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Synthesis and antimicrobial studies of 6-*O*-lauroyl-1,2-*O*-isopropylidene-α-D-*gluco*-furanose derivatives

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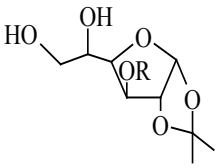
Abstract: Direct unimolecular lauroylation of 1,2-*O*-isopropylidene-α-D-*gluco*-furanose (**4**) at low temperature provided the desired selective 6-*O*-lauroate (**5**) in good yield. For structural elucidation and to get newer glucofuranose derivatives of biological importance 3,5-di-*O*-acetate (**6**), 3,5-di-*O*-mesylate (**7**) and 3,5-di-*O*-benzoate (**8**) were also prepared from lauroate **5**. All the glucofuranoses (**3**-**8**) were employed as test chemicals for *in vitro* antibacterial and antifungal functionality test against ten human pathogenic bacteria and seven fungi, respectively. The study revealed that some of the tested glucofuranose derivatives (**5**,**6**,**8**) showed moderate to good antimicrobial functionalities as compared to the standard antibiotics.

Keywords: Bisacetone D-glucose, glucofuranose, lauroylation, antimicrobial activity, structure activity relationship (SAR).

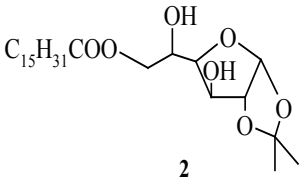
Introduction

Various methods for acylation of carbohydrates and nucleosides have so far been developed and employed successfully [1-2]. Of these, protections of the undesired hydroxyl groups followed by direct acylation of the remaining hydroxyl group were used [3]. But these methods increase the number of steps and are expensive. Hence, selective acylation of the desired hydroxyl group by direct method maintaining proper reaction conditions are used to reduce the number of steps. Such selectively acylated products have synthetic utility as versatile intermediates [4]. It was observed that if an active nucleus is linked to one or more heteroaromatic and acyl groups, the biological activity of the resulting nucleus enhances many fold than its parent nucleus [5]. Monosaccharides and nucleosides in combination with acyl nuclei (e.g. acetyl, mesyl, benzoyl etc) play important role as common denominator for various biological activities, which is also revealed by a number of our previous studies

[6-8]. Catelani *et al*. [9] reported the synthesis of various 3-*O*-acyl-1,2-*O*-isopropylidene-D-glucofuranose derivatives (**1a-c**) from triol **4** and tested their effects in augmenting the proportion of benzidine-positive (hemoglobin-containing) cells in treated K562cell populations. The results obtained demonstrated that two of these newly synthesized compounds were potent inducers of erythroid differentiation of K562cells. Recently Kobayashi *et al*. [10] reported the synthesis of 6-*O*-palmitoyl-1,2-*O*-isopropylidene-α-D-*gluco*-1,4-furanose (**2**) by lipase catalyzed esterification. But the yield was very low due to low solubility of the reaction mixture in organic solvent.



1a: R = $COCH_2CH_2CH_3$;
1b: R = $COCH_2CH(CH_3)CH_3$;
1c: R = $COC(CH_3)_3$;
4: R = H.



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Acylated disaccharide [11] and monosaccharide [12] derivatives exhibited antimicrobial activities. For example lauroylated sucrose was found primarily active against certain Gram-positive bacteria [11]. Lauroylated glucose, galactose, fructose, mannose etc showed the highest inhibitory effect against the growth *Streptococcus mutans* [12-13]. Considering the synthetic and biological importance, we describe here the synthesis of some 6-*O*-lauroyl derivatives of 1,2-*O*-isopropylidene-α-D-*gluco*-1,4-furanose (**4**) employing direct acylation technique and their antimicrobial activities against a variety bacterial and fungal pathogens.

Materials and methods

Physical measurements: 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). IR spectra were recorded on a FTIR spectrophotometer (Shimadzu, IR Prestige-21) using KBr and $CHCl_3$ technique. ^1H (400 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 of 1,2:5,6-di-*O*-isopropylidene-α-D-*gluco*-1,4-furanose (3):
The title compound **3** was prepared from D-glucose, anhydrous acetone and $CuSO_4$ according to the literature procedure [14]. The product was obtained in 46% yield as a white amorphous solid, mp 108-110 °C (lit. [14] mp 108-109 °C).

Synthesis of 1,2-*O*-isopropylidene-α-D-*gluco*-1,4-furanose (4):
To a solution of bisacetone D-glucose **3** (4.0 g, 15.36 mmol) in methanol (62 ml) and water (12.5 ml) was added 15% H_2SO_4 (3.3 ml) slowly at room temperature. Stirring was continued at this temperature for 5 h and saturated potassium carbonate (K_2CO_3) solution was added to neutralize the reaction mixture to pH = 7~8. Methanol was evaporated and the residue was extracted with ethyl acetate (4×20 ml) with occasional warming. The organic layer was dried (Na_2SO_4) and evaporated to give a thick liquid of triol, which after column chromatography with *n*-hexane/ethyl acetate (1/9) afforded pure 3,5,6-triol **4** as a white solid (2.57 g, 76%), mp

158-160 ºC (reported [15] mp 159-160 ºC).

Synthesis of 1,2-*O*-isopropylidene-6-*O*-lauroyl-α-D-*gluco*-1,4-furanose (5):
Lauroyl chloride (2.185 g, 9.98 mmol) was added slowly to a stirred solution of the triol **4** (2.0 g, 9.09 mmol) in anhydrous pyridine (3 ml) at 0 ºC followed by addition of catalytic amount of 4-dimethylaminopyridine (DMAP). The reaction mixture was stirred at this temperature for 6 h and then at room temperature for 12 h. Usual work-up and column chromatography (elution with *n*-hexane/ethyl acetate = 3/1) gave the title compound **5** (2.56 g, 70%) as needles, mp 77-78 ºC.

R_f = 0.49 (*n*-hexane/ethyl acetate = 1/1). IR (KBr, cm^{-1}): 3410-3480 (br OH), 1717 (CO), 1379 [$C(CH_3)_2$]. ^{1}H NMR (400 MHz, $CDCl_3$): δ 5.96 (1H, d, *J* = 3.7 Hz, H-1), 4.51 (1H, d, *J* = 3.7 Hz, H-2), 4.39-4.46 (1H, m, H-5), 4.35 (1H, d, *J* = 2.5 Hz, H-3), 4.22-4.29 (2H, m, H-6a and H-6b), 4.07 (1H, dd, *J* = 7.5 and 2.5 Hz, H-4), 2.59-2.93 (2H, br s, exchange with D_2O, 2×O*H*), 2.34 [2H, t, *J* = 7.7 Hz, $CH_3(CH_2)_9CH_2CO$], 1.55-1.62 [2H, m, $CH_3(CH_2)_8CH_2CH_2CO$], 1.47 [3H, s, $C(CH_3)_2$], 1.31 [3H, s, $C(CH_3)_2$], 1.10-1.29 [16H, m, $CH_3(CH_2)_8CH_2CH_2CO$], 0.86 [3H, t, *J* = 7.1 Hz, $CH_3(CH_2)_{10}CO$].

Synthesis of 3,5-di-*O*-acetyl-1,2-*O*-isopropylidene-6-*O*-lauroyl-α-D-*gluco*-1,4-furanose (6):
Acetic anhydride (0.23 g, 2.25 mmol) was added to a solution of diol **5** (0.4 g, 0.994 mmol) in dry pyridine (1 ml) at 0 ºC with continuous stirring. The mixture was allowed to attain room temperature and stirring was continued overnight at this temperature. Work-up followed by chromatography gave the diaceate (**6**) (0.44 g, 91%) as a solid, mp 48-50 ºC.

R_f = 0.45 (*n*-hexane/ethyl acetate = 4/1). IR ($CHCl_3$, cm^{-1}): 1746, 1745, 1743 (CO), 1375 [$C(CH_3)_2$]. ^{1}H NMR (400 MHz, $CDCl_3$): δ 5.90 (1H, d, *J* = 3.7 Hz, H-1), 5.35 (1H, d, *J* = 2.8 Hz, H-3), 5.17-5.24 (1H, m, H-5), 4.56 (1H, dd, *J* = 12.0 and 3.2 Hz, H-6a), 4.47 (1H, d, *J* = 3.7 Hz, H-2), 4.40 (1H, dd, *J* = 12.0 and 7.5 Hz, H-6b), 4.13 (1H, dd, *J* = 7.6 and 2.5 Hz, H-4), 2.30 [2H, t, *J* = 7.6 Hz, $CH_3(CH_2)_9CH_2CO$], 2.05 (3H, s, CH_3CO), 1.98 (3H, s, CH_3CO), 1.55-1.62 [2H, m, $CH_3(CH_2)_8CH_2CH_2CO$], 1.51 [3H, s, $C(CH_3)_2$], 1.31 [3H, s, $C(CH_3)_2$], 1.15-1.28 [16H, m, $CH_3(CH_2)_8CH_2CH_2CO$], 0.86 [3H, t, *J* = 7.2 Hz, $CH_3(CH_2)_{10}CO$].

Synthesis of 1,2-*O*-isopropylidene-3,5-di-*O*-mesyl-6-*O*-lauroyl-α-D-*gluco*-1,4-furanose (7):
To a solution of lauroate **5** (0.5 g, 1.24 mmol) in dry pyridine (1 ml) was added methanesulfonyl (mesyl) chloride (0.313 g, 2.73 mmol) dropwise at −5 ºC followed by addition of catalytic amount of DMAP. The reaction mixture was slowly allowed to attain 25 ºC and stirring was continued for 4 h. A few pieces of ice were added to the reaction flask to destroy the excess of mesyl chloride and extracted with chloroform (3×3 ml). Work-up and chromatography elution with *n*-hexane/ethyl acetate (18/1) furnished the title compound **7** (0.555 g, 80%), as solid mass, mp 60-62 ºC.

R_f = 0.52 (*n*-hexane/ethyl acetate = 5/1). IR ($CHCl_3$, cm^{-1}): 1740 (CO), 1376 [$C(CH_3)_2$], 1320 (SO_2). ^{1}H NMR (400 MHz, $CDCl_3$): δ 5.91 (1H, d, *J* = 3.7 Hz, H-1), 5.35 (1H, d, *J* = 2.6 Hz, H-3), 5.15-5.21 (1H, m, H-5), 4.58 (1H, dd, *J* = 12.0 and 3.2 Hz, H-6a), 4.46 (1H, d, *J* = 3.7 Hz, H-2), 4.43 (1H, dd, *J* = 12.0 and 7.5 Hz, H-6b), 4.10 (1H, dd, *J* = 7.6 and 2.5 Hz, H-4), 3.13 (3H, s, SO_2CH_3), 3.05 (3H, s, SO_2CH_3), 2.33 [2H, t, *J* = 7.5 Hz, $CH_3(CH_2)_9CH_2CO$], 1.55-1.64 [2H, m, $CH_3(CH_2)_8CH_2CH_2CO$], 1.49 [3H, s, $C(CH_3)_2$], 1.30 [3H, s, $C(CH_3)_2$], 1.16-1.26 [16H, m, $CH_3(CH_2)_8CH_2CH_2CO$], 0.86 [3H, t, *J* = 7.2 Hz, $CH_3(CH_2)_{10}CO$].

Synthesis of 3,5-di-*O*-benzoyl-1,2-*O*-

isopropylidene-6-*O*-lauroyl-α-D-*gluco*-1,4-furanose (8):
Benzoylation of 6-*O*-laurate **5** (0.5 g, 1.24 mmol) with 2.2 molar equivalent of benzoyl chloride (0.384 g, 2.73 mmol) in dry pyridine (1 ml) for 12 h gave a faster moving product. This on usual work-up followed by chromatography with *n*-hexane/ethyl acetate gave the di-*O*-benzoate **8** (0.63 g, 83%) as an oil.

R_f = 0.51 (*n*-hexane/ethyl acetate = 4/1). IR ($CHCl_3$, cm^{-1}): 1738, 1730 (CO), 1379 [$C(CH_3)_2$]. ^1H NMR (400 MHz, $CDCl_3$): δ 7.93-8.01 (5H, m, Ar-H), 7.21-7.32 (5H, m, Ar-H), 5.98 (1H, d, *J* = 3.6 Hz, H-1), 5.35 (1H, d, *J* = 2.7 Hz, H-3), 5.20-5.25 (1H, m, H-5), 4.56 (1H, dd, *J* = 12.0 and 3.2 Hz, H-6a), 4.45 (1H, d, *J* = 3.6 Hz, H-2), 4.43 (1H, dd, *J* = 12.0 and 7.6 Hz, H-6b), 4.11 (1H, dd, *J* = 7.6 and 2.7 Hz, H-4), 2.30 [2H, t, *J* = 7.6 Hz, $CH_3(CH_2)_9CH_2CO$], 1.51-1.58 [2H, m, $CH_3(CH_2)_8CH_2CH_2CO$], 1.46 [3H, s, $C(CH_3)_2$], 1.30 [3H, s, $C(CH_3)_2$], 1.10-1.19 [16H, m, $CH_3(CH_2)_8CH_2CH_2CO$], 0.88 [3H, t, *J* = 7.2 Hz, $CH_3(CH_2)_{10}CO$].

Antimicrobial screening studies

Test human and phytopathogens: Ten human pathogenic bacteria were used in the present study. Of these four were Gram-positive viz. *Bacillus cereus* BTCC 19, *Bacillus megaterium* BTCC 18, *Bacillus subtilis* BTCC 17 and *Staphylococcus aureus* ATCC 6538 and six were Gram-negative viz. *Escherichia coli* ATCC 25922, *Pastunella maltosida*, *Salmonella gallinarium*, *Salmonella typhi* AE 14612, *Shigella dysenteriae* AE 14369 and *Vibrio cholerae*. Seven plant pathogenic fungi viz. *Aspergillus acheraccus*, *Aspergillus flavus*, *Aspergillus fumigates*, *Aspergillus niger*, *Aspergillus nodusus*, *Candida albicans* and *Fuserium equiseti* (Corda) Sacc. were selected for *in vitro* mycelial growth test for these glucofuranoses (**3**-**8**).

Screening of antibacterial activity: Dimethylformamide (DMF) was used as a solvent for test chemicals and a 2% solution of the compound was used in the investigation. The plates were incubated at 37 °C for 48 h. Proper control was maintained with DMF without chemicals. Mueller-Hinton (agar and broth) medium was used for culture of bacteria. Each experiment was carried out three times. For the detection of antibacterial activities, the disc diffusion method [16] was followed. All the results were compared with the standard antibacterial antibiotic kanamycin (50 µg/disc, Taj Pharmaceuticals Ltd., India).

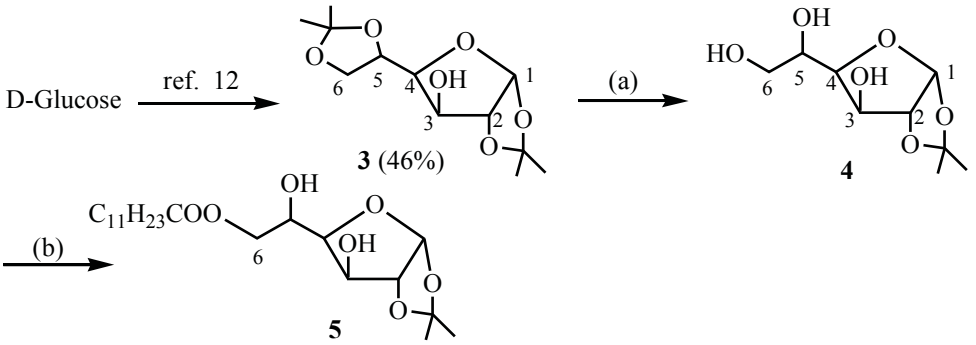
Screening of mycelial growth: Food-poisoning technique [17] was used for the antifungal activities of the glucofuranose derivatives (**3**-**8**). Sabouraud (agar and broth, PDA) medium was used for culture of fungi. Linear mycelial growth of fungus was measured after 3~5 days of incubation. The percentage inhibition of radial mycelial growth of the test fungus was calculated as follows:

$$I = \left\{\frac{C - T}{C}\right\} \times 100$$

Where, I = percentage of inhibition, C = diameter of the fungal colony in control (DMF), T = diameter of the fungal colony in treatment. The results were compared with standard antifungal antibiotic fluconazole (100 µg/ml medium, brand name Omastin, Beximco Pharmaceuticals Ltd., Bangladesh).

Results and discussion

Synthesis of 6-*O*-lauroylglucofuranose 5: Our main aim was selective 6-*O*-lauroylation of 1,2-*O*-isopropylidene-α-D-*gluco*-1,4-furanose (**4**) and antimicrobial evaluation of the synthesized products. For this reason, we prepared 1,2:5,6-di-*O*-isopropylidene-α-D-*gluco*-1,4-furanose (**3**) from D-glucose treating with anhydrous acetone and $CuSO_4$ [14] in

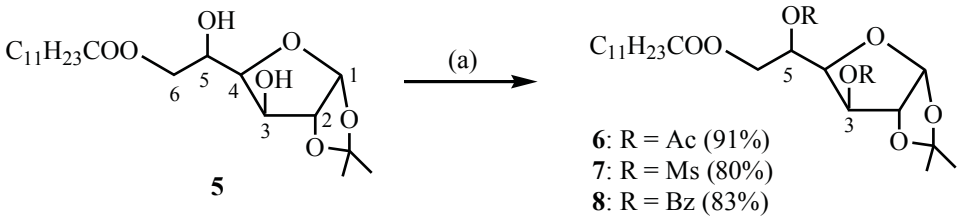


Scheme 1. *Reagents and conditions*: (a) 15% H_2SO_4, MeOH-H_2O, rt, 5 h, 76%; (b) $C_{11}H_{23}COCl$, pyridine, DMAP, 0 ºC-rt, 18 h, 70%.

46% yield as a white amorphous solid, mp 108-110 °C (Scheme 1). Selective deprotection of 5,6-*O*-acetonide functionality of bisacetone **3** was achieved by treating **3** with 15% H_2SO_4 in methanol for 5 h and afforded pure 3,5,6-triol (**4**) as a white solid (76%), mp 158-160 ºC. Its IR and ^{1}H spectra were similar to that of reported spectra [15].

Having 1,2-*O*-isopropylidene-α-D-*gluco*-1,4-furanose (**4**) in hand, selective 6-*O*-lauroylation was carried out using with one molar equivalent of lauroyl chloride ($C_{11}H_{23}COCl$) in anhydrous pyridine at 0 °C (Scheme 1). IR spectrum of this product showed the presence of a carbonyl stretching band at 1717 cm^{-1} and hydroxyl stretching band at 3410-3480 cm^{-1} indicating the attachment of partial lauroyl group in the molecule. In the ^{1}H NMR spectrum, a two-proton triplet at δ 2.34, a two-proton multiplet at δ 1.55-1.62, a sixteen-proton multiplet at δ 1.10-1.29 and a three-proton triplet at δ 0.86 were indicative of the presence of one lauroyloxy group in the molecule. In addition, the downfield shift of H-6 protons (~δ 4.22-4.29) as compared to the precursor compound **4** (δ 3.67-3.76) confirmed the attachment of the lauroyloxy group at position C-6. The rest of the ^{1}H NMR spectrum was in complete accord with the structure assigned as 1,2-*O*-isopropylidene-6-*O*-lauroyl-α-D-*gluco*-1,4-furanose (**5**). It is known that primary OH group is more reactive than that of secondary OH group. Thus, unimolar reaction of triol **4** with bulky lauroyl chloride at low temperature will react preferentially with primary OH group at C-6 position. The product formation was in complete accord with our desire although slightly in lower yield (70%).

Synthesis of 3,5-di-*O*-acyl derivatives of lauroate 5: To get newer derivatives of biological importance and to confirm the



Scheme 2. *Reagents and conditions*: (a) Ac_2O/MsCl/BzCl, pyridine, DMAP, 0 ºC-rt, 6~18 h.

structure of lauroate **5**, three 3,5-di-*O*-acyl derivatives (**6-8**) containing various groups (e.g. acetyl, methanesulfonyl and benzoyl) were prepared (Scheme 2). Thus, reaction of diol **5** with acetic anhydride in dry pyridine provided a solid (91%). Its IR spectrum showed peaks at 1746, 1745, 1743 (CO), 1375 cm^{-1} [$C(CH_3)_2$] and no band for hydroxyl stretching. The ^1H NMR spectrum of this compound showed two three-proton singlets at δ 2.05 and 1.98 corresponding to two acetyl methyl groups and hence indicated the attachment of two acetyloxy groups in the molecule. So, the structure was assigned as 3,5-di-*O*-acetyl-1,2-*O*-isopropylidene-6-*O*-lauroyl-α-D-*gluco*-1,4-furanose (**6**). The 3,5-di-*O*-acetate (**6**) formation also confirmed the structure of 6-*O*-lauroate (**5**).

In the next step, treatment of **5** with methanesulfonyl chloride in pyridine gave a solid in 80% yield (Scheme 2). Its IR spectrum resonated at 1740 (CO), 1376 [$C(CH_3)_2$] and 1320 cm^{-1} (SO_2). In the ^1H NMR spectrum, two three-proton singlets at δ 3.13 and 3.05 clearly indicated the attachment of two mesyloxy groups in the molecule. The reasonable down field shift of H-3 (δ 5.35) and H-5 (δ 5.15-5.21) protons as compared to that of compound **5** confirmed the attachment of two mesyloxy groups at position C-3 and C-5. Complete analysis of its IR and ^1H NMR spectra led us to assign the structure as 1,2-*O*-isopropylidene-3,5-di-*O*-mesyl-6-*O*-laurroyl-α-D-*gluco*-1,4-furanose (**7**).

Finally, 6-*O*-lauroate **5** was treated with dimolar benzoyl chloride to introduce aromatic moiety in the molecule and obtained an oil in 83% yield. Its IR spectrum gave peaks at 1738, 1730 (CO) and 1379 cm^{-1} [$C(CH_3)_2$]. Appearance of two five-proton multiplets at δ 7.93-8.01 and 7.21-7.32 in its ^1H NMR spectrum indicated the incorporation of two benzoyl groups in the molecule. Analysis of the rest of the spectrum as well as correlation with diacetate (**6**) and

Table 1. Inhibition against bacterial organism by the glucofuranose derivatives (**3-8**).

Name of bacteria	Diameter of zone of inhibition in mm, 50 µg.dw./disc						
	3	**4**	**5**	**6**	**7**	**8**	**Kanamycin
Bacillus cereus	NI	NI	09	17	14	15	*20
Bacillus megaterium	NI	NI	14	18	14	10	*20
Bacillus subtilis	NI	NI	12	14	NI	16	*21
Staphylococcus aureus	NI	NI	12	*20	14	*20	*22
Escherichia coli	NI	NI	18	*20	18	*19	*22
Pastunella maltosida	NI	NI	13	14	12	12	*23
Salmonella gallinarium	NI	NI	NI	09	10	09	*24
Salmonella typhi	NI	NI	NI	16	NI	NI	*23
Shigella dysenteriae	NI	17	09	NI	14	12	*24
Vibrio cholerae	NI	NI	NI	17	NI	12	18

"*" shows good inhibition, "NI" indicates no inhibition,
"**" indicates standard antibiotic, "dw" means dry weight

dimesylate (**7**) led us to assign the structure of the compound as 3,5-di-*O*-benzoyl-1,2-*O*-isopropylidene-6-*O*-lauroyl-α-D-*gluco*-1,4-furanose (**8**).

Antimicrobial activities: The *in vitro* inhibition zone against four Gram-positive and six Gram-negative bacteria due to the effect of the glucofuranose derivatives (**3-8**) are mentioned in Table 1. It was found from Table 1 that bisacetone D-glucose **3** and triol **4** were inactive against all the tested bacteria. It was observed that the lauroylated glucofuranose derivatives (**5-8**) were more effective against Gram-positive organisms than that of the Gram-negative pathogens. Diacetate **6** and dibenzoate **8** exhibited marked inhibition against *S. aureus* and *E. coli* which were comparable to that of standard antibacterial antibiotic kanamycin.

The *in vitro* percentage inhibition results of mycelial growth of seven plant pathogenic fungi due to the effect of glucofuranose derivatives (**3-8**) are mentioned in Table 2. All the lauroylated glucofuranoses (**5-8**) were found potential against the tested fungal pathogens. Bisacetone D-glucose **3** and triol **4** were found to be inactive against the tested fungi.

Structure activity relationship (SAR): It was evident from Table 1 and Table 2 that incorporation of lauroyl group increased the antimicrobial potentiality of glucofuranose **4**. Again, these 6-*O*-lauroyl glucofuranose derivatives (**5-8**) were more active against fungal pathogens than that of bacterial organisms. An important observation was that, compounds **3** and **4** showed poor toxicity than that of compounds **5-8** against these pathogens. This is probably due to the presence of more hydroxyl groups in **3** and **4**. While compounds **5-8** having fewer or no hydroxyl groups showed much better antimicrobial potentiality. Here the hydrophobicity of the molecules increased gradually from compound **2-3** to **5-8**. The hydrophobicity of materials is an important parameter with respect to such bioactivity as toxicity or alteration of membrane integrity, because it is directly related to membrane permeation [18]. Hunt [19] also proposed that the potency of aliphatic alcohols is directly related to their lipid solubility through the hydrophobic interaction between alkyl chains from alcohols and lipid regions in the membrane. We believe that a similar hydrophobic interaction might occur between the acyl chains of glucofuranoses accumulated in the lipid like nature of the bacteria membranes. As a consequence of their hydrophobic interaction, bacteria lose their membrane permeability, ultimately causing

Table 2. Antifungal activities of the glucofuranose derivatives (**3-8**).

Name of fungus	% inhibition of fungal mycelial growth, sample 100 µg.dw./ml PDA						
	3	**4**	**5**	**6**	**7**	**8**	**Fluconazole
Aspergillus acheraccus	NI	NI	30	48	52	53	58
Aspergillus flavus	NI	NI	48	56	52	58	*62
Aspergillus fumigatus	NI	NI	40	50	46	51	*70
Aspergillus niger	NI	NI	35	42	42	48	58
Aspergillus nodusus	NI	NI	47	53	51	55	*64
Candida albicans	NI	NI	29	58	NI	NI	*60
Fuserium equiseti	NI	NI	36	48	NI	45	*65

"*" shows good inhibition, "NI" indicates no inhibition,
"**" indicates standard antibiotic, "dw" means dry weight

death of the bacteria [18-20].

Previously we observed that, due to the slight distortion of furanose ring in the presence of 1,2-*O*-isopropylidene ring [7], acetylated sugars with five-membered furanose form were less effective against both Gram-negative, Gram-positive and fungal pathogens than that of the corresponding acetylated sugars with six-membered pyranose form. It was observed from Table 1 and Table 2 that 6-*O*-lauroate (**5**) and its 3,5-di-*O*-aceatae (**6**) and 3,5-di-*O*-benzoate (**8**) exhibited good activity against both bacterial and fungal pathogens which was, in some cases, similar to that of the standard antibiotics. This led us to conclude that incorporation of 6-*O*-lauroyl group in glucofuranose frame work along with 3,5-di-*O*-acetyl or 3,5-di-*O*-benzoyl group increased the antimicrobial potentiality of the glucofuranose **4**.

Conclusion

Thus, 6-*O*-lauroyl derivative (**5**) of glucofuranose **4** was synthesized successfully in reasonably good yield from D-glucose in just three steps. To get newer derivatives of biological importance three 2,3-di-*O*-acyl substituted derivatives (**6-8**) of **5** were also prepared. All the glucofuranose derivatives (**3-8**) were employed as test chemicals for *in vitro* antibacterial and antifungal functionality test against ten human pathogenic bacteria and seven fungi. The structure activity relationship (SAR) study revealed that incorporation of 6-*O*-lauroyl group in glucofuranose frame work along with 3,5-di-*O*-acetyl or 3,5-di-*O*-benzoyl groups increased the antimicrobial potentiality of the glucofuranose **4**.

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References

1. Y. Tsuda, M. E. Haque, K. Yoshimoto, *Chem. Pharm. Bull.* (Japan), **1983**, *31*(5), 1612-1624.
2. K. Yoshimoto, Y. Itatani, K. Shibata, Y. Tsuda, *Chem. Pharm. Bull.* (Japan), **1980**, *28*(1), 208-219.
3. M. M. Matin, M. Ibrahim, *J. Appli. Sci. Res.*, **2010**, *6*(10), 1527-1532.
4. C. Andry, C. Wylde, C. Laffite, G. Privat, I. Winternitz, *Phytochem.*, **1982**, *21*, 1123-1127.
5. R. Gupta, S. Paul, A. K. Gupta, P. L. Kachroo, S. Bani, *Indian J. Chem.,* **1997**, *36B*, 707-710.
6. M. M. Matin, *Orbital: Electron. J. Chem.*, **2014**, *6*(1), 20-28.
7. M. M. Matin, M. M. H. Bhuiyan, A. K. M. S. Azad, *RGUHS J. Pharm. Sci*., **2013**, *3*(1), 53-59.
8. M. M. Matin, M. M. H. Bhuiyan, D. C. Debnath, M. A. Manchur, *Int. J. Biosci.*, **2013**, *3*(8), 279-287.
9. G. Catelani, F. Osti, N. Bianchi, M. C. Bergonzi, F. D'Andrea, R. Gambari, *Bioorg. Med. Chem. Lett*., **1999**, *9*(21), 3153-3158.
10. T. Kobayashi, T. Ehara, T. Mizuoka, S. Adachi, *Biotechnol. Lett.*, **2010**, *32*(11), 1679-1684.
11. K. S. Devulapalle, A. G. de Segura, M. Ferrer, M. Alcalde, G. Mooser, F. J. Plou, *Carbohydr. Res.*, **2004**, *339*, 1029-1034.
12. A. Smith, P. Nobmann, G. Henehan, P. Bourke, J. Dunne, *Carbohydr. Res.*, **2008**, *343*(15), 2557-2566.
13. T. Watanabe, S. Katayama, M. Matsubara, Y. Honda, M. Kuwahara, *Curr. Microbiol.*, **2000**, *41*, 210-213.
14. B. S. Furniss, A. J. Hannaford, P. W. G. Smith, A. R. Tatchell, *Vogel's Text Book of Practical Organic Chemistry*, Addision Wesley Longman Limited, England, **1996**, *5*, 654.
15. R. E. Gramera, A. Park, R. L. Whistler, *J. Org. Chem.*, **1963**, *28*(11), 3230-3231.
16. A. W. Bauer, W. M. M. Kirby, J. C. Sherris, M. Turck, *Am. J. Clin. Pathol.,* **1966**, *45*(4), 493-496.
17. R. K. Grover, J. D. Moore, *Phytopathol.,* **1962**, *52*, 876-

880.

18. Y. M. Kim, S. Farrah, R. H. Baney, *Int. J. Antimicrob. Agents*, **2007**, *29*(2), 217-222.
19. W. A. Hunt, *Adv. Exp. Med. Biol.,* **1975**, *56*, 195-210.
20. V. Judge, B. Narasimhan, M. Ahuja, D. Sriram, P. Yogeeswari, E. D. Clercq, C. Pannecouque, J. Balzarini, *Med. Chem*., **2013**, *9*(1), 53-76.