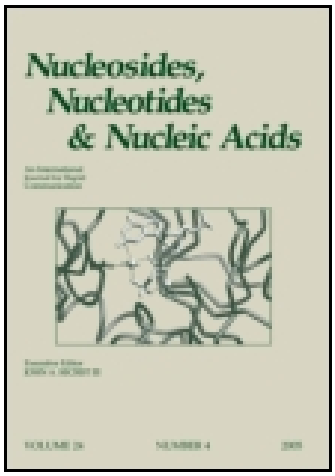

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A New Approach to the Synthesis of Benzothiazole, Benzoxazole, and Pyridine Nucleosides as Potential Antitumor Agents

Ahmed I. Khodair [a d], Najim A. Al-Masoudi [b] & Jean-Pierre Gesson [c]

[a] Chemistry Department, Faculty of Education, Tanta University (Kafr El-Sheikh Branch), Kafr El-Sheikh, Egypt

[b] Fakultät für Chemie, Universität Konstanz, Konstanz, Germany

[c] Laboratoire de Chimie XII, Université de Poitiers et CNRS, Poitiers, France

[d] Chemistry Department, Faculty of Education, Tanta University (Kafr El-Sheikh Branch), Kafr El-Sheikh, Egypt

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A New Approach to the Synthesis of Benzothiazole, Benzoxazole, and Pyridine Nucleosides as Potential Antitumor Agents

Ahmed I. Khodair,[1,*] Najim A. Al-Masoudi,[2] and Jean-Pierre Gesson[3]

[1]Chemistry Department, Faculty of Education, Tanta University (Kafr El-Sheikh Branch), Kafr El-Sheikh, Egypt
[2]Fakultät für Chemie, Universität Konstanz, Konstanz, Germany
[3]Laboratoire de Chimie XII, Université de Poitiers et CNRS, Poitiers, France

ABSTRACT

A modified nitrogen and sulfur glycosylation reaction involving benzothiazole benzoxazole and pyridine nucleoside bases with furanose and pyranose sugars are described. Conformational analysis has been studied by homo- and hetero-nuclear two-dimensional NMR methods (2D DFQ-COSY, HMQC and HMBC). The *N* and *S* sites of glycosylation were determined from the ^{1}H, ^{13}C hetero-nuclear multiple-quantum coherence (HMQC) experiments. All the deprotected nucleosides were tested for their potential antitumor activity.

*Correspondence: Ahmed I. Khodair, Chemistry Department, Faculty of Education, Tanta University (Kafr El-Sheikh Branch), Kafr El-Sheikh, Egypt; Fax: 20-472-23415; E-mail: khodair_62@yahoo.com.

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INTRODUCTION

Important biological processes are carried out by carbohydrate processing enzymes and in particular by glycosides.[1–3] Their roles in therapeutic and biological applications as a consequence of modifying or blocking their action have attracted the attention of organic chemists and biochemists. These strategies have been applied to glycosides involved in intestinal digestion, post-translational processing of glycoproteins, and lysosomal catabolism of glycoconjugates. Thus, a number of them show promise as antidiabetes,[4] antitumor metastasis,[5] and antiobesity drugs,[6] and as antifeedents[7] and antivirals.[8–11] We have recently reported that *S*-glycosylated hydantoin derivatives showed potent activity against the herpes simplex virus (HSV),[12] the human immunodeficiency virus (HIV)[13] and the leukemia subpanel.[14] The importance of such compounds prompted our interest in the synthesis and chemistry of this type of compounds. In the course of identifying new chemical structures which may serve as leads for designing novel antitumor and antiviral agents, we were particularly interested in *S*-glycosylation of 2-thiohydantoins.[12–16] In this respect, it seemed worth-while to link the benzothiazole, benzoxazole and pyridine to an hydrophilic moiety such as a glycoside. It was thus anticipated a better water solubility of these heterocycles and an improved selectivity toward cancer cells which are known to be specifically enriched in carbohydrate receptors such as lectins.[17,18] The present work describes the synthesis of a series of nitrogen glycosylated and their sulfur analogues bearing benzothiazole, benzoxazole and pyridine bases via new synthetic strategies. Furthermore, the confirmation of their most stable conformation and the antitumor screening has been studied.

RESULTS AND DISCUSSION

The silylation of the nucleoside bases **1a–c** was accomplished with bis(trimethylsilyl)-acetamide (BSA) in anhydrous MeCN at 70–80°C, and furnished the trimethylsilylated derivatives **2a–c**. These derivatives were condensed, devised by Vorbrüggen et al.,[21] with 1,2,3,5-tetra-*O*-acetyl-β-D-ribofuranose (**3**) in the presence of trimethylsilyl trifluoromethyanesulfonate (TMSOTf) as a catalyst at 70–80°C for 60 min. The nucleosides **4a,b**[22] were isolated by silica gel column chromatography in 72–76% yields. Removal of the acetyl groups from the glycon moiety of **4a,b** with 16% NH_3/MeOH solution at r. t. furnished 3-(β-D-ribofuranosyl)-2-thiobenzothiazole (**5a**)[22] and 3-(β-D-ribofuranosyl)-2-thiobenzoxazole (**5b**)[22] instead of *N*-(hydroxy-2-phenyl)-*N*-(β-D-ribofuranosyl)thiocarbamide,[22] respectively (Sch. 1). The proton spin systems were identified from DFQ-COSY[23] spectra. The anomeric coupling constants of **5a** is a typical for the β-configurated ribofuranoses (7.5 Hz). The rotating from nuclear overhauser effect (NOE)[24–26] between 1′-H at δ_H 6.84 and 4′-H is an additional proof for β-configuration, and these data are in agreement with those reported earlier by Gosselin et al.[22] The ribosylation occurred at the *N*-site of the benzothiazole **1a**. This was also visible in the HMBC spectrum where the anomeric proton of **5a** showed cross peak to C-3a (only one rotator about the glycosidic linkage was observed), and no such correlation to C-7a was shown, indicating for the *N*-glycosylation and not the *S*-glycosylation. Protons bearing carbon were detected

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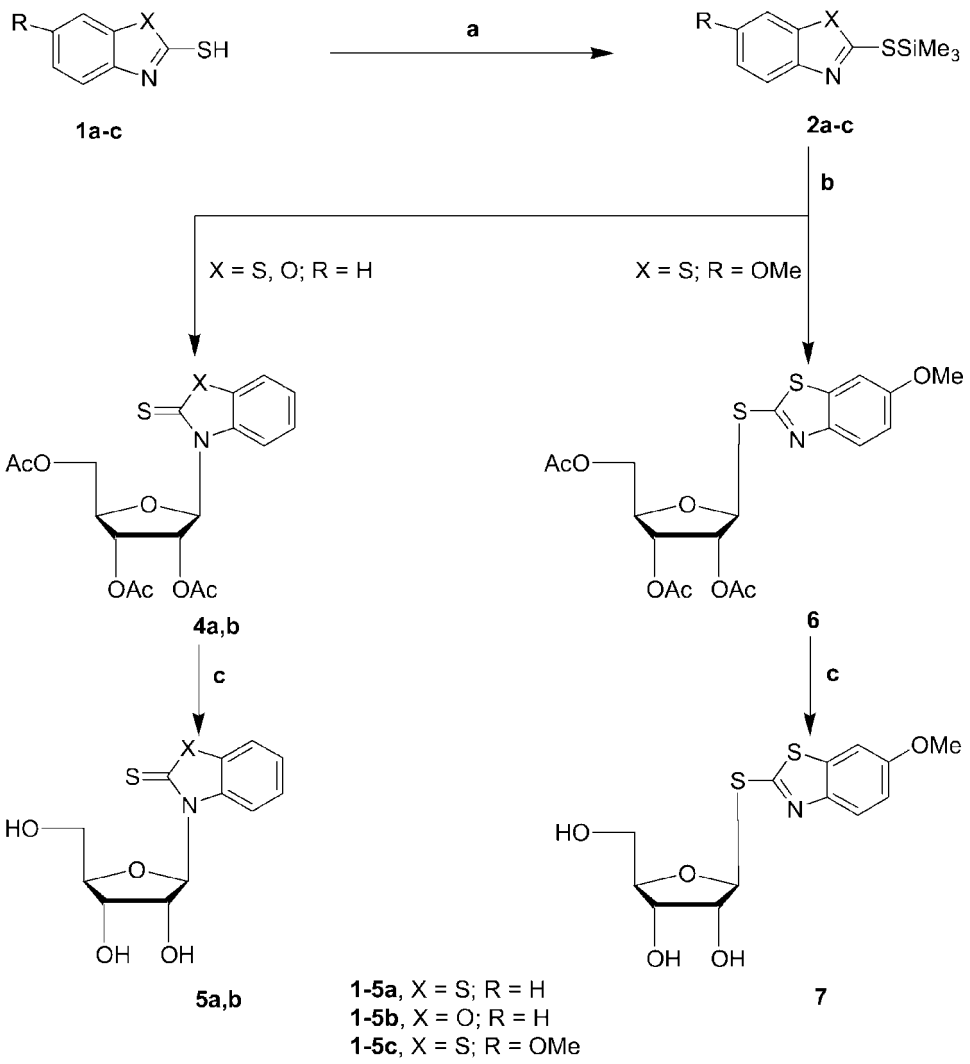
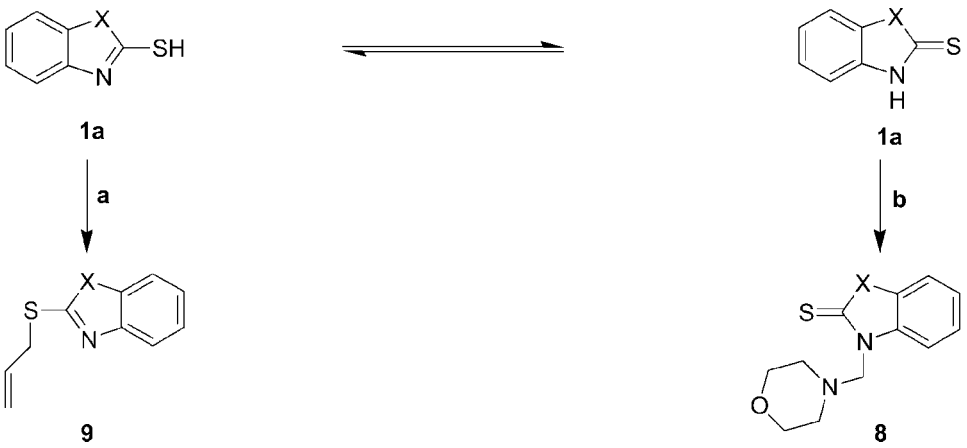


Scheme 1. *Reagents and conditions:* (a) MeCN, BSA, 70–80°C; (b) 1,2,3,5-tetra-*O*-acetyl-β-D-ribofuranose (**3**), TMSOTf, 70–80°C; (c) 16% NH_3/MeOH, r. t.

in HMQC spectra.[27] Carbon 2 resonates at highest field (δ_C 191.2) due to the shielding nature around thiocarbonyl bond, proving the *N*-glycosylation and excluding substitution at the sulfur atom (Sch. 1). These data are also in agreement with the ^{13}C-NMR spectrum of 3-(4-morpholinomethyl)-2-thiobenzothiazole **8**,[28] which in turn was prepared from the reaction of **1a** with morpholine and formaldehyde in EtOH at r. t., since the thiocarbonyl group at C-2 appears at δ_C 190.1 (Sch. 2). More evidence for the formation of *N*-nucleoside **4a** was obtained from the comparison with the spectral data obtained by Schantle et al.[29] during the *N*-methylation of *N*-substituted 4-methyl-5-phenyl-1*H*-imidazole-2-thione. On the other hand,



Scheme 2. *Reagents and conditions:* (a) Allyl iodide, NaOH, H_2O, r. t.; (b) HCHO, morpholine, EtOH, r. t.

2c was condensed with **3** under the same above conditions to give **6** (78%), after purification by chromatography. Deblocking of **6** with 16% NH_3/MeOH solution at r. t. furnished **7** (Sch. 1). The structure of **7** was established on its ^1H, ^{13}C-NMR and mass spectra. The doublet at δ 5.80 ($J_{1',2'}$ 4.57 Hz) was attributed to the anomeric proton of the β-configuration, whereas the ^{13}C NMR spectrum was characterized by a singlet at δ 166.1, corresponding to C-2, then proving *S*-glycosylation and excluding substitution at the nitrogen atom (Sch. 1).

These data are in agreement with the ^{13}C-NMR spectrum of 2-allylmercaptobenzothiazole (**9**),[30] which was prepared from the reaction of **1a** with allyl iodide in aqueous NaOH at r. t. and characterized by the appearance of the mercapto group at δ_C 165.9. (Sch. 2). Again, these data are also in agreement with those of *S*-methylation of some derivatives of *N*-substituted-1*H*-imidazole-2-thione.[29]

When compound **1a** was reacted with 1.1 equivalent of NaH in anhydrous MeCN followed by the addition of 1.1 equivalent of 2,3,4,6-tetra-*O*-acetyl-β-D-glucopyranosyl bromide(**10**),[31] the 2-(2′,3′,4′,6′-tetra-*O*-acetyl-β-D-glucopyranosyl)-2-thiobenzothiazole (**13a**)[32] and 3-(2′,3′,4′,6′-tetra-*O*-acetyl-β-D-glucopyranosyl)-2-thiobenzothiazole (**14a**)[32] in 84 and 4% yield, respectively, were obtained. Similarly, the treatment of compounds **1b** and **1c** with 2,3,4,6-tetra-*O*-benzoyl-β-D-glucopyranosyl bromide (**11**)[31] and **10** under the same above conditions afforded 2-(2′,3′,4′,6′-tetra-*O*-benzoyl-β-D-glucopyranosyl)-2-thiobenzoxazole (**13b**) and 5-methoxy-2-(2′,3′,4′,6′-tetra-*O*-acetyl-β-D-glucopyranosyl)-2-thiobenzothiazole (**13c**) in 82 and 83% yield, respectively.

This series was extended with more sugar moieties such as the acylated galactose bromide[33] bearing the benzothiazole precursors to examine their potential biological activity. Thus, the galactose bromide derivative **12** was selected to react with: **1a**, giving **13d**[34] in 90% yield, **1b** affording **13e** in 45% yield and **14b** in 38% yield, and finally with **1c** to yield **13f** in 60% yield and **14c** in 22% yield, respectively. Deprotection of **13a–f** and **14b,c** with saturated 16% NH_3/MeOH solution at r. t. furnished the corresponding free nucleosides **15a–f** and **16a,b**, respectively (Sch. 3).

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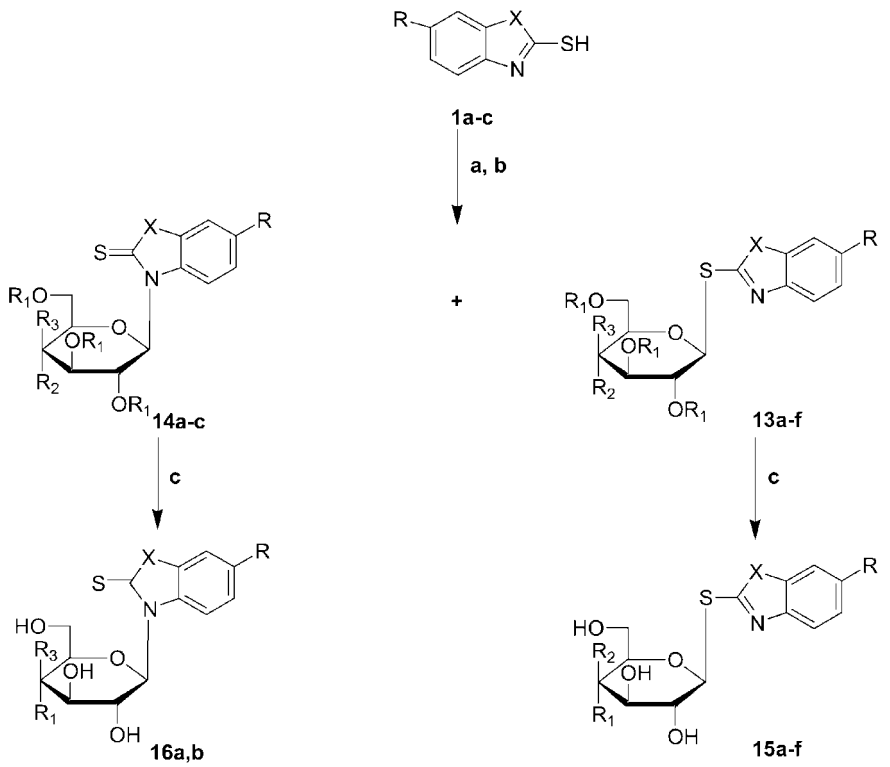

	X	R	R_1	R_2	R_3		X	R	R_1	R_2
13a	S	H	Ac	OAc	H	**15a**	S	H	OH	H
b	O	H	Bz	OAc	H	**b**	O	H	OH	H
c	S	OMe	Ac	OAc	H	**c**	S	OMe	OH	H
d	S	H	Ac	H	OAc	**d**	S	H	H	OH
e	O	H	Ac	H	OAc	**e**	O	H	H	OH
f	S	OMe	Ac	H	OAc	**f**	S	OMe	H	OH
14a	S	H	Ac	OAc	H	**16a**	O	H	H	OH
b	O	H	Ac	H	OAc	**b**	S	H	H	OH
c	S	OMe	Ac	H	OAc					

Scheme 3. *Reagents and conditions:* (a) NaH, MeCN, r. t.; (b) 2,3,4,6-tetra-*O*-acetyl-α-D-glucopyranosyl bromide (**10**) or 2,3,4,6-tetra-*O*-benzoyl-α-D-glucopyranosyl bromide (**11**) or 2,3,4,6-tetra-*O*-acetyl-α-D-galactopyranosyl bromide (**12**), r. t.; (c) 16% NH_3/MeOH, r. t.

The structures of **15a–f** and **16a,b** were confirmed on the basis of their spectroscopic and mass spectral data and the earlier results of Zinner and Peseke.[32] The mass spectrum of **15e** showed a molecular ion peak at m/z 313, while the ^{1}H-NMR spectrum showed a doublet at δ_H 5.36 with $J_{1',2'}$ 9.8 Hz, corresponding to the 1′-H and indicating a β-configuration. C-2 of **15e** resonated at δ_C 162.5, establishing the *S*-glycosylation. The structure of **16a** was assigned from the mass (molecular ion peak at m/z 313), ^{1}H and ^{13}C-NMR spectra. The anomeric proton appeared as a doublet at

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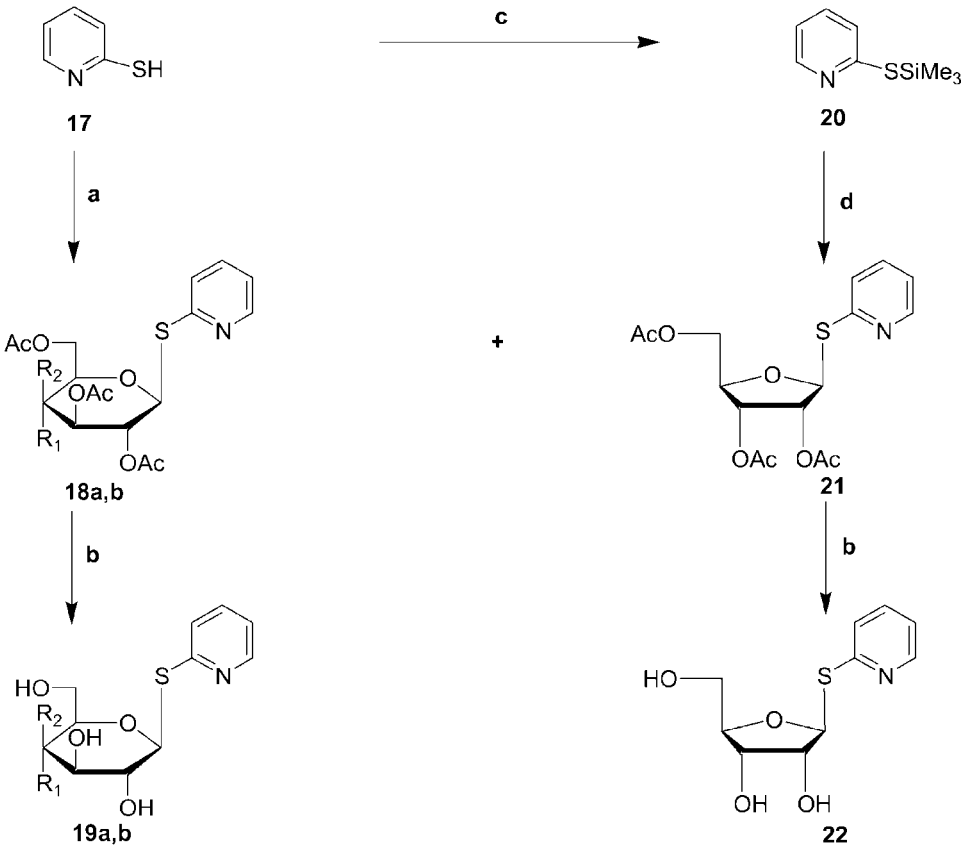
δ_H 6.03 ($J_{1',2'}$ 9.1 Hz), corresponding to the diaxial coupling and then the β-configuration. The ^{13}C NMR spectrum was characterized by a singlet at δ_C 181.4, corresponding to C-2, and then proving the *N*-glycosylation. Furthermore, the heteronuclear spectra (HMQC, DFQ-COSY) of **16a,b** showed $^3J_{C,H}$ correlation between C-3a and 1′-H, which is an additional proof for *N*-glycosylation, since no such correlation was shown by **15a-f**, which is indication of the *S*-glycosylation.

When 2-mercapto-pyridine **17** was reacted with 1.1 equivalent of NaH in anhydrous MeCN followed by addition of 1.1 equivalent of **10** and **12**, two products **18a**[35] and **18b**[35] were isolated in 77 and 86% yields, respectively. On the other hand, silylation of **17** with BSA in anhydrous MeCN at 70–80°C afforded the trimethylsilylated derivative **20**. Condensation of **20**, by applying Vorbrüggen et al.[21] method, with **3** in the presence of TMSOTf as catalyst at 70–80°C for 60 min gave, after purification by column chromatography, **21**[36] (72% yield). Deblocking of **18a,b** and **21** with 16% NH_3/MeOH solution at r. t. furnished **19a**[37] (85%), **19b** (97%) and **22** (90%), respectively (Sch. 4). The structures of **18–22** were identified by the spectroscopic methods, since the structure of **19b** was supported by the mass



Scheme 4. *Reagents and conditions:* (a) **10** or **12**, NaH, MeCN, r. t.; (b) 16% NH_3/MeOH, r. t.; (c) MeCN, BSA, 70–80°C; (d) **3**, TMSOTf, 70–80°C.

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spectra, which showed a molecular ion peak at m/z 273. 1′-H appeared as a doublet at δ_H 5.07 with $J_{1',2'}$ 9.7 Hz, confirming the diaxial coupling with the β-configuration. C-2 at **19b** resonates at δ_C 158.8, proving the *S*-glycosylation and excluding substitution at the nitrogen atom. The mass spectrum of **21** was characterized by a molecular ion peak at m/z 369, while the resonance at δ_H 6.09 ($J_{1',2'}$ 4.6 Hz) as a doublet was attributed to 1′-H with a β-configuration, and these data are in agreement with the ^{1}H-NMR data of 1-(2-thiopyridyl-2,3-*O*-isopropylidene-5-*O*-(*tert*-butyldiphenylsilyl)-β-D-ribofuranose and its α-anomer (the anomeric protons appeared at δ_H 6.19 and 6.68, respectively).[38] The ^{13}C NMR spectrum of compound **22** was characterized by a singlet at δ_C 158.1, corresponding to C-2, and again proving the *S*-glycosylation.

In conclusion, we have described the successful syntheses of benzothiazole, benzoxazole and pyridine nucleosides bearing the furanose and pyranose sugar moieties, and established their configuration and most stable conformation by analysis of their spectral data (ROESY, DFQ-COSY, HMBC and HMQC NMR spectra). Compounds **5a,b**, **15a–f**, **16a,b**, **19a,b** and **22** were screened against leukemia-1210[39,40] and were found to be inactive. The antiviral and the other antitumor activities of the prepared compounds are under investigation.

EXPERIMENTAL

General Methods. Melting points (°C) are uncorrected. Aluminum sheets coated with silica gel 60 F_{254} (Merck) were used for TLC. Viewing under a short wavelength UV lamp effected detection. IR spectra (KBr disc) were obtained on a Pye Unicam spectra 1000. NMR spectra were measured in DMSO-d_6 and $CDCl_3$ using $SiMe_4$ as internal reference on a Bruker Advance DPX 300 MHz spectrometer. Analytical data were obtained from the Service Central de Microanalyse (CNRS, Lyon). Mass spectra were recorded by EI on a Varian MAT 311A spectrometer and FAB on a Kratos MS 50 spectrometer.

3-(2′,3′,5′-Tri-*O*-acetyl-β-D-ribofuranosyl)-2-thiobenzothiazole (4a). *General Procedure*: A suspension of **1a** (835 mg, 5.0 mmol) in anhydrous MeCN (25 mL) and BSA (1.25 mL, 5.0 mmol) was heated at 70–80°C for 30 min. 1,2,3,5-Tetra-*O*-acetyl-β-D-ribofuranose (**3**) (1.75 g, 5.0 mmol) dissolved in anhydrous MeCN (25 mL) was added to the reaction mixture via a cannula, followed by the addition of TMSOTf (1.0 mL, 1.0 mmol) and the reaction mixture was heated at 70–80°C for 1 h. After cooling, a saturated aqueous $NaHCO_3$ solution was added and the resulting mixture extracted with CH_2Cl_2. The combined organic fractions were washed with saturated NaCl solution, dried ($MgSO_4$), filtered, and evaporated to dryness. The residue obtained was purified by flash chromatography (eluent EtOAc/petroleum ether 40–60°C, 1:3) to give **4a** (1.62 g, 76%) as a white foam (lit.[22] mp 134–136°C, 75%). MS; m/z: 425 (M^+). ^{1}H-NMR ($CDCl_3$): δ 2.05, 2.16, 2.22, (3s, 9H, 3 Ac), 4.12 (dd, J = 7.1, 7.1 Hz, 1H, 5′-H), 4.36 (m, 2H, 4′-H, 5″-H), 5.52 (dd, J = 4.3, 6.7 Hz, 1H, 3′-H), 5.79 (dd, J = 6.9, 6.9 Hz, 1H, 2′-H), 7.22 (d, J = 6.8 Hz, 1H, 1′-H), 7.27–7.62 (m, 4H, Ar-H). ^{13}C-NMR ($CDCl_3$): δ 20.3, 20.5, 20.8 (3 Ac),

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62.6 (C-5′), 68.7 (C-3′), 69.7 (C-2′), 79.4 (C-4′), 88.1 (C-1′), 113.2, 121.4, 125.1, 125.9, 126.7, 139.4 (C-Ar), 169.4, 169.7, 170.1 (3 CO), 191.8 (C-2).

3-(2′,3′,5′-Tri-*O*-acetyl-β-D-ribofuranosyl)-2-thiobenzoxazole (4b). From **1b** (755 mg, 5.0 mmol) in the manner described for **4a**. Yield 1.47 g (72%) as a white foam (lit.[22] mp 107–108°C, 47%). MS; *m/z*: 409 (M^+). ^{1}H-NMR ($CDCl_3$): δ 2.07, 2.18; 2.21 (3s, 9H, 3 Ac), 4.12 (dd, $J = 7.0$, 7.1 Hz, 1H, 5′-H), 4.40 (m, 2H, 4′-H, 5″-H), 5.48 (dd, $J = 4.4$, 6.7 Hz, 1H, 3′-H), 5.70 (dd, $J = 6.9$, 6.9 Hz, 1H, 2′-H), 6.67 (d, 1H, $J = 7.0$ Hz, 1′-H), 7.24–7.47 (m, 4H, Ar-H). ^{13}C-NMR ($CDCl_3$): δ 20.2, 20.4, 20.6 (3 Ac), 62.7 (C-5′), 69.2 (C-3′), 70.0 (C-2′), 79.9 (C-4′), 88.3 (C-1′), 110.4, 110.8, 124.6, 124.7, 128.9, 146.8 (C-Ar), 169.3, 169.5, 169.9 (3 CO), 180.1 (C-2).

3-(β-D-Ribofuranosyl)-2-thiobenzothiazole (5a). *General Procedure*: To a stirred solution of **4a** (850 mg, 2.0 mmol) in anhydrous MeOH (20 mL) was added a solution of 16% NH_3/MeOH (10 mL) at r. t. and the stirring was continued for 16 h. The solvent was evaporated and the residue was chromatographed on silica gel using MeOH, in gradient, (0–5%) and CH_2Cl_2 as eluent to give **5a** (514 mg, 86%) as a white solid, mp 129–131°C (lit.[22] mp 153–154°C, 91%). MS; *m/z*: 299 (M^+). ^{1}H-NMR (DMSO-d_6): δ 3.73 (m, 2H, 5′-H, 5″-H), 3.92 (m, 1H, 4′-H), 4.17 (dd, $J = 4.9$, 5.0 Hz, 1H, 3′-H), 4.55 (dd, $J = 6.6$, 7.1 Hz, 1H, 2′-H), 5.19 (d, $J = 4.9$ Hz, 1H, 3′-OH), 5.24 (t, $J = 4.9$ Hz, 1H, 5′-OH), 5.34 (d, $J = 6.5$ Hz, 1H, 2′-OH), 6.84 (d, $J = 7.5$ Hz, 1H, 1′-H), 7.28–8.08 (m, 4H, Ar-H). ^{13}C-NMR (DMSO-d_6): δ 61.1 (C-5′), 69.2 (C-3′), 70.2 (C-2′), 85.9 (C-4′), 90.2 (C-1′), 115.3, 121.8, 125.1, 125.8, 127.1, 139.7 (C-Ar), 191.2 (C-2).

3-(β-D-Ribofuranosyl)-2-thiobenzoxazole (5b). From **4b** (818 mg, 2.0 mmol) in the manner described for **5a**. Yield 475 mg (84%) as a white solid, mp 206–208°C (lit.[22] mp 183–185°C, 75%). MS; *m/z*: 283 (M^+). ^{1}H-NMR (DMSO-d_6): δ 3.74 (m, 2H, 5′-H, 5″-H), 4.02 (m, 1H, 4′-H), 4.21 (m, 1H, 3′-H), 4.53 (dd, $J = 6.2$, 7.3 Hz, 1H, 2′-H), 5.12 (d, $J = 4.8$ Hz, 1H, 3′-OH), 5.16 (t, J=4.7 Hz, 1H, 5′-OH), 5.32 (d, $J = 6.1$ Hz, 1H, 2′-OH), 6.36 (d, $J = 7.4$ Hz, 1H, 1′-H), 7.25–8.00 (m, 4H, Ar-H). ^{13}C-NMR (DMSO-d_6): δ 61.1 (C-5′), 69.6 (C-3′), 70.9 (C-2′), 85.9 (C-4′), 90.6 (C-1′), 109.8, 112.9, 124.2, 124.8, 129.3, 146.5 (C-Ar), 180.12 (C-2).

5-Methoxy-2-(2′,3′,5′-tri-*O*-acetyl-β-D-ribofuranosylmercapto)benzothiazole (6). From **1c** (985 mg, 5.0 mmol) in the manner described for **4a**. Yield 1.77 g (78%) of **6** as pale yellow foam. MS; *m/z*: 455 (M^+). Calculated for $C_{19}H_{21}NO_8S_2$ (455.49): C, 50.10; H, 4.65; N, 3.07. Found: C, 49.86; H, 4.53; N, 2.84. $[\alpha]_D + 21°$ (*c* 0.7, $CHCl_3$). ^{1}H-NMR ($CDCl_3$): δ 2.10, 2.13, 2.14 (3s, 9H, 3 Ac), 3.86 (s, 3H, OCH_3), 4.12 (dd, $J = 7.1$, 7.1 Hz, 1H, 5′-H), 4.46 (m, 2H, 4′-H, 5″-H), 5.47 (dd, $J = 5.2$, 5.2 Hz, 1H, 3′-H), 5.60 (dd, $J = 4.5$, 4.8 Hz, 1H, 2′-H), 6.14 (d, $J = 4.3$ Hz, 1H, 1′-H), 6.96–7.63 (m, 3H, Ar-H). ^{13}C-NMR ($CDCl_3$): δ 20.0, 20.1, 20. 6 (3 Ac), 55.2 (OCH_3), 62.6 (C-5′), 70.8 (C-3′), 74.3 (C-2′), 80.3 (C-4′), 86.9 (C-1′), 104.6, 114.4, 120.9, 126.9, 153.9, 158.6 (C-Ar), 162.7 (C-2), 168.9, 169.2, 169.9 (3 CO).

5-Methoxy-2-(β-D-ribofuranosylmercapto)benzothiazole (7). From **6** (910 mg, 2.0 mmol) in the manner described for **5a**. Yield 580 mg (88%) as a white solid,

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mp 125–127°C. MS; *m/z*: 329 (M^+). Calculated for $C_{13}H_{15}NO_5S_2$ (329.38): C, 47.40; H, 4.59; N, 4.25. Found: C, 47.22; H, 4.82; N, 3.93. $[\alpha]_D$ −25° (*c* 0.5, MeOH). ^{1}H-NMR (DMSO-d_6): δ 3.50 (m, 2H, 5′-H, 5″-H), 3.84 (s, 3H, OCH_3), 3.90 (m, 1H, 4′-H), 4.04 (m, 1H, 3′-H), 4.15 (m, 1H, 2′-H) 4.87 (br. s, 1H, 3′-OH), 5.24 (br. s, 1H, 5′-OH), 5.65 (br. s, 1H, 2′-OH), 5.80 (d, $J = 4.6$ Hz, 1H, 1′-H), 7.01–7.90 (m, 3H, Ar-H). ^{13}C-NMR (DMSO-d_6): δ 55.7 (OCH_3), 61.8 (C-5′), 70.9 (C-3′), 75.6 (C-2′), 86.5 (C-4′), 89.8 (C-1′), 104.9, 114.2, 122.3, 126.7, 154.1, 158.9 (C-Ar), 166.0 (C-2).

3-(4-Morpholinomethyl)-2-thiobenzothiazole (8). A mixture of **1a** (167 mg, 1.0 mmol) and morpholine (87 mg, 1 mmol) in anhydrous EtOH (5 mL) and aqueous formaldehyde (1 mL) was stirred for 6 h at r. t. until the starting material was consumed (TLC). The separated solid was collected by filtration and recrystallized from EtOH to give 245 mg (92%) of **8** as a white solid, mp 140–142°C (lit.[28] mp 149–150°C, 79%). MS; $m/z = 266$ (M^+). ^{1}H NMR (DMSO-d_6): δ 2.66 (m, 4H, 2′-H, 6′-H), 3.52 (m, 4H, 3′-H, 5′-H), 5.15 (s, 2H, NCH_2N), 7.36–7.74 (m, 4H, Ar-H); ^{13}C NMR (DMSO-d_6): δ 50.9 (C-2′, C-6′), 65.8 (C-3′, C-5′), 65.9 (CH_2), 114.4, 121.9, 124.8, 125.3, 126.9, 141.6 (C-Ar), 190.1 (C-2).

2-Allylmercaptobenzothiazole (9). To a solution of **1a** (167 mg, 1.0 mmol) in 1% aqueous NaOH (5 mL) was added allyl iodide (185 mg, 1.1 mmol) at r. t., with stirring. After 16 h at the same temperature, an aqueous solution of saturated $NaHCO_3$ was added and the reaction mixture was extracted with CH_2Cl_2 (3×10 mL). The combined organic extract was washed with saturated NaCl solution, dried ($MgSO_4$), filtered, and evaporated to dryness. The residue was purified by flash chromatography (eluent: EtOAc/pet. ether 40–60°C, 10–30%) to afford **9** (200 mg, 96%) as pale yellow oil (lit.,[30] oil). MS; *m/z*: 207 (M^+). ^{1}H-NMR ($CDCl_3$): δ 3.95 (m, 2H, CH_2), 5.14–5.37 (m, 2H, NCH_2), 6.00 (m, 1H, =CH), 7.22–7.87 (m, 4H, Ar-H). ^{13}C-NMR ($CDCl_3$): δ 35.9 (CH_2), 118.9 (=CH), 120.7 (NCH_2), 121.3, 124.0, 125.62, 132.1, 135.1, 153.0 (C-Ar), 165.9 (C-2).

2-(2′,3′,4′,6′-Tetra-*O*-acetyl-β-D-glucopyranosylmercapto)benzothiazole (13a) and 3-(2′,3′,4′,6′-Tetra-*O*-acetyl-β-D-glucopyranosyl)-2-thiobenzothiazole (14a). *General Procedure*: To a suspension of **1a** (0.85 g, 5 mmol) in anhydrous MeCN (5 mL) at r. t. was added NaH (50%, 0.26 g, 5.0 mmol), and the mixture was stirred at the same temperature for 30 min. The mixture became clear after 15 min. The sugar bromide **10** (2.26 g, 5.5 mmol) was added, and the mixture was stirred at r. t. for 12 h until the starting material was consumed (TLC) and then filtered. Evaporation of the filtrate afforded an oil, purified by flash chromatography (eluent: EtOAc/pet. ether, 40–60°C, 10–30%,) to afford **13a** (2.10 g, 84%) as a white foam (lit.,[32] mp 138–139°C, 34%) and 0.01 g (4%) of **14a** as pale yellow foam (lit.,[32] mp 195–196°C, 3.8%).

13a: MS; *m/z*: 497 (M^+). ^{1}H-NMR ($CDCl_3$): δ 2.03, 2.04, 2.05 (3s, 9H, 3 Ac), 3.94 (ddd, $J = 2.2$, 4.7, 6.9 Hz, 1H, 5′-H), 4.20 (dd, $J = 2.0$, 12.4 Hz, 1H, 6′-H), 4.33 (dd, $J = 4.9$, 12.4 Hz, 1H, 6″-H), 5.15–5.26 (m, 2H, 2′-H, 4′-H), 5.36 (dd, $J = 9.2$, 10.1 Hz, 1H, 3′-H), 5.60 (d, $J = 10.2$ Hz, 1H, 1′-H), 7.30–7.95 (m, 4H, Ar-H). ^{13}C-NMR ($CDCl_3$): δ 20.4, 20.5, 20.6 (4 Ac), 61.7 (C-6′), 67.9 (C-2′), 69.5

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(C-3′), 73.6 (C-4′), 76.1 (C-5′), 83.8 (C-1′), 120.9, 122.2, 124.9, 126.3, 135.6, 152.5 (C-Ar); 161.7 (C-2), 169.2, 169.3, 169.9, 170.4 (4 CO).

14a: MS; m/z 497 (M^+). ^{1}H-NMR($CDCl_3$): δ 2.03, 2.05 2.08, 2.12 (4s, 12H, 4 Ac), 4.08 (m, 1H, 5′-H), 4.30 (m, 2H, 6′-H, 6″-H), 5.26 (dd, $J = 9.7$, 10.1 Hz, 1H, 4′-H), 5.57 (dd, $J = 9.2$, 9.5 Hz, 1H, 2′-H), 5.76 (dd, $J = 9.4$, 9.4 Hz, 1H, 3′-H), 6.93 (d, 1H, $J = 9.5$ Hz, 1H, 1′-H), 7.28–7.7.90 (m, 4H, Ar-H).

2-(2′,3′,4′,6′-Tetra-*O*-benzoyl-β-D-glucopyranosylmercapto)benzoxazole (13b). From **1b** (0.76 g, 5.0 mmol) and **11** (3.62 g, 5.5 mmol) in the manner described for **13a**. Yield 0.60 g (82%) as white foam. MS; m/z: 729 (M^+). Calculated for $C_{41}H_{31}NO_{10}S$ (729.75): C, 67.48; H, 4.28; N, 1.92. Found: C, 67.12; H, 4.59; N, 1.78. $[\alpha]_D + 54°$ (c 1.2, $CHCl_3$). ^{1}H-NMR ($CDCl_3$): δ 4.48 (dd, $J = 4.5$, 5.8 Hz, 2H, 6′-H, 6″-H), 4.64 (dd, $J = 5.6$, 5.6 Hz, 1H, 5′-H), 5.69–5.81 (m, 2H, 3′-H, 4′-H), 6.07–6.14 (m, 2H, 1′-H, 2′-H), 7.22–7.7.95 (m, 24H, Ar-H). ^{13}C-NMR ($CDCl_3$): δ 63.1 (C-6′), 69.2 (C-2′), 70.4 (C-3′), 73.9 (C-4′), 77.0 (C-5′), 83.7 (C-1′), 110.11–151.9 (C-Ar), 161.1 (C-2), 165.16, 165.3, 165.7, 166.1 (4 CO).

5-Methoxy-2-(2′,3′,4′,6′-tetra-*O*-acetyl-β-D-glucopyranosylmercapto)benzothiazole (13c). From **1c** (1.15 g, 5.0 mmol) in the manner described for **13a**. Yield 0.88 g (83%) as pale yellow foam. MS; m/z: 527 (M^+). Calculated for $C_{22}H_{25}NO_{10}S_2$ (527.56): C, 50.09; H, 4.78; N, 2.66. Found: C, 49.87; H, 5.08; N, 2.80. $[\alpha]_D + 72°$ (c 0.7, $CHCl_3$). ^{1}H-NMR ($CDCl_3$): δ 2.03, 2.05, 2.06, 2.70 (4s, 12H, 4 Ac), 3.88 (s, 3H, OCH_3), 3.94 (ddd, $J = 2.6$, 5.0, 7.5 Hz, 1H, 5′-H), 4.21 (d, $J = 12.4$ Hz, 1H, 6′-H), 4.30 (dd, $J = 4.9$, 12.4 Hz, 1H, 6″-H), 5.15-5.25 (m, 2H, 2′-H, 4′-H), 5.40 (m, 1H, 3′-H), 5.54 (d, $J = 10.2$ Hz, 1H, 1′-H), 7.00–7.65 (m, 3H, Ar-H). ^{13}C-NMR ($CDCl_3$): δ 20.3, 20.3, 20.4, 20.7 (4 Ac), 55.4 (OCH_3), 61.6 (C-6′), 67.8 (C-2′), 69.4 (C-3′); 73.5 (C-4′), 75.9 (C-5′), 83.8 (C-1′), 104.8, 114.9, 121.0, 127.3, 153.7, 158.9 (C-Ar), 162.6 (C-2), 169.2, 169.8, 170.3 (4 CO).

2-(2′,3′,4′,6′-Tetra-*O*-acetyl-β-D-galactopyranosylmercapto)benzothiazole (13d). From **1a** (0.84 g, 5.0 mmol) and **12** (2.26 g, 5.5 mmol) in the manner described for **13a**. The product was purified by flash chromatography (eluent: EtOAc/pet. ether 40–60°C 10–30%) to afford **13d** (2.25 g, 90%) as a colorless oil (lit.[34] mp 110–111°C, 73%). MS; m/z: 497 (M^+). ^{1}H-NMR ($CDCl_3$): δ 2.00, 2.01, 2.07, 2.18 (4s, 12H, 4 Ac), 3.88 (s, 3H, OCH_3), 4.07–4.19 (m, 3H, 5′-H, 6-H′, 6″-H), 5.23 (dd, $J = 3.4$, 9.8 Hz, 1H, 4′-H), 5.44 (dd, $J = 9.9$, 10.1 Hz, 1H, 2′-H), 5.52 (d, $J = 3.3$ Hz, 1H, 3′-H), 5.56 (d, $J = 10.1$ Hz, 1H, 1′-H), 7.34–7.95 (m, 4H, Ar-H). ^{13}C-NMR ($CDCl_3$): δ 20.3, 20.4, 20.4, 20.4 (4 Ac), 61.1 (C-6′), 67.7 (C-2′), 69.9 (C-3′), 71.4 (C-4′), 74.7 (C-5′), 84.24 (C-1′), 120.8, 122.0, 124.8, 126.1, 135.5, 152.4 (C-Ar), 161.9 (C-2), 169.3, 169.6, 169.9, 170.0 (4 CO).

2-(2′,3′,4′,6′-Tetra-*O*-acetyl-β-D-galactopyranosylmercapto) benzoxazole (13e) and 3-(2′,3′,4′,6′-Tetra-*O*-acetyl-β-D-galactopyranosyl)-2-thiobenzoxazole (14b). From **1b** (0.76 g, 5.0 mmol) of **1b** and **12** (2.26 g, 5.5 mmol) in the manner described for **13a** and **14a**. Yield 1.09 g (45%) of **13e** as pale yellow foam and 0.92 g (38%) of **14b** as pale yellow oil.

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13e: MS; m/z: 481 (M^+). Calculated for $C_{21}H_{23}NO_{10}S$ (481.47): C, 52.39; H, 4.81; N, 2.91. Found: C, 52.20; H, 4.96; N, 2.68. $[\alpha]_D + 11.5°$ (c 0.7, $CHCl_3$). ^{1}H-NMR ($CDCl_3$): δ 1.98, 2.02, 2.08, 2.19 (4s, 12H, 4 Ac), 4.14–4.29 (m, 3H, 5-H′, 6′-H, 6″-H), 5.22 (dd, $J = 3.4$, 9.9 Hz, 1H, 4′-H), 5.30 (dd, $J = 10.1$, 10.1 Hz, 1H, 2′-H), 5.44 (dd, $J = 3.4$, 10.0 Hz, 1H, H-3′), 5.72 (d, $J = 10.2$ Hz, 1H, 1′-H), 7.20–7.70 (m, 4H, Ar-H). ^{13}C-NMR ($CDCl_3$): δ 20.5, 20.6, 20.6, 20.7 (4 Ac), 61.2 (C-6′), 67.0 (C-2′), 67.1 (C-3′), 71.7 (C-4′), 75.0 (C-5′), 83.9 (C-1′), 110.2, 118.9, 124.7, 125.9, 141.5, 151.9 (C-Ar), 161.0 (C-2), 169.7, 169.9, 170.2, 170.4 (4 CO).

14b: MS; m/z: 481 (M^+). Calculated for $C_{21}H_{23}NO_{10}S$ (481.47): C, 52.39; H, 4.81; N, 2.91. Found: C, 52.28; H, 4.94; N, 2.72. ^{1}H-NMR ($CDCl_3$): δ 2.00, 2.03, 2.07, 2.22 (4s, 12H, 4 Ac), 4.16–4.30 (m, 3H, 5′-H, 6′-H, 6″-H), 5.24 (dd, $J = 9.6$, 10.1 Hz, 1H, 4′-H), 5.38 (dd, $J = 9.2$, 9.5 Hz, 1H, 2′-H), 5.63 (dd, $J = 9.4$, 9.4 Hz, 1H, 3′-H), 6.32 (d, $J = 9.1$ Hz, 1H, 1′-H), 7.20–7.50 (m, 4H, Ar-H).

5-Methoxy-2-(2′,3′,4′,6′-tetra-*O*-acetyl-β-D-galactopyranosylmercapto)benzothiazole (13f) and 5-Methoxy-3-(2′,3′,4′,6′-tetra-*O*-acetyl-β-D-galactopyranosyl)-2-thiobenzothiazole (14c). From **1c** (1.15 g, 5.0 mmol) and **12** (2.26 g, 5.5 mmol) in the manner described for **13a** and **14a**. Yield 1.60 g (60%) of **13f** as pale yellow foam and 0.58 g (22%) of **14c** as pale yellow foam.

13f: MS; m/z: 527 (M^+). Calculated for $C_{22}H_{25}NO_{10}S_2$ (527.56): C, 50.09; H, 4.78; N, 2.66. Found: C, 50.26; H, 5.16; N, 2.52. ^{1}H-NMR ($CDCl_3$): δ 1.98, 2.02, 2.08, 2.19 (4s, 12H, 4 Ac), 3.82 (s, 3H, OCH_3), 4.12–4.32 (m, 3H, 5-H′, 6′-H, 6″-H), 5.22 (dd, $J = 3.4$, 9.8 Hz, 1H, 4′-H), 5.30 (dd, $J = 10.1$, 10.1 Hz, 1H, 2′-H), 5.45 (d, $J = 3.4$ Hz, 1H, H-3′), 5.74 (d, $J = 10.2$ Hz, 1H, 1′-H), 7.15–7.65 (m, 3H, Ar-H).

14c: MS; m/z: 527 (M^+). Calculated for $C_{22}H_{25}NO_{10}S_2$ (527.56): C, 50.09; H, 4.78; N, 2.66. Found: C, 49.92; H, 5.10; N, 2.94. ^{1}H-NMR ($CDCl_3$): δ 2.00, 2.03, 2.07, 2.22 (4s, 12H, 4 Ac), 3.86 s, 3H, OCH_3), 4.20–4.36 (m, 3H, 5′-H, 6′-H, 6″-H), 5.24 (dd, $J = 9.6$, 10.2 Hz, 1H, 4′-H), 5.38 (dd, $J = 9.3$, 9.5 Hz, 1H, 2′-H), 5.64 (dd, $J = 9.4$, 9.4 Hz, 1H, 3′-H), 6.33 (d, $J = 9.1$ Hz, 1H, 1′-H), 7.05–7.53 (m, 3H, Ar-H).

2-(β-D-Glucopyranosylmercapto)benzothiazole (15a). From **13a** (0.50 g, 1.0 mmol) of **13a** in the manner described for **5a**. The product was chromatographed on silica gel using MeOH, in gradient, (0–10%) and CH_2Cl_2, as eluent to give **15a** (0.28 g, 86%) as a white foam (lit.,[32] mp 110–180°C, 75%). MS; m/z: 329 (M^+). ^{1}H-NMR (CD_3OD-d_4): δ 3.17–3.36 (m, 4H, 4′-H, 5′-H, 6′-H, 6″-H), 3.60 (dd, $J = 4.3$, 9.3 Hz, 1H, 2′-H), 3.78 (dd, $J = 1.6$, 12.0 Hz, 1H, 3′-H), 5.57 (d, 1H, $J = 9.1$ Hz, 1′-H); 7.20–7.78 (m, 4H, Ar-H).

2-(β-D-Glucopyranosylmercapto)benzoxazole (15b). From **13b** (0.73 g, 1.0 mmol) of **13b** in the manner described for **5a**. Yield 0.25 g (80%) as white foam. MS; m/z: 313 (M^+). Calculated for $C_{13}H_{15}NO_6S$ (313.32): C, 49.83; H, 4.82; N, 4.47. Found: C, 49.59; H, 4.98; N, 4.60. $[\alpha]_D$ −106° (c 0.5, MeOH). ^{1}H-NMR (CD_3OD-d_4): δ 3.15–3.36 (m, 4H, 4′-H, 5′-H, 6′-H, 6″-H), 3.60 (dd, $J = 4.2$, 9.4 Hz, 1H, 2′-H), 3.78 (dd, $J = 1.6$, 12.1 Hz, 1H, 3′-H), 5.57 (d, $J = 9.4$ Hz, 1H, 1′-H), 7.00–8.00 (m, 4H, Ar-H).

5-Methoxy-2-(β-D-glucopyranosylmercapto)benzothiazole (15c). From **13c** (0.53 g, 1.0 mmol) in the manner described for **5a**. Yield 0.30 g (84%) as a white solid,

mp 127–129°C. MS; m/z: 359 (M^+). Calculated for $C_{14}H_{17}NO_6S_2$ (359.41): C, 46.79; H, 4.77; N, 3.90. Found: C, 46.43; H, 4.60; N, 4.04. $[\alpha]_D$ −87° (*c* 0.23, MeOH). ^{1}H-NMR (CD_3OD-d_4): δ 3.32 (s, 3H, OCH_3), 3.50 (m, 5H, 2′-H, 4′-H, 5′-H, 6′-H, 6″-H), 3.77 (dd, $J = 4.0$, 12.2 Hz, 1H, 3′-H), 5.18 (d, 1H, $J = 9.2$ Hz, 1′-H), 6.94–7.68 (m, 3H, Ar-H). ^{13}C-NMR (CD_3OD-d_4): δ 55.5 (OCH_3), 61.5 (C-6′), 69.8 (C-2′), 72.5 (C-3′), 78.3 (C-4′), 80.9 (C-5′), 86. 6 (C-1′), 104.7, 114.1, 121.2, 127.0, 153.9, 158.8 (C-Ar), 165.5 (C-2).

2-(β-D-Galactopyranosylmercapto)benzothiazole (15d). From **13d** (0.50 g, 1.0 mmol) in the manner described for **5a**. Yield 0.28 g (85%) as a white solid, mp 118–120°C (lit.,[32] mp 100–195°C, 79%). MS; m/z: 329 (M^+). $[\alpha]_D + 5.0°$ (*c* 0.7, MeOH). ^{1}H-NMR (DMSO-d_6): δ 3.37–3.80 (m, 6H, 2′-H, 3′-H, 4′-H, 5′-H, 6′-H, 6″-H), 4.64 (d, 1H, $J =$ 4.6 Hz, 6′-OH), 4.70 (d, 1H, $J = 5.2$ Hz, 4′-OH), 5.05 (d, 1H, $J = 5.5$ Hz, 3′-OH), 5.10 (d, 1H, $J = 9.7$ Hz, 1′-H), 5.50 (d, 1H, $J = 6.0$ Hz, 2′-OH), 7.37–8.04 (m, 4H, Ar-H). ^{13}C-NMR (DMSO-d_6): δ 60.3 (C-6′), 68.4 (C-2′), 69.6 (C-3′), 74.7 (C-4′), 79.9 (C-5′), 87.2 (C-1′), 121.5, 121.8, 124.7, 126.5, 135.2, 152.5 (C-Ar), 165.4 (C-2).

2-(β-D-Galactopyranosylmercapto)benzoxazole (15e). From 13e (0.48 g, 1.0 mmol) in the manner described for 5a. Yield 0.26 g (84%) as pale yellow foam. MS; m/z: 313 (M^+). Calculated for $C_{13}H_{15}NO_6S$ (313.33): C, 49.83; H, 4.82; N, 4.47. Found: C, 49.62; H, 5.00; N, 4.56. $[\alpha]_D$ −71° (*c* 0.4, MeOH). ^{1}H-NMR (DMSO-d_6): δ 3.35–3.76 (m, 6H, 2′-H, 3′-H, 4′-H, 5′-H, 6′-H, 6″-H), 4.62 (d, $J = 5.0$ Hz, 1H, 6′-OH), 4.65 (d, $J = 5.8$ Hz, 1H, 4′-OH), 5.06 (d, $J = 5.6$ Hz, 1H, 3′-OH), 5.36 (d, $J = 9.8$ Hz, 1H, 1′-H), 5.53 (d, $J = 6.2$ Hz, 1H, 2′-OH), 7.33–7.68 (m, 4H, Ar-H). ^{13}C-NMR (DMSO-d_6): δ 60.1 (C-6′), 68.12 (C-2′), 69.3 (C-3′), 74.3 (C-4′), 79.8 (C-5′), 9.70 (C-1′), 110.2, 118.3, 124.5, 124.6, 141.1, 151.2 (C-Ar), 162.5 (C-2).

5-Methoxy-2-(β-D-galactopyranosylmercapto)benzothiazole (15f). From **13f** (0.53 g, 1.0 mmol) in the manner described for **5a**. Yield 0.29 g (80%) as pale yellow foam. MS; m/z: 359 (M^+). Calculated for $C_{14}H_{17}NO_6S_2$ (359.41): C, 46.79; H, 4.77; N, 3.90. Found: C, 46.50; H, 4.94; N, 3.58. $[\alpha]_D$ −20° (*c* 0.2, MeOH). ^{1}H-NMR (DMSO-d_6): δ 3.30–3.83 (m, 9H, OCH_3, 2′-H, 3′-H, 4′-H, 5′-H, 6′-H, 6″-H), 4.59–4.68 (m, 2H, 4′-OH, 6′-OH), 5.00 (d, 1H, $J = 5.4$ Hz, 3′-OH), 5.08 (d, 1H, $J = 9.7$ Hz, Hz, 1′-H), 5.45 (d, 1H, $J = 6.1$ Hz, 2′-OH), 6.99–7.90 (m, 3H, Ar-H).

3-(β-D-Galactopyranosyl)-2-thiobenzoxazole (16a). From **14b** (0.48 g, 1.0 mmol) in the manner described for **5a**. Yield 0.26 g (83%) of **16a** as pale yellow foam. MS; m/z: 313 (M^+). Calculated for $C_{13}H_{15}NO_6S$ (313.33): C, 49.83; H, 4.83; N, 4.47. Found: C, 49.72; H, 4.98; N, 4.18. $[\alpha]_D + 56°$ (*c* 0.4, MeOH). ^{1}H-NMR (CD_3COCD_3-d_6): δ 3.82–3.91 (m, 4H, 4′-H, 5′-H, 6′-H, 6″-H), 4.05 (br. s, 1H, 6′-OH), 4.14 (m, 1H, 3′-H), 4.39–4.45 (m, 2H, 3′-OH, 4′-OH), 4.48 (d, $J = 9.5$ Hz, 1H, 2′-H), 4.72 (d, $J = 3.8$ Hz, 1H, 2′-OH), 6.00 (d, $J = 9.1$ Hz, 1H, H-1′), 7.31–7.73 (m, 4H, Ar-H). ^{13}C-NMR (DMSO-d_6): δ 62.4 (C-6′), 69.2 (C-2′), 69.9 (C-3′), 74.8 (C-4′), 78.9 (C-5′), 88.4 (C-1′), 110.7, 113.5, 125.13, 125.7, 140.8, 147.8 (C-Ar), 181.4 (C-2).

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5-Methoxy-3-(β-D-galactopyranosyl)-2-thiobenzothiazole (16b). From **14c** (0.53 g, 1.0 mmol) in the manner described for **5a**. Yield 0.28 g (77%) as pale yellow foam. MS; m/z: 359 (M^+). Calculated for $C_{14}H_{17}NO_6S_2$ (359.41): C, 46.79; H, 4.77; N, 3.90. Found: C, 46.46; H, 4.88; N, 3.80. $[\alpha]_D + 15°$ (c 0.2, MeOH). ^{1}H-NMR (CD_3COCD_3-d_6): δ 3.83 (s, 3H, OCH_3), 4.03–4.53 (m, 5H, 3′-H, 4′-H, 5′-H, 6′-H, 6″-H), 4.63 (dd, $J = 8.8$, 9.5 Hz, 1H, 2′-H), 6.60 (d, $J = 9.2$ Hz, 1H, H-1′), 6.91–7.90 (m, 3H, Ar-H).

2-(2′,3′,4′,6′-Tetra-*O*-acetyl-β-D-glucopyranosylmercapto)pyridine (18a). From **17** (0.55 g, 5.0 mmol) in the manner described for **13a**. The product was purified by flash chromatography using CH_2Cl_2 as eluent to afford **18a** (1.70 g, 77%) as pale yellow solid, mp 140–142°C (lit.,[35] mp 120–123°C, 72%). MS; m/z: 441 (M^+). ^{1}H-NMR ($CDCl_3$): δ 2.01, 2.02, 2.03,2.04 (4s, 12H, 4 Ac), 3.88 (m, 1H, 5′-H), 4.12 (dd, $J = 2.2$, 12.3 Hz, 1H, 6′-H), 4.25 (dd, $J = 4.7$, 12.4 Hz, 1H, 6″-H), 5.16 (d, $J = 9.9$ Hz, 1H, 4′-H), 5.25 (d, $J = 10.2$ Hz, 1H, 2′-H), 5.35 (dd, $J = 9.3$, 9.3 Hz, 1H, 3′-H), 5.84 (d, $J = 10.4$ Hz, 1H, H-1′), 7.05–8.46 (m, 4H, Ar-H). ^{13}C-NMR ($CDCl_3$): δ 20.6, 20.6, 20.7, 20.7 (4 Ac), 62.0 (C-6′) 68.3 (C-2′), 69.5 (C-3′), 74.2 (C-4′), 75.9 (C-5′), 81.6 (C-1′), 120.90, 123.3, 136.6, 149.7, 155.3 (C-Ar), 169.4, 169.5, 170.2, 170.6 (4 CO).

2-(2′,3′,4′,6′-Tetra-*O*-acetyl-β-D-galactopyranosylmercapto)pyridine (18b). From **17** (0.55 g, 5.0 mmol) and **12** (2.26 g, 5.5 mmol) in the manner described for **13a**. The product was purified by flash chromatography (eluent, CH_2Cl_2) to afford **18b** (1.90 g, 86%) as pale yellow foam (lit.,[35] syrup, 85%). MS; m/z: 441 (M^+). ^{1}H-NMR ($CDCl_3$): δ 1.98, 2.02, 2.15, 2.22 (4s, 12H, 4 Ac), 4.10–4.17 (m, 3H, 5′-H, 6′-H, 6″-H), 5.22 (dd, $J = 3.4$, 9.9 Hz, 1H, 4′-H), 5.40 (d, $J = 10.2$ Hz, 1H, 2′-H), 5.50 (d, $J = 3.4$ Hz, 1H, 3′-H), 5.84 (d, $J = 10.4$ Hz, 1H, 1′-H), 7.09–8.47 (m, 4H, Ar-H). ^{13}C-NMR ($CDCl_3$): δ 20.3, 20.3, 20.4, 20.5 (4 Ac), 61.1 (C-6′), 66.5 (C-2′), 67.2 (C-3′), 71.7 (C-4′), 74.2 (C-5′), 81.8 (C-1′), 120.7, 123.1, 136.6, 149.2, 155.1 (C-Ar), 169.4, 169.7, 169.9, 170.0 (4 CO).

2-(β-D-Glucopyranosylmercapto)pyridine (19a). From **18a** (0.55 g, 1.0 mmol) in the manner described for **15a**. The product was chromatographed on silica gel using MeOH, in gradient, (0–5%) and CH_2Cl_2 as eluent to give **19a** (0.27 g, 97%) as a white foam (lit.,[37] mp 93–101°C, 75%). MS; m/z: 273 (M^+). ^{1}H-NMR (CD_3OD-d_4): δ 3.27–3.41 (m, 4H, 4′-H, 5′-H, 6′-H, 6″-H), 3.60 (m, 1H, 3′-H), 3.76 (m, 1H, 2′-H), 5.12(d, $J = 9.8$ Hz, 1H, 1′-H), 7.04–8.29 (m, 4H, Ar-H). ^{13}C-NMR (DMSO-d_6): δ 62.6 (C-6′), 71.1 (C-2′), 73.7 (C-3′), 79.5 (C-4′), 82.0 (C-5′), 86.1 (C-1′), 122.0, 124.5, 138.7, 150.1 (C-Ar), 159.1 (C-2).

2-(β-D-Galactopyranosylmercapto)pyridine (19b). From **18b** (0.50 g, 1.0 mmol) in the manner described for **5a**. Yield 257 mg (85%) as a yellow solid, mp 162–164°C. MS; m/z: 273 (M^+). Calculated for $C_{11}H_{15}NO_5S$ (273.30): C, 48.34; H, 5.53; N, 5.13. Found: C, 48.00; H, 5.68; N, 4.82. $[\alpha]_D$ −38°C (c 0.5, MeOH). ^{1}H-NMR (DMSO-d_6): δ 3.15–3.74 (m, 6H, 2′-H, 3′-H, 4′-H, 5′-H, 6′-H, 6″-H), 4.54–4.63 (m, 2H, 4′-OH, 6′-OH), 4.93 (d, $J = 5.6$ Hz, 1H, 2′-OH), 5.07 (d, $J = 9.7$ Hz, 1H, 1′-H), 5.24 (d, $J = 5.8$ Hz, 1H, 2′-OH), 7.11–8.37 (m, 4H, Ar-H). ^{13}C-NMR

(DMSO-δ_6): δ 60. 7 (C-6′), 68.6 (C-2′), 69.2 (C-3′), 75.0 (C-4′), 79.9 (C-5′), 84.8 (C-1′), 120.46, 122.1, 137.2, 149.37 (C-Ar), 158.8 (C-2).

2-(2′,3′,5′-Tri-*O*-acetyl-β-D-ribofuranosylmercapto)pyridine (21). From **17** (0.55 g, 5.0 mmol) in the manner described for **4a**. The product was purified by flash chromatography (eluent: EtOAc/pet. ether, 40–60°C, 10–30%,) to give **21** (1.77 g, 96%) as a yellow oil (lit.,[36] syrup, 95%). MS; *m/z*: 369 (M^+). ^{1}H-NMR ($CDCl_3$): δ 1.97, 1.98, 1.99 (3s, 9H, 3 Ac), 4.03 (dd, $J = 5.0$, 12.9 Hz, 1H, 5′-H), 4.27 (m, 2H, 4′-H, 5″-H), 5.32 (dd, $J = 5.0$, 5.0 Hz, 1H, 3′-H), 5.39 (dd, $J = 4.7$, 5.0 Hz, 1H, 2′-H), 6.09 (d, $J = 4.6$ Hz, 1H, 1′-H.), 6.93–8.34 (m, 4H, Ar-H). ^{13}C-NMR ($CDCl_3$): δ 20.5, 20. 8, 22.5 (3 Ac), 63.2 (C-5′), 71.4 (C-3′), 74.5 (C-2′), 80.1 (C-4′), 84.9 (C-1′), 120.7 (C-4), 123.1 (C-5), 136.7 (C-3), 149.7 (C-6), 156.2 (C-2), 169.5, 169.7, 170.4 (3 CO).

2-(β-D-Ribofuranosylmercapto)pyridine (22). From **21** (0.74 g, 2.0 mmol) in the manner described for **5a**. The product was chromatographed on silica gel using MeOH, in gradient, (0–5%) and CH_2Cl_2 as eluent to give **22** (0.44 g, 90%) as a yellow solid, mp 136–138°C. MS; *m/z*: 243 (M^+). Calculated for $C_{10}H_{13}NO_4S$ (243.27): C, 49.37; H, 5.38; N, 5.76. Found: C, 49.15; H, 5.62; N, 5.70. 243 (M^+). $[\alpha]_D + 44°$ (*c* 2.0, MeOH). ^{1}H-NMR (DMSO-d_6): δ 3.50 (m, 2H, 5′-H, 5″-H), 3.90 (m, 1H, 4′-H), 4.02 (m, 2H, 2′-H, 3′-H), 4.70 (t, $J = 5.6$ Hz, 1H, 5′-OH), 4.96 (d, $J = 5.3$ Hz, 1H, 3′-OH), 5.34 (d, $J = 5.5$ Hz, 1H, 2′-OH), 5.80 (d, $J = 4.6$ Hz, 1H, 1′-H), 7.09–8.42 (m, 4H, Ar-H). ^{13}C-NMR (DMSO-d_6): δ 62.1 (C-5′), 71.0 (C-3′), 75.2 (C-2′), 85.5 (C-4′), 86.8 (C-1′) 120.2 (C-4), 122.5 (C-5), 136.8 (C-3), 149.3 (C-6), 158.13 (C-2).

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