Synthesis, Anticancer and Antibacterial Activity of Mannose-based bis-1,2,3-Triazole Derivatives

Lamyaa Salih Mahdi1,2, Adnan Ibrahim Mohammed3, Majed Jari Mohammed4

1Department of Chemistry, Faculty of Science, University of Kufa, Kufa, Iraq 2Department of Pharmacognosy and Medicinal Plant, College of Pharmacy, University of Kerbala, Karbala, Iraq 3Department of Chemistry, College of Science, University of Kerbala, Karbala, Iraq

Abstract: In the current work, aromatic amines and alkyl halides have been converted to the corresponding azides 2a–d and 4a–d by the reaction with sodium nitrite and sodium azide respectively for amines and sodium azide for halides. Then, dipropargyl ether derivative of D-mannose 8 has been synthesized from diacetone mannose that has been obtained by the treatment of D-mannose (5) with dry acetone in the presence of sulfuric acid. Then, aldol condensation has been used to prepare diol 7 from the mannose diacetonide 6. The reaction of compound 7 with propargyl bromide in alkaline media has been afforded dipropargyl derivative 8. In a parallel step, both dialkyne with aromatic and aliphatic azide have been coupled to produce 1,2,3-triazole derivatives 9a–d in the presence of Cu(I) salts. All synthesized compounds have been characterized by 1D and 2D NMR spectra alongside with HRMS data. The antibacterial activity against both gram-positive and gram-negative has been tested. Moreover, the anticancer activity has also been evaluated against AMJ13 cell line.

Keywords: Antibacterial activity, Anticancer activity, Bis-1,2,3-triazoles, Breast cancer, CuAAC, D-Mannose, Propargyl derivatives.

Introduction: Cancer has life serious threats to global health that causes one out of six life losses in the world.1 The triazoles derivatives revealed extensively anti-proliferative potency against human prostate,2 breast,3 liver,4 lung,5 bladder6 and other cancer cells, in drug discovery. Mimicking glycosides, Nerella and co-workers7 built new1,2,3-triazoles based on carbohydrate molecule that have notable anticancer activity against breast and prostate cancer cell lines. Recently, Oubella et al.8 synthesized series of novel (R)-Carvone-based 1,4-disubstituted 1,2,3-triazoles via regioselective copper (I)- catalyzed alkyne-azole click methodology. The hybrids Carvone triazoles in vitro evaluated the anticancer activity against breast adenocarcinoma (MCF-7) and MDA-MB-231), (HT-1080) and fibro sarcoma (A-549) lung carcinoma, cell line. On the other hand, Covid-19 is the most life-threatening disease to global health till now.9 The widely fast spread and aggressive symptoms caused by the crown virus results in tremendous economic loss and mortality during the pandemic. The significant heterocyclic azole compounds have a potential role as antimicrobial10,11 and enzyme inhibitors motivated many researchers to improve pharmaceutically active 1,2,3-triazoles scaffolds.12 The recent in silico studies were confirmed by Holanda et al.,13 that the phthalimide-based 1,2,3-triazoles derivatives were prepared via click are promising drug for COVID-19 treatment as the ability to disrupt virus spike, nucleocapsid or protease proteins. Also, many 1,2,3-triazole derivatives as FDA-approved drugs have exerted their pharmacological activities such as the antibacterial; tazobactam,14 antibiotic; ceftrazine,15 anticancer; Carboxyamido-triazole (CAI),16 anti-HIV; TSAO,17 and anti-Alzheimer; MTSMDL treatment.18 1,2,3-triazole employed superior antimicrobial,19
antifungal, antioxidant and cytotoxic activities. Collections of glycoconjugated 1,2,3-triazoles derivatives from different sugars functionalized with alkyne or azide moieties have been synthesized via CuAAC-click reaction and their antibacterial were evaluated. Many factors improve the 1,2,3-triazoles biological value such as physical and chemical properties, high stability against oxidant agent, hydrolysis resistant in acid/base conditions, the hydrogen bonds forming and amide bioisosteres. As a result of the special physicochemical properties, 1,2,3-triazole derivatives played a versatile role in the material sciences. Anti-corrosions, polymers, dyes, catalysts, ligands, surfactants, chemo sensors for different species. Click strategies is the concept introduced by Sharpless and Meldal in 2002 to design and synthesize wide scope of 1,2,3-triazoles scaffold molecules. The 1,3-dipolar cycloaddition reaction of terminal alkynes and azide catalyzed by Cu(I) CuAAC afforded regioselective 1,4-disubstituted -1,2,3-triazoles in high yield, stereoselective, easily removable by-products, simplicity and green of click protocol. In this work, novel bis-1,2,3-triazole derivatives have been synthesized starting from D-mannose and their structural properties were studied. They also have been examined against bacteria and breast cancer.

**Material and Methods:**

**General Information**

Chemicals were gained from Sigma-Aldrich and Alfa Aesar Chemicals. Infrared spectra were obtained using SHIMADZU 2001 FT-IR. NMR spectra were verified using 600 MHz, Bruker DPX spectrometers, NMR assignments of the synthesized compounds supported by COSY and HSQC. Orbit rap LTQ XL ion trap MS in positive ion mode using electrospray ionization (ESI) source was employed to assemble HRMS. Silica TLC plates were used with an aluminum backing (0.2 mm, 60 F254). The reactions were monitored by TLC and envisioned by development of the TLC plates with an alkaline potassium permanganate solution dip. AMJ13 Cells have been provided by Iraqi Center for Genetics and Cancer Research ICGCR/ Mustansiriyah University -Baghdad / Iraq.

**Synthesis of 2-(Hydroxymethyl)-2,3:5,6-di-O-isopropylidene-D-mannofuranose (7)**

2,3,5,6-Di-O-isopropylidene-α-D-mannofuranose (6) (5 g, 18.5 mmol) was added to MeOH (25 mL) and the mixture was stirred for a while until diacetonide 2 was fully dissolved. Potassium carbonate (16 g, 115.7 mmol) was added and the mixture was stirred at 80 °C in an oil bath to give a milky suspension. Commercially available 37% formaldehyde (formalin, 17 mL) was introduced and the mixture was stirred at 90 °C (reflux began) for 15 min. Two portions of KOH (pellets, 0.52 g, 9.27 mmol) were over 15 minutes with continues stirring. Reflux and stirring was continued at 90 °C for 35 minutes and a third portion of KOH (0.52 g, 9.27 mmol) was added. The mixture was stirred/refluxed for another 35 minutes. After which, the heating bath was removed and cooled in an ice-water bath. All solids were filtered off and the filtrate was cooled in an ice-water bath and neutralized withaq. (10%) H2SO4 (10–15 mL). The MeOH in the filtrate was removed by rotary evaporation and the residue was extracted with CH2Cl2 (3 × 90 mL). The combined organic layers were washed with sat. NaCl solution (50 mL) and dried over anhydrous Na2SO4. The organic layers were concentrated under vacuum and the residue was purified by column chromatography (n-hexane / EtOAc; 2:1) on silica gel (mesh 60) to compound 7 as a ca. 2:1 mixture of two epimers colorless waxy which was solidified to white solid (4.2 g, 78%). M.p. 86–89 °C (lit87 a colourless oil). [α]D 25 +10.7 (c 1.0, MeOH). Rf = 0.52 (EtOAc). FT-IR(KBr) cm−1: 3451, 3312, 2988, 2943, 2891, 1458, 1414, 1377, 1240, 1067, 1032. 1H NMR (600 MHz, CDCl3) δ ppm: 5.37 (1H, s, H-1A), 4.90 (1H, s, H-
Synthesis of 2-C-(Hydroxymethyl)-2,3:5,6-di-O-isopropylidene-D-mannofuranose Dipropargyl Ether (8)³⁴,⁵¹

Crushed NaOH (0.96 g, 24 mmol) was added to the solution of dial 7 (1.74 g, 6 mmol) in DMF (30 mL). The reaction flask was kept in ice-salt bath at −20 °C and the contents stirred for (10 minutes) before propargyl bromide (1.52 mL, 17.08 mmol) was added dropwise. The reaction mixture was then allowed to warm to r.t. and stirred for further 24 hours. The reaction mixture was quenched with distilled water (60 mL) and extracted with Et₂O (3 × 50 mL). The combined organic dried over Na₂SO₄, filtered and the solvent was evaporated to the dryness under reduced pressure to further 24 hours. The reaction mixture was added to the solution of diol 29 (1.74 g, 6 mmol) in Et₂O (8). After the reaction mixture stirring for 60 minutes, anhydrous NaN₃ (2 × 100 mL), water (150 mL) dried with Na₂SO₄ and evaporated to gain aryl azides (2 × 100 mL), water (150 mL) was added to the reaction mixture and extracted with Et₂O (3 × 100 mL), the organic layers were collected, washed with brine solution (2 × 100 mL), water (150 mL) dried with Na₂SO₄ and evaporated to gain n-alkyl azides (2a and 2b) as a colorless liquid.

General Synthesis Procedure for n-alkyl Azide (2a and 2b)²⁴

A solution of n-alkyl halide (48 mmol) in DMF (70 mL) was stirred with sodium azide (9.44 g, 145mmol) at 70 °C for (6 hours), then distilled water (100 mL) was added to the reaction mixture and extracted with Et₂O (3 × 100 mL), the organic layers were collected, washed with brine solution (2 × 100 mL), water (150 mL) dried with Na₂SO₄ and evaporated to gain n-alkyl azides (2a and 2b) as a colorless liquid.

n-Decyl azide (2a) Colorless liquid (9.52 g, 89%) Rf = 0.8 (EtOAc). FT-IR (neat): 2928, 2854, 2094, 1462, 1373, 1257, 1051, 895, 723 cm⁻¹. ¹H NMR (600 MHz, CDCl₃) δ ppm: 3.25 (t, J = 7.2 Hz, 2H, H1), 1.59 (quin, J = 7.2 Hz, 2H, H2), 1.38–1.29 (m, 14H, H3–9), 0.88 (t, J = 6.6 Hz 3H, H10). ¹³C NMR (150 MHz, CDCl₃) δ ppm: 51.6 (C1), 32.0 (C2), 29.6 (2 × C, C3, C4), 29.4 (C5), 29.3 (C6), 29.0 (C7), 26.9 (C8), 22.8 (C9), 14.2 (C10).

n-Decyl azide (2b) Colorless liquid (8.62 g, 85%). Rf = 0.57 (EtOAc), FT-IR (neat): 2926, 2854, 2094, 1462, 1348, 1259, 1128, 895, 723, 557 cm⁻¹. ¹H NMR (600 MHz, CDCl₃) δ ppm: 3.25 (t, J = 7.2 Hz 2H, H1), 1.59 (quin, J = 7.2 Hz 2H, H2), 1.37–1.27 (m, 18H, H3–11), 0.86 (t, J = 7.2, 3H, H12). ¹³C NMR (150 MHz, CDCl₃) δ ppm: 51.6 (C1), 32.1 (C2), 29.8 (C3), 29.7 (C4), 29.6 (C5), 29.5 (C6), 29.3 (C7), 29.0 (C8), 228.9 (C9), 26.7 (C10), 22.8 (C11), 14.2 (C12).

General Synthesis Procedure for Aryl Azide 4a and 4b²²

Aryl amine (2mml) was added to a solution of p-TsOH.H₂O (3.24 g, 18.0 mmol) in H₂O (18.0 mL) and stirred for 1 minute. Anhydrous NaNO₂ (1.24 g, 18 mmol) was added portion-wise during 5 min. After the reaction mixture stirring for 60 minutes, anhydrous Na₃N (0.208 g, 3.2 mmol) was added. The solid aryl azide was filtered, washed with dist. water (100 mL) then dried to gain aryl azides 6c as pale yellow solid 65–69 °C and 6d as white solid 57–59 °C.

p-Azido nitrobenzene (4a): Pale yellow solid (0.30 g, 92%), 65–69 °C. Rf = 0.79 (EtOAc), FT-IR (KBr): 3105, 3072, 2114, 1680, 1599, 1514, 1342, 1286, 1182, 1116, 852, 744, 690, 559, 434 cm⁻¹.

1-Azido-2, 4-dichloro benzene (4b): White solid (0.30 g, 92%), 60–64 °C, Rf = 0.80 (EtOAc), FT-IR
(KBr): 3057, 2915, 1575, 1475, 1435, 1301, 1145, 1097, 1049, 798, 759, 592, 565, 401 cm\(^{-1}\).\(^{1}\) H NMR (600 MHz, CDCl\(_3\)) \(\delta\) ppm: 7.83–7.09 (3H, H-aromatic).\(^{13}\)C NMR (150 MHz, CDCl\(_3\)) \(\delta\) ppm: 136.2, 130.7, 130.6, 128.2, 125.9, 120.5 (6C, C-aromatic).

**General Synthesis Procedure for 2-C-(Oxymethyl)-2,3,5,6-di-O-isopropylidene-D-mannofuranose bis-O-[(1-alkyl-1H-1,2,3-triazol-4-yl)methyl]ether (9a–d)**

The dipropargyl ether 4 (0.366 g, 1 mmol) was dissolved in DMSO (3 mL) and added to a suspension of sodium ascorbate (0.0396 g, 0.2 mmol) and CuSO\(_4\).5H\(_2\)O (0.025g, 0.01 mmol) in DMSO (2 mL), then the reaction mixture was stirred for 2 minutes at room temperature. The azide (2.1 mmol) was added, and the mixture was heated to 60 °C for 48 hours, the reaction mixture was diluted with dist. water (10 mL), then extracted with EtOAc (3 × 25mL), the organic layers were collected, washed with brine solution (25mL), dried with Na\(_2\)SO\(_4\) and evaporated to afford compounds 9a and 9b as white waxy and compounds 9c and 9d as solid. All synthesized compounds were purified under column chromatography (silica gel, n-hexane / EtOAc; 2:1 → 1:2) to yield the corresponding bis-1,2,3-triazole.

2-C-(Oxymethyl)-2,3,5,6-di-O-isopropylidene-D-mannofuranose bis-O-[(1-decyl-1H-1,2,3-triazol-4-yl)methyl]ether (9a)

White solid (0.59 g, 80.5%); mp 50–53 °C, Rf = 0.56 (EtOAc), IR (KBr): 3136, 2926, 2854, 1462, 1375, 1217, 1136,1070, 848, 785, 723, 669, 511 cm\(^{-1}\).\(^{1}\) H NMR (600 MHz, CDCl\(_3\)) \(\delta\) ppm: 7.63 (s, 1H, H triazole), 7.57 (s, 1H, H triazole), 5.03 (s, 1H, H-1), 4.75 (d, J = 12.7 Hz, 1H, −O−C−C−triazole), 4.70 (d, J = 12.2 Hz, 1H, −O−C−C−triazole), 4.66 (d, J = 12.3 Hz, 1H, −O−C−C−triazole), 4.65 (d, J = 12.7 Hz, 1H, −O−C−C−triazole), 4.51 (d, J = 3.1 Hz, 1H, H-3), 4.39 (ddd, J = 8.1, 6.2, 4.2 Hz, 1H, H-5), 3.43–4.30 (m, 4H, −CH\(_2\)−triazole), 4.10 (dd, J = 8.7, 6.4 Hz, 1H, H-6a), 3.98 (dd, J = 8.8, 4.3 Hz, 1H, H-6b), 3.89 (dd, J = 8.3, 3.1 Hz, 1H, H-4), 3.79 (d, J = 10.6 Hz, 1H, −CH\(_2\)O), 3.76 (d, J = 10.6 Hz, 1H, −CH\(_2\)O), 1.92–1.85 (m, 4H, −CH\(_2\)−alkyl), 1.44 (s, 3H, −C(CH\(_3\))\(_2\)), 1.43 (s, 3H, −C(CH\(_3\))\(_2\)), 1.30 (s, 3H, −C(CH\(_3\))\(_2\)), 1.30 (s, 3H, −C(CH\(_3\))\(_2\)), 1.31–1.24 (m, 28H, −CH\(_2\)−alkyl), 0.86 (t, J = 6.9 Hz, 6H, −CH\(_3\)−alkyl).\(^{13}\)C NMR (150 MHz, CDCl\(_3\)) \(\delta\) ppm: 145.0 (C triazole), 144.3 (C triazole), 122.8 (C triazole), 122.7 (C triazole), 114.4 (−C(CH\(_3\))\(_2\)), 109.4 (−C(CH\(_3\))\(_2\)), 106.7 (C-1), 80.6 (C-4), 73.0 (C-5), 69.8 (−CH\(_2\)O), 67.1 (C-6), 65.5 (−O−CH\(_2\)−triazole), 61.1 (−O−CH\(_2\)−triazole), 50.5 (C alkyl), 50.46 (C alkyl), 31.9 (C alkyl), 30.4 (C alkyl), 29.6 (C alkyl), 29.52 (C alkyl), 29.5 (C alkyl), 29.4 (C alkyl), 29.1 (C alkyl), 27.8, 27.7, 27.1, 26.7 (4 × (−C(CH\(_3\))\(_2\))), 26.6 (C alkyl), 25.3 (C alkyl), 22.8 (C alkyl), 14.2 (C alkyl). HRMS-ESI [M + Na]\(^{+}\) calculated for C\(_{38}\)H\(_{43}\)N\(_4\)O\(_5\): 866.58; found: 866.58.

2-C-(Oxymethyl)-2,3,5,6-di-O-isopropylidene-D-mannofuranose bis-O-[(1-p-nitro phenyl)-1H-1,2,3-triazol-4-yl)methyl]ether (9c)

Yellow solid (0.43 g, 87%); mp 97–100°C, Rf = 0.65 (EtOAc), IR (KBr): 3138, 3093, 2978, 2931, 2874, 1600, 1527, 1458, 1375, 1344, 1234, 1111, 1022, 887, 845, 750, 686, 509 cm\(^{-1}\).\(^{1}\) H NMR (600 MHz, CDCl\(_3\)) \(\delta\) ppm: 8.40 (d, J = 8.9 Hz, 2H, Ar-H), 8.39 (d, J = 8.9 Hz, 2H, Ar-H), 8.38 (s, 1H, H triazole), 8.30 (s, 1H, H triazole), 5.10 (s, 1H, H-1), 4.87 (d, J = 13.2 Hz, 1H, −O−C−C−triazole), 4.85 (d, J = 12.7 Hz, 1H, −O−C−C−triazole), 4.78 (d, J = 13.0 Hz, 1H, −O−C−C−triazole), 4.75 (d, J
= 12.3 Hz, 1H, –O–CH2–triazole), 4.51 (d, J = 3.1 Hz, 1H, H-3), 4.43 (ddd, J = 8.1, 6.1, 4.2 Hz, 1H, H-5), 4.13 (dd, J = 8.7, 6.3 Hz, 1H, H-6a), 4.03 (dd, J = 8.7, 4.3 Hz, 1H, H-6b), 3.96 (dd, J = 7.9, 3.0 Hz, 1H, H-4), 3.94 (d, J = 10.5 Hz, 1H, –CH(O)), 3.86 (d, J = 10.5 Hz, 1H, –CH(O)), 1.48 (s, 3H, –C(CH3)2), 1.44 (s, 3H, –C(CH3)2), 1.42 (s, 3H, –C(CH3)2), 1.37 (s, 3H, –C(CH3)2). 13C NMR (150 MHz, CDCl3) δ ppm: 147.4 (ArC), 147.3 (ArC), 146.5 (C triazole), 146.0 (C triazole), 141.2 (ArC), 141.16 (ArC), 125.7 (ArC), 125.7 (ArC), 121.5 (C triazole), 121.4 (C triazole), 120.7 (ArC), 120.6 (ArC), 114.6 (–C(CH3)2), 109.5 (–C(CH3)2), 106.6 (C-1), 94.4 (C-2), 82.7 (C-3), 80.7 (C-4), 73.0 (C-5), 70.6 (–CH2O), 67.0 (–O), 65.1 (–O–CH2–triazole), 60.6 (–O–CH2–triazole), 27.9, 27.6, 27.1, 25.3 (4 × (–C(CH3)2)). HRMS-ESI [M + Na]+ calculated for C31H32N6O11Na: 717.2239; found: 717.2239.

2-C-(Oxymethyl)-2,3:5,6-di-O-isopropylidene-D-mannofuranose bis-O-[(1-(2,4-dichloro phenyl)-1H,1,3-triazol-4-yl)methyl]ether (9d).

White solid (0.43 g, 87%); mp 71–75°C; Rf = 0.56 (EtOAc), IR (KBr): 3142, 3091, 2987, 1761, 1648, 1498, 1456, 1375, 1242, 1107, 1031, 817, 648, 509, 401 cm−1. 1H NMR (600 MHz, CDCl3) δ ppm: 8.05 (s, 1H, H triazole), 7.99 (s, 1H, H triazole), 7.56 (d, J = 8.5 Hz, 1H, Ar–H), 7.55 (t, J = 1.8 Hz, 2H, Ar–H), 7.51 (d, J = 8.6 Hz, 1H, Ar–H), 7.40 (dd, J = 8.6, 2.2 Hz, 2H, Ar–H), 5.10 (s, 1H, H-1), 4.86 (d, J = 12.8 Hz, 1H, –O–CH2–triazole), 4.80 (d, J = 12.5 Hz, 1H, –O–CH2–triazole), 4.76 (d, J = 12.3 Hz, 1H, –O–CH2–triazole), 4.75 (d, J = 12.7 Hz, 1H, –O–CH2–triazole), 4.55 (d, J = 3.1 Hz, 1H, H-3), 4.40 (ddd, J = 8.2, 6.2, 4.1 Hz, 1H, H-5), 4.10 (dd, J = 8.8, 6.4 Hz, 1H, H-6a), 3.99 (dd, J = 8.8, 4.2 Hz, 1H, H-6b), 3.93 (dd, J = 8.0, 3.0 Hz, 1H, H-4), 3.88 (d, J = 10.7 Hz, 1H, –CH2O), 3.84 (d, J = 10.7 Hz, 1H, –CH2O), 1.45 (s, 3H, –C(CH3)2), 1.42 (s, 3H, –C(CH3)2), 1.40 (s, 3H, –C(CH3)2), 1.35 (s, 3H, –C(CH3)2). 13C NMR (150 MHz, CDCl3) δ ppm: 141.5 (C triazole), 144.5 (C triazole), 136.3 (ArC), 133.6 (ArC), 130.7 (ArC), 130.6 (ArC), 129.5 (ArC), 129.4 (ArC), 128.7 (ArC), 128.5 (ArC), 128.4 (ArC), 128.35 (ArC), 124.9 (C triazole), 124.8 (C triazole), 114.5 (–C(CH3)2), 109.4 (–C(CH3)2), 107.1 (C-1), 94.5 (C-2), 82.6 (C-3), 80.8 (C-4), 73.0 (C-5), 69.9 (–CH2O), 67.1 (C-6), 65.3 (–O–CH2–triazole), 60.9 (–O–CH2–triazole), 27.8, 27.7, 27.0, 25.3 (4 × (–C(CH3)2)). HRMS-ESI [M + Na]+ calculated for C31H32Cl3N6O7Na: 866.5746; found: 866.5746.

Biological Activities:

Anticancer Activity

Maintenance of Cell Cultures

AMJ13 Cells were maintained in RPMI-1640 supplemented with 10% fetal bovine serum, 100 units/mL penicillin and 10µg/mL streptomycin. Cells were passaged using Trypsin-EDTA reseeded at 80% confluence twice a week, and incubated at 37 °C.44

Cytotoxicity Assays

To determine the cytotoxic effect of compounds 9a and 9b, the MTT assay was done using 96-well plates.45 Cell line was seeded at 1 × 96 cells/well. After 24 hours or a confluent monolayer was achieved, cells were treated with compounds 9a and 9b different concentrations (6.25 μg/mL–400 μg/mL). Cell viability was measured after 24, 48, and 72 hours of treatment by removing the medium, adding 28 μL of 2 mg/mL solution of MTT and incubating the cells for 2.5 hours at 37 °C. After removing the MTT solution, the crystals remaining in the wells were solubilized by the addition of 130 μL of DMSO (Dimethyl Sulphoxide) followed by 37 °C incubation for 15 minutes with shaking.46 The absorbency was determined on a micro plate reader at 492 nm; the assay was performed in triplicate. The inhibition rate of cell growth (the percentage of cytotoxicity) was calculated as the following equation:47

The rate of Inhibition = A – A × 100

Where A is the optical density of control, and B is the optical density of the samples.48

To visualize the shape of the cells under an inverted microscope, the cells were seeded into 24-well micro-titration plates at a density of 1×105 cells mL−1 and incubated for 24 hours at 37 °C. Then, cells were exposed to 9a and 9b for 24 hours. After the exposure time, the plates were stained with crystal violet stain and incubated at 37 °C for 10–15 minutes. The stain was washed off gently with tap water until the dye was completely removed. The cells were observed under an inverted microscope at 100× magnification and the images were captured with a digital camera attached to the microscope.49

Statistical Analysis:

The obtained data were statically analyzed using an unpaired t-test with GraphPad Prism 6.50 The values were presented as the mean ± SD of triplicate measurements.51

Antibacterial Activity

For assessing the antibacterial activity of the prepared compounds 9a–d, bacterial suspension
was prepared by transferring 2-3 colonies with the same phenotypic characteristics growing on the Nutrient Agar medium to tubes containing the crystalline saline solution. The tubes were compared with a 0.5 McFarland standard, which gives an approximate number of cells to 1.5 × 10^8 colony/mL. The inhibitory efficacy of the prepared compounds with concentrations (50, 100, 200, 400) μg/mL were tested against Gram positive bacteria *S. aureus* and Gram negative bacteria *E. coli* according to the agar gel diffusion method. 0.1 mL of the bacterial suspension was added and spread to the Muller Hinton agar plates by cotton swab and leave the plates for drying at 37 °C for 30 minutes followed by punching wells of 6 mm with the help of a sterile crock borer in appropriate diameter(6) mm under aseptic condition. DMSO and control DMSO 60 μL of each concentration were placed in the labeled wells respectively then incubated in the incubator at 37 °C for 24 hours and the inhibition zone of bacteria (mm) was measured. The antibiogram sensitivity of these bacteria were tested using Levofloxacin, Amoxicillin clavulanic acid, Amikacin and Ciprofloxacin.

**Result and Discussion:**

**Synthesis and Characterization:**

The general route of the synthesis is shown in Scheme (1). In the first step, D-mannose (5) was treated with dry acetone in the presence of concentrated sulfuric acid at room temperature for 4 hours to yield a mixture of α and β-isomers of 2,3:5,6-di-O-isopropylidene-D-mannofuranose (6) in a good yield 75%. The significant stretching bands of FT-IR spectrum showed at ν 3437 cm⁻¹ (O−H), 2985 cm⁻¹ and 2906 cm⁻¹ for aliphatic (C−H). ¹H NMR spectrum verified signals of α and β anomer and the ration of α anomer is the predominant. Four singlets appeared at 1.46 ppm, 1.45 ppm, 1.37 ppm and 1.32 ppm is a good proof of two isopropylidene group formation. ¹³C NMR also afforded another evidence of the formation of compound 6 by the appearance of six signals at 112.8 ppm, 109.2 ppm, 27.0 ppm, 26.0 ppm, 25.3 ppm and 24.6 ppm corresponding to two isopropylidene protecting groups. Also, a base peak assigned at 283.1152 assigned to the suggested formula. Secondly, 2C-(hydroxyl methyl)-2,3:5,6-di-O-isopropylidene-D-mannofuranose (7) was synthesized via aldol condensation of compound 6 with aq. formaldehyde in the presence of K₂CO₃ and excess of KOH to gain in approximately high yield 80%. This protocol was developed by Tan et al., 2016 who reported a new extension of work to gain the branched sugar with quaternary center generating transformation and solved the mysterious retardation attributed to previous work introduced by Ho 1979⁹⁸, the formation of formic acid by a Cannizzaro reaction led to lower the basicity of this reaction. The excess amount of KOH was successfully accelerated the condensation and shorted the reaction time from 48 hours to 100 min in addition to consume the starting materials completely as well as the isolation / purification became easier. FT-IR spectrum of compound 7 afforded good evidence as two hydroxyl groups appeared at ν 3450 cm⁻¹ and 3311 cm⁻¹. Two epimers A and B were detected in the 1H NMR spectrum in 2:1 ratio. The most important evidence of the formation of compound 6 is the appearance of four at δ 3.98 ppm, 3.85 ppm, 3.79 ppm and 3.76 ppm corresponding to (CH2OH) of two epimers A and B in addition to the disappearance of H-2 signal at 4.61 ppm. The formation of diol 7 is also approved by ¹³C NMR when a signal appeared at 63.8 ppm and 62.9 ppm attributed to the extra branched carbon of two epimers. Subsequently, Williamson etherification of the sugar diols were carried to gain dipropargyl ether 8 by using propargyl bromide and NaOH as heterogeneous catalysts in DMF under Sn2 conditions to give compound 4 in a moderate yield 60%. The formation of compound 4 was investigated by FT-IR as hydroxyl bands disappeared and both acetylenic proton and triple bond bands were assigned at 3286 cm⁻¹ and 2117 cm⁻¹ respectively. The attachment of the propargyl moieties to the sugar derivative was assigned by the appearance of two new doublet of doublet at 4.28 ppm and 4.21 ppm attributed to two protons of the methylene of the anomeric propargyl. However, the methylene group of the propargyl attached the position 2' appeared as a doublet with J = 2.4 Hz. Furthermore, a multiplet centered at 2.41 ppm corresponding to two terminal alkyne protons was also observed in ¹H NMR spectrum (Fig. 1). The two propargyls were also assigned by the appearance of six new signals at 79.7 ppm, 79.1 ppm, 74.7 ppm, 74.6 ppm, 59.1 ppm, 54.8 ppm in ¹³C NMR spectrum (Fig. 2). It is important to mention that only one anomer formed after the propargylation of the diol 7 as viewed by the NMR spectra of compound 8 (Figs. 1–4). The formation of compound 8 is confirmed by the appearance of a base peak at m/z 389.1570 corresponding to the formula [M + Na]^+ in HRMS.

In a parallel step, alkyl halides a and b were converted to the corresponding alkyl azides 2a and 2b under Sn2 nucleophilic substitution reaction while the aryl azides 4a and 4b were prepared through direct conversion of the corresponding aryl amines c and d to diazonium salt via one-put...
diazotization with NaNO₂ and p-TsOH in aqueous solution that followed with sodium azide.

The high to excellent yields of the azides 2a and 2b, 4a and 4b about 90% was gained. The significant and strong azide bands of FT-IR spectrum showed around ν 2100 cm⁻¹ (N≡N) for alkyl and aryl azides, and the disappeared of both NH₂ bands in aromatic amines. Proton NMR spectra of compounds 2a and 2b showed the multiplet signals at 1.37‒1.27 ppm attributed to H10′ and H12′-H3′, in addition to signals at 3.3 ppm for H1′ and 1.6 ppm for H2′. Carbon NMR spectra showed 12 and 10 signals for the corresponding compounds 2b and 2a. The compounds 4a and 4b showed a clear signal between 7 to 8 ppm which attributed to the H-aromatic of aryl azides. In addition, the six signals in ¹³C NMR spectra for six C-aromatic provided excellent evidence for azides formation. The following scheme describes the overall synthetic route of the targeted compounds:

\[
\text{Scheme 1. Synthesis of Mannose-based bis-1,2,3-triazoles}
\]

Finally, regioselective ligation between the sugar alkyne 8 as precursor of and the collection of azides 6a-d have been carried out via Cu-catalyzed Azide Alkyne-1,3-dipolarcycloaddition Click reaction to afford the targeted bis-1,2,3-triazoles 9a-d using Cu(I) as catalysts that was produced in situ by treating the CuSO₄·5H₂O with the reducing agent Na ascorbate. Compounds 9a-d were isolated in very good yields 80‒87%. The constructions of these compounds were also confirmed by NMR spectroscopy furthermore to other techniques. Owing to facilitate the detection of NMR spectra, numbering of compounds 9b and c is shown below: Beside the sugar and aromatic azide signals, there was an important singlet at 7.63, 7.57 ppm and 8.38, 8.05 7.99 ppm which clearly referred to the 2H of triazoles for each compounds 9a,b, and 9c,d consequently. In the same way, ¹³C NMR spectra supported the structures of bistriazoles. The signals at 144.3 and 122.7 ppm, for example, were attributed to the 2C of (CH=CN-triazole) of triazole heterocycle 9a, respectively. All assignments of proton and carbon NMR were based on COSY and HSQC. The formation of compounds 9a-d is confirmed by the appearance of a base peak at m/z 755.5041, 811.5660, 717.2230, 765.0956 corresponding to the formula [M + Na]⁺ in HRMS.
Biological Activities:

Anticancer Activity

The cytotoxic effect of compounds 9a and 9b against AMJ13 cells was studied. The anti-proliferative activity of compounds 9a and 9b was tested by studying their ability to inhibit the proliferation of AMJ13 cell line. The results of this study showed there is cytotoxic activity of 9a and 9b compounds against the AMJ13 cell line and the results is concentration dependent manner as shown in Fig. 2 (a and b) as well as in Table 1.

Table 1. Cytotoxic activity of synthesized compounds 9a and 9b against AMJ13 cells

<table>
<thead>
<tr>
<th>Concentration (µg/mL)</th>
<th>Cell viability %</th>
<th>Compound 9a</th>
<th>Compounds 9b</th>
</tr>
</thead>
<tbody>
<tr>
<td>6.25</td>
<td>98.00 ± 0.5774 N=3</td>
<td>98.67</td>
<td>98.67</td>
</tr>
<tr>
<td>12.50</td>
<td>96.67 ± 0.3333 N=3</td>
<td>97.00</td>
<td>97.00</td>
</tr>
<tr>
<td>25.00</td>
<td>90.33 ± 1.856 N=3</td>
<td>91.67</td>
<td>91.67</td>
</tr>
<tr>
<td>50.00</td>
<td>74.33 ± 1.764 N=3</td>
<td>75.33</td>
<td>75.33</td>
</tr>
<tr>
<td>100.00</td>
<td>59.33 ± 2.333 N=3</td>
<td>61.67</td>
<td>61.67</td>
</tr>
<tr>
<td>200.00</td>
<td>52.00 ± 2.646 N=3</td>
<td>54.33</td>
<td>54.33</td>
</tr>
<tr>
<td>400.00</td>
<td>48.33 ± 2.333 N=3</td>
<td>54.67</td>
<td>54.67</td>
</tr>
<tr>
<td>IC50</td>
<td>167.64 µg/mL</td>
<td>171.61 µg/mL</td>
<td></td>
</tr>
</tbody>
</table>

Figure 1. Numbering of compounds 9b and 9c

Figure 2. Cytotoxic effect against AMJ13 cells:
(a) compound 9a (IC50= 167.64 µg/mL); (b) compound 9b (IC50= 171.61 µg/mL)

Figure 3. Morphology of AMJ13 cells (a) Control untreated; (b) treated with compound 9a; (c) treated with compound 9b
Antibacterial Activity:

The antibacterial activity of the prepared bistriazoles 9a–d was verified against pathogenic Gram-positive bacteria *S. aureus* and Gram-negative bacteria *E. coli* via the agar well diffusion method. DMSO was used as control. As shown in Table 2, all compounds 9a–d did not give any activity against Gram-positive bacteria *S. aureus*. In contrast, all the mentioned compounds exhibited moderate to good activity at the concentrations 50–400 µg/mL respectively. On the other hand, compound 9a with C10 in the aliphatic chain and 9c with substituted aryl exhibited maximum antibacterial activity compared to the other measured compounds. The antibacterial activity of bistriazoles 9a–d can be recognized to their performance as glycoconjugate mimics and biosurfactants analogs both asymmetrical structure of the whole molecule or the protein-binding properties.55

<table>
<thead>
<tr>
<th>Table 2. Antibacterial activities of the synthesized compounds 9a–d</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Gram positive bacteria <em>S. aureus</em></strong></td>
</tr>
<tr>
<td>Inhibition Zone in (mm)</td>
</tr>
<tr>
<td>50 µg/mL</td>
</tr>
<tr>
<td>DMSO</td>
</tr>
<tr>
<td>9a</td>
</tr>
<tr>
<td>9b</td>
</tr>
<tr>
<td>9c</td>
</tr>
<tr>
<td>9d</td>
</tr>
<tr>
<td>Ciprofloxacin</td>
</tr>
<tr>
<td>Levofloxacin</td>
</tr>
<tr>
<td>Amoxicillin</td>
</tr>
<tr>
<td>Amikacin</td>
</tr>
</tbody>
</table>

Conclusion:

Four bis-1,2,3-triazole derivatives 9a–9d have been synthesized starting from the readily available monosaccharide (D-Mannose) using convenient reaction conditions particularly the azide-alkyne cycloaddition click reaction. The synthesized compounds were fully identified via modern spectroscopic techniques showing their high purity. These compounds were tested against pathogenic *G*+ bacteria *S. aureus* and *G*– bacteria *E. coli*. All compounds demonstrated no activity against the mentioned types of bacteria. However, compound 9a and 9c demonstrated excellent inhibition zones ~16 mm and 13 mm respectively at concentrations of 50–400 µg/mL. On the other hand, triazole derivatives 9a and 9b were screened against breast cancer AMJ13 cells line and they exhibited remarkable activity IC₅₀ of 167.64 µg/mL 171.61 µg/mL respectively.

Acknowledgment:

The authors express their gratefulness to the staff of Mark Wainwright Analytical Centre, School of Chemistry, The University of New South Wales, Sydney, Australia for the assistance in performing 1D, 2D NMR spectra and HRMS of the synthesized compounds.

Authors’ contributions statement:

L.S.M. contributed to implementation of the research project and writing the manuscript. A.I.M. and M.J.M. contributed to the suggestion of the project idea, interpretation of analytical data and proofreading of research.

Authors’ declaration:

- Conflicts of Interest: None.
- We hereby confirm that all the Figures and Tables in the manuscript are mine ours. Besides, the Figures and images, which are not mine ours, have been given the permission for republication attached with the manuscript.
- Ethical Clearance: The project was approved by the local ethical committee in University of Kufa.

References:


41. Jwad RS. Synthesis of 1-Nonyl-4-{[6-Deoxy-1,2,3,4-Di-O-Isopropylidene-o-D-Galactos-6-yl] oxymethylyl} 1H-1,2,3-Triazole Via Click Chemistry. ANJS. 2011; 14(1): 1–10. Available from: https://doi.org/10.22401/JNUS.14.1.08.


التحضير و الفعالية المضادة للسرطان و البكتيريا لمشتقات ثنائي 3,2,1-تريازول مانوز

لمياء صالح مهدي1
عنوان إبراهيم محمد2
عدنان إبراهيم محمد3
ماجد جاري محمد3

قسم الكيمياء، كلية العلوم، الجامعة الكوفة، العراق
قسم العقاقير والنباتات الطبية، كلية الصيدلة، جامعة كربلاء، كربلاء، العراق
قسم الكيمياء، كلية العلوم، جامعة كربلاء، كربلاء، العراق

الخلاصة:
في العمل الحالي ، تم تحويل هاليدات الألكيل b و الأمينات الأرووماتية 3a−b إلى الأزييدات المقابلة مرة عن مع أزييد الصوديوم في منبج قطبي لا بروتون لتعطي مشتقات الأزييد الأميناتية 2a−b و أخرى عن طريق التفاعل مع نترات الصوديوم ومن ثم أزييد الصوديوم لنتج الأزييدات الأرووماتية 4a−b. و في خروق مشكلة مضادة حمض كبريتيك بوجود أملاح النحاس الأحادية كعامل مساعد. بعد ذلك ، تم استخدام تفاعل النحاس الضارب لتحضير مشتقات 3 من بروباروجيل 8 بدءًا من مشتقات دينوك بروباروجيل 5 لتعطي مشتقات الأزييدات ثلاثية الأليفاتية 2a−b. و في خطوة مقابلة حضر مشتقات ثلاثية بروباروجيل 8 بدءًا من مشتقات دينوك بروباروجيل 5 لتحمل الحمض الكبريتيك بوجود أملاح النحاس الأحادية كعامل مساعد. تم تشخيص جميع المركبات المحضرة النهائية وعدد من المركبات الأولية بتقنيات التفاعلات النحاسية المغناطيسية النموذجية وتفاعل النحاس الأحادي كعامل مساعد. ثم قياس فعالية المركبات المحضرة ضد كل من البكتيريا ونترات الثدي، ونترات المحمولة ونترات الحمضيات الثدي. اعتماداً على ذلك تم قياس فعالية المركبات المحضرة ضد سرطان الثدي (خط خلايا AMJ13).

الكلمات المفتاحية: الفعالية المضادة للبكتيريا، الفعالية المضادة للسرطان، 3,2,1-تريازول مانوز، سرطان الثدي، الإضافة الحلقة المحفزة

الخلاصة:
في العمل الحالي ، تم تحويل هاليدات الألكيل b و الأمينات الأرووماتية 3a−b إلى الأزييدات المقابلة مرة عن مع أزييد الصوديوم في منبج قطبي لا بروتون لتعطي مشتقات الأزييد الأميناتية 2a−b و أخرى عن طريق التفاعل مع نترات الصوديوم ومن ثم أزييد الصوديوم لنتج الأزييدات الأرووماتية 4a−b. و في خروق مشكلة مضادة حمض كبريتيك بوجود أملاح النحاس الأحادية كعامل مساعد. بعد ذلك ، تم استخدام تفاعل النحاس الضارب لتحضير مشتقات 3 من بروباروجيل 8 بدءًا من مشتقات دينوك بروباروجيل 5 لتعطي مشتقات الأزييدات ثلاثية الأليفاتية 2a−b. و في خطوة مقابلة حضر مشتقات ثلاثية بروباروجيل 8 بدءًا من مشتقات دينوك بروباروجيل 5 لتحمل الحمض الكبريتيك بوجود أملاح النحاس الأحادية كعامل مساعد. تم تشخيص جميع المركبات المحضرة النهائية وعدد من المركبات الأولية بتقنيات التفاعلات النحاسية المغناطيسية النموذجية وتفاعل النحاس الأحادي كعامل مساعد. ثم قياس فعالية المركبات المحضرة ضد كل من البكتيريا ونترات الثدي، ونترات المحمولة ونترات الحمضيات الثدي. اعتماداً على ذلك تم قياس فعالية المركبات المحضرة ضد سرطان الثدي (خط خلايا AMJ13).

الخلاصة:
في العمل الحالي ، تم تحويل هاليدات الألكيل b و الأمينات الأرووماتية 3a−b إلى الأزييدات المقابلة مرة عن مع أزييد الصوديوم في منبج قطبي لا بروتون لتعطي مشتقات الأزييد الأميناتية 2a−b و أخرى عن طريق التفاعل مع نترات الصوديوم ومن ثم أزييد الصوديوم لنتج الأزييدات الأرووماتية 4a−b. و في خروق مشكلة مضادة حمض كبريتيك بوجود أملاح النحاس الأحادية كعامل مساعد. بعد ذلك ، تم استخدام تفاعل النحاس الضارب لتحضير مشتقات 3 من بروباروجيل 8 بدءًا من مشتقات دينوك بروباروجيل 5 لتعطي مشتقات الأزييدات ثلاثية الأليفاتية 2a−b. و في خطوة مقابلة حضر مشتقات ثلاثية بروباروجيل 8 بدءًا من مشتقات دينوك بروباروجيل 5 لتحمل الحمض الكبريتيك بوجود أملاح النحاس الأحادية كعامل مساعد. تم تشخيص جميع المركبات المحضرة النهائية وعدد من المركبات الأولية بتقنيات التفاعلات النحاسية المغناطيسية النموذجية وتفاعل النحاس الأحادي كعامل مساعد. ثم قياس فعالية المركبات المحضرة ضد كل من البكتيريا ونترات الثدي، ونترات المحمولة ونترات الحمضيات الثدي. اعتماداً على ذلك تم قياس فعالية المركبات المحضرة ضد سرطان الثدي (خط خلايا AMJ13).

الخلاصة:
في العمل الحالي ، تم تحويل هاليدات الألكيل b و الأمينات الأرووماتية 3a−b إلى الأزييدات المقابلة مرة عن مع أزييد الصوديوم في منبج قطبي لا بروتون لتعطي مشتقات الأزييد الأميناتية 2a−b و أخرى عن طريق التفاعل مع نترات الصوديوم ومن ثم أزييد الصوديوم لنتج الأزييدات الأرووماتية 4a−b. و في خروق مشكلة مضادة حمض كبريتيك بوجود أملاح النحاس الأحادية كعامل مساعد. بعد ذلك ، تم استخدام تفاعل النحاس الضارب لتحضير مشتقات 3 من بروباروجيل 8 بدءًا من مشتقات دينوك بروباروجيل 5 لتعطي مشتقات الأزييدات ثلاثية الأليفاتية 2a−b. و في خطوة مقابلة حضر مشتقات ثلاثية بروباروجيل 8 بدءًا من مشتقات دينوك بروباروجيل 5 لتحمل الحمض الكبريتيك بوجود أملاح النحاس الأحادية كعامل مساعد. تم تشخيص جميع المركبات المحضرة النهائية وعدد من المركبات الأولية بتقنيات التفاعلات النحاسية المغناطيسية النموذجية وتفاعل النحاس الأحادي كعامل مساعد. ثم قياس فعالية المركبات المحضرة ضد كل من البكتيريا ونترات الثدي، ونترات المحمولة ونترات الحمضيات الثدي. اعتماداً على ذلك تم قياس فعالية المركبات المحضرة ضد سرطان الثدي (خط خلايا AMJ13).