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The Reaction of Heteroaroyl-Substituted Heterocyclic Ketene Aminals with 2,3,4,6-Tetra-*O*-acetyl-β-D-glucopyranosyl Azide

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ABSTRACT: *The reaction of heteroaroyl-substituted heterocyclic ketene aminals with 2,3,4,6-tetra-O-acetyl-β-D-glucopyranosyl azide was investigated and a series of potential bioactive compounds, 1-glucopyranosyl-4-heterocyclic-5-heteroaryl-1,2,3-triazoles, were obtained in good yields. Both the reaction rate and the yield were strongly affected by the heteroaryl and heterocyclic groups. In order to improve their water solubility, the deprotection of 1-glucopyranosyl-4-heterocyclic-5-heteroaryl-1,2,3-triazole was carried out.* © 2002 Wiley Periodicals, Inc. Heteroatom Chem 13:242–247, 2002; Published online in Wiley Interscience (www.interscience.wiley.com). DOI 10.1002/hc.10023

INTRODUCTION

Heterocyclic ketene aminals are versatile intermediates for the synthesis of a wide variety of new heterocycles and fused heterocycles [1], some of which showed high biological activity. The reaction of heterocyclic ketene aminals with 1,3-dipolar reagents, such as an azide [2–9], a nitrile imine [10,11], benzonitrile oxide [12,13], or its precursor [14,15] have been reported. To continue our studies, we decided to explore the reaction of heteroaroyl-substituted heterocyclic ketene aminals with 2,3,4,6-tetra-*O*-acetyl-β-D-glucopyranosyl azide and to obtain bioactive compounds. In this paper, we report the results of the reaction between heteroaroyl-substituted heterocyclic ketene aminals and 2,3,4,6-tetra-*O*-acetyl-β-D-glucopyranosyl azide.

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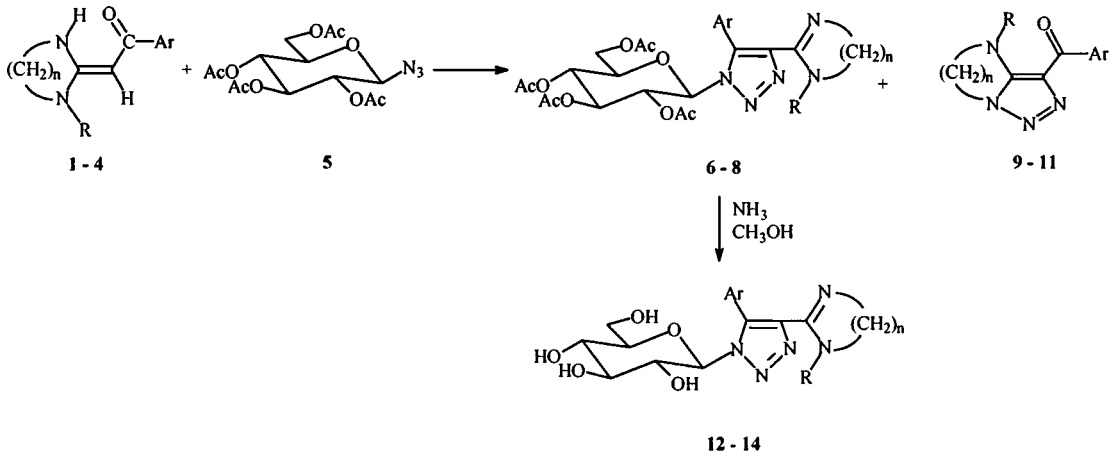
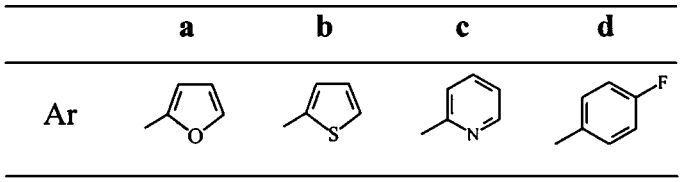
RESULTS AND DISCUSSION

The heteroaroyl groups incorporated in the ketene aminals used in this article are furoyl, thienoyl, and picolinoyl groups, as well as the *p*-fluorobenzoyl group. Aroyl-substituted heterocyclic ketene aminals **1–4** were prepared by the reaction of aroyl-substituted ketene-*S*,*S*-diacetals with the corresponding diamines or methyl-substituted diamines according to the literature procedure [16].

Compounds **1a, 1b**, and **1d** reacted with 2,3,4,6-tetra-*O*-acetyl-β-D-glucopyranosyl azide (**5**) in methylene chloride at room temperature to give polysubstituted 1,2,3-triazoles **6** as major products in excellent yields, and only low yields (<8%) of fused heterocycles **9** [9] were isolated as minor products (Scheme 1). Compound **6c** was obtained sucessfully by the reaction of **1c** with **5** in tetrahydrofuran instead of methylene chloride as solvent and 10% of **9c** was isolated as a minor product. Compounds **2a, 2b**, and **2d** reacted with **5** to give polysubstituted 1,2,3-triazoles **7** in good yields, with 5–15% of fused heterocycles **10a, 10b**, and **10d** as minor products. Compound **2c** did not react at all with **5** under these conditions. Compound **3a**



1, 6, 9, 12, n = 3, R = H; **2, 7, 10, 13,** n = 3, R = CH_3;
3, 8, 11, 14, n = 2, R = H; **4,** n = 2, R = CH_3.



SCHEME 1

reacted with **5** to give **8a** in good yield (71%) and about 25% of the fused heterocycle **11a** was isolated as a minor product. Compound **3b** gave only about 25% yield of **8b**, which wasn't isolated because of its instability, but the yield of **11b** was as high as 60%. Compounds **3c** and **3d** did not give corresponding products when reacted under similar conditions. Compound **4** did not react with **5** under these conditions. The reaction conditions, yields, and melting points of compounds **6–8** are listed in Table 1.

The structures of compunds **6–8** were determined on the basis of IR, ^{1}H NMR, ^{13}C NMR, and positive SIMS spectra. The disappearance of the aroyl carbonyl absorption (ca. 1610 cm^{-1}) in the IR spectra and of the carbonyl signal (ca. 180–190 ppm) in the ^{13}C NMR spectra of compounds **1–3**, the appearance of acetyl carbonyl bands/signals in the IR and NMR spectra, and the disappearance of the ethylenic proton signal in the ^{1}H NMR spectra are all consistent with the structures shown for compounds

TABLE 1 Reaction Conditions, Yields, and Melting Points of Products **6–8**

	Reaction Conditions				
Compd.	*Solvent*	*Temp. (°C)*	*Time (days)*	*Yield[a] (%)*	*m.p. (°C)*
6a	CH_2Cl_2	30	7	95	75–77
6b	CH_2Cl_2	30	8	90	67–69
6c	THF	30	15	86	132–133
6d	CH_2Cl_2	30	10	92	79–81
7a	CH_2Cl_2	30	30	81	71–73
7b	CH_2Cl_2	30	30	80	65–67
7d	CH_2Cl_2	30	33	85	76–78
8a	CH_2Cl_2	30	46	71	55–57

[a]Isolated yield.

6–8. The ^{1}H NMR signals, especially those of the glucopyranosyl ring, were assigned by reference to the literature [8]. The β-configuration of the glucopyranosyl ring was confirmed by the coupling constant $J_{H1,H2} = 8.73–9.53$ Hz for compounds **6–8** [17,18].

The above results are similar to those of the reaction of benzoyl-substituted heterocyclic ketene aminals with phenyl azides. The polysubstituted 1,2,3-triazoles are formed by the nucleophilic attack of the α-carbon of the ketene aminal on the terminal nitrogen atom of the azide, the reaction then being completed by cyclocondensation and aromatization sequences. The fused heterocycles resulted by a 1,3-dipolar addition reactions at first, and then through Dimroth rearrangements and deamination reactions [7]. These two reactions are competitive, the ratio of the products **6–8** to **9–11** being affected by the nucleophilities of the α-carbon of the ketene aminals, which, in turn, are affected by the nature of the heterocyclic rings and the substituted aroyl groups of the ketene aminals.

Deacetylations of compounds **6–8** proceeded easily with ammonia in methanol at room temperature within 2 h to give the deprotected triazole derivatives **12–14** in nearly quantitative yields (Scheme 1). The disappearance of acetyl groups of compounds **6–8** was evident in both IR and NMR spectra. The spectra data were all consistent with the structures of compounds **12–14**, and the coupling constant $J_{H1,H2} = 9.03–9.28$ Hz confirmed the β-configuration. The reaction conditions, yields, and melting points of compounds **12–14** are listed in Table 2.

EXPERIMENTAL

Melting points are uncorrected. ^{1}H NMR and ^{13}C NMR spectra are determined with a Varian Unity 200 spectrometer. The chemical shifts are reported in ppm downfield from Me_4Si. *J* values are given in Hz. IR spectra were obtained with a Perkin–Elmer 782 spectrometer. Positive SIMS were recorded with a Bruker APEX II instrument.

TABLE 2 Yields and Melting Points of Compounds **12–14**

Compd.	*Yields*[a] *(%)*	*m.p. (°C)*
12a	97	152–154
12b	98	148–150
12c	98	150–152
12d	95	178–180
13a	99	136–138
13b	98	146–148
13d	98	142–144
14a	98	153–155

[a]Isolated yield.

General Procedure for the Syntheses of Compounds **6–8**

A mixture of each heteroaroyl-substituted heterocyclic ketene aminal **1, 2**, or **3** (2 mmol), and **5** (2.2 mmol) was stirred in CH_2Cl_2 or THF at room temperature. When TLC ($CHCl_3$/CH_3OH 10:1, silica gel) showed the absence of **1, 2**, or **3** and the presence of one or two new major spot(s), the reaction was stopped. After removal of solvent, the product was purified by column chromatography on Al_2O_3 (200–300 mesh), $CHCl_3$ being used as eluants to give the pure compounds **6–8**.

1-(2,3,4,6-Tetra-O-acetyl-β-D-glucopyranosyl)-4-(2-tetrahydropyrimidinyl)-5-furyl-1,2,3-triazole (**6a**). IR (KBr): 3420 (N—H), 1745 (C=O), 1640 cm^{-1}; ^{1}H NMR ($CDCl_3$): δ 7.85 (d, 1H, Ar-H), 7.62 (d, 1H, Ar-H), 6.63–6.58 (m, 1H, Ar-H), 6.16–6.08 (m, 2H, Glu-H_1, H_2), 5.45–5.21 (m, 2H, Glu-H_3, H_4), 4.25–4.12 (m, 2H, Glu-H_6), 4.08–3.98 (m, 1H, Glu-H_5), 3.52 (t, 4H, N—CH_2), 2.07 (s, 3H, $COCH_3$), 2.04 (s, 3H, $COCH_3$), 2.01 (s, 3H, $COCH_3$), 1.94–1.82 (m, 2H, C—CH_2—C), 1.85 (s, 3H, $COCH_3$); ^{13}C NMR ($CDCl_3$): δ 170.34, 170.17, 169.12, 168.30, 147.51, 143.94, 140.24, 127.70, 116.64, 111.87, 109.51, 84.30, 74.34, 73.52, 69.20, 67.73, 61.73, 41.62, 20.93, 20.40, 20.39, 20.38, 20.19; Positive SIMS (Glycerol): Calcd. for $C_{24}H_{30}N_5O_{10}$ (M + 1) 548.1987004, Found 548.1989720.

1-(2,3,4,6-Tetra-O-acetyl-β-D-glucopyranosyl)-4-(2-tetrahydropyrimidinyl)-5-thienyl-1,2,3-triazole (**6b**). IR (KBr): 3410 (N—H), 1750 (C=O), 1640 cm^{-1}; ^{1}H NMR ($CDCl_3$): δ 7.62 (d, 1H, Ar-H), 7.58 (d, 1H, Ar-H), 7.20–7.15 (m, 1H, Ar-H), 6.18–6.10 (m, 1H, Glu-H_2), 5.54 (d, 1H, Glu-H_1, $J_{H1,H2} = 9.52$ Hz), 5.37–5.21 (m, 2H, Glu-H_3, H_4), 4.30–4.17 (m, 2H, Glu-H_6), 4.00–3.90 (m, 1H, Glu-H_5), 3.42 (t, 4H, N—CH_2), 2.11 (s, 3H, $COCH_3$), 2.06 (s, 3H, $COCH_3$), 2.03 (s, 3H, $COCH_3$), 1.90–1.83 (m, 2H, C—CH_2—C), 1.83 (s, 3H, $COCH_3$); ^{13}C NMR ($CDCl_3$): δ 170.17, 170.02, 168.99, 168.07, 147.02, 141.42, 131.28, 131.17, 129.97, 126.86, 124.77, 82.72, 74.16, 73.28, 68.86, 67.43, 61.73, 41.55, 20.44, 20.30, 20.29, 20.28, 20.11; MS: 564 ([M + 1]$^+$, 37), 234 (100); Positive SIMS (Glycerol): Calcd. for $C_{24}H_{30}N_5O_9S$ (M + 1): 564.1758563, Found: 564.1767260.

*1-(2,3,4,6-Tetra-O-acetyl-β-D-glucopyranosyl)-4-(2-tetrahydropyrimidinyl)-5-pyridyl-1,2,3-triazole (***6c***).* IR (KBr): 3410 (N—H), 1750 (C=O), 1640 cm^{-1}; ^1H NMR ($CDCl_3$): δ 8.70 (d, 1H, Ar-H), 8.20 (d, 1H, Ar-H), 7.85–7.77 (m, 1H, Ar-H), 7.40–7.34 (m, 1H, Ar-H), 6.55 (d, 1H, Glu-H_1, $J_{H1,H2} = 9.52$ Hz), 6.20–6.10 (m, 1H, Glu-H_2), 5.43–5.17 (m, 2H, Glu-H_3, H_4), 4.18–3.92 (m, 2H, Glu-H_6), 3.83–3.75 (m, 1H, Glu-H_5), 3.43 (t, 4H, N—CH_2), 2.04 (s, 6H, $COCH_3$), 1.95 (s, 3H, $COCH_3$), 1.90–1.79 (m, 2H, C—CH_2—C), 1.88 (s, 3H, $COCH_3$); ^{13}C NMR ($CDCl_3$): δ 170.20, 170.14, 169.04, 168.36, 148.68, 147.49, 146.10, 141.63, 136.00, 134.52, 127.31, 123.80, 83.46, 74.14, 73.56, 69.31, 67.62, 61.47, 41.62, 20.41, 20.40, 20.35, 20.34, 20.26; MS: 559 ($[M+1]^+$, 20), 229 (100); Positive SIMS (Glycerol): Calcd. for $C_{25}H_{31}N_6O_9$ (M + 1) 559.2146849, Found 559.2145980.

*1-(2,3,4,6-Tetra-O-acetyl-β-D-glucopyranosyl)-4-(2-tetrahydropyrimidinyl)-5-p-fluorophenyl-1,2,3-triazole (***6d***).* IR (KBr): 3410 (N—H), 1755 (C=O), 1635 cm^{-1}; ^1H NMR ($CDCl_3$): δ 7.63–7.56 (m, 2H, Ar-H), 7.22–7.16 (m, 2H, Ar-H), 6.07–5.97 (m,1H, Glu-H_2), 5.38 (d, 1H, Glu-H_1, $J_{H1,H2} = 9.52$ Hz), 5.32–5.13 (m, 2H, Glu-H_3, H_4), 4.30–4.12 (m, 2H, Glu-H_6), 3.88–3.78 (m, 1H, Glu-H_5), 3.39 (t, 4H, N—CH_2), 2.11 (s, 3H, $COCH_3$), 2.04 (s, 3H, $COCH_3$), 2.01 (s, 3H, $COCH_3$), 1.90–1.73 (m, 2H, C—CH_2—C), 1.84 (s, 3H, $COCH_3$); ^{13}C NMR ($CDCl_3$): δ 170.20, 170.12, 169.05, 168.13, 147.12, 141.02, 136.29, 132.69, 121.61, 115.66, 115.23, 82.93, 74.50, 73.22, 69.12, 67.51, 61.85, 41.66, 20.52, 20.51, 20.36, 20.35, 20.17; MS: 576 ($[M + 1]^+$, 25), 246 (100); Positive SIMS (Glycerol): Calcd. for $C_{26}H_{31}FN_5O_9$ (M + 1) 576.2100141, Found 576.2098220.

*1-(2,3,4,6-Tetra-O-acetyl-β-D-glucopyranosyl)-4-(3-N-methyl-2-tetrahydropyrimidinyl)-5-furyl-1,2,3-triazole (***7a***).* IR (KBr): 1760 (C=O), 1618 cm^{-1}; ^1H NMR ($CDCl_3$): δ 7.63 (d, 1H, Ar-H), 7.13 (d, 1H, Ar-H), 6.61–6.57 (m, 1H, Ar-H), 6.16–6.08 (m, 1H, Glu-H_2), 6.04 (d, 1H, Glu-H_1, $J_{H1,H2} = 9.28$ Hz), 5.47–5.22 (m, 2H, Glu-H_3, H_4), 4.30–4.15 (m, 2H, Glu-H_6), 4.10–4.00 (m, 1H, Glu-H_5), 3.53 (t, 2H, N—CH_2), 3.32 (t, 2H, N—CH_2), 2.74 (s, 3H, N—CH_3), 2.08 (s, 3H, $COCH_3$), 2.05 (s, 6H, $COCH_3$), 2.07–1.93 (m, 2H, C—CH_2—C), 1.88 (s, 3H, $COCH_3$); ^{13}C NMR ($CDCl_3$): δ 170.41, 170.21, 169.17, 168.47, 149.64, 144.10, 140.99, 140.32, 127.85, 113.57, 111.98, 84.70, 74.47, 73.40, 69.20, 67.73, 61.73, 48.09, 44.24, 39.34, 21.47, 20.58, 20.57, 20.51, 20.32; MS: 562 ($[M + 1]^+$, 65), 232 (100); Positive SIMS (Glycerol): Calcd. for $C_{25}H_{32}N_5O_{10}$ (M + 1) 562.2143496, Found 562.2148990.

*1-(2,3,4,6-Tetra-O-acetyl-β-D-glucopyranosyl)-4-(3-N-methyl-2-tetrahydropyrimidinyl)-5-thienyl-1,2,3-triazole (***7b***).* IR (KBr): 1750 (C=O), 1620 cm^{-1}; ^1H NMR ($CDCl_3$): δ 7.63–7.58 (m, 2H, Ar-H), 7.22–7.17 (m, 1H, Ar-H), 6.16–6.07 (m, 1H, Glu-H_2), 5.63 (d, 1H, Glu-H_1, $J_{H1,H2} = 9.53$ Hz), 5.39–5.22 (m, 2H, Glu-H_3, H_4), 4.35–4.20 (m, 2H, Glu-H_6), 4.03–3.94 (m, 1H, Glu-H_5), 3.52 (t, 2H, N—CH_2), 3.29 (t, 2H, N—CH_2), 2.72 (s, 3H, N—CH_3), 2.12 (s, 3H, $COCH_3$), 2.07 (s, 3H, $COCH_3$), 2.03 (s, 3H, $COCH_3$), 2.00–1.82 (m, 2H, C—CH_2—C), 1.86 (s, 3H, $COCH_3$); ^{13}C NMR ($CDCl_3$): δ 170.26, 170.03, 169.09, 168.49, 150.04, 140.54, 132.04, 130.91, 130.11, 127.77, 124.19, 83.43, 74.42, 73.31, 68.74, 67.51, 61.77, 48.04, 42.94, 39.46, 22.54, 20.86, 20.60, 20.40, 20.39; MS: 578 ($[M + 1]^+$, 91), 452 (10), 411 (12), 248 (100); Positive SIMS (Glycerol): Calcd. for $C_{25}H_{32}N_5O_9S$ (M + 1) 578.1915055, Found 578.1920790.

*1-(2,3,4,6-Tetra-O-acetyl-β-D-glucopyranosyl)-4-(3-N-methyl-2-tetrahydropyrimidinyl)-5-p-fluorophenyl-1,2,3-triazole (***7d***).* IR (KBr): 1750 (C=O), 1620 cm^{-1}; ^1H NMR ($CDCl_3$): δ 7.70–7.60 (m, 2H, Ar-H), 7.25–7.14 (m, 2H, Ar-H), 5.95–5.86 (m, 1H, Glu-H_2), 5.56 (d, 1H, Glu-H_1, $J_{H1,H2} = 9.23$ Hz), 5.35–5.12 (m, 2H, Glu-H_3, H_4), 4.33–4.13 (m, 2H, Glu-H_6), 3.94–3.84 (m, 1H, Glu-H_5), 3.42 (t, 2H, N—CH_2), 3.21 (t, 2H, N—CH_2), 2.65 (s, 3H, N—CH_3), 2.12 (s, 3H, $COCH_3$), 2.07 (s, 3H, $COCH_3$), 2.02 (s, 3H, $COCH_3$), 1.97–1.90 (m, 2H, C—CH_2—C), 1.84 (s, 3H, $COCH_3$); ^{13}C NMR ($CDCl_3$): δ 170.14, 169.99, 169.03, 168.27, 166.04, 161.04, 149.60, 142.17, 136.06, 131.96, 121.49, 116.04, 115.61, 83.72, 74.57, 73.13, 69.08, 67.51, 61.83, 47.95, 44.17, 39.15, 21.36, 20.51, 20.32, 20.23, 20.22; MS: 590 ($[M + 1]^+$,73), 260 (100); Positive SIMS (Glycerol): Calcd. for $C_{27}H_{33}FN_5O_9$ (M + 1) 590.2256633, Found 590.2258620.

*1-(2,3,4,6-Tetra-O-acetyl-β-D-glucopyranosyl)-4-(2-imidazolinyl)-5-furyl-1,2,3-triazole (***8a***).* IR (KBr): 3410 (N—H), 1750 (C=O), 1630 cm^{-1}; ^1H NMR ($CDCl_3$): δ 8.14 (d, 1H, Ar-H), 7.65 (d, 1H, Ar-H), 6.63–6.66 (m, 1H, Ar-H), 6.24–6.16 (m, 1H, Glu-H_2), 6.13 (d, 1H, Glu-H_1, $J_{H1,H2} = 8.73$ Hz), 5.47–5.22 (m, 2H, Glu-H_3, H_4), 4.28–4.16 (m, 2H, Glu-H_6), 4.10–4.00 (m, 1H, Glu-H_5), 3.81 (s, 4H, N—CH_2), 2.07 (s, 3H, $COCH_3$), 2.05 (s, 3H, $COCH_3$), 2.02 (s, 3H, $COCH_3$), 1.85 (s, 3H, $COCH_3$); ^{13}C NMR ($CDCl_3$): δ 170.49, 170.35, 169.21, 168.40, 157.34, 144.50, 140.01, 135.17, 129.00, 117.62, 112.34, 84.62, 74.60, 73.63, 69.36, 67.86, 61.81, 50.00, 20.57, 20.56, 20.54, 20.34; MS: 534 ($[M + 1]^+$, 52), 349 (12), 331 (16), 204 (94), 154 (100); Positive SIMS (Glycerol): Calcd. for $C_{23}H_{28}N_5O_{10}$ (M + 1) 534.1830512, Found 534.1839710.

General Procedure for the Preparation of Compounds **12–14**

Ammonia was bubbled into the anhydrous methanol solution of each compounds **6–8** (1 mmol) at room temperature. When TLC ($CHCl_3$:CH_3OH 10:1, silica gel) showed the disappearance of each compounds **6–8** and the presence of a new spot, the reaction was stopped and the solvent was removed. The residue was purified by chromatography on Al_2O_3 (200–300) eluting with $CHCl_3$ and CH_3OH, respectively, to give each pure compound **12–14**.

*1-β-D-Glucopyranosyl-4-(2-tetrahydropyrimidinyl)-5-furyl-1,2,3-triazole (***12a***).* IR (KBr): 3380 (O—H, N—H), 1655 cm^{-1}; ^1H NMR (D_2O): δ 7.68 (d, 1H, Ar-H), 6.94 (d, 1H, Ar-H), 6.60–6.55 (m, 1H, Ar-H), 5.56 (d, 1H, Glu-H_1, $J_{H1,H2}$ = 9.03 Hz), 4.28–4.16 (m, 1H, Glu-H_2), 3.82–3.40 (m, 5H, Glu- H_3, H_4, H_5, H_6), 3.42 (t, 4H, N—CH_2), 1.93 (quin, 1H, C—CH_2—C); ^{13}C NMR (D_2O): δ 146.96, 136.15, 133.33, 131.30, 116.58, 112.60, 96.24, 86.02, 78.83, 75.90, 70.94, 68.93, 60.38, 39.01, 38.96, 17.38; MS: 380 ([M + 1]$^+$, 13), 307 (9), 218 (17); Positive SIMS (Glycerol): Calcd. for $C_{16}H_{22}N_5O_6$ (M + 1) 380.1564472, Found 380.1557330.

*1-β-D-Glucopyranosyl-4-(2-tetrahydropyrimidinyl)-5-thienyl-1,2,3-triazole (***12b***).* IR (KBr): 3400 (O—H), 1650 cm^{-1}; ^1H NMR (D_2O): δ 7.68 (d, 1H, Ar-H), 7.32 (d, 1H, Ar-H), 7.12 (m, 1H, Ar-H), 5.29 (d, 1H, Glu-H_1, $J_{H1,H2}$ = 9.27 Hz), 4.14 (m, 1H, Glu-H_2), 3.79–3.58 (m, 2H, Glu-H_6), 3.50 (m, 1H, Glu-H_5), 3.53–3.38 (m, 2H, Glu-H_3, H_4), 3.27 (t, 4H, N—CH_2), 1.81 (quin, 1H, C—CH_2—C); ^{13}C NMR (D_2O): δ 135.26, 119.45, 118.67, 117.19, 116.62, 113.02, 105.08, 80.35, 69.49, 62.91, 60.20, 55.04, 53.25, 44.76, 33.11, 23.57; Positive SIMS (Glycerol): Calcd. for $C_{16}H_{22}N_5O_5S$ (M + 1) 396.1336031, Found 396.1342250.

*1-β-D-Glucopyranosyl-4-(2-tetrahydropyrimidinyl)-5-pyridyl-1,2,3-triazole (***12c***).* IR (KBr): 3370 (O—H), 1655 cm^{-1}; ^1H NMR (D_2O): δ 8.78 (d, 1H, Ar-H), 8.12 (m, 1H, Ar-H), 7.85 (d, 1H, Ar-H), 7.67 (m, 1H, Ar-H), 5.61 (d, 1H, Glu-H_1, $J_{H1,H2}$ = 9.26 Hz), 4.34 (m, 1H, Glu-H_2), 3.82–3.60 (m, 2H, Glu-H_6), 3.70 (m, 1H, Glu-H_5), 3.66–3.40 (m, 2H, Glu-H_3, H_4), 3.54 (t, 4H, N—CH_2), 2.04 (quin, 1H, C—CH_2—C); ^{13}C NMR (D_2O): δ 151.29, 150.49, 142.16, 139.39, 139.24, 134.59, 126.65, 126.52, 85.87, 79.03, 75.92, 71.49, 69.08, 60.57, 39.01, 17.48; Positive SIMS (Glycerol): Calcd. for $C_{17}H_{23}N_6O_5$ (M + 1) 391.1724317, Found 391.1719950.

*1-β-D-Glucopyranosyl-4-(2-tetrahydropyrimidinyl)-5-p-fluorophenyl-1,2,3-triazole (***12d***).* IR (KBr): 3410 (O—H), 1660 cm^{-1}; ^1H NMR (D_2O): δ 7.51 (m, 2H, Ar-H), 7.28 (m, 2H, Ar-H), 5.27 (d, 1H, Glu-H_1, $J_{H1,H2}$ = 9.28 Hz), 4.18 (m, 1H, Glu-H_2), 3.84–3.57 (m, 2H, Glu-H_6), 3.48 (m, 1H, Glu-H_5), 3.52–3.31 (m, 2H, Glu-H_3, H_4), 3.39 (t, 4H, N—CH_2), 1.93 (quin, 1H, C—CH_2—C); ^{13}C NMR (D_2O): δ 167.01, 162.02, 151.64, 140.21, 134.18, 132.56, 132.38, 118.40, 118.34, 117.33, 116.89, 85.37, 78.95, 75.93, 71.23, 69.11, 60.56, 39.10, 17.59; Positive SIMS (Glycerol): Calcd. for $C_{18}H_{23}FN_5O_5$ (M + 1) 408.1677609, Found 408.1675390.

*1-β-D-Glucopyranosyl-4-(3-N-methyl-2-tetrahydropyrimidinyl)-5-furyl-1,2,3-triazole (***13a***).* IR (KBr): 3370 (O—H), 1645 cm^{-1}; ^1H NMR (D_2O): δ 7.74 (d, 1H, Ar-H), 6.98 (d, 1H, Ar-H), 6.66–6.61 (m, 1H, Ar-H), 5.74 (d, 1H, Glu-H_1, $J_{H1,H2}$ = 9.03 Hz), 4.35–4.25 (m, 1H, Glu-H_2), 3.84–3.50 (m, 5H, Glu- H_3, H_4, H_5, H_6), 3.59 (t, 2H, N—CH_2), 3.42 (t, 2H, N—CH_2), 2.82 (t, 3H, N—CH_3), 2.10 (quin, 1H, C—CH_2—C); ^{13}C NMR (D_2O): δ 152.51, 147.13, 136.87, 132.48, 131.66, 115.83, 112.80, 86.36, 78.97, 76.08, 71.02, 69.10, 60.53, 48.26, 40.05, 38.94, 18.45; MS: 394 ([M + 1]$^+$, 37), 232 (39); Positive SIMS (Glycerol): Calcd. for $C_{17}H_{24}N_5O_6$ (M + 1) 394.1720964, Found 394.1722190.

*1-β-D-Glucopyranosyl-4-(3-N-methyl-2-tetrahydropyrimidinyl)-5-thienyl-1,2,3-triazole (***13b***).* IR (KBr): 3410 (O—H), 1650 cm^{-1}; ^1H NMR (D_2O): δ 7.71 (dd, 1H, Ar-H), 7.36–7.33 (m, 1H, Ar-H), 7.16 (dd, 1H, Ar-H), 5.49 (d, 1H, Glu-H_1, $J_{H1,H2}$ = 9.28 Hz), 4.26–4.17 (m, 1H, Glu-H_2), 3.82–3.40 (m, 5H, Glu- H_3, H_4, H_5, H_6), 3.43 (t, 2H, N—CH_2), 3.34 (t, 2H, N—CH_2), 2.72 (s, 3H, N—CH_3), 1.98 (quin, 1H, C—CH_2—C); ^{13}C NMR (D_2O): δ 152.24, 135.30, 133.95, 132.80, 132.32, 128.98, 120.96, 85.45, 76.73, 75.94, 70.77, 68.98, 60.42, 48.13, 39.94, 38.79, 18.27; MS: 410 ([M + 1]$^+$, 31), 248 (33), 154 (100); Positive SIMS (Glycerol): Calcd. for $C_{17}H_{24}N_5O_5S$ (M + 1) 410.1492523, Found 410.1488200.

*1-β-D-Glucopyranosyl-4-(3-N-methyl-2-tetrahydropyrimidinyl)-5-p-fluorophenyl-1,2,3-triazole (***13c***).* IR (KBr): 3370 (O—H), 1645 cm^{-1}; ^1H NMR (D_2O): δ 7.57–7.49 (m, 2H, Ar-H), 7.37–7.28 (m, 2H, Ar-H), 5.45 (d, 1H, Glu-H_1, $J_{H1,H2}$ = 9.03 Hz), 4.32–4.22 (m, 1H, Glu-H_2), 3.91–3.55 (m, 5H, Glu-H_3, H_4, H_5, H_6), 3.54 (t, 2H, N—CH_2), 3.42 (t, 2H, N—CH_2), 2.84 (s, 3H, N—CH_3), 2.06 (quin, 1H, C—CH_2—C); ^{13}C NMR (D_2O): δ 166.88, 161.89, 152.38, 140.45, 134.15, 131.78, 116.95, 85.53, 78.96, 75.96, 71.24, 69.13, 60.58, 48.23, 40.24, 39.00, 18.51; MS: 422

([M + 1]$^+$, 33), 260 (31); Positive SIMS (Glycerol): Calcd. for $C_{19}H_{25}FN_5O_5$ (M + 1) 422.1834101, Found 422.1828240.

*1-β-D-Glucopyranosyl-4-(2-imidazolinyl)-5-furyl-1,2,3-triazole (***14a***).* IR (KBr): 3380 (O—H, N—H), 1630 cm^{-1}; ^{1}H NMR (D_2O): δ 7.84 (d, 1H, Ar-H), 7.12 (d, 1H, Ar-H), 6.76–6.70 (m, 1H, Ar-H), 5.65 (d, 1H, Glu-H_1, $J_{H1,H2}$ = 9.03 Hz), 4.40–4.30 (m, 1H, Glu-H_2), 3.90 (s, 4H, N—CH_2), 3.80–3.55 (m, 5H, Glu-H_3, H_4, H_5,H_6); ^{13}C NMR (D_2O): δ 147.04, 136.33, 131.62, 131.50, 117.13, 117.10, 112.72, 86.03, 78.89, 76.04, 71.10, 69.08, 60.54, 48.94, 45.43; Positive SIMS (Glycerol): Calcd. for $C_{15}H_{20}N_5O_6$ (M + 1) 366.1407980, Found 366.1399150.

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