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Synthesis And Characterization Of New 1,2,3-Triazole Fused Phenol Based Glucose Triazole For Biological Evaluation

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1. The synthesis and characterization of novel 1,2,3-triazole fused phenol-based glucose triazole derivatives have garnered significant interest due to their potential biological applications and unique structural properties. In this study, a series of glucose-triazole hybrids were synthesized via copper(I)-catalyzed azide-alkyne cycloaddition (CuAAC), a cornerstone reaction in click chemistry known for its efficiency, regioselectivity, and biocompatibility. The synthetic route involved the modification of glucose to introduce an azide moiety, followed by its reaction with phenol-derived alkynes to yield 1,4-disubstituted triazole derivatives under mild conditions. The synthesized compounds were thoroughly characterized using spectroscopic techniques, including ^{1}H NMR, FTIR, and mass spectrometry, confirming the successful formation of the triazole ring and the retention of key structural features. Biological evaluations, demonstrated promising results, highlighting the potential therapeutic applications of these glucose-triazole derivatives. The findings suggest that these triazole-fused glucose hybrids could serve as valuable scaffolds in the design and development of novel bioactive molecules with enhanced pharmacological profiles.

2. Keywords: Click Chemistry, Copper(I)-CatalyzedAzide-Alkyne Cycloaddition (CuAAC), Glucose Derivatives, Bioactive Compounds, Carbohydrate Functionalization.

3. Introduction:

Carbohydrates are vital biomolecules involved in numerous biological processes, including cell signaling, immune response, and pathogen recognition(K et al., 2024). Beyond their traditional roles as energy reservoirs and structural components, carbohydrates serve as key mediators in complex biological events through their participation in glycosylation and glycan-related pathways. These molecules play a critical role in disease progression, cell-cell communication, and the regulation of molecular recognition events at the cellular level(Mishra et al., 2016). Their structural diversity and functional specificity have made them attractive targets in medicinal chemistry for developing therapeutic agents and diagnostic tools(Wang et al., 2021).

Among carbohydrates, glucose and its derivatives have garnered considerable attention due to their biocompatibility, natural abundance, and unique structural properties(Seddiqi et al., 2021). Glucose serves as a building block in glycoconjugates such as glycoproteins, glycolipids, and proteoglycans, which play essential roles in cell adhesion, immune modulation, and pathogen-host interactions(Varki, 2017). In recent years, the incorporation of 1,2,3-triazole moieties into glucose frameworks has emerged as a promising strategy to improve biological activity, chemical stability, and therapeutic potential(El Malah et al., 2020). Triazole rings, formed through the Copper(I)-CatalyzedAzide-Alkyne Cycloaddition (CuAAC) reaction, are well-known for their metabolic stability, hydrogen-bonding capabilities, and bioisosteric properties, which make them ideal linkers in glycoconjugate synthesis(Hein &Fokin, 2010; Thakur &Khare, 2019).

Click chemistry, particularly CuAAC, has revolutionized the synthesis of triazole-linked glycoconjugates due to its simplicity, high efficiency, regioselectivity, and compatibility with aqueous conditions(Slavin et al., 2011). The reaction proceeds under mild conditions and generates stable 1,4-disubstituted triazoles, which are resistant to enzymatic degradation and hydrolysis. These advantages have made click chemistry an indispensable tool for designing glycosylated bioactive molecules, with applications ranging from drug discovery to imaging probes(KhodadadiYazdi et al., 2022).

Incorporating phenolic moieties into glucose-triazole hybrids further enhances their biological potential. Phenols are well-recognized for their antioxidant, antimicrobial, and anticancer properties, and their integration into carbohydrate frameworks creates multifunctional molecules capable of targeting multiple biological pathways(Tiwari et al., 2016). The fusion of phenolic structures with glucose-triazole derivatives allows for the development of hybrid therapeutic agents that exhibit synergistic effects, enhancing pharmacological activity and cellular uptake(Chen et al., 1999). These hybrid molecules are particularly valuable in applications such as antimicrobial therapy, enzyme inhibition, and cancer treatment, where both glucose and phenol moieties contribute to the therapeutic outcome(Zhang et al., 2015).

Biological evaluations of 1,2,3-triazole-linked glucose derivatives have shown promising results in targeting pathogenic microorganisms, tumor cells, and enzyme inhibition pathways(Sharma et al., 2024). Recent studies highlight the potential of these derivatives as drug delivery agents, leveraging the natural affinity of certain receptors, such as galectins and lectins, for glucose-containing structures(Iraji et al., 2022). These receptor-mediated interactions enable selective targeting of disease-related pathways, reducing off-target effects and improving drug efficacy. Additionally, triazole-linked glucose derivatives have been investigated for their potential to inhibit enzymes like β-galactosidase, which is implicated in disorders such as lysosomal storage diseases(Campo et al., 2012).

In this study, we report the synthesis, characterization, and biological evaluation of 1,2,3-triazole fused phenol-based glucose derivatives using click chemistry methodologies. The synthesis involves the modification of glucose through azidation, followed by coupling with phenolic alkynes under CuAAC reaction conditions. The resulting compounds were characterized using advanced spectroscopic techniques (^{1}H NMR, FTIR, and mass spectrometry) to confirm their structure and purity. Furthermore, these glucose-triazole hybrids were evaluated for their biological activities, to explore their therapeutic potential. This research aims to contribute to the growing field of glycoconjugate chemistry by providing insights into the design and application of novel glucose-triazole derivatives as bioactive agents.

3. Materials and Methods

3.1 Materials Used:

All chemicals and reagents used in this study were of analytical grade and procured from reputed suppliers. D-glucose, propargyl bromide, sodium azide, phenol derivatives, and copper(I) iodide (CuI) were utilized as key starting materials for the synthesis of 1,2,3-triazole fused phenol-based glucose derivatives. Solvents including dimethyl sulfoxide (DMSO), tetrahydrofuran (THF), acetonitrile, and ethanol were of HPLC grade and used without further purification unless specified. Deionized water was used for all aqueous workup and washing processes.

3.2 Methods Used:

The synthesis of glucose azide derivatives began with the tosylation of glucose, followed by azidation using sodium azide under mild conditions. The resulting glucose azide intermediate was subjected to a Copper(I)-Catalyzed Azide-Alkyne Cycloaddition (CuAAC) reaction with phenol-based alkynes to yield the 1,2,3-triazole fused derivatives. The reaction was carried out in dimethylformamide (DMF) under an inert nitrogen atmosphere with CuI serving as a catalyst and triethylamine (TEA) as a base. The reaction mixture was stirred at a controlled temperature of 60–80°C for 12–24 hours, and the progress was monitored via Thin Layer Chromatography (TLC) using an ethyl acetate: hexane (1:4) solvent system.

Upon completion, the reaction mixture was quenched with water and extracted with ethyl acetate. The organic layer was washed sequentially with brine solution (NaCl) and sodium bicarbonate solution to remove any unreacted starting materials and impurities. The organic phase was dried over anhydrous sodium sulphate , filtered, and the solvent was evaporated under reduced pressure using a rotary evaporator. The crude product was purified using silica gel column chromatography, employing a hexane: ethyl acetate gradient as the mobile phase. In some cases, further purification was achieved through recrystallization from ethanol or methanol.

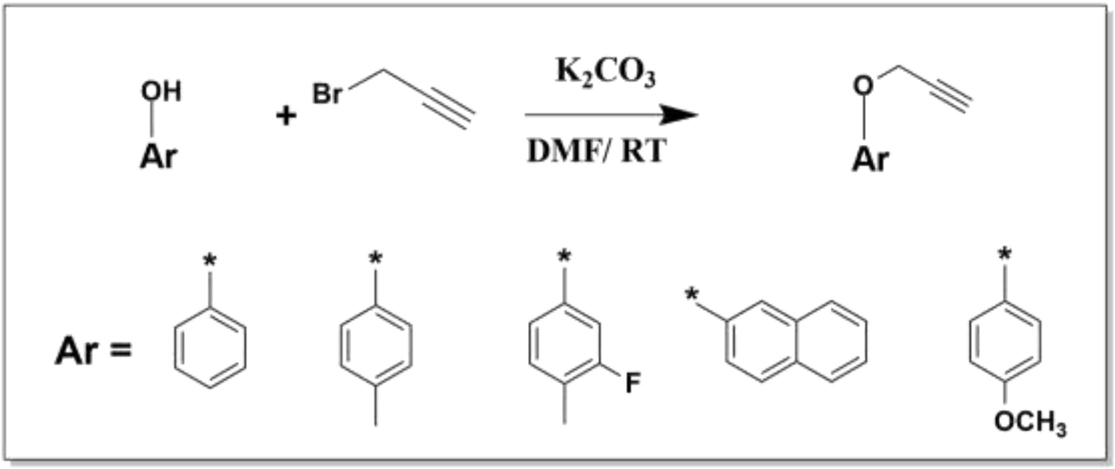
The characterization of the synthesized compounds was carried out using advanced spectroscopic and analytical techniques. ^{1}H NMR (Bruker, 400 MHz) was used to confirm the structural integrity and chemical environment of the triazole and glucose moieties. FTIR spectroscopy was employed to identify key functional groups and ensure successful coupling reactions. Mass spectrometry (MS) provided molecular weight confirmation and structural validation of the synthesized compounds.

For the biological evaluation, the synthesized derivatives were screened for their antimicrobial and anticancer activities. Antimicrobial assays were performed using the agar well diffusion method against selected bacterial and fungal strains. Minimum inhibitory concentration (MIC) values were determined using standard protocols. All experiments were conducted in triplicate, and the results were statistically analyzed to ensure reproducibility and reliability.

This methodology provides a robust framework for synthesizing and characterizing novel glucose-triazole derivatives, enabling their evaluation for biological activity and therapeutic potential. The integration of CuAAC click chemistry with glycosylation strategies ensures efficient synthesis while preserving the bioactivity and structural integrity of the resulting molecules. Future studies will focus on structure-activity relationship (SAR) analysis and optimizing these compounds for specific pharmacological applications.

4. Experimental Procedure:

4.1 Synthesis of phenol-based alkynes:



SCHEME 1 Synthesisof phenol-based alkynes

This is an essential method for introducing alkyne functionality into phenolic compounds, providing versatile intermediates for various organic transformations. The reaction begins with the setup in a dry round-bottom flask under a nitrogen atmosphere, ensuring an inert environment to prevent unwanted side reactions(Devaraj & Finn, 2021).

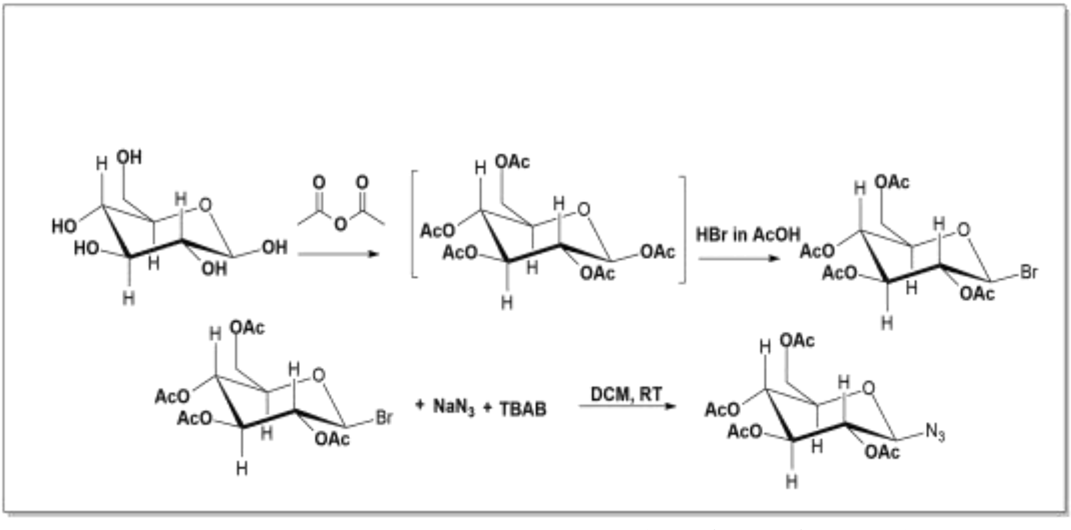
Procedure: In the flask, a mixture of the phenol derivative (1 mmol) and potassium carbonate (2mmol) is added to a suitable solvent, typically Dimethylformamide (DMF) or tetrahydrofuran (THF), both known for their ability to solubilize reactants and facilitate smooth nucleophilic substitution. Once the system is prepared, the alkynylating agent, such as propargyl bromide (1.1 mmol) or trimethylsilylacetylene (1.1 mmol), is added dropwise with continuous stirring to ensure uniform mixing and controlled reaction kinetics.

The reaction mixture is then stirred at either room temperature or heated to 60–80°C for a duration of 4–12 hours, depending on the reactivity of the phenolic substrate and the alkynylating agent. The progress of the reaction is carefully monitored using Thin Layer Chromatography (TLC), employing an ethyl acetate: hexane (1:4) solvent system, to ensure the complete conversion of starting materials into the desired alkyne-substituted phenol. Once the reaction is deemed complete, the reaction mixture is quenched with water to stop further reaction, and the product is extracted using ethyl acetate (3 × 20 mL) to separate the organic phase from the aqueous impurities.

Purification: The purification of alkyne derivatives of phenols follows a multi-step protocol to ensure high purity and yield. The organic layer containing the product is washed sequentially with water, brine solution (NaCl solution), and sodium bicarbonate solution to remove inorganic impurities, residual salts, and unreacted starting materials. After washing, the organic phase is dried over anhydrous sodium sulfate to eliminate any trace water content, followed by filtration to separate the drying agent. The solvent from the organic layer is then carefully evaporated under reduced pressure using a rotary evaporator, leaving behind a crude residue of the alkyne derivative.

Purification by column chromatography: In this process, silica gel column chromatography is employed with an eluent system consisting of hexane: ethyl acetate (4:1 to 1:1). The use of a gradient solvent system allows for optimal separation of the desired product from by-products and impurities. Fractions containing the purified product are identified using TLC analysis, collected, and combined.

4.2 Synthesis of Glucose Azide:



SCHEME 2 Synthesis of Glucose Containing Azide(Nayak& Yadav, 2023)

4.2.1 STEP-I: Tosylationof D-glucose:

Initially, D-glucose (1 mmol) was dissolved in a suitable solvent such as pyridine or dimethylformamide (DMF) under ice-cold conditions to maintain control over the reaction.

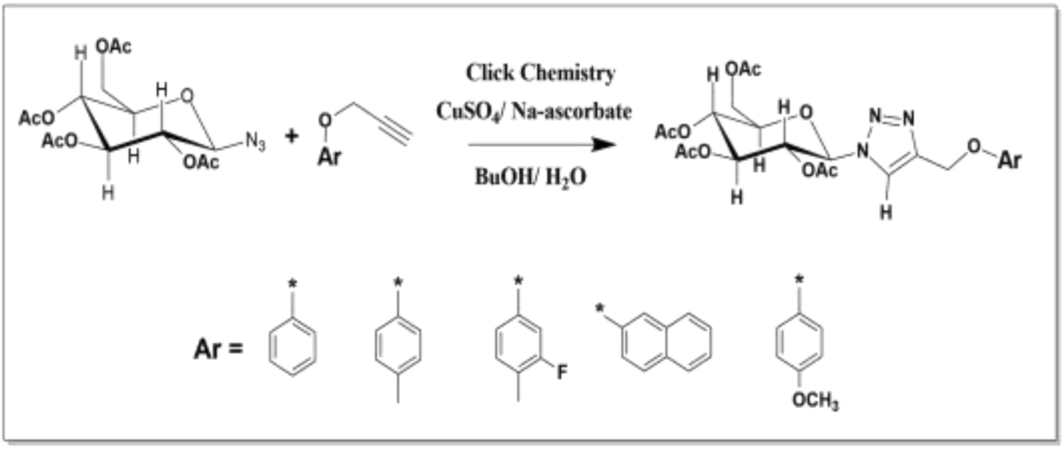
To this mixture, p-toluenesulfonyl chloride (TsCl, 1.2 mmol) was added slowly with constant stirring to ensure complete dissolution and homogeneous mixing. The reaction was allowed to proceed at 0–5°C for a few hours and subsequently brought to room temperature to ensure the complete tosylation of glucose. The progress of the reaction was monitored via Thin Layer Chromatography (TLC) using an ethyl acetate: hexane (1:4) solvent system. After completion, the reaction mixture was quenched with ice-cold water, and the crude product was extracted using an organic solvent like ethyl acetate. The organic layer was washed thoroughly with water, brine solution, and sodium bicarbonate solution to remove excess reagents and impurities.

4.2.1 STEP-II: Azidation of D-glucose: The resulting glucose tosylate was dried and subjected to azidation using an excess of sodium azide (1.5 mmol) in DMF. The reaction mixture was stirred at 60–80°C for 8 hours under an inert nitrogen atmosphere to prevent side reactions. The progress of the azidation reaction was again monitored using TLC. Upon completion, the reaction mixture was cooled to room temperature, and the solvent was removed under reduced pressure using a rotary evaporator. The residue was dissolved in water, and the aqueous layer was extracted with ethyl acetate to isolate the desired glucose azide.

Purification: For purification, the crude glucose azide was subjected to silica gel column chromatography using an ethyl acetate: hexane gradient as the mobile phase to achieve high purity. The fractions containing the desired product were identified using TLC, combined, and concentrated under reduced pressure. In some cases, recrystallization from ethanol was performed to further purify the compound. The final purified glucose azide was obtained as a white to off-white solid with high purity and yield.

4.3 Reaction of Glucose with phenol-based alkynes :

The synthesis of glucose-phenol triazole derivatives was achieved through a Copper(I)-CatalyzedAzide-Alkyne Cycloaddition (CuAAC) reaction, a hallmark of click chemistry known for its regioselectivity and efficiency under mild conditions.



SCHEME 3 Synthesis of Glucose Containing 1,2,3-Triazole

Experimental Procedure: Initially, glucose azide (1 mmol) was dissolved in a suitable solvent such as dimethylformamide (DMF) or acetonitrile (ACN) to ensure complete solubility. To this solution, a phenol-based alkyne derivative (1.1 mmol) was added dropwise with continuous stirring. A catalytic amount of copper(I) iodide (CuI, 0.05 mmol) was introduced as the catalyst, and triethylamine (TEA, 1 mmol) was used as the base to facilitate the cycloaddition reaction. The mixture was stirred under an inert nitrogen atmosphere at 60–80°C for 24 hours. The progress of the reaction was monitored at regular intervals using Thin Layer Chromatography (TLC) with an ethyl acetate: hexane (1:4) mobile phase system.

Once the reaction was deemed complete, as indicated by the disappearance of starting materials on the TLC plate, the reaction mixture was allowed to cool to room temperature. The mixture was then quenched with deionized water to stop the reaction and reduce excess reagents. The aqueous phase was extracted multiple times with ethyl acetate (3 × 20 mL) to ensure maximum recovery of the organic product. The combined organic layers were washed with brine solution (NaCl) and sodium bicarbonate solution to remove residual impurities and unreacted reagents. The organic layer was then dried over anhydrous sodium sulfate ,filtered, and concentrated under reduced pressure using a rotary evaporator.

Purification: For purification, the crude product was subjected to silica gel column chromatography using a gradient of hexane: ethyl acetate (4:1 to 1:1) as the eluent. Fractions containing the desired glucose-phenol triazole derivative were identified by TLC analysis and collected. The solvent from the purified fractions was removed under vacuum, yielding the product as a white to off-white solid. In some cases, further purification was achieved by recrystallization from ethanol to ensure high purity.

5. Results and Discussion:

The synthesis of glucose-phenol triazole derivatives via Copper(I)-CatalyzedAzide-Alkyne Cycloaddition (CuAAC) was successfully achieved under mild reaction conditions, resulting in a series of 1,4-disubstituted triazole derivatives with high regioselectivity and purity. The synthesized compounds were characterized using advanced analytical techniques, including FTIR spectroscopy, NMR spectroscopy (^1H), and mass spectrometry, to confirm their structural integrity and chemical composition.

5.1 FTIR Spectroscopy:

The IR spectrum of acylated glucose azide provides essential insights into the functional groups present and confirms the successful acylation of glucose azide. The spectrum reveals characteristic absorption bands corresponding to the azide group ($–N_3$), carbonyl group (C=O), and other structural features associated with both the glucose and acyl moieties.

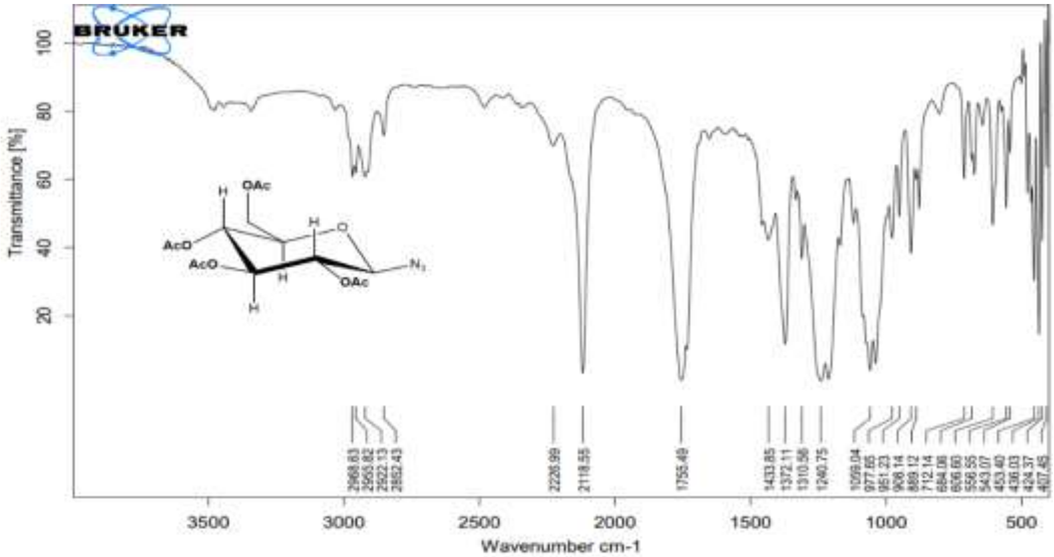


Figure 1 FTIR Spectra for Glucose Azide

A sharp and intense absorption band observed in the region of 2118 cm⁻¹ corresponds to the asymmetric stretching vibration of the azide group .The presence of this band indicates that the azide functionality remains intact after acylation, confirming that the reaction specifically targeted the hydroxyl groups without affecting the azido group.A strong absorption band in the range of 1755 cm⁻¹ corresponds to the C=O stretching vibration of the ester carbonyl group introduced during acylation. This band confirms the successful attachment of acyl groups to the glucose moiety.Absorption bands observed in the range of 2800–3000 cm⁻¹ correspond to the aliphatic C–H stretching vibrations. These peaks are associated with both the glucose backbone and the alkyl chains of the introduced acyl groups.The C–O stretching vibrations of ester linkages appear as strong bands in the region of 1200–1300 cm⁻¹, confirming the presence of ester bonds formed during acylation.A peak in the 1250–1350 cm⁻¹ region indicates C–N stretching vibrations from the azide functionality and additional contributions from the esterified glucose structure.

The IR spectral analysis of acylated glucose azide conclusively confirms the successful functionalization of glucose azide with acyl groups while maintaining the azide functionality. This derivative serves as an ideal precursor for further transformations.

5.2 ^{1}H NMR Spectroscopy:

The ^{1}H-NMR spectrum of glucose-1,2,3-triazole with phenol provides valuable insights into the structure and successful synthesis of the desired compound through Copper(I)-CatalyzedAzide-Alkyne Cycloaddition (CuAAC). The spectrum reveals distinct chemical shifts corresponding to the triazole proton, phenolic protons, glucose protons, and hydroxyl groups, all of which confirm the structural integrity and regioselectivity of the synthesized molecule.

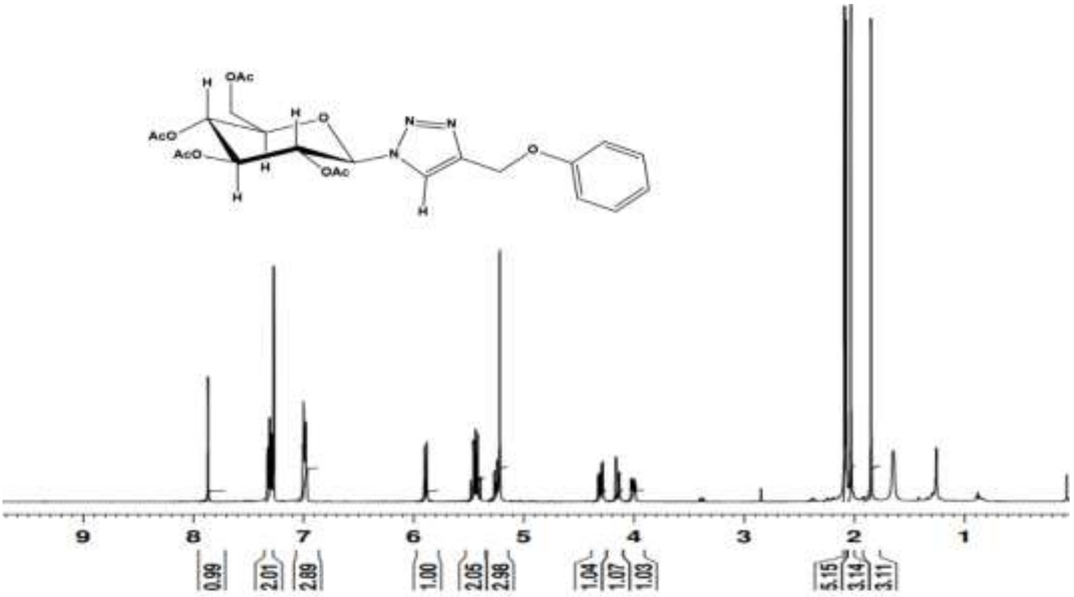


Figure 2^{1}H-NMR Spectrum of Glucose1,2,3-triazole with phenol

A singlet signal in the region of 7.9 ppm corresponds to the triazole proton (CH-triazole), which is characteristic of the 1,4-regioisomer formed during the CuAAC reaction. The chemical shift is influenced by the electron-withdrawing nature of the adjacent nitrogen atoms, resulting in a downfield shift. The aromatic protons of the phenol moiety appear as multiplets in the range of 6.9–7.4 ppm, corresponding to the protons attached to the aromatic ring. These signals indicate the retention of the phenol functionality in the final product, and the multiplicity suggests the presence of neighbouring protons influencing the splitting pattern.

The anomeric proton (H^1) of glucose is observed as a doublet in the range of 5.1–5.5 ppm, confirming the preservation of the glycosidic carbon during the cycloaddition process. This signal is characteristic of the glucose structure and arises from coupling with the adjacent proton. The hydroxyl protons (–OH) of glucose and phenol are observed as broad singlets between 4.0–4.5 ppm, indicating their involvement in hydrogen bonding interactions with neighbouring groups or solvent molecules. Methyl or methylene protons of the acyl group signals in 1.5-2.2 ppm region, depending on the specific acyl group attached to the glucose shown in **Figure 2**.

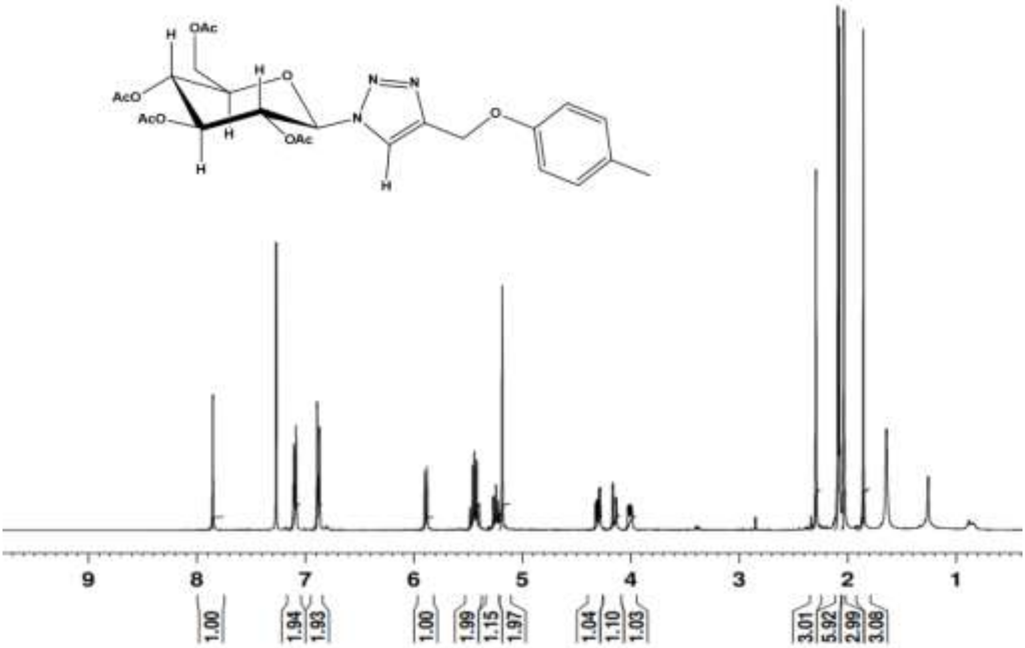


Figure 3^{1}H-NMR Spectrum of Glucose1,2,3-triazole with para-cresol

The anomeric proton (H-1) of glucose generally appears as a doublet at 4.4 ppm, confirming the attachment of glucose to the triazole core. The remaining protons of the glucose ring (H-2 to H-6) resonate in the range of 3.9- 4.3 ppm, indicating their involvement in the cyclic sugar structure.

The triazole proton (C-H on the triazole ring) typically resonates at 7.9 ppm as a sharp singlet, confirming the successful formation of the 1,2,3-triazole ring through the copper(I)-catalyzed azide-alkyne cycloaddition (CuAAC) reaction. The aromatic protons of para-cresol appear as two sets of doublets in the 6.8–7.2 ppm region, reflecting the symmetric substitution pattern on the benzene ring. Additionally, the methyl group ($-CH_3$) attached to the aromatic ring of para-cresol gives rise to a singlet peak around 2.2–2.4 ppm, consistent with its electron-donating nature.Methyl or methylene protons of the acyl group signals in 1.5-2.2 ppm regiondepending on the specific acyl group attached to the glucose shown in **Figure 3**.

The integration values and coupling constants observed in the spectrum align well with the expected proton count and splitting patterns, confirming the connectivity between glucose, triazole, and para-cresol moieties. The absence of any unreacted alkyne or azide proton peaks further supports the completion of the cycloaddition reaction. Overall, the ^{1}H-NMR spectrum serves as a reliable analytical tool to verify the successful synthesis and structural integrity of glucose-1,2,3-triazole with para-cresol, showcasing clear and well-resolved signals that correspond to each functional group in the molecule.

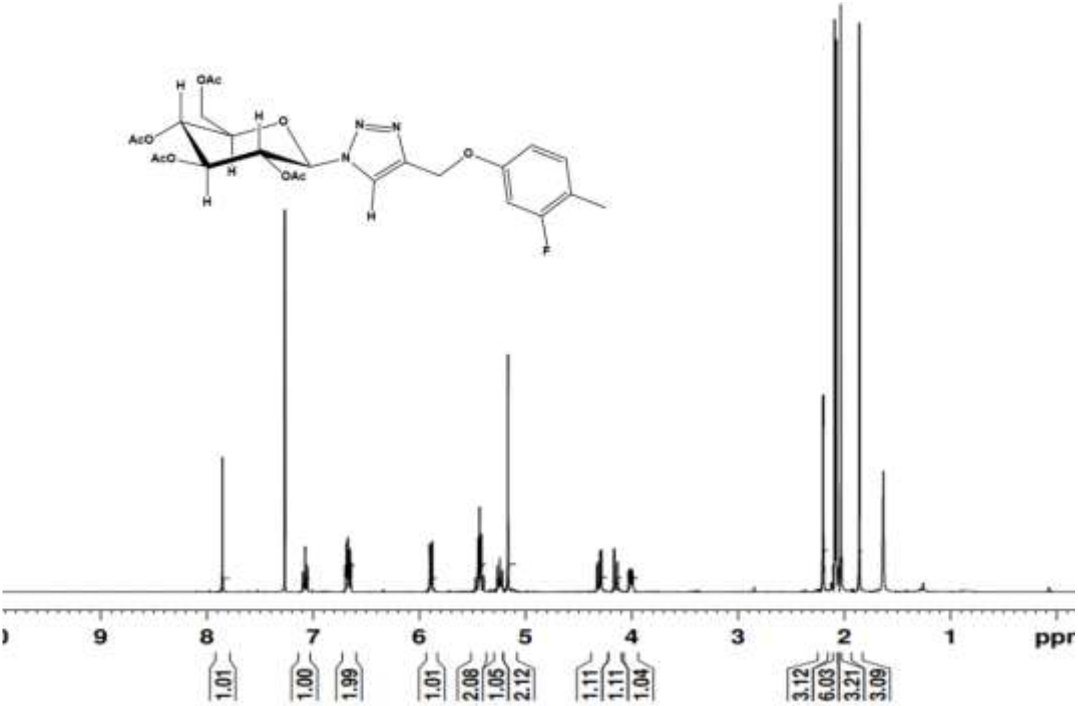


Figure 4^{1}H-NMR Spectrum of Glucose1,2,3-triazole with 3-fluoro phenol

The ^{1}H-NMR spectrum of acylated glucose-1,2,3-triazole with 3-fluorophenol offers a detailed understanding of the structural framework, confirming the successful synthesis and functionalization of the compound. The glucose moiety in the acylated derivative exhibits characteristic proton signals, with the anomeric proton (H-1) appearing as a doublet at 4.4 ppm, indicating its attachment to the triazole ring and confirming the glycosidic linkage. The remaining protons of the glucose backbone, specifically H-2 to H-6, resonate within the 3.9–4.2 ppm range, consistent with the cyclic structure of glucose and the electron-withdrawing effects from the adjacent functional groups. The signals corresponding to the hydroxyl (-OH) protons of glucose are typically absent or significantly reduced due to acylation, which replaces hydroxyl hydrogens with acyl groups, thereby shielding the hydroxyl proton resonances.

he triazole proton attached to the carbon (C-H) resonates as a sharp singlet peak at 7.9 ppm, confirming the successful formation of the 1,2,3-triazole ring through the Cu(I)-catalyzed azide-alkyne cycloaddition (CuAAC) reaction. This signal remains well-separated from the aromatic proton signals, which further supports the structural clarity of the triazole functionality. The aromatic protons of the 3-fluorophenol moiety display a characteristic splitting pattern due to the influence of the fluorine substituent (-F) attached to the benzene ring. Typically, the ortho and meta protons appear as singlet, doublets and multiplets between 7.2 ppm, 7.1 ppm and 6.8 ppm, while the para-position proton may resonate as a distinct peak in the same region, influenced by the fluorine atom's electron-withdrawing nature shown in **Figure 4**.

The proton corresponding to the acyl group (or related functional groups) attached to the glucose unit appears as a singlet around 2.0–2.5 ppm, indicating the presence of the carbonyl-linked hydrogen atoms from the acyl substituent. This signal confirms successful acylation and substitution at the glucose hydroxyl positions.

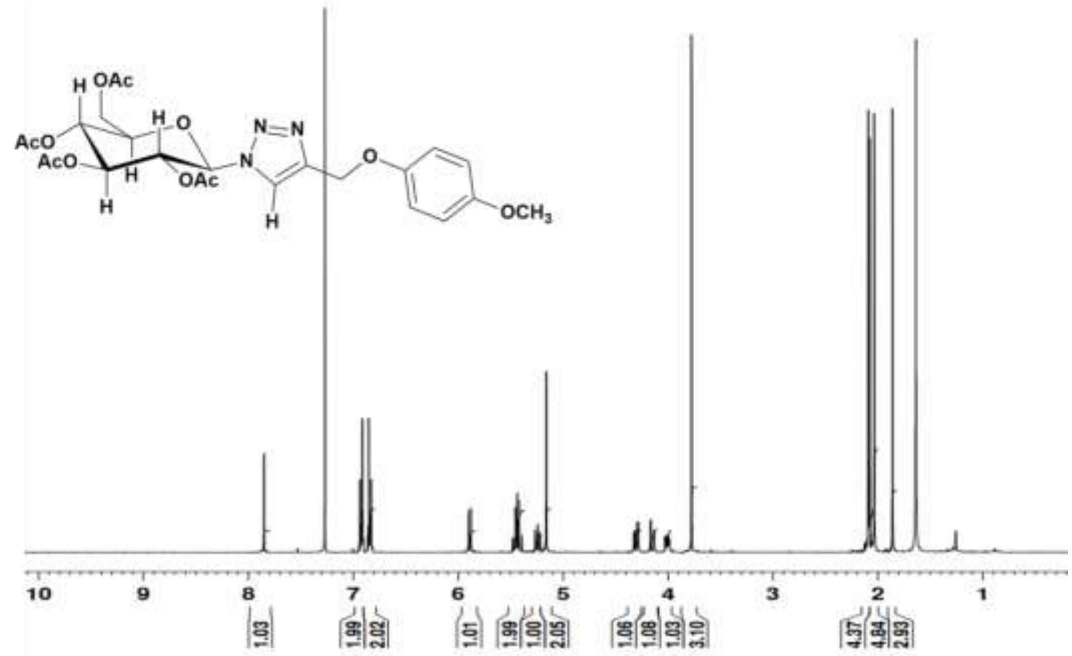


Figure 5^{1}H-NMR Spectrum of Glucose1,2,3-triazole with mesiquinol

The ^{1}H-NMR spectrum of acylated glucose-1,2,3-triazole with mesiquinol provides valuable insights into the chemical structure, confirming the successful synthesis and functionalization of the target compound. The glucose moiety in the acylated derivative displays characteristic proton signals, with the anomeric proton (H-1) appearing as a doublet in the region of 4.0–4.5 ppm, indicating its linkage to the triazole ring. This coupling pattern confirms the presence of a stable glycosidic bond, which is consistent with the expected chemical structure. The remaining protons of the glucose ring (H-2 to H-6) resonate within the 3.8 ppm range, corresponding to the cyclic sugar backbone. The chemical shifts and splitting patterns of these protons are influenced by the acylation of hydroxyl groups on the glucose moiety, which reduces hydrogen bonding and shields the protons from the surrounding chemical environment.

The triazole proton (C-H attached to the triazole ring) appears as a distinct singlet around 7.9 ppm, a signature signal indicating the successful formation of the 1,2,3-triazole ring through the Cu(I)-catalyzed azide-alkyne cycloaddition (CuAAC) reaction.

The mesiquinol moiety, characterized by its aromatic and hydroxyl groups, contributes distinct signals in the aromatic region (6.8–7.0 ppm). The protons on the aromatic ring of mesiquinol exhibit splitting patterns corresponding to the substitution pattern on the ring. The ortho and meta protons generate characteristic doublets and multiplets, while the hydroxyl (-OH) protons on the aromatic ring resonate as broad singlets in the range of 5.2–5.5 ppm. These signals confirm the presence of hydroxyl groups on the aromatic ring, which remain unaffected during the cycloaddition reaction. Additionally, the acyl protons ($-COCH_3$ or related acyl group protons) resonate as sharp singlets around 1.6–2.1 ppm, further supporting the presence of the acyl substituents shown in the **Figure 5**.

Overall, the ^1H-NMR spectrum of glucose-1,2,3-triazole with phenol reveals well-resolved signals corresponding to triazole, phenol, and glucose protons, confirming the successful attachment of the phenol-based alkyne to glucose azide via click chemistry. The observed chemical shifts, multiplicities, and coupling constants align well with expected patterns, validating the formation of a 1,4-disubstituted triazole linkage and the preservation of the glucose and phenol functional groups. These findings are consistent with the proposed structure and provide strong evidence for the successful synthesis of the desired compound.

Mass Spectrometry (MS):
The mass spectra of the glucose-phenol triazole derivatives provided molecular weight confirmation and further validated the proposed structure. The molecular ion peak ($[M+H]^+$) was observed at the expected m/z value, confirming the successful coupling of glucose azide and the phenol alkyne. Additional peaks corresponding to fragment ions provided insight into the fragmentation pattern of the molecule, supporting the triazole ring formation and stability of the glycosyl conjugate. The observed isotopic distribution was consistent with the theoretical calculations, further supporting the structural elucidation.

Discussion:
The analytical data from FTIR, NMR, and MS collectively confirmed the successful synthesis and structural integrity of the glucose-phenol triazole derivatives. The disappearance of the azide stretching band in the FTIR spectrum, the appearance of the triazole proton and carbon signals in ^1H and ^{13}C NMR spectra, and the expected molecular ion peak in mass spectrometry all indicated the efficient formation of 1,4-disubstituted triazole linkages. The observed chemical shifts and absorption bands aligned well with literature values, further validating the identity of the synthesized compounds.

The successful synthesis and characterization of these glucose-phenol triazole derivatives highlight the utility of click chemistry in generating bioactive glycoconjugates with high regioselectivity and reproducibility. These findings establish a robust platform for exploring the biological activities of these derivatives, including their potential applications in antimicrobial, anticancer, and enzyme inhibition studies. Future investigations will focus on evaluating the structure-activity relationship (SAR) to optimize their pharmacological profiles and broaden their therapeutic potential. final purified compound was characterized using ^1H NMR, ^{13}C NMR, FTIR, and mass spectrometry. The successful formation of the 1,4-

disubstituted triazole ring was confirmed by ^{1}H NMR spectroscopy, showing characteristic signals for the triazole proton (7.5–8.0 ppm) and the retention of glucose and phenolic functionalities. Additionally, the FTIR spectrum exhibited a distinct absorption band corresponding to the C=N bond (around 1600 cm^{-1}) and the absence of the azide stretching band (2100–2150 cm^{-1}), indicating successful cycloaddition.

This methodology effectively combines the bioactive nature of glucose and phenolic scaffolds via a robust click chemistry approach, yielding highly pure glucose-phenol triazole conjugates suitable for further biological evaluations. The optimized synthetic and purification protocols ensure reproducibility and scalability for larger-scale preparations.

The purified compound was characterized using spectroscopic techniques, including ^{1}H NMR, ^{13}C NMR, FTIR, and mass spectrometry, to confirm the presence of the azido group (–N_3) and verify the structural integrity of the glucose moiety. The characteristic FTIR absorption band near 2100–2150 cm^{-1} corresponding to the azide group further validated the successful synthesis. This method ensured an efficient and reproducible synthetic route for glucose azide, providing a reliable precursor for downstream click chemistry reactions in the preparation of triazole-linked derivatives.

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