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Comparative Antimicrobial Activities of some Monosaccharide and Disaccharide Acetates

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Abstract

A number of furanose (**2**,**4**) and pyranose (**5**,**7**,**9**,**11**,**13**) acetates were prepared by direct acetylation method. For comparative antimicrobial studies sucrose octaacetate (**14**) was also prepared. All the compounds (**1**-**14**) were screened for *in vitro* antibacterial activity against ten human pathogenic bacteria viz. *Bacillus subtilis*, *Bacillus cereus*, *Bacillus megaterium*, *Staphylococcus aureus*, *Escherichia coli*, INABA ET (*Vibrio*), *Pseudomonas* species, *Salmonella paratyphi*, *Salmonella typhi* and *Shigella dysenteriae*. These compounds were also screened for *in vitro* antifungal activity against four pathogenic fungi viz. *Aspergillus niger*, *Alternaria alternata*, *Curvularia lunata* and *Fusarium equiseti*. The study revealed that the pyranose acetate derivatives (**5**,**7**,**9**,**11**,**13**) are more prone towards antimicrobial functionality than those of the furanose acetates (**2**,**4**) and sucrose octaacetate (**14**).

Keywords: Glucofuranose; Glucopyranose; Acetylation; Antimicrobial activity; Structure activity relationship (SAR).

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1. Introduction

Acyl and alkyl glycoses and glycoside derivatives of carbohydrates have immense importance and some of them have potential biological activities [1]. Protection of a particular functional group of carbohydrates, especially monosaccharides, is not only necessary for the modification of the remaining functional groups but also for the synthesis of newer derivatives of great importance [2]. Various methods for acylation of carbohydrates and nucleosides have so far been developed and employed successfully [3-6]. A large number of biologically active compounds possess aromatic and heteroaromatic

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nuclei. It is also known that if an active nucleus is linked to another nucleus, the resulting nucleus may possesses greater potential for biological activity [7]. The benzene and substituted benzene nuclei play important role as common denominator for various biological activities, which is also revealed in a number of our previous reports [8-12]. Change of the aromatic or heteroaromatic nuclei to acyl group e.g. acetyl group may be interesting and will introduce new information in this field. Considering the above facts, we have taken a project to synthesize some monosaccharide derivatives (e.g. D-glucose, D-mannose, L-rhamnose etc.) in the furanose and pyranose form and disaccharide (e.g. sucrose) containing acetyl (CH_3CO) moieties in a single molecular framework and to evaluate their comparative antimicrobial activities using a variety of pathogens.

2. Experimental

2.1. *General experimental procedures*

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. IR spectra were recorded on a FT IR spectrophotometer (Shimadzu, IR Prestige-21) using KBr and $CHCl_3$ techniques. Thin layer chromatography 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 ºC until coloration took place. Column chromatography was carried out with silica gel (100-200 mesh). ^1H (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. All reagents used were commercially available (Aldrich) and were used as received unless otherwise specified.

2.2. *Synthesis*

1,2:5,6-Di-O-isopropylidene-α-D-gluco-1,4-furanose (**1**): The title compound **1** was prepared from D-glucose and anhydrous acetone according to the literature procedure [13]. The product was obtained in 46% yield as a white amorphous solid, mp. 108-110 °C (lit. [13] mp. 108-109 °C).

General procedure for direct acetylation: To a solution of the hydroxyl compound in anhydrous pyridine (1 mL) was added acetic anhydride at 0 ºC followed by addition of catalytic amount of 4-dimethylaminopyridine (DMAP). The reaction mixture was allowed to attain room temperature and stirring was continued for 10-16 h. A few pieces of ice was added to the reaction mixture to decompose unreacted (excess) acetic anhydride and extracted with dichloromethane (DCM) (3×5 mL). The organic (DCM) layer was washed successively with 5% hydrochloric acid, saturated aqueous sodium hydrogen carbonate solution and brine. The DCM layer was dried and concentrated under reduced pressure.

The residue thus obtained on column chromatography (*n*-hexane/ethyl acetate) gave the corresponding acetyl product.

3-O-Acetyl-1,2:5,6-di-O-isopropylidene-α-D-gluco-1,4-furanose (**2**): Acetylation of the bisacetone D-glucose **1** (0.5 g, 1.92 mmol) with acetic anhydride (2.04 g, 2.0 mmol) gave 3-*O*-acetate **2** (0.528 g, 91%) as a colourless semi-solid. R_f = 0.63 (*n*-hexane/ethyl acetate = 4/1). IR ($CHCl_3$): 1744 (CO), 1375 cm^{-1} [$C(CH_3)_2$]. ^1H NMR (400 MHz, $CDCl_3$): δ 5.85 (1H, d, *J* = 3.6 Hz, H-1), 5.23 (1H, d, *J* = 2.8 Hz, H-3), 4.48 (1H, d, *J* = 3.6 Hz, H-2), 4.26-4.30 (1H, m, H-5), 4.19 (1H, dd, *J* = 8.9 and 3.0 Hz, H-6a), 4.05 (1H, dd, *J* = 8.6 and 7.0 Hz, H-4), 3.99 (1H, dd, *J* = 8.9 and 5.9 Hz, H-6b), 2.08 (3H, s, $COCH_3$), 1.50 [3H, s, $C(CH_3)_2$], 1.39 [3H, s, $C(CH_3)_2$], 1.30 [3H, s, $C(CH_3)_2$], 1.28 [3H, s, $C(CH_3)_2$].

1,2-O-Isopropylidene-α-D-gluco-1,4-furanose (**3**): Compound **3** was prepared from bisacetone D-glucose **1** using reported procedure [14] as a white solid (76%), mp. 158-160 ºC (reported [14] mp. 159-160 ºC).

3,5,6-Tri-O-acetyl-1,2-O-isopropylidene-α-D-gluco-1,4-furanose (**4**): Direct acetylation of triol **3** (0.4 g, 1.816 mmol) with 3.3 molar equivalent of acetic anhydride (0.834 g, 8.169 mmol) yielded 3,5,6-tri-*O*-acetate **4** (0.554 g, 88%) as a white solid, which was recrystallized from *n*-hexane/ethyl acetate (9/1) as needles, mp. 77-78 °C (lit. [15] mp. 78 °C). R_f = 0.49 (*n*-hexane/ethyl acetate = 5/1). IR ($CHCl_3$): 1753, 1737 (CO), 1375 cm^{-1} [$C(CH_3)_2$]. ^1H NMR (400 MHz, $CDCl_3$): δ 5.87 (1H, d, *J* = 3.6 Hz, H-1), 5.29 (1H, d, *J* = 2.8 Hz, H-3), 5.13-5.19 (1H, m, H-5), 4.51 (1H, dd, *J* = 12.0 and 3.1 Hz, H-6a), 4.43 (1H, d, *J* = 3.6 Hz, H-2), 4.35 (1H, dd, *J* = 12.0 and 5.2 Hz, H-6b), 4.01-4.09 (1H, m, H-4), 2.00 (6H, s, 2×$COCH_3$), 1.95 (3H, s, $COCH_3$), 1.47 [3H, s, $C(CH_3)_2$], 1.26 [3H, s, $C(CH_3)_2$].

1,2,3,4,6-Penta-O-acetyl-α-D-glucopyranose (**5**): The title compound **5** was prepared from α-D-glucose and acetic anhydride according to the literature procedure [16]. Yield 65%, mp. 109-110 ºC (lit. [16] mp. 110-111 ºC).

Methyl 2,3,4,6-tetra-O-acetyl-α-D-glucopyranoside (**7**): Methyl α-D-glucopyranoside (**6**) (1.0 g, 5.15 mmol) on acetylation with acetic anhydride (2.63 g, 25.76 mmol) afforded 2,3,4,6-tetra-*O*-acetate **7** (1.605 g, 86%) as a white solid, mp. 104-105 °C (lit. [17] mp. 104 °C). R_f = 0.43 (*n*-hexane/ethyl acetate = 4/1). IR (KBr): 1730, 1762 cm^{-1} (CO). ^1H NMR (400 MHz, $CDCl_3$): δ 5.46 (1H, app t, *J* = 10.0 Hz, H-3), 5.04 (1H, app t, *J* = 10.0 Hz, H-4), 4.93 (1H, d, *J* = 3.6 Hz, H-1), 4.87 (1H, dd, *J* = 10.1 and 3.6 Hz, H-2), 4.24 (1H, dd, *J* = 12.3 and 4.6 Hz, H-6a), 4.08 (1H, dd, *J* = 12.3 and 2.3 Hz, H-6b), 3.96 (1H, ddd, *J* = 10.2, 4.6 and 2.3 Hz, H-5), 3.39 (3H, s, OCH_3), 2.08 (3H, s, CH_3), 2.05 (3H, s, CH_3), 2.01 (3H, s, CH_3), 1.99 (3H, s, CH_3). ^{13}C NMR (100 MHz, $CDCl_3$): δ 170.6, 170.1, 170.0, 169.6 ($COCH_3$), 96.8 (C-1), 70.8 (C-2), 70.1 (C-3), 68.6 (C-4), 67.2 (C-5), 61.9 (C-6), 55.5 (OCH_3), 20.7 ($COCH_3$), 20.6 (2×$COCH_3$), 20.5 ($COCH_3$).

Methyl 6-O-triphenylmethyl-α-D-glucopyranoside (**8**): The title compound **8** was prepared from methyl α-D-glucopyranoside (**6**) and triphenylmethyl (trityl) chloride (3.73 g, 13.38 mmol) in 72% yield as a crystalline solid, mp. 150-151 ºC (lit. mp. 151-152 ºC) according to the reported procedure [18].

Methyl 2,3,4-tri-O-acetyl-6-O-triphenylmethyl-α-D-glucopyranoside (**9**): Glucopyranoside **8** (0.4 g, 0.916 mmol) on acetylation with acetic anhydride (0.350 g, 3.428 mmol) furnished the triacetate **9** (0.469 g, 91%) as a white solid, mp. 121-122 ºC. R_f = 0.55 (*n*-hexane/ethyl acetate = 4/1). IR ($CHCl_3$): 1751 cm^{-1} (CO). ^1H NMR (400 MHz, $CDCl_3$): δ 7.41-7.46, 7.18-7.31 (15H, 2×m, Ar-H), 5.44 (1H, t, *J* = 9.5 Hz, H-3), 5.07 (1H, t, *J* = 9.6 Hz, H-4), 5.02 (1H, d, *J* = 3.6 Hz, H-1), 4.94 (1H, dd, *J* = 9.5 and 3.6 Hz, H-2), 4.11 (1H, m, H-5), 3.93 (2H, m, H-6a and H-6b), 3.46 (3H, s, OCH_3), 2.08 (3H, s, COCH_3), 1.99 (3H, s, COCH_3), 1.73 (3H, s, COCH_3).

Methyl 2,3,4,6-tetra-O-acetyl-α-D-mannopyranoside (**11**): Acetylation of methyl α-D-mannopyranoside (**10**) (0.5 g, 2.57 mmol) with acetic anhydride (1.32 g, 12.93 mmol) afforded the title compound **11** (0.664 g, 89%) as a thick oil, which resisted crystallization. R_f = 0.57 (*n*-hexane/ethyl acetate = 5/3). IR ($CHCl_3$): 1747 cm^{-1} (CO). ^1H NMR (400 MHz, $CDCl_3$): δ 5.32 (1H, dd, *J* = 10.0 and 3.0 Hz, H-3), 5.26 (1H, app t, *J* = 9.9 Hz, H-4), 5.22 (1H, d, *J* = 3.0 Hz, H-2), 4.69 (1H, s, H-1), 4.26 (1H, dd, *J* = 12.2 and 5.3 Hz, H-6a), 4.12 (1H, dd, *J* = 12.2 and 2.0 Hz, H-6b), 3.97-3.92 (1H, m, H-5), 3.39 (3H, s, OCH_3), 2.14 (3H, s, CH_3), 2.09 (3H, s, CH_3), 2.02 (3H, s, CH_3), 1.97 (3H, s, CH_3). ^{13}C NMR (100 MHz, $CDCl_3$): δ 170.6, 170.1, 169.8, 169.7 (*C*OCH_3), 96.6 (C-1), 69.6 (C-2), 69.1 (C-3), 68.4 (C-4), 66.2 (C-5), 62.6 (C-6), 55.3 (O*C*H_3), 20.9 (CO*C*H_3), 20.7 (2×CO*C*H_3), 20.6 (CO*C*H_3).

Methyl 2,3,4-tri-O-acetyl-α-L-rhamnopyranoside (**13**): Acetylation of methyl α-L-rhamnopyranoside (**12**) (0.4 g, 2.245 mmol) with acetic anhydride (0.459 g, 4.50 mmol) gave 2,3,4-tri-*O*-acetate **12** (0.657 g, 96%) as a white solid, mp. 89-90 ºC (reported [19] mp. 88-89 ºC). R_f = 0.54 (*n*-hexane/ethyl acetate = 4/1). IR (KBr): 1743 cm^{-1} (CO). ^1H NMR (400 MHz, $CDCl_3$): δ 5.21-5.27 (2H, m, H-2 and H-3), 5.03 (1H, t, *J* = 9.5 Hz, H-4), 4.60 (1H, s, H-1), 3.79-3.84 (1H, m, H-5), 3.36 (3H, s, *O*-CH_3), 2.12 (3H, s, COCH_3), 2.02 (3H, s, COCH_3), 1.95 (3H, s, COCH_3), 1.20 (3H, d, *J* = 6.2 Hz, 6-CH_3).

Octa-O-acetylsucrose (**14**): Finely powdered and dried sucrose (1.0 g, 2.92 mmol) on acetylation for 16 h gave a clear solution. The mixture was poured into an ice water beaker with the formation of solid crystals of sucrose octa-acetate. This on column chromatography with *n*-hexane/ethyl acetate (9/1) afforded octa-*O*-acetylsucrose (14) (1.328 g, 67%) as a crystalline solid, mp. 88-89 °C (reported [20] mp. 89 ºC). R_f = 0.51 (*n*-hexane/ethyl acetate = 2/1). IR (KBr): 1764, 1726 cm^{-1} (CO). ^1H NMR (400 MHz, $CDCl_3$): δ 5.61 (1H, d, *J* = 3.6 Hz, H-1), 5.38 (1H, d, *J* = 5.7 Hz, H-3′), 5.36 (1H, t, *J* = 10.2 Hz), 5.29 (1H, t, *J* = 5.8 Hz, H-4′), 4.99 (1H, t, *J* = 10.0 Hz, H-4), 4.79 (1H, dd, *J* =

10.3 and 3.6 Hz, H-2), 4.29-4.22, 4.20-4.05 (8H, 2×m, H-5, H-6, H-1′, H-5′ and H-6′), 2.12 (3H, s, COCH_3), 2.04 (6H, s, 2×COCH_3), 2.03 (3H, s, COCH_3), 2.02 (6H, s, 2×COCH_3), 1.96 (3H, s, COCH_3), 1.94 (3H, s, COCH_3). ^{13}C NMR (100 MHz, $CDCl_3$): δ 170.5, 170.3, 170.0, 169.9, 169.8, 169.7, 169.5, 169.4 (8×*C*OCH$_3$), 103.9 (C-2′), 89.8 (C-1), 79.0 (C-5′), 75.6, 74.9, 70.2, 69.5, 68.4, 68.1 (C-2, C-3, C-4, C-5, C-3′, C-4′), 63.5, 62.8, 61.7 (C-6, C-6′, C-1′), 20.5 (8×CO*C*H$_3$).

2.3. *Antimicrobial 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.* [21] was followed. Nutrient agar (NA) was used as basal medium for test bacteria. Dimethylformamide (DMF) was used as a solvent to prepare desired solution (1%) of the compounds initially. The plates were incubated at 37 °C for 48 h. Proper control was maintained with DMF. Each experiment was carried out three times. For antifungal screening tests one human and three phytopathogenic fungi viz. *Aspergillus niger*, *Alternaria alternata* (Fr) Kedissler, *Curvularia lunata* (Wakker Boedijin) and *Fusarium equiseti* (Corda) Sacc were used. The antifungal activities were assessed by poisoned food technique [22] as modified by Miah *et al.* [23]. Potato dextrose agar (PDA) was used as basal medium to test fungi.

3. Results and Discussions

It is observed that some acylated derivatives of monosaccharides exhibited effective antibacterial and antifungal activities [8-12]. Encouraged by these results and to compare biological activities of monosaccharide (furanose and pyranose form) acetates with those of disaccharide (e.g. sucrose) acetates, our main aim was to synthesize some acetyl derivatives of D-*gluco*-1,4-furanose (**1** and **3**), D-glucopyranose (**6** and **8**), D-mannopyranoside (**10**), L-rhamnopyranoside (**12**) and sucrose.

3.1. *Synthesis of furanose acetates*

Our first effort was to synthesize 3-*O*-acetyl derivative of 1,2:5,6-di-*O*-isopropylidene-α-D-*gluco*-1,4-furanose (**1**). For this reason, initially, 1,2:5,6-di-*O*-isopropylidene-α-D-*gluco*-1,4-furanose (**1**) was prepared from D-glucose [13]. In the 1,2:5,6-*O*-protected glucofuranose (**1**), the C-3 position OH remain free and can be easily acylated. Thus, treatment of **1** with acetic anhydride in pyridine gave a compound in quantitative yield (91%). The IR spectrum of the compound showed a band at 1744 cm^{-1} corresponding to

carbonyl frequency and the absence of hydroxyl stretching band indicated the attachment of acetyl group. In the ^{1}H NMR spectrum, the presence of a three-proton singlet at δ 2.08 was due to the acetyl group. Also, C-3 proton shifted considerably to downfield at δ 5.23 (as d, J = 2.8 Hz) as compared to its usual value (~4.30 ppm), thus confirming the attachment of the acetyl group at position C-3 of the molecule.

In the next step, we prepared 1,2-*O*-isopropylidene-α-D-*gluco*-1,4-furanose (**3**) from bisacetone D-glucose (**1**) by selective de-protection of 5,6-acetonide functionality [14]. Having 3,5,6-triol (**3**) in hand, we carried out tri-*O*-acetylation. Reaction of triol **3** with acetic anhydride in pyridine afforded a white solid, mp. 77-78 ºC. IR spectrum of this compound showed signals at 1753, 1737 (CO) and 1375 cm^{-1} [C(CH_3)$_2$]. It showed no peaks corresponding to hydroxyl stretching and hence indicated the complete acetylation. In its ^{1}H NMR spectrum, one six-proton singlet at δ 2.00 and one three-proton singlet at δ 1.95 indicated the incorporation of three acetyloxy groups in the molecule. Thus, the structure of the compound was assigned as 3,5,6-tri-*O*-acetyl-1,2-*O*-isopropylidene-α-D-*gluco*-1,4-furanose (**4**).

3.2. *Synthesis of pyranose acetates*

For pyranose sugar acetates, our first effort was to prepare glucose pentaacetate (**5**). This was accomplished by reaction of powdered α-D-glucose with excess amount of acetic anhydride in presence of anhydrous zinc chloride at 90 ºC using literature procedure [16]. In the subsequent step, we attempted to prepare tetra-*O*-acetyl-D-glucopyranose. Thus, acetylation of methyl α-D-glucopyranoside (**6**) afforded a white solid, mp. 104-105 °C in 86% yield. The IR spectrum of this solid exhibited no band for hydroxyl stretching. It showed bands at 1730 and 1762 cm^{-1} corresponding to carbonyl frequency indicating the attachment of acetyloxy groups in the molecule. In the ^{1}H NMR spectrum, four three-proton singlets at δ 2.08, 2.05, 2.01 and 1.99 were assigned for the four acetyloxy methyl protons. This was also confirmed by its ^{13}C NMR spectrum where four carbonyl carbon peaks at δ 170.6, 170.1, 170.0 and 169.6 and four acetyl methyl carbon peaks at δ 20.7, 20.6 (×2) and 20.5 were observed. Hence the structure of the compound was assigned as methyl 2,3,4,6-tetra-*O*-acetyl-α-D-glucopyranoside (**7**).

To increase biological activities we were interested to synthesize acylated glucopyranosides with aromatic moiety. So, we prepared methyl 6-*O*-trityl-α-D-glucopyranoside (**8**) according to the literature procedure [18]. Acetylation of triol **8** furnished a white solid (91%), mp. 121-122 ºC. The IR spectrum of this solid showed a band at 1751 cm^{-1} corresponding to carbonyl frequency and exhibited no band for hydroxyl stretching. In the ^{1}H NMR spectrum, three three-proton singlets at δ 2.08, 1.99 and 1.73 were assigned for the three acetyloxy methyl protons. The H-2, H-3 and H-4 protons appeared considerably downfield [δ 4.94 (H-2), 5.44 (H-3) and 5.07 (H-4)] as compared to its precursor **8**. These downfield shifts clearly indicated the attachment of acetyl groups at C-2, C-3 and C-4 positions. In the next step, acetylation of methyl α-D-mannopyranoside (**10**) gave a compound in 89% yield as a thick oil. Its IR spectrum

showed a band at 1747 cm^{-1} for carbonyl frequency hence indicating the attachment of acetyloxy groups in the molecule. In the ^1H NMR spectrum, four three-proton singlets at δ 2.14, 2.09, 2.02 and 1.97 were assigned for the four acetyloxy methyl protons. The IR and ^1H NMR spectra of this compound were in complete agreement with the structure accorded as methyl 2,3,4,6-tetra-*O*-acetyl-α-D-mannopyranoside (**11**).

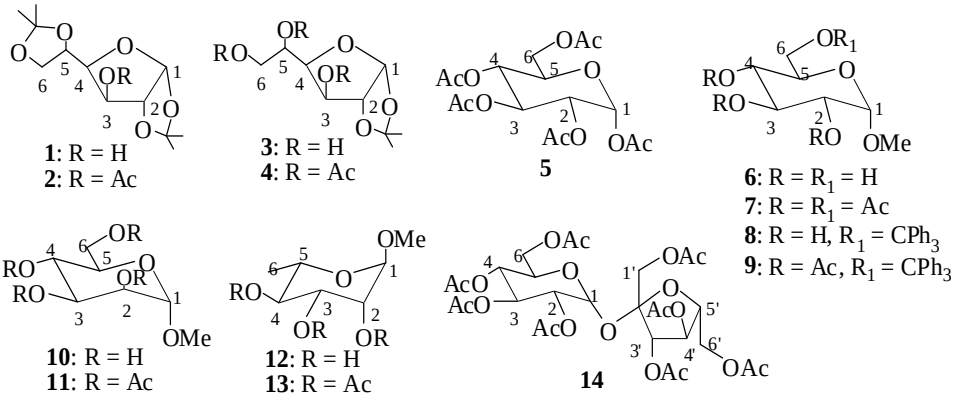

Fig. 1. Structure of compound **1**-**14**.

Finally, direct acetylation methyl α-L-rhamnopyranoside (**12**) afforded a white solid, mp. 89-90 ºC. The IR spectrum of the compound showed a band at 1743 cm^{-1} corresponding to carbonyl frequency. In the ^1H NMR spectrum, a three-proton singlet at δ 3.36 and a three-proton doublet at δ 1.20 (J = 6.2 Hz) were due to C-1 methoxy and C-6 methyl groups, respectively. In addition, three three-proton singlets at δ 2.12, 2.02 and 1.95 were assigned for the three acetyloxy methyl protons. Based on the spectral analysis the structure of the compound was assigned as methyl 2,3,4-tri-*O*-acetyl-α-L-rhamnopyranoside (**13**).

3.3. *Synthesis of acetylated disaccharide: octa-O-acetylsucrose (14)*

To compare the antimicrobial activities of acylated disaccharide with those of furanose and pyranose sugar acetates we deliberately prepared octa-*O*-acetylsucrose (**14**). Thus, sucrose on reaction with slight excess acetic anhydride in anhydrous pyridine for 16 h afforded a crystalline solid in 67% yield. In its IR spectrum, the carbonyl stretching peaks were observed at 1764 and 1726 cm^{-1}. But, absence of frequency corresponding to hydroxyl group indicated the per-*O*-acetylation of the molecule. In the ^1H NMR spectrum, twenty four protons resonated at δ 2.12 (3H, s), 2.04 (6H, s), 2.03 (3H, s), 2.02 (6H, s), 1.96 (3H, s) and 1.94 (3H, s) corresponding to eight acetyloxy groups. This was further confirmed by its ^{13}C NMR spectrum where eight acetyl carbonyl peaks appeared at δ 170.5, 170.3, 170.0, 169.9, 169.8, 169.7, 169.5 and 169.4. Also, all the acetyl methyl-

carbons appeared at δ 20.5 (8×CO*C*H_3). Therefore, the compound was unambiguously given the structure as 1′,2,3,3′,4,4′,6,6′-octa-*O*-acetylsucrose (**14**).

3.4. *Antimicrobial activities*

3.4.1. *Antibacterial potentiality 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**-**14**) 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 2,3,4-tri-*O*-acetyl-6-*O*-trityl-α-D-glucopyranoside (**9**) exhibited considerable inhibition (20 mm) against *Bacillus subtilis*.

Table 1. Inhibition against Gram-positive organisms by the test chemicals (**1**-**14**).

Compound no.	Diameter of zone of inhibition in mm (50 µg. dw./disc)			
	Bacillus cereus	*Bacillus megaterium*	*Bacillus subtilis*	*Staphylococcus aureus*
1	--	--	--	--
2	09	--	--	--
3	--	--	--	--
4	11	--	--	--
5	18	--	11	08
6	--	--	--	--
7	10	--	12	--
8	--	--	18	07
9	--	12	20*	--
10	--	--	--	--
11	--	--	14	--
12	--	--	--	--
13	13	--	--	--
14	--	10	--	--
Ampicillin**	22*	19*	25*	21*

"--" 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 chemicals (**1**-**14**) are mentioned in Table 2. The study revealed that the tested chemicals were more effective against these Gram-negative organisms. These compounds were more active against *Salmonella paratyphi* and *Salmonella typhi*. It was observed from Table 2 that monosaccharides in the six-membered pyranose form viz. methyl 2,3,4,6-tetra-*O*-acetyl-α-D-glucopyranoside (**7**), methyl α-D-mannopyranoside (**10**), methyl 2,3,4,6-tetra-*O*-acetyl-α-D-mannopyranoside (**11**) and methyl 2,3,4-tri-*O*-acetyl-α-L-rhamnopyranoside

(**13**) were most effective against these pathogens. These pyranose monosaccharides were more effective than five-membered furanose form (**1**-**4**) and sucrose octaacetate (**14**).

3.4.2. *Antifungal potentiality of the newly synthesized compounds*

The results of the percentage inhibition of mycelial growth of the four plant pathogenic fungi due to the effect of chemicals (**1**-**14**) are presented in Table 3. It was observed that the compounds (**1**-**14**) were more toxic towards human pathogenic *Aspergillus niger* than that of the plant pathogenic fungi. Again, pyranose acetates were more prone towards antifungal activities than that of the furanose and disaccharide acetates.

Table 2. Inhibition against Gram-negative organisms by the test chemicals (**1**-**14**).

Compound no.	Diameter of zone of inhibition in mm (50 μg.dw./disc)					
	Escherichia coli	*INABAET (vibrio)*	*Pseudomonas aeruginosa*	*Salmonella paratyphi*	*Salmonella typhi*	*Shigella dysenteriae*
1	--	--	--	16	--	--
2	--	08	--	18	18	--
3	--	--	--	16	--	17
4	--	--	08	19	--	15
5	13	07	15	16	10	--
6	--	--	--	08	--	--
7	--	12	17	14	22*	16
8	--	08	10	10	18	17
9	--	10	14	17	18	16
10	--	--	--	21*	20*	--
11	--	--	21*	19	23*	--
12	--	--	--	--	--	--
13	--	--	16	22*	18	13
14	--	--	--	17	10	--
Ampicillin**	25*	24*	17	35*	13	35*

"--" indicates no zone of inhibition, dw. = dry weight, "**" indicates standard antibiotic, "*" shows good inhibition.

3.4.3. *Structure activity relationship (SAR)*

In vitro antimicrobial study (section 3.4.1 and 3.4.2) revealed that these compounds (**1**-**14**) were more active against Gram-negative organisms than that of Gram-positive and fungal organisms. An important observation was that, acetylated sugars with five-membered furanose form are less effective against both Gram-negative, Gram-positive and fugal pathogens than that of the corresponding acetylated sugars with six-membered pyranose form. This is because of the slight distortion of furanose ring in the presence of 1,2-*O*-isopropylidene ring. But monosaccharides (**5**-**13**) in pyranose form with regular $^4C_1$ or $^1C_4$ conformation exhibited excellent antimicrobial potentiality. Again, acylated

monosaccharides with pyranose form showed much better antibacterial potentiality than that of sucrose (disaccharide) octaacetate (**14**) due to the presence of five-membered furanose ring.

Table 3. Antifungal activities of the synthesized compounds (**1**-**14**).

Compound no.	% inhibition of fungal mycelial growth, 100 µg (dw) sample/mL PDA			
	Aspergillus niger	*Alternaria alternata*	*Curvularia lunata*	*Fusarium equiseti*
1	--	--	--	--
2	--	8.0	--	--
3	--	--	--	--
4	14.0	--	--	--
5	23.0	31.0	--	41.0
6	13.0	--	--	--
7	38.5	55.0	27.0	--
8	22.5	8.0	--	12.0
9	42.0	31.0	8.0	20.5
10	--	--	--	--
11	26.0	--	--	19.0
12	15.5	--	8.0	30.0
13	22.5	--	--	37.5
14	--	8.5	11.5	--
Nystatin[**]	36.0	55.5	70.0[*]	45.8

"--" indicates no zone of inhibition, dw. = dry weight, "**" indicates standard antibiotic, "*" shows good inhibition.

4. Conclusion

Thus, we have successfully synthesized acetylated furanose (**2**,**4**), pyranose (**5**,**7**,**9**,**11**,**13**) and sucrose acetate (**14**) derivatives. A comparative study of *in vitro* antimicrobial activities of monosaccharide (furanose and pyranose form) acetates with sucrose (disaccharide) acetates was carried out successfully. The structure activity relationship (SAR) study revealed that the acetate derivatives in six-membered pyranose form were more prone towards antimicrobial functionality than that of the corresponding acetate derivatives in five-membered furanose form and sucrose octaacetate (**14**).

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