfonic acid (0.01 mmol) was added under air (see Table 4). The mixture was kept under stirring at 90 °C, allowing distillation of the volatiles. The reaction was quenched with a few drops of pyridine and the mixture was concentrated under vacuum. The mixture was submitted to silica-gel flash chromatography (eluents: dichloromethane/methanol or hexane/ethyl acetate mixtures) for purification of the acetal products.

One-Pot Fischer Glycosidation/Benzylidenation of Free Sugars

For the relative amounts of reagents and the reaction temperatures see entries in Scheme 1. To a mixture of the free sugar, the acetalating agent, methyl orthoformate (when necessary), and allyl alcohol (when necessary), ytterbium(III) triflate was added under air. The mixture was heated to the reaction temperature and kept under stirring allowing distillation of the volatiles. Upon completion (TLC analysis) the reaction was quenched with a few drops of pyridine and the mixture was concentrated under vacuo. The mixture was submitted to silica-gel flash chromatography (eluents: dichloromethane/methanol or hexane/ethyl acetate mixtures) for purification of the acetal products.

Methyl 2,3-di-*O*-acetyl-4,6-*O*-benzylidene-α-D-glucopyranoside (2):[15] Eluted with hexane/ethyl acetate from 7:3 to 1:1; white solid; mp 107–109 °C; ^{1}H NMR (400 MHz, $CDCl_3$): $\delta = 7.45$–7.30 (aromatic H, 5H), 5.59 (H-3, t, $J = 9.6$ Hz, 1H), 5.50 (benzylidene acetal CH, s, 1H), 4.94 (H-1, d, $J = 3.2$ Hz, 1H), 4.91 (H-2, dd, $J = 3.6$, 9.6 Hz, 1H), 4.29

(H-6eq, dd, $J=4.8$, 10.0 Hz, 1H), 3.92 (H-5, m, 1H), 3.77 (t, $J=10.0$ Hz, 1H), 3.65 (t, $J=10.0$ Hz, 1H), 3.40 (1-OCH_3, s, 3H), 2.09 and 2.05 (2×$COCH_3$, 2×6H); ^{13}C NMR (100 MHz, $CDCl_3$): $\delta=170.3$ and 169.7 (-$COCH_3$), 136.8 (aromatic C), 129.1, 128.4, 126.0 (aromatic CH), 101.4 and 97.4 (acetal CH), 79.1, 71.5, 68.9, 68.7, 62.1, 55.2, 20.7, 20.6; MALDI-MS: $m/z=389.35$ $[M+Na]^+$, calcd. for ($C_{18}H_{22}O_8$): 389.12; anal. calcd. for $C_{13}H_{16}O_4$: C 59.01, H 6.05; found: C 58.94, H 6.10.

Methyl 2,3-di-*O*-benzoyl-4,6-*O*-benzylidene-α-D-glucopyranoside (4):[16] Eluted with hexane/ethyl acetate from 8:2 to 7:3; white solid; mp 152–154 °C; ^{1}H NMR (400 MHz, $CDCl_3$): $\delta=8.00$–7.30 (aromatic H, 15H), 6.11 (H-3, t, $J=9.6$ Hz, 1H), 5.60 (s, 1H), 5.31 (H-2, dd, $J=3.6$, 9.6 Hz, 1H), 5.21 (H-1, d, $J=3.6$ Hz, 1H), 4.40 (H-6eq, dd, $J=4.8$, 10.0 Hz, 1H), 4.11 (H-5, m, 1H), 3.95 (H-4, t, $J=10.0$ Hz, 1H), 3.89 (H-6ax, t, $J=10.0$ Hz, 1H), 3.45 (3H, s, -OCH_3); ^{13}C NMR (100 MHz, $CDCl_3$): $\delta=165.9$, 165.5 (2×-*C*OPh); 136.8, 133.3, and 132.9 (aromatic C); 130.0–126.1 (aromatic CH); 101.5 and 97.7 (acetal CH), 79.3, 72.5, 69.4, 68.8, 62.5, 55.4; MALDI-MS: $m/z=513.20$ $[M+Na]^+$, calcd. for ($C_{28}H_{26}O_8$); 513.15; anal. calcd. for $C_{28}H_{26}O_8$: C 68.56, H 5.34; found: C 68.40, H 5.40.

***p*-Methoxyphenyl 2,3-di-*O*-acetyl-4,6-*O*-benzylidene-β-D-glucopyranoside (5):**[17] Eluted with hexane/ethyl acetate from 8:2 to 3:7'; white solid; mp 211–212 °C; ^{1}H NMR (400 MHz, $CDCl_3$): $\delta=7.45$–6.80 (aromatic H, 9H), 5.52 (s, 1H), 5.39 (H-3, t, $J=9.6$ Hz, 1H), 5.25 (H-2, dd, $J=8.0$, 9.6 Hz, 1H), 5.06 (H-1, d, $J=7.6$ Hz, 1H), 4.38 (H-6eq, dd, $J=4.8$, 10.0 Hz, 1H), 3.84 (H-4, t, $J=10.0$ Hz, 1H), 3.81 (H-6ax, t, $J=10.0$ Hz, 1H), 3.77 (3H, s, -OCH_3), 3.60 (1H, m, H-5), 2.08 and 2.07 (2×-$COCH_3$, 2×s, 6H); ^{13}C NMR (100 MHz, $CDCl_3$): $\delta=170.1$, 169.5 (2×-*C*OCH_3); 155.8, 150.8, 136.7 (aromatic C); 130.1, 129.1, 128.4, 126.1, 118.7, 114.7 (aromatic CH); 101.5 and 100.8 (acetal CH), 78.0, 72.2, 71.7, 68.5, 66.4, 55.6, 20.7, 20.6; MALDI-MS: $m/z=481.20$ $[M+Na]^+$, calcd. for ($C_{24}H_{26}O_9$): 481.15; anal. calcd. for $C_{24}H_{26}O_9$: C 62.88, H 5.72; found: C 62.70, H 5.75.

Methyl 2,3-di-*O*-acetyl-4,6-*O*-cyclohexylidene-α-D-glucopyranoside (6): Eluted with hexane/ethyl acetate from 7:3 to 6:4; oil; $[\alpha]_D^{23}$: +87.8 (*c* 1.8, $CHCl_3$); ^{1}H NMR (400 MHz, $CDCl_3$): $\delta=5.25$ (H-3, t, $J=9.6$ Hz, 1H), 4.80–4.70 (H-1 and H-2, overlapped signals, 2H), 3.75 (H-6eq, dd, $J=4.0$, 10.0 Hz, 1H), 3.66 (t, $J=9.6$ Hz, 1H), 3.61 (H-5, m, 1H), 3.54 (t, $J=9.6$ Hz, 1H), 3.25 (1-OCH_3, s, 3H), 2.25–2.00 (m, 3H), 1.95 and 1.92 (2×-$COCH_3$, 2×s, 6H), 1.80–1.20 (m, 7H); ^{13}C NMR (100 MHz, $CDCl_3$): $\delta=170.0$ and 169.4 (-*C*OCH_3), 99.4 and 97.3 (acetal CH), 71.2, 71.1, 69.1, 63.0, 61.3, 54.8, 37.4, 27.2, 25.2, 22.4, 22.3, 20.4; MALDI-MS: $m/z=381.35$ $[M+Na]^+$, calcd. for ($C_{17}H_{26}O_8$): 381.15; anal. calcd. for $C_{17}H_{26}O_8$: C 56.97, H 7.31; found: C 56.84, H 6.35.

Methyl 2,3-di-*O*-acetyl-4,6-*O*-(2-furyl)methylene-α-D-glucopyranoside (7):[18] Eluted with hexane/ethyl acetate 6:4; foam; ^{1}H NMR (400 MHz, $CDCl_3$): $\delta=7.34$ (bs, 1H), 6.40 (bs, 1H), 6.31 (bs, 1H), 5.51 (s, 1H), 5.50 (H-3, t, $J=10.0$ Hz, 1H), 4.88 (H-1, d, $J=3.2$ Hz, 1H), 4.84 (H-2, dd, $J=3.2$, 10.0 Hz, 1H), 4.24 (H-6eq, dd, $J=4.8$, 10.4 Hz, 1H), 3.88 (H-5, m, 1H), 3.69 (t, $J=10.4$ Hz, 1H), 3.57 (t, $J=10.4$ Hz, 1H), 3.35 (1-OCH_3, s, 3H), 2.08 and 2.03 (2×-$COCH_3$, 2×s, 6H); ^{13}C NMR (100 MHz, $CDCl_3$): $\delta=170.2$ and 169.6 (-*C*OCH_3), 149.2 (aromatic C); 142.5, 110.0, and 107.9 (aromatic CH); 97.3 and 96.0 (acetal CH), 78.9, 71.3, 68.6, 68.5, 61.9, 55.1, 20.6 and 20.5; MALDI-MS: $m/z=389.30$ $[M+Na]^+$, calcd. for ($C_{16}H_{20}O_9$): 389.11; anal. calcd. for $C_{16}H_{20}O_9$: C 56.97, H 7.31; found: C 53.93, H 5.66.

Methyl 2,3-di-*O*-acetyl-4,6-*O*-(2-naphtyl)methylene-α-D-glucopyranoside (8):[6a] Eluted with dichloromethane/hexane from 80:20 to 100:0; foam; ^{1}H NMR (400 MHz, $CDCl_3$): $\delta=7.95$–7.45 (aromatic H, 7H), 5.67 (s, 1H), 5.64 (H-3, t, $J=9.6$ Hz, 1H), 4.98 (H-1, d, $J=4.0$ Hz, 1H), 4.95 (H-2, dd, $J=4.0$ and 9.6 Hz, 1H), 4.37 (H-6eq, dd, $J=4.8$ and 10.0 Hz, 1H), 4.00 (H-5, m, 1H), 3.84 (t, $J=10.0$ Hz, 1H), 3.72 (t, $J=10.0$ Hz, 1H), 3.44 (1-OCH_3, s, 3H), 2.12 and 2.07 (2×-$COCH_3$, 2×s, 6H); ^{13}C NMR (100 MHz, $CDCl_3$): $\delta=170.4$ and 169.7 (-*C*OCH_3), 134.2, 133.5, 132.7 (aromatic C); 128.3, 128.0, 127.6, 126.4, 126.0, 125.6, 123.6 (aromatic CH); 101.7 and 97.5 (acetal CH), 79.2, 71.5, 68.9, 62.3, 55.3, 20.7; MALDI-MS: $m/z=439.05$ $[M+Na]^+$, calcd. for ($C_{22}H_{24}O_8$): 439.14; anal. calcd. for $C_{22}H_{24}O_8$: C 63.45, H 5.81; found: C 63.65, H 5.75.

Methyl 2,3-di-*O*-acetyl-4,6-*O*-isopropylidene-α-D-glucopyranoside (9): Eluted with hexane/acetone 8:2; oil; $[\alpha]_D^{23}$: +85.1 (*c* 1.2, $CHCl_3$); ^{1}H NMR (400 MHz, $CDCl_3$): $\delta=5.43$ (H-3, t, $J=9.6$ Hz, 1H), 4.96 (H-1, d, $J=3.6$ Hz, 1H), 4.90 (H-2, dd, $J=3.6$ and 9.6 Hz, 1H), 3.95 (m, 1H), 3.87–3.65 (overlapped signals, 3H), 3.46 (1-OCH_3, s, 3H), 2.12 and 2.09 (2×-$COCH_3$, 2×s, 6H), 1.53 and 1.44 (2×isopropylidene methyls, 2×s, 6H); ^{13}C NMR (100 MHz, $CDCl_3$): $\delta=170.2$ and 169.7 (-*C*OCH_3), 99.6 [-*C*$(CH_3)_2$] and 97.4 (C-1), 71.8, 71.5, 69.2, 63.0, 62.0, 55.0, 28.8, 20.6, 20.5, 18.8; MALDI-MS: $m/z=341.10$ $[M+Na]^+$, calcd. for ($C_{14}H_{22}O_8$): 341.31, anal. calcd. for $C_{14}H_{22}O_4$: C 52.82, H 6.97; found: C 53.03, H 6.90.

Ethyl 2,3-di-*O*-acetyl-4,6-*O*-benzylidene-1-thio-β-D-glucopyranoside (10):[19] Eluted with hexane/ethyl acetate from 8:2 to 7:3; foam; ^{1}H NMR (400 MHz, $CDCl_3$): $\delta=7.50$–7.30 (aromatic H, 5H), 5.50 (s, 1H), 5.34 (H-3, t, $J=10.0$ Hz, 1H), 5.04 (H-2, t, $J=10.0$ Hz, 1H), 4.59 (H-1, d, $J=10.0$ Hz, 1H), 4.37 (H-6eq, dd, $J=4.8$ and 10.4 Hz, 1H), 3.78 (t, $J=10.4$ Hz, 1H), 3.66 (t, $J=10.4$ Hz, 1H), 3.52 (H-5, m, 1H), 2.69 (m, -S*C*$H_2$$CH_3$, 2H), 2.07 and 2.04 (2×-$COCH_3$, 2×s, 6H), 1.26 (-SCH_2C*H*$_3$, t, $J=7.2$ Hz, 3H); ^{13}C NMR (100 MHz, $CDCl_3$): $\delta=170.0$ and 169.6 (-*C*OCH_3), 136.6 (aromatic C); 129.0, 128.2, 126.6 (aromatic CH); 101.4 (acetal CH), 84.0 (C-1), 79.1, 72.6, 71.3, 70.6, 70.5, 68.4, 24.2, 20.7 and 14.8; MALDI-MS: $m/z=419.20$ $[M+Na]^+$, calcd. for ($C_{19}H_{24}O_7S$): 419.11; anal. calcd. for $C_{19}H_{24}O_7S$: C 57.56, H 6.10; found: C 57.70, H 6.05.

Methyl 4,6-*O*-benzylidene-α-D-glucopyranoside (13):[20] Eluted with dichloromethane/methanol from 100:0 to 95:5; white solid; mp 165–167 °C; ^{1}H NMR (400 MHz, $CDCl_3$): $\delta=7.60$–7.40 (aromatic H, 5H), 5.65 (s, 1H), 4.92 (H-1, d, $J=3.6$ Hz, 1H), 4.41 (H-6eq, dd, $J=4.4$ and 10.0 Hz, 1H), 4.04 (t, $J=9.6$ Hz, 1H), 3.93 (H-5, m, 1H), 3.87 (t, $J=9.6$ Hz, 1H), 3.76 (H-2, dd, $J=3.6$, 9.6 Hz, 1H), 3.60 (t, $J=9.6$ Hz, 1H), 3.58 (1-OCH_3, s, 3H), 2.82 (-OH, 1H), 2.36 (-OH, d, $J=9.2$ Hz, 1H); ^{13}C NMR (100 MHz, $CDCl_3$): $\delta=137.0$ (aromatic C), 129.1, 128.2, and 126.3 (aromatic CH); 101.7 and 99.8 (acetal CH), 80.8, 72.5, 71.0, 68.8, 62.3, 55.3; MALDI-MS: $m/z=305.00$ $[M+Na]^+$, calcd. for ($C_{14}H_{18}O_6$): 305.10; anal. calcd. for $C_{14}H_{18}O_6$: C 59.57, H 6.43; found: C 59.55, H 6.40.

Methyl 4,6-*O*-(*p*-methoxy)benzylidene-α-D-glucopyranoside (14):[21] Eluted with dichloromethane/methanol from

100:0 to 90:10; solid; mp 193–195 °C; ^{1}H NMR (400 MHz, $CDCl_3$): $\delta = 7.42$ and 6.90 (2×d, $J = 8.4$ Hz, aromatic H, 4H), 5.50 (s, 1H), 4.82 (H-1, d, $J = 3.2$ Hz, 1H), 4.29 (H-6eq, dd, $J = 4.4$, 10.0 Hz, 1H), 3.96 (t, $J = 9.6$ Hz, 1H), 3.81 (aromatic-OCH_3, s, 3H), 3.80 (H-2, dd, $J = 3.6$, 9.6 Hz, 1H), 3.78 (t, $J = 9.6$ Hz, 1H), 3.77 (H-5, m, 1H), 3.50 (t, $J = 9.6$ Hz, 1H), 3.48 (1-OCH_3, s, 3H), 2.63 and 2.23 (2×bs, 2×OH); ^{13}C NMR (100 MHz, $CDCl_3$): $\delta = 160.2$ and 129.4 (aromatic C); 127.5, 113.6 (aromatic CH), 101.8 and 99.6 (acetal CH), 80.7, 72.7, 71.7, 68.8, 62.2, 55.4, 55.2; MALDI-MS: $m/z =$ 335.25 $[M+Na]^+$, calcd. for ($C_{15}H_{20}O_7$): 335.12; anal. calcd. for $C_{15}H_{20}O_7$: C 57.69, H 6.45; found: C 57.80, H 6.35.

Methyl 4,6-*O*-(2-furyl)methylene-α-D-glucopyranoside (15):[18] Eluted with ethyl acetate/methanol from 100:0 to 80:20; foam; ^{1}H NMR (400 MHz, $CDCl_3$): $\delta = 7.37$ (bs, 1H), 6.45 (d, $J = 2.8$ Hz, 1H), 6.32 (bd, $J = 2.8$ Hz, 1H), 5.54 (s, 1H), 4.69 (H-1, d, $J = 3.6$ Hz, 1H), 4.19 (H-6eq, dd, $J = 4.8$, 10.0 Hz, 1H), 3.87 (t, $J = 9.6$ Hz, 1H), 3.75 (H-5, m, 1H), 3.65 (t, $J = 9.6$ Hz, 1H), 3.55 (H-2, dd, $J = 3.6$, 10.0 Hz, 1H), 3.39 (t, $J = 9.6$ Hz, 1H), 3.36 (1-OCH_3, s, 3H); ^{13}C NMR (100 MHz, $CDCl_3$): $\delta = 149.4$ (aromatic C), 142.6, 110.1, 108.2 (aromatic CH), 99.8 and 95.6 (acetal CH), 80.8, 72.4, 70.7, 68.7, 62.0, 55.2; MALDI-MS: $m/z = 295.30$ $[M+Na]^+$, calcd. for ($C_{12}H_{16}O_7$): 295.08; anal. calcd. for $C_{12}H_{16}O_7$: C 52.94, H 5.92; found: C 52.75, H 5.80.

Methyl 4,6-*O*-nonylidene-α-D-glucopyranoside (16):[22] Eluted with ethyl acetate/hexane 7:3; oil; ^{1}H NMR (400 MHz, $CDCl_3$): $\delta = 4.78$ (H-1, d, $J = 3.6$ Hz, 1H), 4.59 (nonylidene acetal CH, t, $J = 5.2$ Hz, 1H), 4.15 (H-6eq, dd, $J = 4.8$, 10.0 Hz, 1H), 3.90 (t, $J = 9.6$ Hz, 1H), 3.67 (H-5, m, 1H), 3.62 (H-2, dd, $J = 3.6$ and 9.6 Hz, 1H), 3.52 (t, $J =$ 9.6 Hz, 1H), 3.46 (1-OCH_3, s, 3H), 3.30 (t, $J = 9.6$ Hz, 1H), 2.15–2.10 (m, 2H), 1.80–1.65 (m, 2H), 1.40–1.20 (m, 10H), 0.93 (nonylidene -CH_3, s, 3H); ^{13}C NMR (100 MHz, $CDCl_3$): $\delta = 102.6$ and 99.9 (acetal CH), 80.4, 72.7, 71.1, 68.4, 62.5, 55.2, 34.1, 31.7, 29.4 (×2), 29.1, 24.0, 22.5, 14.0: MALDI-MS: $m/z = 341.10$ $[M+Na]^+$, calcd. for ($C_{16}H_{30}O_6$): 341.20; anal. calcd. for $C_{16}H_{30}O_6$: C 60.35, H 9.50; found: C 60.40, H 9.40.

Methyl 4,6-*O*-(*o*-hydroxy-*m*-methoxy)benzylidene-α-D-glucopyranoside (17): Eluted with ethyl acetate/methanol from 100:0 to 90:10; foam; $[\alpha]_D^{23}$: +80.8 (*c* 1, $CHCl_3$); ^{1}H NMR (400 MHz, $CDCl_3$): $\delta = 7.10$–6.80 (aromatic H, 3H), 6.44 (phenol OH), 5.83 (s, 1H), 4.73 (H-1, bs, 1H), 4.26 (H-6eq, dd, $J = 3.6$, 9.6 Hz, 1H), 3.90–3.60 (overlapped signals, 3H), 3.77 (aromatic -OCH_3, s, 3H), 3.52 (m, 1H), 3.43 (t, $J = 9.6$ Hz, 1H), 3.42 (1-OCH_3, s, 3H); ^{13}C NMR (100 MHz, $CDCl_3$): $\delta = 147.0$, 143.4, 122.8 (aromatic C); 119.6, 118.9, 111.6 (aromatic CH), 99.9 and 98.4 (acetal CH), 81.0, 72.5, 70.9, 68.9, 62.2, 56.0, 55.4; MALDI-MS: $m/z = 351.00$ $[M+Na]^+$ calcd. for ($C_{15}H_{20}O_8$): 351.11; anal. calcd. for $C_{15}H_{20}O_8$: C 54.87, H 6.14; found: C 54.70, H 6.25.

Ethyl 4,6-*O*-benzylidene-1-thio-β-D-glucopyranoside (18):[23] Eluted with dichloromethane/methanol from 100:0 to 90:10; foam; ^{1}H NMR (400 MHz, $CDCl_3$): $\delta = 7.50$–7.30 (aromatic H, 5H), 5.48 (s, 1H), 4.38 (H-1, d, $J = 9.6$ Hz, 1H), 4.29 (H-6eq, dd, $J = 4.0$, 10.0 Hz, 1H), 3.75–3.60 (overlapped signals, 3H), 3.50–3.35 (overlapped signals, 2H), 2.71 (m, -S$CH_2$$CH_3$, 2H), 1.29 (-$SCH_2CH_3$, t, $J = 7.2$ Hz, 3H); ^{13}C NMR (100 MHz, $CDCl_3$): $\delta = 136.8$ (aromatic C), 129.2, 128.2, 126.2 (aromatic CH); 101.7 (acetal CH), 86.2 (C-1), 80.2, 74.3, 73.0, 70.3, 68.4, 24.5, 15.1; MALDI-MS: $m/z =$ 335.37 $[M+Na]^+$, calcd. for ($C_{15}H_{20}O_5S$): 335.09; anal. calcd. for $C_{15}H_{20}O_5S$: C 57.67, H 6.45; found: C 57.45, H 6.50.

Ethyl 4,6-*O*-(*p*-methoxy)benzylidene-1-thio-β-D-glucopyranoside (19):[24] Eluted with dichloromethane/methanol from 100:0 to 90:10; foam; ^{1}H NMR (400 MHz, $CDCl_3$): $\delta =$ 7.40 and 6.84 (2×d, $J = 8.4$ Hz, aromatic H, 4H), 5.42 (s, 1H), 4.36 (H-1, d, $J = 10.0$ Hz, 1H), 4.24 (H-6eq, dd, $J = 4.8$, 10.4 Hz, 1H), 3.75 (-OCH_3, s, 3H), 3.75–3.60 (overlapped signals, 2H), 3.50–3.30 (overlapped signals, 3H), 2.68 (m, -S$CH_2$$CH_3$, 2H), 1.26 (-$SCH_2CH_3$, t, $J = 7.2$ Hz, 3H); ^{13}C NMR (100 MHz, $CDCl_3$): $\delta = 160.0$, 129.3 (aromatic C), 127.8, 113.7 (aromatic CH); 101.6 (acetal CH), 86.2 (C-1), 80.1, 74.3, 73.1, 70.3, 68.4, 55.2, 24.5, 15.1; MALDI-MS: $m/z = 365.30$ $[M+Na]^+$, calcd. for ($C_{16}H_{22}O_6S$): 365.40; anal. calcd. for $C_{16}H_{22}O_6S$: C 56.12, H 6.48; found: C 56.35, H 6.40.

Ethyl 4,6-*O*-(2-naphthyl)methylene-1-thio-β-D-glucopyranoside (20): Eluted with dichloromethane/methanol from 100:0 to 95:5; foam; $[\alpha]_D^{23}$: −18.0 (*c* 1.1, $CHCl_3$); ^{1}H NMR (400 MHz, $CDCl_3$): $\delta = 7.96$–7.40 (aromatic H, 7H), 5.62 (s, 1H), 4.37 (H-1, d, $J = 9.6$ Hz, 1H), 4.34 (H-6eq, dd, $J = 4.8$, 10.4 Hz, 1H), 3.80 (t, $J = 10.0$ Hz, 1H), 3.74 (t, $J = 10.0$ Hz, 1H), 3.60–3.40 (overlapped signals, 3H), 2.70 (m, -S$CH_2$$CH_3$, 2H), 1.27 (-$SCH_2CH_3$, t, $J = 7.2$ Hz, 3H); ^{13}C NMR (100 MHz, $CDCl_3$): $\delta = 134.2$, 133.6, 132.8 (aromatic C), 128.3, 128.2, 127.6, 16.5, 126.2, 125.9, 123.7 (aromatic CH); 101.8 (acetal CH), 86.3, 80.3, 74.4, 73.2, 70.3, 68.5, 24.5, 15.1; MALDI-MS: $m/z = 385.05$ $[M+Na]^+$, calcd. for ($C_{19}H_{22}O_5S$): 385.11; anal. calcd. for $C_{19}H_{22}O_5S$: C 62.96, H 6.12; found: C 62.75, H 6.25.

Allyl 4,6-*O*-benzylidene-α-D-galactopyranoside (21):[25] Eluted with ethyl acetate/methanol from 100:0 to 90:10; foam; ^{1}H NMR (400 MHz, $CDCl_3$): $\delta = 7.60$–7.30 (aromatic H, 5H), 6.02 ($CH_2=CHCH_2$-, m, 1H), 5.63 (s, 1H), 5.42 ($CH_{cis}H_{trans}=CHCH_2$-, bd, $J = 17.2$ Hz, 1H), 5.33 ($CH_{cis}H_{trans}=CHCH_2$-, bd, $J = 10.4$ Hz, 1H), 5.17 (H-1, bs, 1H), 4.40–4.30 ($CH_2=CHCH_aH_b$-, H-4, H-6a; overlapped signals, 3H), 4.20–4.10 ($CH_2=CHCH_aH_b$-, H-6b; overlapped signals, 2H), 4.04 (H-2 and H-3, overlapped signals, 2H), 3.80 (H-5, s, 1H), 3.02, 2.78 (2×OH, 2H); ^{13}C NMR (100 MHz, $CDCl_3$): $\delta = 137.5$ (aromatic C), 133.5 ($CH_2=$ $CHCH_2$-), 129.1, 128.1, 126.2 (aromatic CH), 117.9 ($CH_2=$ $CHCH_2$-), 101.1, 98.2 (acetal CH), 75.9, 69.6, 69.4, 69.2, 68.7, 62.9; MALDI-MS: $m/z = 331.35$ $[M+Na]^+$, calcd. for ($C_{16}H_{20}O_6$): 331.12; anal. calcd. for $C_{16}H_{20}O_6$: C 62.33, H 6.54; found: C 62.20, H 6.45.

Ethyl 4,6-*O*-benzylidene-1-thio-β-D-galactopyranoside (22):[26] Eluted with hexane/acetone 1:1; foam; ^{1}H NMR (400 MHz, $CDCl_3$): $\delta = 7.50$–7.30 (aromatic H, 5H), 5.47 (s, 1H), 4.30 (H-1, d, $J = 9.6$ Hz, 1H), 4.26 (H-6a, bd, $J =$ 12.0 Hz, 1H), 4.13 (H-4, $J = 2.4$ Hz, 1H), 3.94 (H-6b, bd, $J =$ 12.0 Hz, 1H), 3.78 (H-2, t, $J = 9.6$ Hz, 1H), 3.62 (H-3, dd, $J = 2.4$, 9.6 Hz, 1H), 3.37 (H-5, bs, 1H), 2.80 (m, -S$CH_2$$CH_3$, 2H), 1.31 (t, $J = 7.2$ Hz, -S$CH_2$$CH_3$, 3H); ^{13}C NMR (100 MHz, $CDCl_3$): $\delta = 137.4$ (aromatic C), 128.9, 128.0, 126.2 (aromatic CH), 101.0 (acetal CH), 84.9 (C-1), 75.4, 73.4, 69.6, 69.2, 68.9, 23.2, 14.9; MALDI-MS: $m/z = 335.20$ $[M+Na]^+$, calcd. for ($C_{15}H_{20}O_5S$): 335.09; anal. calcd. for $C_{15}H_{20}O_5S$: C 57.67, H 6.45; found: C 57.55, H 6.40.

Methyl 3-*O*-benzyl-4,6-*O*-benzylidene-α-D-mannopyranoside (23):[27] Eluted with hexane/ethyl acetate from 7:3 to 1:1; oil; ^{1}H NMR (400 MHz, $CDCl_3$): $\delta = 7.60$–7.30 (aromatic

H, 10H), 5.63 (s, 1H), 4.86 and 4.72 (-CH_2Ph, AB, J= 12.0 Hz, 2H), 4.76 (H-1, s, 1H), 4.29 (H-3, dd, J=3.6 and 9.6 Hz, 1H), 4.12 (H-4, t, J=9.6 Hz, 1H), 4.05 (H-2, bs, 1H), 3.95–3.80 (H-5 and H_2-6, overlapped signals, 3H), 3.38 (1-OCH_3, s, 3H), 2.79 (OH-2, s, 1H); ^{13}C NMR (100 MHz, $CDCl_3$): δ=137.8, 137.4 (aromatic C), 133.3–126.0 (aromatic CH), 101.5, 101.0 (acetal CH), 78.7, 75.5, 72.9, 69.7, 68.7, 63.1, 54.8; MALDI-MS: m/z=395.20 $[M+Na]^+$, calcd. for ($C_{21}H_{24}O_6$): 395.15; anal. calcd. for $C_{21}H_{24}O_6$: C 67.73, H 6.50; found: C 67.50, H 6.60.

Methyl 3-*O*-benzyl-4,6-*O*-(*p*-methoxy)benzylidene-α-D-mannopyranoside (24): Eluted with hexane/ethyl acetate from 7:3 to 1:1; oil; $[\alpha]_D^{23}$: +35.3 (*c* 2, $CHCl_3$); ^{1}H NMR (400 MHz, $CDCl_3$): δ=7.60–7.00 (aromatic H, 9H), 5.71 (s, 1H), 4.97 and 4.82 (-CH_2Ph, AB, J=12.0 Hz, 2H), 4.86 (H-1, d, J=1.2 Hz, 1H), 4.40 (H-6eq, dd, J=3.6 and 9.6 Hz, 1H), 4.25 (t, J=9.6 Hz, 1H), 4.13 (H-2, dd, J=1.2, 9.6 Hz, 1H), 4.02 (H-3, dd, J=3.6, 9.6 Hz, 1H), 4.01 (t, J=9.6 Hz, 1H), 3.97 (H-5, m, 1H), 3.95 (aromatic -OCH_3, s, 3H), 3.49 (1-OCH_3, s, 3H); ^{13}C NMR (100 MHz, $CDCl_3$): δ=159.8, 137.9, 128.3 (aromatic C), 128.3, 127.7, 127.2, 113.4 (aromatic CH), 101.4, 101.0 (acetal CH), 78.6, 75.5, 72.8, 69.6, 68.6, 63.1, 55.1, 54.7; MALDI-MS: m/z=425.00 $[M+Na]^+$, calcd. for ($C_{22}H_{26}O_7$): 425.16; anal. calcd. for $C_{22}H_{26}O_7$: C 65.66, H 6.51; found: C 65.40, H 6.45.

Allyl 4,6-*O*-benzylidene-2-deoxy-2-acetamido-α-D-glucopyranoside (25):[28] Eluted with dichloromethane/methanol from 100:0 to 95:5; solid; mp 207–209 °C; ^{1}H NMR (400 MHz, $CDCl_3$): δ=7.50–7.30 (aromatic H, 5H), 6.00–5.80 (CH_2=C*H*CH_2- and NH-2, overlapped signals, 2H), 5.57 (s, 1H), 5.31 ($CH_{cis}H_{trans}$=C*H*CH_2-, bd, J=17.2 Hz, 1H), 5.25 (C$H_{cis}H_{trans}$=C*H*CH_2-, bd, J=10.8 Hz, 1H), 4.87 (H-1, d, J=3.6 Hz, 1H), 4.30–4.20 (CH_2=CHC*Ha*Hb-, H-6eq and H-2; overlapped signals, 3H), 3.98 (CH_2=CHCHa*Hb*-, m, 1H), 3.94 (t, J=10.0 Hz, 1H), 3.85 (m, H-5, 1H), 3.76 (t, J=10.0 Hz, 1H), 3.58 (t, J=10.0 Hz, 1H), 2.07 (-$NHCOCH_3$, s, 3H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 171.4 (CO), 137.0 (aromatic C), 133.2 (CH_2=*C*HCH_2-), 129.1, 128.2, 126.2 (aromatic CH), 118.1 (*C*H_2=CHCH_2-), 101.7, 96.9 (acetal CH), 81.9, 71.7, 70.3, 70.1, 62.6, 53.9; MALDI-MS: m/z=372.30 $[M+Na]^+$, calcd. for ($C_{18}H_{23}NO_6$): 372.14; anal. calcd. for $C_{18}H_{23}NO_6$: C 61.88, H 6.64; found: C 61.70, H 6.70.

Ethyl 4,6-*O*-benzylidene-2-deoxy-2-phthalimido-1-thio-β-D-glucopyranoside (26):[29] Eluted with hexane/ethyl acetate from 7:3 to 6:4; foam; ^{1}H NMR (400 MHz, $CDCl_3$): δ= 7.85–7.30 (aromatic H, 9H), 5.59 (s, 1H), 5.42 (H-1, d, J= 10.4 Hz, 1H), 4.68 (t, J=9.6 Hz, 1H), 4.41 (H-6eq, dd, J= 4.8, 10.4 Hz, 1H), 4.35 (t, J=9.6 Hz, 1H), 3.83 (t, J=9.6 Hz, 1H), 3.71 (H-5, m, 1H), 3.62 (t, J=9.6 Hz, 1H), 2.71 (-S*C*$H_2$$CH_3$, m, 2H), 1.22 (-S*C*$H_2$$CH_3$, t, J=7.2 Hz, 3H); ^{13}C NMR (100 MHz, $CDCl_3$): δ=168.1 and 167.6 (-*C*O), 136.9, 134.0, 131.2, 128.2, 126.2, 123.6, 123.2 (aromatic signals); 101.7 (acetal CH), 81.9, 81.7, 70.2, 69.2, 68.4, 55.4, 24.0,14.7. MALDI-MS: m/z=463.20 $[M+Na]^+$; calcd. for ($C_{23}H_{23}NO_6S$): 463.11; anal. calcd. for $C_{23}H_{23}NO_6S$: C 62.57, H 5.25; found: C 62.75, H 5.10.

2,3-*O*-Benzylidenediisopropyl-D-tartrate (27):[30] Eluted with hexane/ethyl acetate from 95:5 to 85:15; oil; ^{1}H NMR (400 MHz, $CDCl_3$): δ=7.45–7.30 (aromatic H, 5H), 6.15 (-CHPh, s, 1H), 5.14 (2×isopropyl CH, hept, J=6.0 Hz, 2H), 4.85 and 4.75 (H-2 and H-3, 2×d, J=3.6 Hz, 2H), 1.31 (2×-CH_3, d, J=6.0 Hz, 6H), 1.28 (CH_3, d, J=6.0 Hz, 3H), 1.26 (CH_3, d, J=6.0 Hz, 3H); ^{13}C NMR (100 MHz, $CDCl_3$): δ=169.1 and 168.4 (2×-CO), 135.6 (aromatic C), 129.8, 128.2, 127.1 (aromatic CH), 106.6 (-*C*HPh), 77.6, 77.5, 69.7, 21.6 (×2), 21.5, 21.4; MALDI-MS: m/z=345.30 $[M+Na]^+$, calcd. for ($C_{17}H_{22}O_6$): 345.13; anal. calcd. for $C_{17}H_{22}O_6$: C 63.34, H 6.88; found: C 63.55, H 6.75.

3,4,6-Tri-*O*-benzyl-1,2-*O*-benzylidene-D-sorbitol (29): Eluted with hexane/ethyl acetate from 8:2 to 6:4; foam; $[\alpha]_D^{23}$: −1.0 (*c* 1.8, $CHCl_3$); ^{1}H NMR (400 MHz, $CDCl_3$): δ= 7.48–7.29 (aromatic H, 20H), 5.63 (s, 1H), 4.90–4.33 (3×-CH_2Ph, 3×AB, J=11.2 Hz, 6H), 4.15 (d, J=9.6 Hz, 1H), 4.06 (bd, J=8.0 Hz, 1H), 4.00 (bd, J=6.4 Hz, 1H), 3.95 (d, J=11.2 Hz, 1H), 3.90–3.75 (ovelapped signals, 3H), 3.58 (dd, J=4.8, 11.2 Hz, 1H), 1.90 (bs, OH); ^{13}C NMR (100 MHz, $CDCl_3$): δ =138.2 (×3), 137.8 (aromatic C); 128.3–126.2 (aromatic CH); 100.9 (acetal CH), 80.5, 78.1, 76.0, 73.9, 73.3, 71.0, 69.9, 67.4, 62.5; MALDI-MS: m/z= 563.35 $[M+Na]^+$, calcd. for ($C_{34}H_{36}O_6$): 563.24, anal. calcd. for $C_{34}H_{36}O_6$: C 75.53, H 6.71; found: C 75.40, H 6.75.

Allyl 4,6-*O*-benzylidene-α/β-D-glucopyranoside (30): Eluted with dichloromethane/methanol from 100:0 to 95:5; foam; ^{1}H NMR (400 MHz, $CDCl_3$, significant signals at): δ= 7.60–7.30 (aromatic H), 6.00 (CH_2=C*H*CH_2-, m, 1H), 5.52 (s, 1H), 5.34 ($CH_{cis}H_{trans}$=C*H*CH_2-, bd, J=17.2 Hz, 1H), 5.17 (C$H_{cis}H_{trans}$=C*H*CH_2-, bd, J=9.6 Hz, 1H), 4.91 (H-1α, d, J= 3.6 Hz, 1H), 4.43 (H-1β, d, J=7.6 Hz, 1H), 3.95 (t, J= 9.6 Hz, 1H), 3.85 (m, 1H), 3.75 (t, J=9.6 Hz, 1H), 3.72 (H-2α, dd, J=3.6, 9.6 Hz, 1H); ^{13}C NMR (100 MHz, $CDCl_3$; significant signals at): δ=137.1 (aromatic C), 133.2 (CH_2= *C*HCH_2-), 129.2, 128.3, 126.3 (aromatic signals); 118.2 (*C*H_2=CHCH_2-), 101.8, 97.9 (acetal CH), 80.9, 72.7, 71.4, 68.8, 62.5; MALDI-MS: m/z=331.20 $[M+Na]^+$, calcd. for ($C_{16}H_{20}O_6$): 331.12; anal. calcd. for $C_{16}H_{20}O_6$: C 62.33, H 6.54; found: C 62.40, H 6.50.

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