Asian Journal of Chemistry; Vol. 35, No. 6 (2023), 1408-1416

ASIAN JOURNAL OF CHEMISTRY

https://doi.org/10.14233/ajchem.2023.27842

P_2O_5-Al_2O_3 Catalyzed One Pot Acetylation, Benzylidene Acetal Protection and Benzylidene Removal of Sugar Derivatives

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Received: 29 March 2023; *Accepted*: 20 April 2023; *Published online*: 27 May 2023; AJC-21256

An environment-friendly, simple and efficient one-pot acetylation and benzylidene acetal formation procedure has been introduced for the synthesis of sugar derivatives using P_2O_5-Al_2O_3 as a solid acid catalyst under solvent-free condition at room temperature, with excellent overall yield. This benzylidene acetal has been deprotected using the same reagent but in a moist condition.

Keywords: Carbohydrate, P_2O_5/Al_2O_3, Acetylation, Benzylidene acetal, Ring opening.

INTRODUCTION

Suitably protected and functionalized monosaccharide motifs act as useful and important intermediates for the synthesis of biologically important oligosaccharides [1]. Acetylation and benzylidene acetal used most often or commonly used protecting groups for hydroxyl groups in carbohydrate synthesis [2]. Natural glycosides, oligosaccharides and other glycoconjugates are promptly synthesized with cheap and readily available acetylated benzylidene acetal sugars [3,4]. For the preparation of acetylated and acetalated derivatives, several methodologies are available in the literature. The formation of benzylidene acetals occurs typically by reacting an aldehyde or ketone with a Lewis acid [5]. This reaction can be facilitated by using dimethyl acetals [6] or ketals [7] or enol-ether [8] in presence of other catalysts including $CuSO_4$ [9], H_2SO_4 [10], CH_2O_2 [11], I_2 [12], $ZnCl_2$ [13], camphorsulfonic acid [14] and *p*-toluenesulfonic acid [15]. Perchloric acid and sulphuric acid immobilized on silica gel have also been used for acetalation and subsequent O-acetylation of glycosides in a one-pot system [16,17]. Acetylation of the carbohydrate hydroxyl group usually involves a large amount of acetic anhydride and pyridine [18]. Pyridine is toxic to the environment as well as it has an unpleasant odour [19]. Catalysts that have been effective for the acetylation of sugar alcohols include $HClO_4$ [20], H_2SO_4 [21], sodium acetate [22] and some Lewis acid catalysts for instance $ZnCl_2$ [23], $FeCl_3$ [24], $Sc(OTf)_3$ [25], iodine [26], $Cu(OTf)_2$ [27], $CoCl_2$ [28], $BiCl_3$ [29], $BiOCl–SOCl_2$ [30], $LiClO_4$ [31]. Several heterogeneous catalysts for example H_2SO_4 on silica [32], $FeCl_3 \cdot 6H_2O$ on silica [33], montmorillonite K-10 [34], Nafion-H [35], $NaHCO_4$ on silica [36], $HClO_4$ on silica [37] and zeolites [38] are also used for the acetylation of sugars. Each of the reported methodologies has some limitations.

The removal of benzylidene acetal is also an important reaction to generate a dihydroxy compound. These dihydroxy derivatives can be further used as glycosyl acceptors or as a starting material for complex carbohydrate synthesis. Developing heterogeneous catalysts for fine chemical synthesis is another wide-scope research endeavor [32]. The great majority of practical heterogeneous catalysts are solids and reactants are gases or liquids. The use of catalysts and reagents immobilized on solid supports has recently been developed, which helps to reduce the reaction time and simplify the purification process while preventing toxic reaction residues from entering the environment. It is common for these reactions to need longer reaction times and excessive acetic anhydride is often used as the solvent, leading to troublesome neutralization work-up. Despite having several reported methods, it is essential to expound a rapid and refine reaction methodology for the acetylated benzylidene acetal derivatives of sugars using an economically convenient heterogeneous catalyst and methods for their easy introduction and removal. Herein, a convenient one-pot synthesis of acetylated benzylidene acetal derivatives of sugars by the stoichiometric quantity of acetic anhydride and

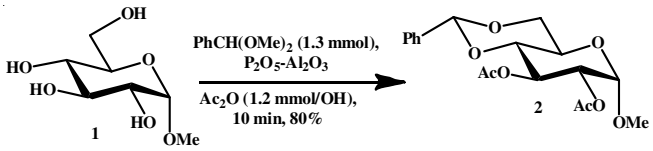
benzaldehyde dimethyl acetal in the presence of a P_2O_5-Al_2O_3 catalyst is reported. The removal of benzylidene acetal ring with the same catalyst is also reported. This catalyst was previously used for the synthesis of the heterocyclic compound [39]. To our best of knowledge, it is first report on the use of P_2O_5-Al_2O_3 as catalyst in carbohydrate chemistry.

EXPERIMENTAL

All the reagents were purchased from Sigma-Aldrich and Merck companies and used used without purification. The progress of the chemical reaction was monitored by thin-layer chromatography using silica gel G-coated TLC plates. Using a hot plate, sulphuric acid (10% conc. H_2SO_4 in CH_3OH) sprayed plates were visualized for TLC spots. Silica gel 60-120 and 200-400 mesh were used in column chromatography. ^1H & ^{13}C NMR spectra were recorded on Brucker Avance DPX 200-500 MHz using $CDCl_3$ as solvents and TMS as an internal reference.

Preparation of P_2O_5-Al_2O_3: Phosphorous pentoxide (2 g, 7.045 mmol) was added to acidic alumina (2 g, 19.61 mmol) in a sealed round bottom flask and stirred at room temperature for 10 min until a clear powder was obtained. This homogenous reagent was heated in an oven at 120 ºC for 1 h and then stored in a sealed flask for further use.

General protocol for one-pot acetelation and acylation of sugar derivatives: P_2O_5-Al_2O_3 (20 mg) was added to a suspension of sugar derivatives (100 mg, l equiv.) and benzaldehyde dimethyl acetal (0.1 mL, 1.3 equiv.) in round bottom flask and stirred for 3-5 min. Then acetic anhydride (0.242 mL, 5 equiv.) was added to the reaction mixture and stirred for further 2-3 min. The reaction mixture was diluted with CH_2Cl_2 (20 mL) and filtered through a Celite® bed. The organic layer was washed with $NaHCO_3$ solution, dried (Na_2SO_4) and purified over SiO_2 using hexane-ethyl acetate (7:1) as eluant to furnish pure solid (**Scheme-I**).



Scheme-I: Formation of methyl 2,3-di-*O*-acetyl-4,6-*O*-benzylidene-α-D-glucopyranoside

Methyl 2,3-di-O-acetyl-4,6-O-benzylidene-α-D-glucopyranoside (2): Yield: 82%; White solid; m.p.: 164-165 ºC; IR (neat, cm^{-1}): 2973, 2850, 1772, 1678, 1398, 1071, 991, 751; ^1H NMR (200 MHz, $CDCl_3$): δ 7.46-7.33 (m, 5 H, Ar-H), 5.50 (s, 1 H, PhC*H*), 5.36-5.27 (t, *J* = 9.3 Hz each, 1 H, H-2), 4.97 (dd, *J* = 7.8 Hz each, 1 H, H-3), 4.50 (d, *J* = 7.8 Hz, 1 H, H-1), 4.36 (dd, *J* = 10.4 and 5.6 Hz, 1 H, H-4), 3.85-3.65 (m, 2 H, H-6_{ab}), 3.58-3.53 (m, 1 H, H-5), 3.51 (s, 3 H, OCH_3), 2.06, 2.04 (2 s, 6 H, 2×COCH_3). ESI-MS: *m/z* = 389.21 $[M+Na]^+$; Anal. calcd. (found) % for $C_{18}H_{22}O_8$ (*m.w.* 366): C, 59.01 (59.06); H, 6.09 (6.14).

Propargyl 2,3-di-O-acetyl-4,6-O-benzylidene-α-D-glucopyranoside (4): Yield: 88%, white solid, m.p.: 84-86 ºC; IR (neat, cm^{-1}): 3265, 2917, 2121, 1744, 1457, 1373, 1231, 1033, 986, 704. ^1H NMR (300 MHz, $CDCl_3$): δ 7.51-7.18 (m, 5H, Ar-H), 7.20 (d, 2 H, *J* = 8.6 Hz, Ar-H), 6.83 (d, 2H, *J* = 8.6 Hz, Ar-H), 5.58 (s, 1 H, PhC*H*), 5.34 (t, 1 H, *J* = 9.5 Hz each, H-3), 5.25 (d, 1 H, *J* = 3.5 Hz each, H-1), 5.14 (dd, 1H, *J* = 3.5 Hz and 9.5 Hz, H-2), 4.42 (m, 2 H, CH_2–C≡CH), 4.28 (m, 2H, H-4, H-6a), 4.15 (m, 2 H, H-5, H-6b), 2.38 (t, 1H, *J* = 1.0 Hz, CH_2–C≡C*H*), 2.08 (s, 3 H, COCH_3), 2.04 (s, 3 H, COCH_3). ^{13}C NMR ($CDCl_3$, 125 MHz): δ 170.7 (*C*OCH$_3$), 170.5 (*C*OCH$_3$), 96.1 (C-1), 78.3, 75.3, 70.8, 69.5, 68.0, 67.7, 61.8, 55.3, 20.7 (CO*C*H$_3$), 20.6 (CO*C*H$_3$). ESI-MS: *m/z* = 399.18 $[M+Na]^+$; Anal. calcd. (found) % for $C_{19}H_{20}O_8$ (*m.w.* 376.3): C, 60.23 (60.29), H, 5.36 (5.42).

2-Trimethylsilylethyl-2,3-di-O-acetyl-4,6-O-benzylidene-β-D-glucopyranoside (6) [40]**:** Yield: 80%, gum, IR (neat, cm^{-1}): 2932, 1756, 1462, 1368, 1224, 1039, 997, 758, 702. ^1H NMR (200 MHz, $CDCl_3$): δ 7.47- 7.33 (m, 5 H, Ar-H), 5.50 (bs, 1 H, PhCH), 5.36-5.27 (m, 2 H), 4.99 (t, *J* = 8.0 Hz, 1 H, H-2), 4.61 (d, *J* = 8.0 Hz, 1 H, H-1), 4.39 (dd, *J* = 4.8, 10.4 Hz, 1 H, H-), 4.04-3.99 (m, 2 H, H-3, H-4), 3.86-3.56 (m, 2 H, H-6_{ab}), 2.05, 2.04 (s, 6 H, 2COCH_3), 1.03-0.91 (m, 2 H), 0.07, 0.02, 0.01 (s, 9 H, -Si(CH_3)$_3$). ESI-MS (*m/z*): 358 [M+Na]. Anal. calcd. (found) % for $C_{17}H_{19}O_7$: C, 60.89 (60.80), H, 5.71 (5.79).

Allyl-2,3-di-O-acetyl -4,6-O-benzylidene-α-D-glucopyranoside (8): Yield: 82%, white solid, m.p.: 90-92 ºC; IR (neat, cm^{-1}): 2934, 1746, 1460, 1375, 1224, 1038, 990, 760, 701. ^1H NMR (400 MHz, $CDCl_3$): δ 7.3-7.5 (m, 5 H, Ph), 5.95-5.80 (m, 1 H, OCH$_2$C*H*=CH$_2$), 5.55 (s, 1 H. PhC*H*), 5.40 (t, *J* = 10.3, 9.8, 1 H, H-3), 5.34 (dq, *J* = 17.2, 1.6, 1 H, OCH$_2$-CH=CH_2), 5.26 (dq, *J* = 10.4, 1.4, 1 H, OCH$_2$CH=CH_2), 5.13 (dd, *J* = 10.2, 4.0, 1 H, H-2), 4.97 (d, *J* = 4.0, 1 H, H-1) , 4.29 (t, *J* = 10.1, 9.2, 1 H, H-4), 4.25 (dd, *J* = 13.3, 5.3, 1 H, H-6), 4.07 (m, *J* = 9.2, 5.3, 1.4, 1 H, H-5), 3.78-3.73 (m, 2 H, OCH_2-CH=CH$_2$), 3.75 (dd, *J* = 10.0, 5.6, 1 H, H-6), 2.18 (s, 6H, C(=O)-CH_3). ^{13}C NMR ($CDCl_3$, 125 MHz): δ 170.4, 136.7, 133.2, 129.1, 128.2, 126.2, 117.6, 101.4, 100.2, 78.3, 72.2, 70.2, 68.7, 66.3, 20.8, 20.7. ESI-MS: *m/z* = 415.16 $[M+Na]^+$; Anal. calcd. (found) % for $C_{20}H_{24}O_8$ (*m.w.* 392.3): C, 61.22 (61.29), H, 6.16 (6.20).

Phenyl 3-O-Acetyl-4,6-O-benzylidene-2-deoxy-2-phthalimido-1-thio-β-D-glucopyranoside (10) [40]**:** Yield: 91%, white solid; m.p.: 115 ºC. ^1H NMR ($CDCl_3$, 300 MHz): δ 7.85-7.71 (m, 4 H, Ar-H), 7.42-7.25 (m, 10 H, Ar-H), 5.85 (t, *J* = 9.5 and 9.0 Hz, 1H, 3-H), 5.80 (d, *J* = 10.6 Hz, 1 H, 1-H), 5.50 (s, 1 H, PhCH), 4.41 (d, *J* = 5.9 Hz, 1 H, 4-H), 4.30 (t, *J* = 10.2 and 10.1 Hz, 1 H, 2-H), 3.82-3.70 (m, 3 H, 5-H and 6-H_{ab}), 1.87 (s, 3 H, COCH_3). ^{13}C NMR ($CDCl_3$, 75 Hz): δ 170.5, 168.2, 167.6, 137.3-124.1 (Ar-C), 102.1, 84.3, 79.4, 70.9, 69.0, 54.7, 20.9 ppm. IR (KBr, ν_{max}, cm^{-1}): 2934, 2829, 2367, 1715, 1595, 1366, 1228, 1105, 1030, 966, 719. ESI-MS: *m/z* = 554 $[M + Na]^+$; Anal. calcd. (found) % for $C_{29}H_{25}NO_7S$ (*m.w.* 531): C, 65.52 (65.68), H, 4.74 (5.00).

Ethylcarbamate 3-*O*-acetyl-4,6-*O*-benzylidine-2-azido-2-deoxy-α-D-glucopyranoside (12): Yield: 84%, White solid, m.p.: 118-125 ºC. IR (neat, cm^{-1}): 2984, 2829, 1772, 1464, 1357, 1244, 1039, 992, 787, 706. ^1H NMR (300 MHz, $CDCl_3$): δ 8.6 (s, 1H, *sec.* amide), 7.43-7.32 (m, 10H, Ar-H), 5.50 (s, 1H, PhC*H*), 5.48 (s, 1 H, PhC*H*), 5.14 (d, *J* = 8 Hz, 1 H, H-1), 4.49 (dd, *J* = 5.2 Hz each, 1 H, H-3), 4.34 (dd, *J* = 10.4 and

5.6 Hz, 1 H, H-4), 3.97 (d, J = 12.3 Hz, 1 H, H-6_a), 3.77 (t, J = 7.3 Hz, 1 H, H-6_b), 3.66 (t, 2H, CH_2-CH_2), 3.51-3.45 (m, 1H, H-5), 3.22 (dd, J = 4.2 each, 2H, CH_2-CH_2), 2.94 (s, 1H, $COCH_3$). ^{13}C NMR ($CDCl_3$, 400 MHz): δ 170.3 (*C*OCH_3), 136.7-127.9 (Ar-C), 156.4 (*C*$OOCH_2$), 102.6(C-1), 101.6 (Ph*C*H), 78.4 (C-4), 76.4 (C-5), 70.9 (C-3), 66.7 (Ph*C*O), 64.5(*C*H_2-*C*H_2), 40.8 (*C*H_2-*C*H_2), 20.8 (CO*C*H_3). ESI-MS: *m/z* = 535.21 $[M+Na]^+$; Anal. calcd. (found) % for $C_{25}H_{28}N_4O_8$ (*m.w.* 512): C, 58.59 (58.62), H, 5.51 (5.56).

Phenyl 2,3-di-O-acetyl-4,6-O-benzylidene-1-thio-β-D-galactopyranoside (14) [40]**:** Yield: 82%, amorphous white solid; ^{1}H NMR ($CDCl_3$, 400 MHz) δ 7.61-7.24 (10 H, m, Ph), 5.47 (s, 1H, PhCH), 5.36 (t, 1H, J = 10.0 Hz, H-2), 5.00 (d, J = 3.2 Hz, 1H, H-4), 4.98 (d, J = 3.2 Hz, 1H, H-3), 4.75 (d, 1H, J = 10.4 Hz, H-1), 4.39-4.35 (m, 2H,), 4.04 (dd, J = 1.6 Hz each, 1H, H-3), 3.59 (d J = 0.8 Hz, 1H, H-3), 2.08-2.02 (2s, 6H, $COCH_3$); ^{13}C NMR ($CDCl_3$, 400 MHz): δ 169.3 (CO), 137.1 (C*q*), 132.6-125.9 (Ar-C), 101.1 (PhCH), 86.8 (C-1), 81.0 (C-4), 79.9 (C-3) 73.4 (C-7), 71.3 (C-5) 70.5 (C-2), 68.5 (C-6), 20.1 (CO*C*H_3); ESI-MS: *m/z* = 444.16 $[M+Na]^+$; Anal. calcd. (found) % for $C_{23}H_{24}O_7S$ (*m.w.* 444.12): C, 62.15 (62.22), H, 5.44 (5.46).

Methyl-2,3-di-*O*-acetyl-4,6-*O*-benzylidene-α-D-mannopyranoside (16) [40]**:** Yield: 85%, colourless gum; IR (neat, cm^{-1}): 1750, 1456, 1370, 1242, 1220, 1030, 894, 759; ^{1}H NMR (200MHz, $CDCl_3$): δ 7.47-7.26 (m, 5H, Ar), 5.58 (bs, 1H), 5.43-5.34 (m, 2H), 4.67 (d, J = 3.3 Hz, 1H), 4.31 (dd, J = 2.7, 8.6 Hz, 1H), 4.05-3.81 (m, 3H), 3.41 (bs, 3H, -OMe), 2.17 (s, 3H, -OAc), 2.02 (s, 3H, -OAc). ^{13}C NMR ($CDCl_3$, 50MHz): δ 169.9, 169.8, 137.2, 129.6, 128.4 × 2, 126.9 × 2, 101.9, 98.3, 75.7, 70.1, 68.7, 68.3, 63.8, 55.1, 20.8, 20.7. ESI MS (*m/z*): 389 [M+Na]. Anal. calcd. (found) % for $C_{18}H_{22}O_8$: C, 59.01 (59.09), H, 6.05 (6.11).

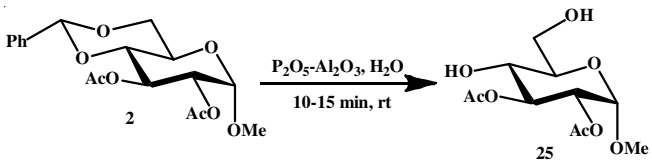
4-Methoxyphenyl 2,3-di-*O*-acetyl-4,6-*O*-benzylidine-β-D-galactopyranoside (18): Yield: 78%, Yellow oil; IR (neat, cm^{-1}): 2986, 2847, 1772, 1678, 1398, 1071, 991, 751; ^{1}H NMR (300 MHz, $CDCl_3$): δ 7.51-6.76 (m, 9 H, Ar-H), 5.57 (dd, J = 8.1 Hz, 10.2 Hz, 1 H, H-2), 5.45 (s, 1 H, PhC*H*), 5.04 (dd, J = 3.3 Hz each, 1 H, H-3), 4.89 (d, J = 8.1Hz, 1 H, H-1), 4.35 (d, J = 3.3 Hz, 1 H, H-4), 4.29 (d, J = 12.3 Hz, 1 H, H-6_a), 4.20 (d, J = 12.3 Hz, 1 H, H-6_b), 3.71 (s, 3 H, O*C*H_3), 3.54-3.53 (m, 1 H, H-5), 2.09, 2.05 (2 s, 6 H, 2 CO*C*H_3). ^{13}C NMR ($CDCl_3$, 125 MHz): δ 170.9 (*C*OCH_3), 169.4 (*C*OCH_3), 155.7-114.5 (Ar-C), 101.2(Ph*C*H), 101.1 (C-1), 73.3 (C-4), 72.0 (C-5), 68.9 (C-3), 68.6 (C-2), 55.7 (O*C*H_3), 21.0 (CO*C*H_3), 20.9 (CO*C*H_3). ESI-MS: *m/z* = 481.16 $[M+Na]^+$; Anal. calcd. (found) % for $C_{24}H_{26}O_9$ (*m.w.* 458.4): C, 62.88 (62.91), H, 5.72 (5.75).

Ethyl 2,3-di-*O*-acetyl-4,6-*O*-benzylidine-1-thio-α-D-mannopyranoside (20): Yield: 85%, white solid; m.p.: 90-95 ºC; IR (neat, cm^{-1}): 3080, 2929, 2837, 1777, 1481, 1314, 1189, 1061, 993, 758, 679; ^{1}H NMR (300 MHz, $CDCl_3$): δ 7.50-7.35 (m, 5H, Ar-H), 5.60 (s, 1H, Ph*CH*), 5.46 (d, 1H, J = 3.3 Hz, H-2), 5.36 (dd, 1H, J =10.5 Hz each, H-3), 4.38-4.24 (m 2H, H-6a, H-6b), 4.11 (t, 1H, J = 10.5 Hz, H-4), 3.89 (m, 1H, H-5), 2.64 (m, 2H, S-CH_2-CH_3), 2.18 (s, 3H, $COCH_3$), 2.01 (s, 3H, $COCH_3$), 1.30 (t, 3H, S-CH_2-CH_3). ESI-MS: *m/z* = 419.20 $[M+Na]^+$; Anal. calcd. (found) % for $C_{19}H_{24}O_7S$ (*m.w.* 396.4): C, 57.56 (57.66), H, 6.10 (6.18).

Ethyl 2-*O*-acetyl-4,6-*O*-benzylidene-3-*O*-(4-methoxybenzyl)-1-thio-β-D-glucopyranoside (22): Yield: 81%, White solid, m.p.: 84-85 ºC; IR (neat, cm^{-1}): 2945, 2892, 1725, 1457, 1378, 1233, 1068, 989, 754, 701, 685. ^{1}H NMR (300 MHz, $CDCl_3$): δ 7.51-7.18 (m, 5 H, Ar-H), 7.20 (d, J = 8.6 Hz, 2 H, Ar-H), 6.83 (d, J = 8.6 Hz, 2 H, Ar-H), 5.58 (s, 1H, PhC*H*), 5.02 (dd, J = 10.0, 8.6 Hz, 1 H, H-2), 4.80 (d, J = 11.7 Hz, 1H, PhCH_2), 4.62 (d, J = 11.7 Hz, 1 H, PhCH_2), 4.43 (d, J = 10.1 Hz, 1 H, H-1), 4.38 (dd, J = 10.5, 5.0 Hz, 1 H, H-4), 3.81 (s, 3H, O*C*H_3), 3.78-3.70 (m, 3 H, H-3, H-6_{ab}), 3.51-3.48 (m, 1 H, H-5), 2.71 (ddd, J = 9.9, 7.4, 2.5 Hz, 2 H, SC$H_2$$CH_3$), 2.03 (s, 3 H, OCOC$H_3$), 1.27 (t, J = 7.5 Hz, 3 H, SCH_2CH_3); ^{13}C NMR ($CDCl_3$, 75 MHz): δ 169.1 (*C*OCH_3), 159.2 (Ar-C), 137.2-113.6 (Ar-C), 101.1 (Ph*C*H), 84.0 (C-1), 81.5, 79.0, 73.8, 71.1, 70.6, 68.5, 55.1 (O*C*H_3), 23.6 (S*C*$H_2$$CH_3$), 20.8 (CO*C*$H_3$), 14.7 ($SCH_2$*C*$H_3$). ESI-MS: *m/z* = 497.19 $[M+Na]^+$; Anal. calcd. (found) % for $C_{25}H_{30}O_7S$ (*m.w.* 474.17): C, 63.27 (63.06); H, 6.37 (6.60).

Ethyl 2,3-di-*O*-acetyl-4,6-*O*-(*p*-methoxy) benzylidene-1-thio-α-D-mannopyranoside (24): Yield: 90%, White solid; m.p.: 82-84 ºC; IR (neat, cm^{-1}): 3082, 2956, 2831, 1742, 1411, 1343, 1126, 1022, 997, 724, 692; ^{1}H NMR (500 MHz, $CDCl_3$): δ 7.38 (d, J = 8.7 Hz, 2 H, Ar-H), 6.88 (d, J = 8.7 Hz, 2 H, Ar-H), 5.53 (s, 1 H, PhC*H*), 5.44-5.43 (m, 1 H, H-2), 5.33 (dd, J = 10.3, 3.4 Hz, 1 H, H-3), 5.23 (br s, 1 H, H-1), 4.35-4.31 (m, 1H, H-5), 4.23 (dd, J = 10.3, 4.9 Hz, 1 H, H-6_a), 4.06 (t, J = 10.0 Hz each, 1H, H-4), 3.86 (t, J = 10.3 Hz each, 1H, H-6_b), 3.79 (s, 3 H, O*C*H_3), 2.68-2.60 (m, 2H, SC$H_2$$CH_3$), 2.16, 2.00 (2 s, 6H, 2 CO*C*H_3), 1.29 (t, J = 7.4 Hz each, 3H, SCH_2CH_3); ^{13}C NMR (125 MHz, $CDCl_3$): δ 170.2 (2 C, 2 *C*OCH_3), 160.6-114.0 (Ar-C), 102.3 (Ph*C*H), 83.6 (C-1), 76.7 (C-5), 72.1 (C-3), 69.1 (C-2), 68.9 (C-6), 64.9 (C-4), 55.6 (O*C*H_3), 25.8 (S*C*$H_2$$CH_3$), 21.3, 21.2 (2 CO*C*$H_3$), 15.2 ($SCH_2$*C*$H_3$); ESI-MS: *m/z* = 449.18 $[M+Na]^+$; Anal. calcd. (found) % for $C_{20}H_{26}O_8S$ (*m.w.* 426.4): C, 56.32 (56.33); H, 6.14 (6.18).

General protocol for removal of benzylidene acetal of sugar derivatives: To a mixture of benzylidene-protected sugar derivative (**2**, 180 mg), 0.18 g of P_2O_5-Al_2O_3 and H_2O (2-3 drops) were added and the reaction mixture was allowed to stir at room temperature for 12 min. The reaction was followed by thin-layer chromatography (hexane:ethyl acetate = 1:1), which showed the completion of the reaction. After the completion of reaction, it was diluted with DCM and filtered. The solvent was reduced and crude was purified over silica gel using hexane-ethyl acetate (ratio 6:1.5) as eluent to get the desired product (**Scheme-II**).



Scheme-II: Removal of benzylidiene acetal using P_2O_5-Al_2O_3

Methyl 2,3-di-*O*-acetyl-α-D-glucopyranoside (25): Yield: 162 mg (88%); white solid; m.p.: 152-154 ºC; IR (neat, cm^{-1}): 3500-3000 br, 2931, 1748, 1353, 1192, 1054, 753, 606; ^{1}H NMR (200 MHz, $CDCl_3$): δ 5.24 (1H, t, J = 9.8 Hz, H-3);

4.84 (1H, d, *J* = 3.8 Hz, H-1); 4.73 (1H, dd, *J* = 3.8 and 9.8 Hz, H-2); 3.65-3.78 (2H, overlapped signals, H-4, H-5); 3.61-3.63 (2H, overlapped signals, H-6, H-2); 3.35 (3H, s, 1-OCH_3); 2.03 and 2.01 (3H each, s's, two –$COCH_3$). ^{13}C NMR (50 MHz, $CDCl_3$): δ 171.2 and 170.3 ($COCH_3$); 96.8 (C-1); 72.8, 71.3, 71.0 and 68.9 (C-2, C-3, C-4 and C-5); 61.4 (C-6); 55.1 (1-OCH_3); 20.8 and 20.6 ($COCH_3$). ESI-MS: *m/z* = 278.84 $[M+Na]^+$; Anal. calcd. (found) % for $C_{11}H_{18}O_8$ (*m.w.* 278): C, 47.48 (47.66); H, 6.52 (6.78).

Allyl-2,3-di-*O*-acetyl-α-D-glucopyranoside (26) [41]**:** Yield: 88%, Amorphous colourless solid, IR (neat, cm^{-1}): 2930, 2855, 1742, 1375, 1212, 1035, 914, 762; ^{1}H NMR (500 MHz, $CDCl_3$): δ 6.00-5.80 (m, 1H) 5.40-5.30 (m 1H), 5.20-5.10 (m, 1H), 5.00-4.90 (m, 3H) 4.80-4.60 (m, 1H), 4.40-4.20 (m, 1H), 4.20-4.00 (m, 1H) 3.90-3.40 (m, 4H), 2.00-1.80 (2s, 6H). ESI-MS: 304.5 $[M + Na]^+$; Anal. calcd. (found) % for $C_{13}H_{20}O_8$ (*m.w.* 304.11): C, 51.31 (51.53); H, 6.62 (6.52).

Allyl-2,3-di-*O*-acetyl-β-D-galactopyranoside (28) [42]**:** Yield: 85%, colourless oil; IR (neat, cm^{-1}): 2928, 2853, 1744, 1371, 1222, 1045, 914, 761; ^{1}H NMR ($CDCl_3$, 500 MHz): δ 5.17 (dd, *J* = 8.0 Hz each, 1 H, H-2), 4.83 (dd, *J* = 10.5, 3.5 Hz, 1H, H-3), 4.64-4.60 (m, 3H), 4.39 (d, *J* = 7.5 Hz, 1H, H-1), 4.08 (d, *J* = 3.0 Hz, 1H, H-4), 3.85-3.76 (m, 3H, H-6_{ab}), 3.53-3.51 (m, 1 H, H-5), 3.38-3.34 (m, H, CH_2), 2.02, 1.97 (2 s, 6H, 2×$COCH_3$), 1.55-1.45 (m, 2H, CH_2); ^{13}C NMR ($CDCl_3$, 125 MHz): δ 170.3, 169.6 (2×$COCH_3$), 101.3 (C-1), 74.0 (C-5), 73.5 (OCH_2), 71.6 (C-3), 69.5 (C-2), 68.0 (C-4), 62.0 (C-6), 22.7 (CH_2), 20.8, 20.7 (2×$COCH_3$), 10.3 (CH_3); ESI-MS: 305.1 $[M + Na]^+$; Anal. calcd. (found) % for $C_{13}H_{20}O_8$ (*m.w.* 304.11): C, 51.31 (51.79); H, 6.62 (6.46).

Methyl-3-*O*-acetyl-2-deoxy-2-*N*-phthalimido-β-D-glucopyranoside (30): Yield: 86%, Syrup, IR (neat, cm^{-1}): 3062, 2988, 2876, 1772, 1692, 1451, 1319, 1275, 1181, 1012, 988, 793, 702. ^{1}H NMR (300 MHz, $CDCl_3$): δ 7.87-7.73 (m, 4 H); 5.65 (d, *J* = 8.4 Hz, 1H, H-1); 5.31 (d, *J* = 8.2 Hz, 1H, H-3); 4.23 (t, *J* = 10.2 Hz, 1H, H-2); 4.02 (d, *J* = 8.4 Hz, 2H, H-4); 3.99 (dd, *J* = 4.2, 8.6 Hz, 1H, H-6a); 3.85 (t, 1H, H-5); 3.65 (m, 1H, H-6b); 3.49 (s, 3H); 1.98 (s, 3H); ^{13}C NMR (300 MHz, $CDCl_3$): δ 134.2 (Ar-C), 123.6 (Ar-C), 99.0 (C-1), 75.4 (C-2), 73.9 (C-3), 70.4 (C-5), 62.3 (C-4), 57.1 (C-6) 54.4 (OCH_3), 20.7 ($COCH_3$); ESI-MS: *m/z* = 365.12 $[M+Na]^+$; Anal. calcd. (found) % for $C_{17}H_{19}NO_8$ (*m.w.* 365): C, 55.89 (55.34); H, 5.24 (5.21).

4-Methoxyphenyl 3-*O*-acetyl-2-deoxy-2-*N*-phthalimido-β-D-glucopyranoside (32): Yield: 83%, colourless gum, IR (neat, cm^{-1}): 3132, 3022, 2936, 2881, 1742, 1692, 1451, 1322, 1215, 1134, 1022, 997, 889, 783, 704; ^{1}H NMR (300 MHz, $CDCl_3$): δ 7.87-7.73 (m, 4H), 6.84 (d, *J* = 8.7 Hz, 2H), 6.73 (d, *J* = 9.0 Hz, 2H), 5.94 (dd, *J* = 8.4 Hz each, 1 H, H-1), 5.71 (d, *J* = 8.2 Hz, 1H, H-2), 4.47 (d, 1H, H-3), 4.12 (t, *J* = 10.2 Hz, 1H, H-4), 4.0 (d, *J* = 8.2Hz, 1H, H-5) 3.91 (m, 2H, H-6), 3.73 (s, 3 H, PhC*H*), 1.97 (s, 3 H, $COCH_3$); ^{13}C NMR (100 MHz, $CDCl_3$): δ 171.1 ($COCH_3$), 134.2, 123.6, 118.4, 114.4 (Ar-C), 96.1 (C-1) 77.2 (C-5), 76.9 (C-3), 70.2 (C-4), 62.2 (C-6), 55.5 (C-2), 54.5 ($PhCH_3$), 20.6 ($COCH_3$); ESI-MS: *m/z* = 442.11 $[M+Na]^+$; Anal. calcd. (found) % for $C_{23}H_{23}NO_8$ (441): C, 62.58 (62.34); H, 5.25 (5.19).

4-Methoxyphenyl-2,3-di-*O*-acetyl-β-D-glucopyranoside (34) [42]**:** Yield: 86%, colourless oil; IR (neat, cm^{-1}): 2988, 2942, 1748, 1433, 1377, 1226, 1085, 1056, 918, 756; ^{1}H NMR ($CDCl_3$, 500 MHz): δ 6.84 (d, *J* = 9.0 Hz, 2 H, Ar-H), 6.70 (d, *J* = 9.0 Hz, 2 H, Ar-H), 5.40 (dd, *J* = 8.0 Hz each, 1 H, H-2), 4.90 (dd, *J* = 10.5, 3.5 Hz, 1 H, H-3), 4.85 (d, *J* = 8.0 Hz, 1 H, H-1), 4.11 (br s, 1 H, H-4), 3.84-3.80 (m, 2 H, H-6_{ab}), 3.67 (s, 3 H, OCH_3), 3.62- 3.60 (m, 1 H, H-5), 3.44, 2.92 (2 br s, 1 H each, 2 O*H*), 2.03, 1.99 (2s, 6 H, 2 $COCH_3$); 13C NMR ($CDCl_3$, 125 MHz): δ 170.3, 169.6 (2 $COCH_3$), 155.5-114.6 (Ar-C), 100.7 (C-1), 74.4 (C-5), 73.4 (C-3), 69.3 (C-4), 67.8 (C-2), 62.0 (C-6), 55.5 (O*C*H3), 20.8, 20.7 (2 $COCH_3$); ESI-MS: 393.1 $[M + Na]^+$; Anal. calcd. (found) % for $C_{17}H_{22}O_9$ (*m.w.* 370.12): C, 55.13 (54.97); H, 5.99 (6.25).

Methylphenyl 2-*O*-benzyl-3-*O*-napthelene-1-thio-b-D-galactopyranoside (36): Yield: 80%, light yellow solid; m.p.: 162-163 ºC; IR (neat, cm^{-1}): 3500-3200 (br), 2977, 2895, 1747, 1601, 1370, 1222, 1032, 985, 884, 729. ^{1}H NMR (700 MHz, $CDCl_3$): δ 7.83-7.11 (m, 17H, Ar-H), 4.89 (overlapped signal, 1H, Napthelene H); 4.88 (overlapped signal, 1H, H-1); 4.85 (d, *J* = 11.9Hz ,1H, Bn-H); 4.09 (s, 1H, H-5); 3.97(dd, *J* = 6.3 and 7Hz, 1H, H-4); 3.81-3.75 (overlapped signals, 2H, H-6_{ab}); 3.62 (d, *J* = 2.8Hz, 1H, H-2); 3.45(t, *J* = 5.6Hz, 1H, H-3); 2.35 (3H, s, two S-CH_3). ^{13}C NMR (700 MHz, $CDCl_3$): δ 132.5-125.7 (Ar-C); 96.1 (C-1); 87.9, 82.3 and 77.1 (C-2, C-3 and C-4), 76.8 (Nap-C), 75.7 (Bn-C), 72.2 (C-5); 62.6 (C-6); 21.1 (S-CH_3). ESI-MS: *m/z* = 516.13 $[M+Na]^+$; Anal. calcd. (found) % for $C_{31}H_{32}O_4S$ (*m.w.* 516): C, 72.07 (72.66); H, 6.24 (6.32).

Propagyl 2,3 di-*O*-benzyl-α-D-glucopyranoside (38): Yield: 84%, syrup, IR (neat, cm^{-1}): 3500-3300 (br), 3093, 2991, 2829, 2288, 1480, 1354, 1187, 1068, 975, 712. ^{1}H NMR (700 MHz, $CDCl_3$): δ 7.27-7.17 (m, 10H, Ar-H), 5.0 (s, 1H, H-1); 4.8 (d, *J* = 11.2Hz, 2H, Bn-H); 4.5 (dd, *J* = 5.6 and 9.1 Hz, 2H, Bn-H); 4.17 (s, 2H, CH_2-C≡CH); 3.71, 3.65, 3.51, 3.48, 3.39, (overlapped signals, 6H, H-3, H-5, H-2, H-4, H-6_{ab}); 2.37 (1H, s, CH_2-C≡C*H*). ^{13}C NMR (700 MHz, $CDCl_3$): 138.8-127.7 (Ar-C); 101.1 (C-1); 83.9, 81.2 (C-2, C-3), 81.5, 79.2 (CH_2-*C*≡*C*H), 77.3, 76.9 (Bn-CH_2), 74.6, 71.7 (C-5, C-4), 54.4 (CH_2-C≡CH). ESI-MS: *m/z* = 400.18 $[M+Na]^+$; Anal. calcd. (found) % for $C_{23}H_{26}O_6$ (*m.w.* 398): C, 69.33 (70.66); H, 6.58 (7.11).

Allyl 2,3 di-*O*-benzyl-α-D-glucopyranoside (40): Yield: 84%, syrup, IR (neat, cm^{-1}): 3500 (br), 3125, 3047, 2987, 2829, 1617, 1478, 1354, 1190, 1088, 989, 752, 669. ^{1}H NMR (700 MHz, $CDCl_3$): δ 7.47-7.40 (m, 10 H), 6.06 (m, 1H, CH_2-C*H*=CH_2), 5.46(d, *J* = 16.8Hz, 1H, CH_2-CH=CH_2), 5.36 (d, *J* = 11.2Hz, 1H, CH_2-CH=CH_2), 5.12 (d, *J* = 12.2Hz, 1H, H-1), 4.93 (d, *J* = 3.5Hz, 1H, PhCH_2), 4.77 (d, *J* = 11.9Hz, 1H, PhCH_2), 4.52 (d, *J* = 4.9Hz, 1H, CH_2-CH=CH_2), 4.32 (m, 2H, H-5, CH_2-CH=CH_2), 4.13(d, *J* = 6.3Hz, 1H, H-2), 3.94 (m, 1H, H-4), 3.65 (d, *J* = 3.5Hz, 1H, H-3), 3.5 (m, 2H, H-6_{ab}); ^{13}C NMR (700 MHz, $CDCl_3$): 138.6, 138.4 (Ar-C), 133.6 (CH_2-*C*H=CH_2), 128.5-127.7(Ar-C), 118.3 (CH_2-CH=*C*H_2), 102.7(C-1),83.6(C-2), 81.1(C-3), 79.5(C-5), 77.1 (Ph*C*H_2), 75.5(C-4), 68.3 (*C*H_2-CH=*C*H_2), 63.2 (C-6). ESI-MS: *m/z* = 400.12 $[M+Na]^+$; Anal. calcd. for $C_{23}H_{28}O_6$ (*m.w.* 400): C, 68.98 (68.66); H, 7.05 (7.08).

4-Methoxyphenyl-2,3-di-*O*-benzyl-β-D-glucopyranoside (42): Yield: 86%, white solid; m.p.: 127-128 ºC; IR (neat, cm^{-1}): 3500-3200 (br), 3030, 2902, 2865,1504, 1448, 1358, 1207, 1066, 821, 741, 689. ^{1}H NMR (700 MHz, $CDCl_3$): δ 7.41-7.28 (m, 10 H), 7.03-6.85 (2d, *J* = 2.1Hz, 4H), 5.02 (d, *J* = 1.4Hz, 1 H), 4.97 (d, *J* = 11.9Hz, 1 H, H-1), 4.90 (d, *J* = 11.2Hz, 1H), 4.41 (t, *J* = 4.2Hz, 1H, H-2), 3.86-3.51 (overlapped signal, 5H, H-3, H-5, H-4, H-6_{ab}); ^{13}C NMR (700 MHz, $CDCl_3$): δ 155.3-114.6 (Ar-C), 101.2 (C-1), 81.8, 77.1, 75.5, 68.7, 66.1(C-2 to C-6), 24.5(O*C*H$_3$); ESI-MS: 579.2 $[M+Na]^+$; Anal. calcd. (found) % for $C_{34}H_{36}O_7$ (*m.w.* 556.24): C, 73.36 (73.20); H, 6.52 (6.70).

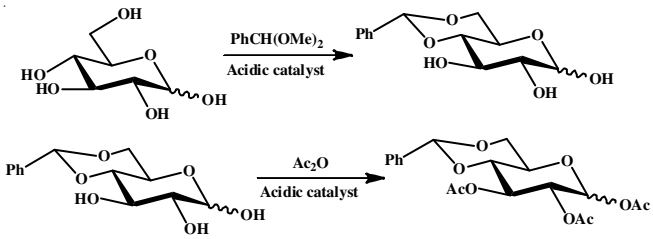
4-Methoxyphenyl-2,3-di-*O*-benzoyl-β-D-glucopyranoside (44): Yield: 88%, white solid, m.p.: 162-163 ºC; IR (neat, cm^{-1}): 3500-3000 (br), 2927, 1725, 1455, 1373, 1277, 1180, 1073, 1035, 1029, 974, 749, 704, 680. ^{1}H NMR (300 MHz, $CDCl_3$): δ 7.98-7.26 (m, 15 H), 5.74 (t, *J* = 4.2 Hz, 1H, H-1), 5.24 (d, *J* = 8.2 Hz, 1 H, H-2), 5.12 (d, *J* = 9.6 Hz, 1 H, H-3), 3.97-3.85 (m, 3H, H-5,H-6_{ab}), 3.43 (s, 3H); ^{13}C NMR (125 MHz, $CDCl_3$): δ 167.6, 166.0 (Ph*C*O), 133.3-114.5 (Ar-C), 97.1 (C-1), 77.2 (C-2), 78.7, 75.4, 73.7, 73.5, 72.5, 69.2, 66.8, 55.4, 20.6 (*C*H$_3$); ESI-MS: 478.11 $[M+Na]^+$; Anal. calcd. (found) % for $C_{27}H_{26}O_8$ (*m.w.* 478): C, 67.77 (67.79); H, 5.48 (5.70).

Methyl 2,3-di-*O*-benzyl-a-D-glucopyranoside (46): Yield: 85%, syrup, IR (neat, cm^{-1}): 2924, 1719, 1454, 1363, 1198, 1054, 743, 700; ^{1}H NMR ($CDCl_3$, 300 MHz): δ 7.30-7.25 (m, 10 H, Ar-H), 4.95 (d, *J* = 11.5 Hz, 1 H), 4.75 (d, *J* = 11.5 Hz, 1 H), 4.69 (d, *J* = 11.5 Hz, 1 H), 4.58 (d, *J* = 11.5 Hz, 1 H), 4.54 (d, *J* = 3.5 Hz, 1 H, H-1), 3.77-3.60 (m, 3 H), 3.56-3.51 (m, 1 H), 3.47-3.38 (m, 2 H), 3.34 (s, 3 H, OC<u>H</u>$_3$); ^{13}C NMR ($CDCl_3$, 75 MHz): δ 139.3, 138.6, 128.7-127.9 (Ar-C), 98.5 (C-1), 81.8, 80.2, 76.3, 73.3, 71.6, 70.3, 62.0, 55.5; ESI-MS: *m/z* = 397 $[M+Na]^+$; Anal. calcd. (found) % for $C_{21}H_{26}O_6$ (*m.w.* 374): C, 67.36 (67.10); H, 7.00 (7.28).

RESULTS AND DISCUSSION

A conventional chemical approach for the synthesis of acetal ketal compound involves two steps reaction, which is schematically illustrated in **Scheme-III**. In the straightforward synthesis of these sugar derivatives (**Scheme-II**) was envisioned, where the unprotected sugars can be protected by one pot acetylation and acetelation process to yield various derivatives of carbohydrates.

To optimize the reaction condition, first, the influence of solvent was examined as well as solvent-free conditions on the reaction, time and yield of the product. The reaction between methyl-α-D-glucopyranoside (1 mmol) and benzaldehyde dimethyl acetal (1.3 mmol) in presence of P_2O_5-Al_2O_3 allowed



Scheme-III: Preparation of acylated benzylidene acetal (conventional method)

to stir for a respective time at room temperature using different solvents as well as solvent-free conditions (**Scheme-II**). Following the addition of Ac_2O (5 mmol), the reaction mixture was stirred for a while. The requirement of 5 mol equiv. of acetic anhydride is obligatory, since 1 mol of benzaldehyde dimethyl acetal release 2 mol of methanol on the synthesis of benzylidene acetal sugar, so the methanol formed reacts with 2 mol of acetic anhydride to produce methyl acetate as byproduct. Table-1 showed that the solvent-free condition was more appropriate for this reaction, resulting in higher yields and less time compatible with solvents.

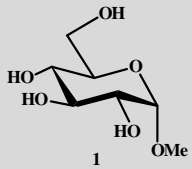
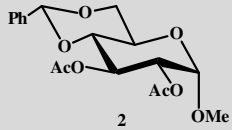
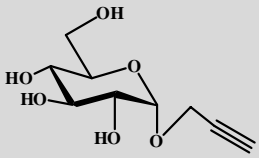
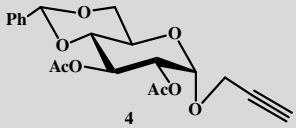
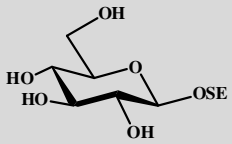
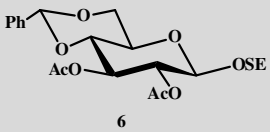
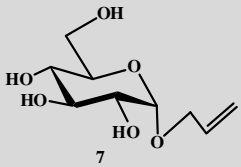
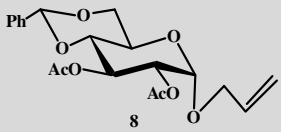
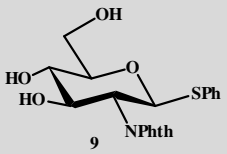
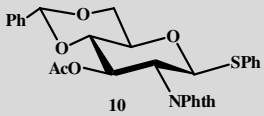
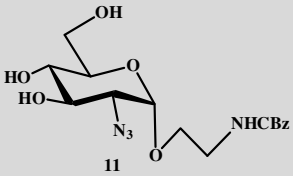
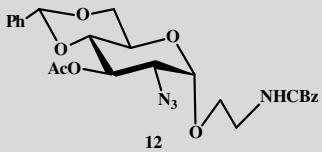
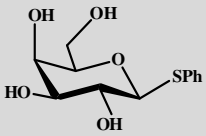
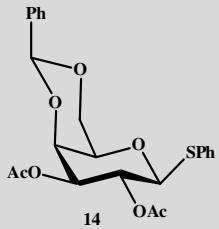
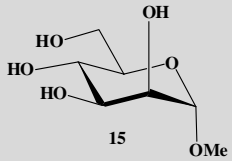
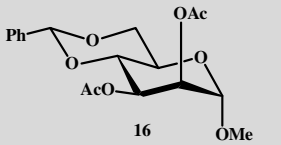
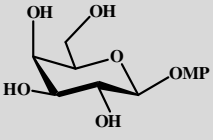
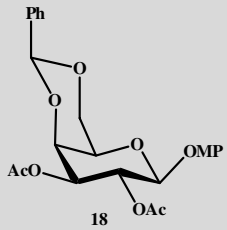
The catalyst was filtered and the crude product was purified over a silica bed and the formation of pure product was confirmed by NMR. The presence of a singlet for one proton in the region of δ 6-5.5 ppm for benzylidene proton (PhC*H*) and two singlets for six protons in the region of δ 2-2.18 ppm for CO*CH*$_3$ in proton NMR confirmed the structure of the product. The ^{13}C NMR spectra displayed signals of carbon atoms in the molecule, like at 170-160 ppm (carbon atom in *C*OCH$_3$), 100.1-101.8 ppm (aromatic carbon atom) and about 20 ppm (methylene carbon atom) for the protection of benzylidene and an acetyl group. In a similar fashion, a series of acylated benzylidene acetal sugar derivatives were synthesized using a P_2O_5-Al_2O_3 catalyst with solvent-free conditions in excellent yield (Table-2). This reaction methodology can be applied to large-scale chemical synthesis also. An acetyl-protected benzylidene derivative using methyl-α-D-glucopyranoside in 10 g scale as a starting material have been synthesized.

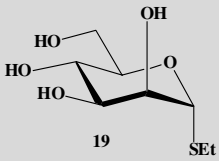
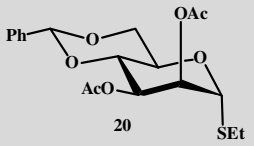
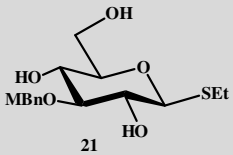
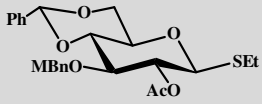
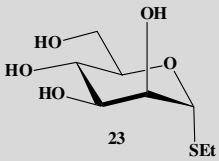
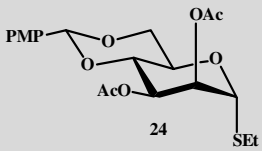
For ring opening of 4,6-O-benzylidene-protected carbohydrates, initially methyl 2,3-di-O-acetyl-4,6-O-benzylidene-α-D-glucopyranoside (**2**) was allowed to stir with this reagent and 2 drops of water at room temperature, the quantity of reagents being varied. When the compound was treated with 2 equiv. of P_2O_5-Al_2O_3, methyl 2,3-di-O-acetyl-α-D-glucopyranoside was efficiently obtained at room temperature in 12 min. A reduction in reagent quantities resulted in the incomplete transformation even after 3 h. The results of compound formation were not similar when other organic solvents, like DCM and

TABLE-1
OPTIMIZATION OF A REACTION PROTOCOL

Substrate	Product	Solvent							
		Acetonitrile		DCM		THF		Neat	
		Time	Yield	Time	Yield	Time	Yield	Time	Yield
1	2	2.5 h	68%	6 h	62%	4 h	70%	7 min	82%

TABLE-2
SYNTHESIS OF ACETYLATED BENZYLIDENE ACETAL SUGAR DERIVATIVES CATALYZED BY P_2O_5-Al_2O_3 AT ROOM TEMPERATURE[a]

Entry	Sugars	Products	Time (min)	Ref.
1	 1	 2	7	–
2	 3	 4	8	–
3	 5	 6	8	[40]
4	 7	 8	7	–
5	 9	 10	10	[40]
6	 11	 12	8	–
7	 13	 14	8	[40]
8	 15	 16	10	[40]
9	 17	 18	8	–

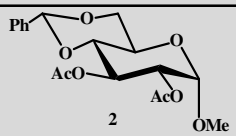
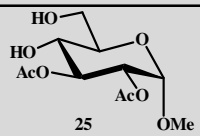
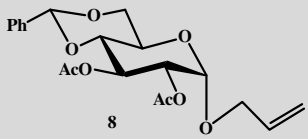
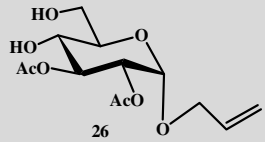
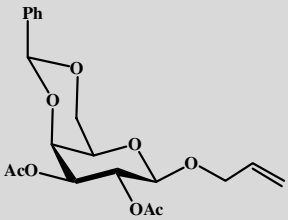
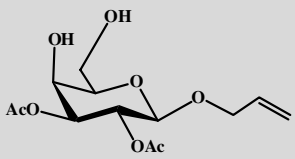
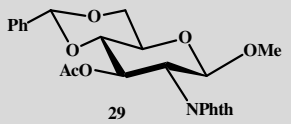
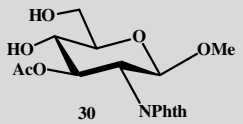
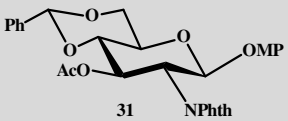
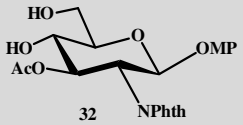
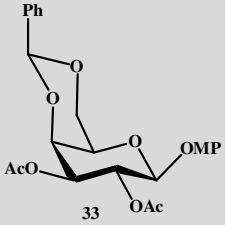
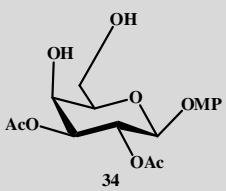
10	 19	 20	7	–
11	 21	 22	10	–
12	 23	 24	8	–

[a]Reaction condition: substrate (1 mmol), benzaldehyde dimethyl acetal (1.3 mmol), acetic anhydride (5 mmol), P_2O_5-Al_2O_3(0.1 mmol), rt. m.p.: 4-methoxyphenyl, SE: trimethylsilylethyl.

THF were used. Based on these conditions, 4,6-O-benzylidene acetal derivatives of D-glucose and D-galactose were converted into their respective dihydroxy derivatives (Table-3).

Conventionally, deprotection of benzylidene acetal was carried out by heating with 80% aqueous solution of acetic acid. This method usually takes a long time and heat is required.

TABLE-3
A REMOVAL OF BENZYLIDENE ACETAL OF SUGAR DERIVATIVES USING P_2O_5-Al_2O_3 CATALYST

Entry	Substrates	Diol products	Time (min)	Yield (%)	Ref.
1	 2	 25	12	85	–
2	 8	 26	10	82	[41]
3	 27	 28	10	85	[42]
4	 29	 30	15	86	–
5	 31	 32	12	83	–
6	 33	 34	15	86	[42]

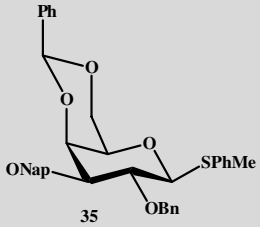
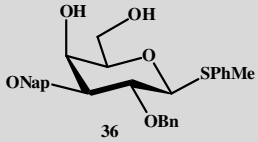
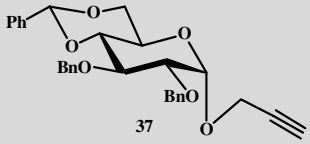
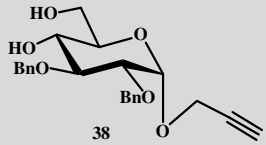
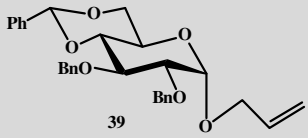
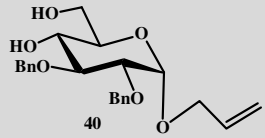
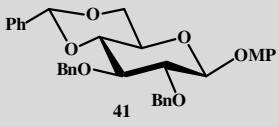
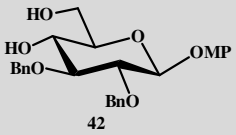
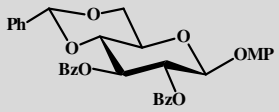
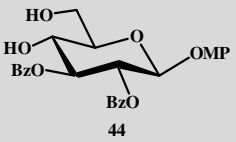
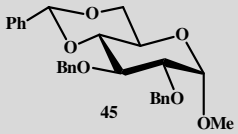
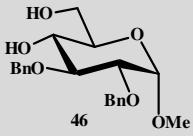
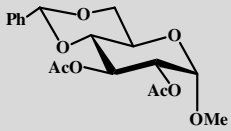
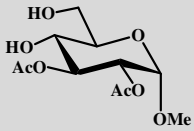
7	 35	 36	10	80	–
8	 37	 38	10	84	–
9	 39	 40	12	84	–
10	 41	 42	12	86	–
11	 43	 44	15	88	–
12	 45	 46	12	85	–

TABLE-4
COMPARISON OF THE STANDARD METHOD FOR THE SYNTHESIS OF DI-HYDROXY SUGAR DERIVATIVES

Substrate	Product	Reaction condition	Time	Yield (%)
		a) 80% Acetic acid, 80 °C	2 h	88
		b) P_2O_5-Al_2O_3, H_2O, rt	12 min	85

A comparison study is carried out between the conventional method and the reported method (Table-4). The study shows that P_2O_5-Al_2O_3 catalyzed removal of the benzylidene group is less time-consuming and more eco-friendly.

Conclusion

The present methodology offers an efficient, eco-friendly method for the synthesis of acylated benzylidene acetal of sugar derivatives using benzaldehyde dimethyl acetal and acetic anhydride in catalytic amounts of P_2O_5-Al_2O_3 through the one-pot solvent-free condition. Another removal of benzylidene acetal of sugar derivatives using the same P_2O_5-Al_2O_3 catalyst has been performed successfully. Easy to handle, requires minimum work-up and uses fewer toxic reagents are the advantage of this method. This protocol can be used for a wide range of carbohydrate derivatives in presence of several acids and base-sensitive protecting groups.

ACKNOWLEDGEMENTS

The authors acknowledge to the Department of Chemistry, Assam University and SERB, New Delhi for the financial support.

CONFLICT OF INTEREST

The authors declare that there is no conflict of interests regarding the publication of this article.

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