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Synthesis and Comparative Antibacterial Studies of some Benzylidene Monosaccharide Benzoates

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Abstract: Methyl α-D-glucopyranoside on reaction with benzaldehyde followed by direct dimolar benzoylation afforded 4,6-*O*-benzylidene-protected 2,3-di-*O*-benzoate **3** in good yield. Regioselective monobenzoylation of methyl α-D-mannopyranoside employing dibutyltin oxide method furnished 3-*O*-benzoate **5**. Compound **5**, on treatment with excess benzaldehyde followed by direct benzoylation, provided 2,3-di-*O*-benzoate **7** in high yield. *In vitro* antibacterial activity studies of the synthesized compounds along with the precursor materials (**1-7**) were evaluated against ten bacterial pathogens. The structure activity relationship study revealed that the benzoyl mannopyranosides (**5-7**) exhibited more antibacterial inhibitory property as compared to that of glucopyranosides (**2-3**).

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Keywords: Monosaccharide, benzoylation, antibacterial activity, structure activity relationship (SAR).

Introduction

Monosaccharides are wide spread in nature, being a component of some plant glycosides and bacterial polysaccharides of immunological importance [1-2]. Monosaccharide derivatives, especially acylated monosaccharides (esters), have synthetic utility as versatile intermediates in the syntheses of many natural products and their analogues which have great medicinal importance [3-4]. Various methods for acylation of monosaccharides have so far been developed and employed successfully such as direct acylation [5-6], protection-deprotection technique [7], organotin (bistributyltin oxide or dibutyltin oxide) mediated regioselective acylation [8-10] *etc*. Yet, regioselective acylation (esterification) is a prominent challenge as monosaccharides contain several hydroxyl groups of similar reactivity. In this context, enzyme catalyzed acylation [11] and microwave assisted acylation [12] were also investigated in the past decade. In the present synthetic strategy, we employed direct acylation technique for both methyl α-D-glucopyranoside (**1**) and methyl α-D-mannopyranoside (**4**). We have also used dibutyltin oxide method for the regioselective 3-*O*-benzoylation of mannopyranoside **4**.

The emergence of multiple antibiotic resistant pathogenic bacteria represents a growing threat to human health worldwide. Thus, search for new antibacterial agents with novel mode of action represents a major target in chemotherapy [13]. Acylated sugars (esters) have been widely used as cosmetic and pharmaceutical industries for many years because they are considered biocompatible, biodegradable, and nontoxic [14-15].

In ^{1}H NMR analysis of **1** in DMSO-d_6, aromatic protons appear at 8.58, 8.28, 8.02, 7.59, 7.11, 7.05 ppm as a doublet, singlet, multiple, triplet, doublet and doublet, respectively. The OH proton appear at 10.28 ppm as singlet. The ^{1}H NMR spectra of the compounds **2** and **3** are somewhat broader than corresponding signals in the compound **1** due to aggregation of the phthalocyanine isomers which is frequently encountered at the concentrations used for NMR spectroscopy. The inner NH protons of **2** were also identified in the ^{1}H NMR spectra with a broad chemical shift at -4.03 ppm.

In ^{13}C NMR analysis of **1** in DMSO-d_6, aromatic carbons appear at 158.53, 146.53, 135.11, 130.37, 129.48, 129.01, 128.38, 128.33, 127.87, 126.51, 126.11, 123.50, 123.16, 120.22, and 116.35 ppm, C-OH group appeared at 153.49 ppm, nitrile carbons appeared at 115.72 and 114.87 ppm, respectively.

In the EI^{+} mass spectrum of **1**, the presence of the characteristic molecular ion peak at m/z 298.0 $[M]^{+}$ confirmed the proposed structure. In the case of **2**, the molecular ion peak was found at m/z 1233.5 $[M+K]^{+}$ according to MALDI-TOF spectrum (Fig. 1). Also, the molecular ion peak for compound **3** found at m/z = 1260.7 $[M+2]^{+}$. The elemental analyses were satisfactory.

Materials and Methods

Chemicals and Apparatus

FT-IR spectra were recorded on an FT-IR spectrometer (Shimadzu, IR Prestige-21) using $CHCl_3$ mulls. Thin layer chromatography (TLC) was performed on Kieselgel GF_{254} and visualization was accomplished by spraying the plates with 1% H_2SO_4 followed by heating the plates at 150-200 ^{0}C until coloration took place. ^{1}H (400 MHz) and ^{13}C (100 MHz) NMR spectra were recorded using $CDCl_3$ as a solvent. Chemical shifts were reported in δ unit (ppm) with reference to TMS as an internal standard and *J* values are given in Hz. Melting points (mp) were determined on an Electrothermal melting point apparatus and are uncorrected. Evaporations were performed under diminished pressure on a Büchi rotary evaporator. All reagents used were commercially available (Aldrich) and were used as received unless otherwise specified.

Synthesis

Methyl 4,6-*O*-benzylidene-α-D-glucopyranoside (2): Benzaldehyde (3.0 g, 28.27 mmol) was added to methyl α-D-glucopyranoside (1) (0.4 g, 2.06 mmol) followed by addition of anhydrous zinc chloride (1.0 g, 7.337 mmol) at room temperature. The reaction mixture was stirred for 12 h and filtered through Celite® 545. Ice was added to the filtrate with constant shaking and the mixture was extracted several times with *n*-hexane to remove unreacted benzaldehyde. The aqueous layer was then extracted with ethyl acetate (3×5 mL) with occasional warming. The organic layer was dried ($MgSO_4$), and concentrated under reduced pressure to yield a residue which, upon chromatographic purification with *n*-hexane/ethyl acetate (1/2, v:v), yielded the title compound **2** (0.401 g, 69%) as a white crystalline solid, mp 162-163 °C (lit. [22], mp 163-164 °C).

R_f = 0.48 (*n*-hexane/ethyl acetate = 1/2, v/v). FT-IR ($CHCl_3$, v, cm^{-1}): 3310-3400 (OH). ^{1}H NMR (400 MHz, $CDCl_3$, δ, ppm): 7.53-7.47 (2H, m, Ar-H), 7.42-7.35 (3H, m, Ar-H), 5.54 (1H, s, PhCH-), 4.80 (1H, d, *J*= 4.0 Hz, H-1), 4.30 (1H, dd, *J*= 9.7 and 4.4 Hz, H-6a), 3.94 (1H, dd, *J*= 9.3 and 9.2 Hz, H-3), 3.82 (1H, ddd, *J*= 10.3, 9.2 and 4.4 Hz, H-5), 3.75 (1H, dd, *J*= 10.3 and 9.7 Hz, H-6b), 3.64 (1H, dd, *J*= 9.2 and 4.0 Hz, H-2), 3.50 (1H, dd, *J*= 9.3 and 9.2 Hz, H-4), 3.47 (3H, s, OCH_3). ^{13}C NMR (100 MHz, $CDCl_3$): δ 137.1 (Ar-C), 129.3, 128.3, 126.3 (Ar-CH), 102.0 (PhCH-), 99.7 (C-1), 80.8 (C-4), 72.9 (C-2), 71.9 (C-3), 68.9 (C-6), 62.4 (C-5), 55.6 (OCH_3).

Methyl 4,6-*O*-benzylidene-2,3-di-*O*-benzoyl-α-D-glucopyranoside (3): A solution of compound **2** (0.3 g, 1.281 mmol) in dry pyridine (1 mL) was cooled to 0 ^{0}C whereupon benzoyl chloride (0.396 g, 2.817 mmol) and DMAP (cat.) were added to it. The mixture was stirred overnight at room temperature. Usual work-up and silica gel column chromatography furnished the di-*O*-benzoyl derivative, 3 (0.521 g, 92%) as a crystalline solid. Recrystallization from ethyl acetate-*n*-hexane gave the analytically pure sample as colorless needles, mp 146-148 °C. R_f = 0.51 (n-hexane/ethyl acetate = 4/1, v/v). FT-IR ($CHCl_3$, v, cm^{-1}): 1735, 1719 (CO). ^{1}H NMR (400 MHz, $CDCl_3$, δ, ppm): 7.81-8.05 (5H, m, Ar-H), 7.31-7.48 (6H, m, Ar-H), 7.21-7.30 (4H, m, Ar-H), 6.02 (1H, t, *J*= 9.8 Hz, H-3), 5.52 (1H, s, PhCH-), 5.21 (1H, dd, *J*= 9.8 and 3.6 Hz, H-2), 5.13 (1H, d, *J*= 3.6 Hz, H-1), 4.28-4.32 (1H, m, H-5), 4.03 (1H, t, *J*= 9.7 Hz, H-4), 3.78-3.87 (2H, m, H-6a and H-6b), 3.37 (3H, s, OCH_3).

Methyl 3-*O*-benzoyl-α-D-mannopyranoside (5): To a solution of methyl α-D-mannopyranoside (**4**) (0.3 g, 1.545 mmol) in dry methanol (10 mL) was added dibutyltin oxide (Bu_2SnO) (0.423 g, 1.699 mmol) and the mixture was heated under reflux. After 2 h the reaction mixture became homogeneous and clear. The mixture was then refluxed for an additional hour and the solvent was evaporated off *in vacuo* to leave a white solid. The solid tin complex was suspended in dry 1,4-dioxane (3 mL) and benzoyl chloride (0.239 g, 1.70 mmol) was slowly added to this solution, with stirring, at room temperature. The solution became clear upon addition of benzoyl chloride and stirring was continued for 4 h. The solvent was evaporated off in vacuo to leave a syrupy mass, which was subjected to column chromatography (chloroform/methanol = 6/1, v/v) to give 3-*O*-benzoate **5** (0.313 g, 68%) as a thick syrup [11].
R_f = 0.48 (chloroform/methanol = 4/1, v/v). FT-IR ($CHCl_3$, v, cm^{-1}): 3260-3350 (br OH), 1746 (CO). ^{1}H NMR (400 MHz, $CDCl_3$, δ, ppm): 7.55-7.73 (5H, m, Ar-H), 6.07 (1H, dd, *J*= 10.0 and 3.1 Hz, H-3), 4.62 (1H, d, *J*= 1.5 Hz, H-1), 4.22 (1H, dd, *J*= 3.1 and 1.5 Hz, H-2), 4.13 (1H, dd, *J*= 12.1 and 5.2 Hz, H-6a), 3.91-3.97 (1H, m, H-5), 3.88 (1H, app t, *J*= 9.8 Hz, H-4), 3.75 (1H, dd, *J*= 12.1 and 2.0 Hz, H-6b), 3.16 (3H, s, OCH_3).

Methyl 3-*O*-benzoyl-4,6-*O*-benzylidene-α-D-mannopyranoside (6): A solution of the 2,4,6-triol **5** (0.4 g, 1.341 mmol) in dry benzaldehyde (3.0 g, 28.27 mmol) was treated with anhydrous zinc chloride (1.0 g, 7.337 mmol) at room temperature. The reaction mixture was stirred at this temperature overnight and filtered through celite. Usual work-up as described for compound **2** and chromatographic purification (*n*-hexane/ethyl acetate = 1/2, v/v) yielded the title compound **6** (0.389 g, 75%) as white needles, mp 135-136 °C. R_f = 0.45 (*n*-hexane/ethyl acetate = 3/1, v/v). FT-IR ($CHCl_3$, v, cm^{-1}): 3290-3500 (br OH), 1735 (CO). ^{1}H NMR (400 MHz, $CDCl_3$, δ, ppm): 8.05 (2H, d, *J*= 8.1 Hz, Ar-H), 8.05 (1H, t, *J*= 7.6 Hz, Ar-H), 7.39-7.46 (5H, m, Ar-H), 7.27-7.35 (2H, m, Ar-H), 5.59 (1H, s, PhCH-), 5.54 (1H, dd, *J*= 10.4 and 3.2 Hz, H-3), 4.78 (1H, d, *J*= 1.2 Hz, H-1), 4.32 (1H, dd, *J*= 3.2 and 1.2 Hz, H-2), 4.22-4.31 (2H, m, H-5 and H-6a), 3.95-4.03 (1H, m, H-6b), 3.92 (1H, t, *J*= 10.1 Hz, H-4), 3.43 (3H, s, OCH_3).

Methyl 4,6-*O*-benzylidene-2,3-di-*O*-benzoyl-α-D-mannopyranoside (7): The reaction of compound 6 (0.3 g, 0.776 mmol) and benzoyl chloride (0.396 g, 2.817 mmol) in anhydrous pyridine (1 mL) at 0 ^{0}C to room temperature for overnight followed by chromatography (*n*-hexane/ethyl acetate =10/1, v/v) gave the di-*O*-benzoyl derivative, **7** (0.343 g, 90%) as a white crystalline solid. Recrystallization from ethyl acetate/*n*-hexane (1/1, v/v) gave the analytically pure sample as needles, mp 121-122 °C.

R_f = 0.51 (*n*-hexane/ethyl acetate = 4/1, v/v). FT-IR ($CHCl_3$, v, cm^{-1}): 1687, 1682 (CO). ^1H NMR (400 MHz, $CDCl_3$, δ, ppm): 8.12-8.19 (5H, m, Ar-H), 7.57-7.69 (4H, m, Ar-H), 7.41-7.54 (6H, m, Ar-H), 5.81 (1H, dd, *J*= 10.0 and 3.1 Hz, H-3), 5.79 (1H, dd, *J*= 3.1 and 1.2 Hz, H-2), 5.69 (1H, s, PhCH-), 4.93 (1H, d, *J*= 1.2 Hz, H-1), 4.32-4.41 (2H, m, H-5 and H-6a), 4.11-4.19 (1H, m, H-6b), 4.00 (1H, t, *J*= 10.0 Hz, H-4), 3.50 (3H, s, OCH_3).

Antibacterial screening tests

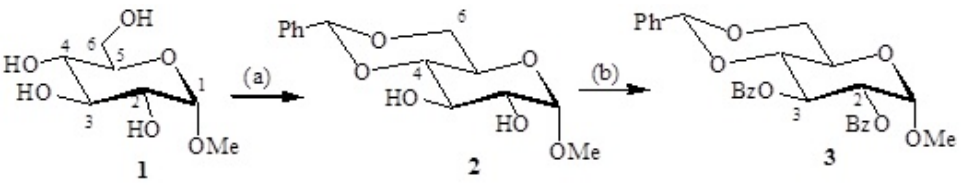
Four Gram-positive bacteria *viz. Bacillus cereus* BTCC 19, *Bacillus megaterium* BTCC 18, *Bacillus subtilis* BTCC 17 and *Staphylococcus aureus* ATCC 6538 and six Gram-negative bacteria *viz*. *Escherichia coli* ATCC 25922, INABAET (vibrio) AE 14748, *Pseudomonas aeruginosa* CRL (ICDDR,B), *Salmonella paratyphi* AE 14613, *Salmonella typhi* AE 14612, and *Shigella dysenteriae* AE 14369 were selected for antibacterial potentiality test. For the detection of antibacterial activities, the disc diffusion method described by Bauer *et al*. [23] was followed. Mueller-Hinton (agar and broth) medium was used for the culture of bacteria. Dimethylformamide (DMF) was initially used as a solvent to prepare the desired solution (1%) of the compounds. The plates were incubated at 37 °C for 48 h. Proper control was maintained with DMF. Each experiment was carried out in triplicate. All the results were compared with the standard antibacterial antibiotic ampicillin [50 µg/disc, Beximco Pharmaceuticals Ltd., Bangladesh].

Results and Discussion

Our main aim was to synthesize 2,3-di-*O*-benzoyl derivatives (**3** and **7**) of methyl α-D-glucopyranoside (**1**) and methyl α-D-mannopyranoside (**4**), respectively, to study and compare their antibacterial properties.

Synthesis of methyl 4,6-*O*-benzylidene-2,3-di-*O*-benzoyl-α-D-glucopyranoside (3)

Initially we prepared methyl 4,6-*O*-benzylidene-α-D-glucopyranoside (**2**) from methyl α-D-glucopyranoside (**1**). The reaction of methyl α-D-glucopyranoside (**1**) with benzaldehyde in the presence of anhydrous zinc chloride for 12 h followed by work-up and chromatography gave a white crystalline solid, mp 162-163 °C (Scheme 1). The FT-IR spectrum of this solid showed bands at 3310-3400 cm^{-1} corresponding to hydroxyl stretching. In its ^1H NMR spectrum, a two-proton multiplet at δ 7.53-7.47, a three-proton multiplet at δ 7.42-7.35 and a one-proton singlet at δ 5.54 clearly indicated the formation of benzylidene acetal in the molecule. This was also confirmed by its ^{13}C NMR spectrum where signals at δ 137.1 (Ar-C), 129.3, 128.3, 126.3 (Ar-CH) and 102.0 (PhCH-) were found for the benzylidene acetal. Complete analysis of its FT-IR, ^1H and ^{13}C NMR spectra led us to assign the structure as methyl 4,6-O-benzylidene-α-D-glucopyranoside (**2**).

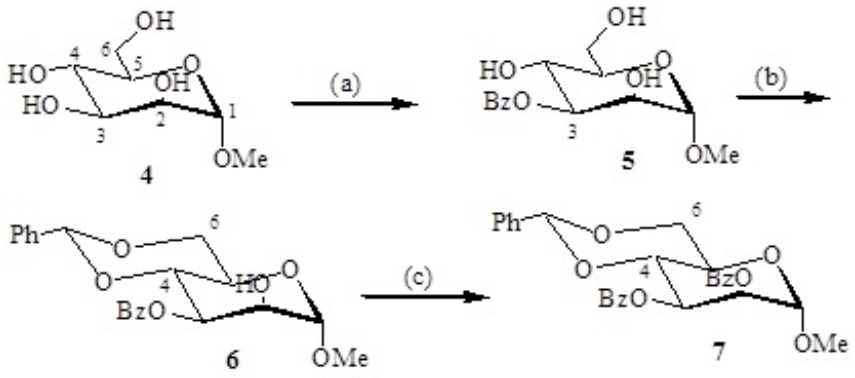


Scheme 1. Reagents and conditions: (a) PhCHO, dry $ZnCl_2$, 25 ^0C, 12 h, 69%. (b) BzCl, dry pyridine, 0 ^0C-RT, 12 h, 92%.

Having protected glucopyranoside **2** in hand, we carried out its dibenzoylation (Scheme 1). Thus, treatment of glucopyranoside **2** with dimolar benzoyl chloride (BzCl) in anhydrous pyridine for 12 h using a catalytic amount of DMAP gave a compound almost in quantitative yield (92%) as needles, mp 146-148 °C. In the FT-IR spectrum of this compound, bands at 1735 and 1719 cm^{-1} were observed for carbonyl frequency and hence indicated the attachment of benzyloxy groups in the molecule. The FT-IR spectrum showed no band for hydroxyl stretching. In the ^1H NMR spectrum, the following peaks were observed in the aromatic region: δ 7.81-8.05 (5H, m), 7.31-7.48 (6H, m) and 7.21-7.30 (4H, m) and a one-proton singlet at δ 5.52 for PhCH-. The more ten aromatic protons in addition to benzylidene acetal protons indicated the attachment of two benzoyloxy groups in the molecule. Also, H-2 (at δ 5.21 as dd) and H-3 (at δ 6.02 as t) protons shifted down field as compared to its precursor compound **2**. This confirmed the attachment of benzoyloxy groups at position C-2 and C-3. So, the structure was established as methyl 4,6-*O*-benzylidene-2,3-di-*O*-benzoyl-α-D-glucopyranoside (**3**).

Synthesis of methyl 4,6-*O*-benzylidene-2,3-di-*O*-benzoyl-α-D-mannopyranoside, 7

Our next attempt was to synthesize methyl 4,6-*O*-benzylidene-2,3-di-*O*-benzoyl-α-D-mannopyranoside, (**7**). For this reason we prepared methyl 3-*O*-benzoyl-α-D-mannopyranoside (**5**) from methyl α-D-mannopyranoside (**4**) by dibutyltin oxide method using literature procedure [8, 24] (Scheme 2).



Scheme 2. Reagents and conditions: (a) Bu_2SnO, dry MeOH, reflux, 3h, BzCl, dioxane, RT, 4h, 68%. (b) PhCHO, dry $ZnCl_2$, 25 ^0C, 12 h, 65%. (c) BzCl, 0 ^0C-RT, 12 h, 90%.

In the dibutyltin oxide method initially a stannylene ring (intermediate tin complex) is formed between *cis*-vicinal glycol at C-2 and C-3 position, where the equatorial C-3 OH group is activated without exception (Figure 1). Hence the unimolecular benzoylation occurs at C-3 position only. Thus, the structure of this compound was established as methyl 3-*O*-benzoyl-α-D-mannopyranoside (**5**) by analyzing its FT-IR and ^1H NMR spectra.

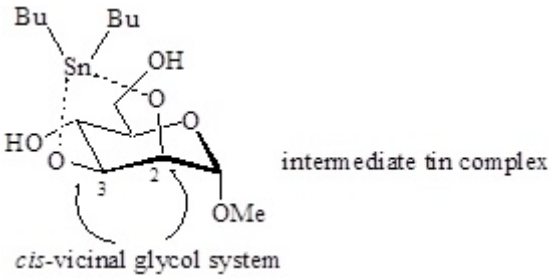


Figure 1. Formation of the intermediate stannylene ring.

The 3-*O*-benzoate **5** was then subjected for 4,6-*O*-benzylidene protection. Thus, the reaction of compound **5** with benzaldehyde in the presence of anhydrous zinc chloride for 12 h followed by work-up and chromatography gave as white needles, mp 135-136 °C. The FT-IR spectrum of this solid showed bands at 3290-3500 (br) and 1735 cm^{-1} corresponding to hydroxyl and carbonyl stretchings, respectively. In its ^1H NMR spectrum, a two-proton doublet at δ 8.05, a one-proton triplet at δ 8.05, a five-proton multiplet at δ 7.39-7.46, a two-proton multiplet at δ 7.27-7.35 and a one-proton singlet at δ 5.59 (PhCH-) clearly indicated the formation of benzylidene acetal and presence of a benzoyl group in the molecule. Complete analysis of its FT-IR and ^1H NMR spectra led us to assign the structure as methyl 3-*O*-benzoyl-4,6-*O*-benzylidene-α-D-mannopyranoside (**6**).

Having protected mannopyranoside **6** in hand, we carried out its 2-*O*-benzoylation. Thus, unimolar benzoylation of **6** with benzoyl chloride in pyridine and chromatography gave a crystalline solid. Recrystallization from ethyl acetate/*n*-hexane (1:1, v:v) gave the analytically pure sample as needles, mp 121-122 °C (Scheme 2). The FT-IR spectrum showed no band for hydroxyl stretching. In the FT-IR spectrum of this compound, bands at 1687 and 1682 cm^{-1} were observed for carbonyl frequency. In the ^1H NMR spectrum of this compound the following peaks were observed in the aromatic region: δ 8.12-8.19 (5H, m), 7.57-7.69 (4H, m), 7.41-7.54 (6H, m) and a one-proton singlet at δ 5.69 (PhCH-). The additional five aromatic protons than that of 3-*O*-benzoate **6** indicated the attachment of one more benzoyloxy groups in the molecule. Also, H-2 (at δ 5.79 as dd) protons shifted down field as compared to its precursor compound **6**. Thus, the structure of the compound was assigned as methyl 4,6-O-benzylidene-2,3-di-O-benzoyl-α-D-mannopyranoside (**7**).

Antibacterial activities of the synthesized compounds

The results of the *in vitro* inhibition zone against the selected Gram-positive bacteria due to the effect of the chemicals (**1-7**) are mentioned in Table 1. It was observed from Table 1 that the tested chemicals were less effective against these Gram-positive organisms. Only methyl 4,6-*O*-benzylidene-2,3-di-*O*-benzoyl-α-D-mannopyranoside (**7**) exhibited considerable inhibition (*20 mm) against *Bacillus cereus* which was comparable to that of the standard antibiotic, ampicillin (*22 mm).

Table 1. Inhibition against Gram-positive organisms by the tested chemicals (**1-7**).

Compound no.	Diameter of zone of inhibition, in mm (50 µg, dw / disc)			
	Bacillus cereus	*Bacillus megaterium*	*Bacillus subtilis*	*Staphylococcus aureus*
1	N/A	N/A	N/A	N/A
2	08	N/A	N/A	N/A
3	08	N/A	N/A	N/A
4	N/A	N/A	N/A	N/A
5	08	N/A	11	N/A
6	N/A	N/A	N/A	N/A
7	*20	N/A	N/A	N/A
****Ampicillin**	*22	19	*25	*21

NB. "N/A" indicates no inhibition, dw = dry weight, "**" indicates standard antibiotic, "*" shows good inhibition.

Inhibition zone against the selected Gram-negative bacteria due to the effect of the monosaccharides (**1-7**) are mentioned in Table 2. The test chemicals showed better activity against these organisms as compared to that of Gram-positive organisms. The compounds (**1-7**) did not show considerable inhibition against *E. coli* and INABAET (vibrio). The study revealed that the tested chemicals were more effective against *Salmonella paratyphi* and *Salmonella typhi*.

Table 2. Inhibition of the tested chemicals **(1-7)** against Gram-negative organisms.

	Diameter of zone of inhibition in mm (50 µg dw / disc)					
Compound no	*E. coli*	INABAET (vibrio)	*Pseudomonas aeruginosa*	Salmonella paratyphi	*Salmonella typhi*	*Shigella dysenteriae*
1	N/A	N/A	N/A	08	N/A	N/A
2	N/A	07	N/A	06	07	N/A
3	06	12	08	09	14	N/A
4	N/A	N/A	N/A	*21	*20	N/A
5	08	N/A	14	*20	*20	N/A
6	N/A	09	12	*21	*22	N/A
7	15	N/A	14	17	18	13
****Ampicillin**	*25	*24	17	*35	13	*35

NB. N/A indicates no zone of inhibition. dw= dry weight. ** indicates standard antibiotic, * shows good inhibition.

Structure activity relationship (SAR)

In vitro antibacterial study revealed that the monosaccharide derivatives (**1-7**) were more active against some Gram-negative organisms than that of Gram-positive organisms. An important observation was that the benzoylated mannopyranosides (**5-7**) were more active than that of the glucopyranosides (**2-3**). Again, compounds **1**, **2** and **4** showed poor toxicity than that of compounds **3**, **6**, and **7** against these pathogens. This is probably due to the presence of more hydroxyl groups in **1**, **2** and **4**. While compounds **3**, **6** and **7** having fewer or no hydroxyl groups showed much better antibacterial potentiality (mannopyranoside **5** was found to be exceptional). Here the hydrophobicity of the molecules increased gradually from compounds **1**, **2**, and **4** to **3**, **6**, and **7**. The hydrophobicity of compounds is an important parameter for bioactivity and is directly related to membrane permeation [25]. We believe that similar hydrophobic interaction might occur between the benzoyl groups of monosaccharides (**3** and **7**) accumulated in the lipid membranes of bacteria. As a consequence of their hydrophobic interaction, bacteria lose their membrane permeability [26], ultimately causing death of the bacteria.

Conclusion

We have synthesized methyl 4,6-*O*-benzylidene-2,3-di-*O*-benzoyl-α-D-glucopyranoside (**3**) and methyl 4,6-*O*-benzylidene-2,3-di-*O*-benzoyl-α-D-mannopyranoside (**7**) from methyl α-D-glucopyranoside (**1**) and methyl α-D-mannopyranoside (**4**), respectively in reasonably good yields. A comparative *in vitro* antibacterial study of these compounds was carried out successfully employing ten bacterial pathogens. The structure activity relationship (SAR) study revealed that the benzoylated mannopyranosides (**5-7**) were more active against the tested organisms than that of the glucopyranosides (**1-3**).

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