Heterocyclic *N*-Glycosyl Derivatives. XIV. Preparation of Some *N*-(2,3-Dideoxyglycopyranosyl)benzotriazoles by Hydrogenation of *N*-(Pent- and Hex-2-enopyranosyl)benzotriazoles

M. Fuertes, G. García-Muñoz, F. G. de las Heras, R. Madronero and M. Stud

Instituto de Química Orgánica General, Departamento de Química Médica, Juan de la Cierva, 3. Madrid-6, Spain

and

M. Rico

Instituto de Química-Física "Rocasolano," Serrano, 119. Madrid-6, Spain

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Catalytic hydrogenation of a series of *N*-(pent- and hex-2-enopyranosyl)benzotriazoles afforded the corresponding saturated *N*-glycosyl derivatives having the same anomeric configuration as the starting compounds. The conformations of all compounds obtained were determined by nmr spectroscopy. The hexopyranosyl nucleosides in solution adopt the Cl conformation. On the other hand, pentopyranosyl nucleosides exist as a mixture of the two chair conformers in equilibrium, with the lC or Cl (L) form predominating.

In previous papers (1) the synthesis of several 2′,3′-unsaturated *N*-glycosylbenzotriazole derivatives from benzotriazoles and suitable acetylated glycals was described. Such 2′,3′-unsaturated nucleoside analogs, and in general all the unsaturated nucleosides have a potential use as starting materials in the preparation of new nucleosides, taking advantage of the double bond reactivity (2).

This work concerns the catalytic hydrogenation of the double bond of several *N*-(pent- and hex-2-enopyranosyl)-benzotriazoles (Figs. 1 and 2), to yield the corresponding 2′,3′-dideoxy derivatives.

It is well known that the catalytic hydrogenation of an allylic system C=C-C-X, where X is an electronegative atom or group can occur with concomitant hydrogenolysis of the C-X bond. Consequently, in our case, it was expected that both hydrogenolysis of the glycosidic bond, as previously observed during the hydrogenation of certain pent-2-enofuranosyl nucleosides (3), and the hydrogenolysis of the acetoxy group at C-4′ (4) might occur. As expected, in a series of exploratory hydrogenation experiments using different solvents and catalysts it was observed that the two mentioned reactions took place to differing degrees depending on the experimental conditions. From these experiments it was also noted that when the solvent was acetic acid or it contained traces of acid, a mixture of anomeric saturated nucleosides was formed as a consequence of the prior acid-catalyzed anomerization of the starting 2′,3′-unsaturated *N*-glycosyl derivatives (5). Since it could be argued that anomerization would take place after the formation of the saturated nucleosides, an already saturated compound, namely 1-(4-*O*-acetyl-2,3-dideoxy-β-D-*glycero*pentopyranosyl)benzotriazole (IIa) was further subjected to hydrogenation. With platinum in acetic acid, the benzenoid ring was reduced to give as the only reaction product 1-(4-*O*-acetyl-2,3-dideoxy-β-D-*glycero*pentopyranosyl)-4,5,6,7-tetrahydrobenzotriazole, which possesses the same β anomeric configuration as the starting compound IIa. It may be concluded, therefore, that in contrast to the 2′,3′-unsaturated *N*-glycosyl compounds, the hydrogenated derivatives are not anomerized by acid.

As a result of these preliminary studies, it was found that hydrogenation of the 2′,3′-unsaturated nucleosides could generally be achieved in good yield (50-60%) through the use of platinum oxide catalyst in purified ethyl acetate, at room temperature and 2-3 atm without anomerization and only partial hydrogenolysis of the glycosidic bond and the acetoxy group at C-4′. However, 1-(4,6-Di-*O*-acetyl-2,3-dideoxy-α- and β-D-*erythro*-hex-2-enopyranosyl)benzotriazole (XIa and IXa) and 2-(4,6-di-*O*-acetyl-2,3-dideoxy-α-D-*erythro*-hex-2-enopyranosyl)-benzotriazole (XIb) underwent rapid cleavage of the glycosidic bond when hydrogenated at room temperature. Nevertheless, in these cases hydrogenolysis could be reduced by working at low temperature (-15, -20°).

Hydrogenation of *N*-(Pent-2-enopyranosyl)benzotriazoles.

Working under conditions already mentioned, we

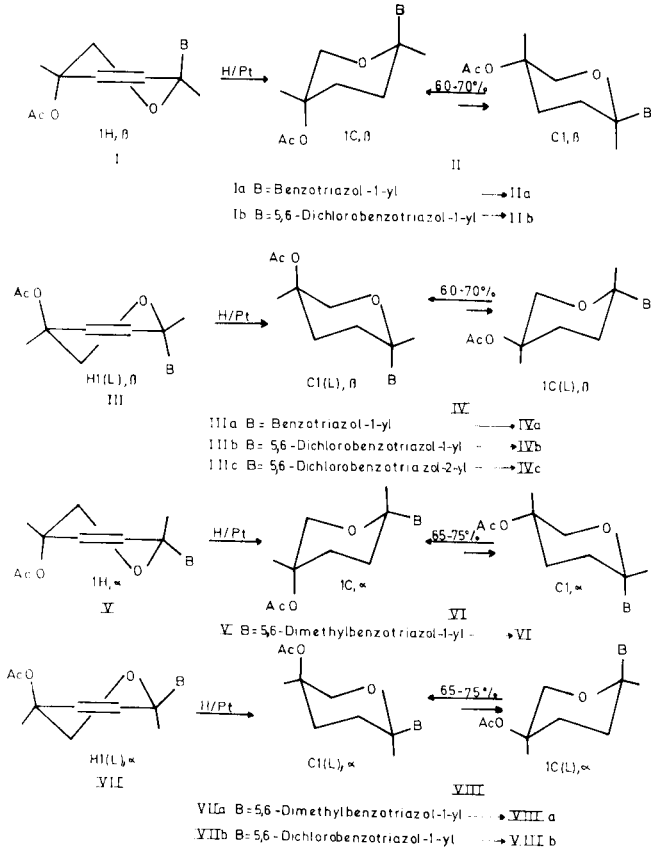

FIG. 1

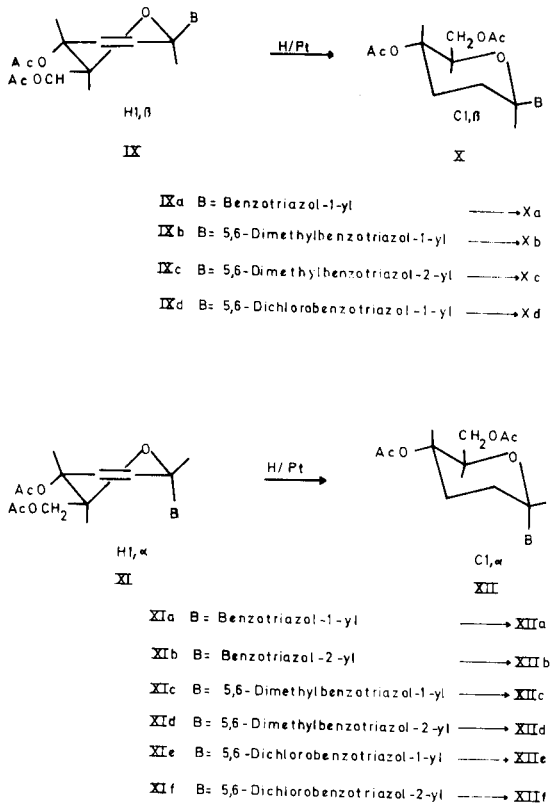

FIG. 2

carried out the hydrogenation of the *N*-(pent-2-enopyranosyl)benzotriazoles shown in Fig. 1 which, as previously demonstrated (1a), are not conformationally homogeneous (represented in Fig. 1 are the more abundant conformers). The study of the nmr spectra of the hydrogenated compounds allowed the assignment of both the anomeric configuration and the conformation of the molecule. Table I lists the nmr parameters (first-order analysis) obtained for these compounds in deuteriochloroform solution. Both the α and β anomers give rise to nmr spectra exhibiting coupling constant values that correspond to the time-averaged spectra of the two chair conformers in rapid equilibrium, with the 1C or C1 (L) form preponderating (60-70%). This conclusion is supported by the values obtained for $J_{1',2'a} + J_{1',2'e}$ and $J_{4',5'a} + J_{4',5'e}$ (Table I). The values of this latter sum for both the α and β anomers range from 6.5 to 7.7 Hz. Conformational populations were calculated from these coupling values (S_{obs}) together with those accepted as model obtained by Horton and Durette (6) (2.3 Hz for β-D-arabinopyranose tetraacetate in the 1C conformation and 17.1 Hz for α-D-xylopyranose tetraacetate in the 1C conformation, S_{1C} and S_{C1}, respectively), using the equation: % 1C or C1 (L) conformation = 100. $(S_{C1}-S_{obs})/(S_{C1}-S_{1C})$.

The α anomers in which the H-1′ proton appears as a quartet, have $J_{1',2'a} + J_{1',2'e}$ values in the range 10.9 to 11.2 Hz. These values are smaller than the ones to be expected (~13.5 Hz) for an axial arrangement of H-1′ (1b). In the β anomers the H-1′ signal was observed as a triplet and the values of $J_{1',2'a} + J_{1',2'e}$ (8.0-8.4 Hz) were intermediate between those that would be expected (1b) for the two chair conformations (6.5 Hz for the 1C form and 13.5 Hz for the C1 form).

In most of the cases studied in chloroform solution the chemical shifts of H-5′a and H-5′e accidentally coincided. When the spectra were recorded in benzene-d_6 solution these chemical shifts were different and we have assigned H-5′e to the signal showing the larger coupling constant with H-4′, since in the less populated C1 or 1C (L) form the mentioned protons are axially oriented. The relative upfield chemical shifts $\Delta\tau$ due to a change in the solvent (deuteriochloroform → perdeuteriobenzene) were found to be larger for H-5′a (0.7 ppm for the α

TABLE I

Nmr Parameters of *N*-(Pentopyranosyl)benzotriazole Derivatives (60 MHz, first-order analysis)

Chemical shifts (τ values)

Compound	Anom.	Solvent	H-1′	H-4′	H-5′a	H-5′e	Base		CH_3	OAc
IIa and IVa	β	$CDCl_3$	3.84	5.07	-------6.31-------		1.78-2.8			7.88
IIb and IVb	β	$CDCl_3$	3.88	5.06	-------6.30-------		1.84	2.14		7.87
IIb and IVb	β	C_6D_6	4.60	5.37	6.85 (a)	6.65 (a)	1.95	2.34		8.27
IVc	β	$CDCl_3$	3.74	4.98	5.94 (a)	6.12 (a)	-------1.90-------			7.87
VI and VIIIa	α	$CDCl_3$	3.99	5.01	-------6.10-------		2.20	2.53	7.58	7.87
VIIIb	α	$CDCl_3$	3.91	4.98	-------6.06-------		1.81	2.06		7.84
VIIIb	α	C_6D_6	4.63	5.36	6.76 (a)	6.48 (a)	2.06	2.24		8.33

Coupling constants (Hz)

Compound	Anom.	Solvent	$J_{1',2'a}$	$J_{1',2'e}$	$J_{3'e,5'e}$	$J_{4',5'e}$		$J_{4',5'a}$	$J_{5'a,5'e}$
IIa and IVa	β	$CDCl_3$	sum 8.4				sum 7.7		
IIb and IVb	β	$CDCl_3$	sum 8.2				sum 7.5		
IIb and IVb	β	C_6D_6	sum 8.0		1.2	4.5 (a)		2.5 (a)	-12.4 (a)
IVc	β	$CDCl_3$	sum 8.2		1.1	4.6 (a)		3.0 (a)	-12.5 (a)
VI and VIIIa	α	$CDCl_3$	7.9	3.0			sum 6.7		
VIIIb	α	$CDCl_3$	7.8	3.2			sum 6.8		
VIIIb	α	C_6D_6	8.1	3.1	1.3	4.3 (a)		2.2 (a)	-12.6 (a)

(a) Values obtained by ABX analysis.

TABLE II

Solvent Dependence of the Couplings, Widths and Conformational Populations for Compounds IIa and VIIIa (100 MHz, 30° C)

Solvent	$J_{1',2'a} + J_{1',2'e}$ (Hz)	$J_{4',5'a} + J_{4',5'e}$ (Hz)	w (H′-4) (a) (Hz)	% 1 C from (b) couplings	% 1 C from (c) widths	$\Delta G°$ (1 C → C 1) (d) kcal/mol
			Compound IIa			
CCl_4	7.5	6.9	14.2	69	76	0.48
$CDCl_3$	8.3	7.7	16.8	64	64	0.35
CH_3CN	9.6	9.4	20.8	52	46	0.05
			Compound VIIIa			
CCl_4	8.8	8.8	18.0	56	59	0.14
$CDCl_3$	10.9	6.7	16.0	70	68	0.51
CH_3CN	12.6	5.0	12.1	82	85	0.92

(a) H′4 signal width. (b) Calculated from equation in text. (c) Calculated from observed and model compounds (8) signal width. (d) Calculated from populations evaluated from coupling data.

anomers and 0.55 ppm for the β anomers) than for H-5′e (0.42 ppm and 0.35 ppm, respectively). These results are in agreement with those previously observed for 1-(3,4-di-*O*-acetyl-2-deoxy-α- and β-L-*erythro*pentopyranosyl)benzotriazole (1a).

The solvent dependence of the conformational populations of pentopyranosyl derivatives IIa (β anomer) and VIIIa (α anomer) was examined (7). The results of this study are collected in Table II. The conformational populations as evaluated from coupling data satisfactorily

TABLE III

Nmr Parameters of *N*-(Hexopyranosyl)benzotriazole Derivatives (60 MHz, Deuteriochloroform, First-order Analysis)

		Chemical Shifts (τ values)								
Compound	Anom.	H-1′	H-2′, H-3′	H-4′	H-5′	H-6′(a)	H-6′(a)	Base	CH_3	OAc
Xa	β	3.83	7.15-8.41	5.00	5.98	5.68	5.75	1.79-2.66		7.89 7.94
Xb	β	3.90	7.20-8.35	5.01	5.99	5.68	5.75	2.17 2.51	7.55 7.57	7.87 7.91
Xc	β	3.95	7.02-8.35	5.04	6.03	5.70	5.78	-----2.34-----	-----7.58-----	7.90 7.95
Xd	β	3.90	7.25-8.40	5.03	5.96	5.65	5.73	1.81 2.08		-----7.88-----
XIIa	α	3.69	6.70-8.20	4.99	6.61	5.73	5.91	1.69-2.61		7.96 7.99
XIIb	α	3.61	7.10-8.35	5.02	6.05	5.69	5.89	2.09 2.60		7.94 7.97
XIIc	α	3.77	6.78-7.97	5.01	6.61	5.73	5.95	2.15 2.42	-----7.56-----	7.95 7.99
XIId	α	3.62	7.05-8.39	4.99	6.07	5.67	5.88	-----2.34-----	-----7.59-----	7.94 7.96
XIIe	α	3.75	6.65-8.20	5.06	6.61	5.76	5.88	1.75 1.93		7.90 7.97
XIIf	α	3.59	6.95-8.36	4.98	6.02	5.65	5.83	-----1.90-----		-----7.89-----

		Coupling Constants (Hz)					
Compound	Anom.	$J_{1',2'a} + J_{1',2'e}$	$J_{3'a,4'} + J_{3'e,4'}$	$J_{4',5'}$	$J_{5',6'}(a)$	$J_{5',6'}(a)$	$J_{6',6'}(a)$
Xa	β	12.8	14.7	10.2	5.5	2.2	-11.8
Xb	β	12.7	15.2	9.7	5.2	2.6	-12.0
Xc	β	13.5	15.0	10.0	5.0	2.4	-12.6
Xd	β	12.7	14.3	9.7	5.1	2.6	-12.2
XIIa	α	7.5	15.1	9.9	5.6	2.0	-12.2
XIIb	α	6.0	14.6	9.6	4.8	1.9	-12.3
XIIc	α	7.0	16.1	9.5	6.2	1.9	-12.4
XIId	α	~7	14.7	9.7	5.2	1.7	-12.3
XIIe	α	7.0	14.7	9.6	7.0	2.4	-12.3
XIIf	α	6.8	14.9	9.5	4.8	2.3	-11.7

(a) Values obtained by ABX analysis.

agree with those deduced from the width of the H-4′ signal (w) (as model values for w_{ax} and w_{eq} were taken those reported (8) for *cis*- and *trans*-5-acetoxy-2-*t*-butyltetrahydropyran, 8.8 Hz and 31.0 Hz, respectively). The ΔG° values for the 1C → C1 interconversion as calculated from coupling data are given in the last column of Table II. The fact that these values are positive indicates the 1C conformation as the preferred for both compounds in the three solvents used. Assuming that the ΔG° (1C → C1) values may be estimated as the sum of the terms $-\Delta G^{\circ}B$ (ax → eq) and $-\Delta G^{\circ}OAc$ (ax → eq) (conformational free-energy of the base at C-1′ and the OAc group at C-4′ (9), respectively), the following values for these two terms were calculated. (Equal effects for the benzotriazole in IIa and 5,6-dimethylbenzotriazole in VIIIa have been assumed).

Solvent	$-\Delta G^{\circ}B$ (ax → eq) kcal/mol	$-\Delta G^{\circ}OAc$ (ax → eq)
CCl_4	-0.17	-0.31
$CHCl_3$	0.08	-0.43
CH_3CN	0.43	-0.48

As inferred from the above values, the preferred conformation adopted by these compounds seems to be a consequence of the term $-\Delta G^{\circ}OAc$ (ax → eq) which is about -0.4 kcal/mole favoring the conformation where the OAc group at C-4′ is axially oriented. This stabilizing effect seems to operate also in contributing to determine the position of the conformational equilibrium for several *N*-(2-deoxy-β-L-*erythro*pentopyranosyl)benzotriazoles (Ia) and also in the case of 6-chloro-9-(3,4,6-tri-*O*-acetyl-2-deoxy-α-D-*arabino*- and *lyxo*hexopyranosyl)purine (Ib).

The variation of the conformational population when changing the polarity of the solvent is dominated by the term $-\Delta G^{\circ}B$ (ax → eq) which vaires in the range of 0.6 kcal/mole. In carbon tetrachloride the anomeric effect of the base overcomes the two 1,3-*syn*-diaxial interactions between the base and the C-H bond atoms at 3′ and 5′ positions, whereas in acetonitrile the opposite is true in a larger extent. In chloroform these two trends nearly cancel out. The variation shown by the term $-\Delta G^{\circ}OAc$ (ax → eq) when changing the solvent from carbon tetrachloride to acetonitrile is small (0.17 kcal/mole) but coincides in magnitude and sign with that observed in 3-acetoxytetrahydropyran (8).

The magnitude of the term $-\Delta G^{\circ}OAc$ (ax → eq) for the compounds studied in this work differs by 0.5 kcal/mole with that obtained for 3-acetoxytetrahydropyran (8). We are not able to advance any obvious rationale for this fact. It seems wise, however, to caution about transferring values for conformational free energies deduced from simple equilibria, such as that in (8) to predict conformational preferences in polisubstituted rings, at least for polar substituents and rings.

Hydrogenation of *N*-(Hex-2-enopyranosyl)benzotriazoles.

The saturated *N*-glycosylbenzotriazoles shown in Fig. 2 were readily obtained and their configurations and conformations were established as before on grounds of the nmr data. Nmr parameters (first-order analyses) are given in Table III.

The nmr spectra of compounds having a β anomeric configuration showed a broad signal at 7-8.5 τ assigned to the H-2′a, H-2′e, H-3′a and H-3′e protons. The close chemical shifts of these protons and the fact that their signals were partially overlapped by those of the acetoxy groups and in the case of the 5,6-dimethylbenzotriazole derivatives (Xb,c), by those due to the methyl groups, precluded any attempt to determine the corresponding magnetic parameters. The signals of the H-5′ and the two H-6′ protons are observed as a multiplet at 5.65-6.03 τ. The magnetic parameters obtained from an ABX analysis of this spin system are listed in Table II. The value of $J_{4',5'} \cong 10$ Hz is indicative of a diaxial coupling and clearly establishes the conformation of the *N*-(2,3-dideoxy-β-D-hexopyranosyl) benzotriazoles (Fig. 2) as C1. Also the value of the sum $|J_{3'a,4'} + J_{3'e,4'}| \cong 15$ Hz is large enough to allow the existence of a diaxial coupling ($J_{3'a,4'}$) indicating that H-4′ is axial. The β configuration at the anomeric carbon atom is given by the $|J_{1',2'a} + J_{1',2'e}|$ value ($\cong$ 13 Hz) which is again large enough to account for a diaxial coupling between H-1′ and H-2′a.

In the case of the α anomers the magnitude of $J_{4',5'} = 9.5$-10 Hz and $|J_{3'a,4'} + J_{3'e,4'}| \cong 15$ Hz established that H-4′ and H-5′ are axially oriented as required by the C1 conformation. The α anomeric configuration was inferred from the value of the sum $|J_{1',2'a} + J_{1',2'e}| \cong 7$ Hz which establishes that H-1′ is equatorial.

As has been shown, the magnitude of the couplings for all the above hexopyranosylnucleosides (α and β anomers) indicates that they exist entirely in the C1 conformation. The reason for this conformational preference must be the strong predisposition of the acetoxymethyl group at C-5′ for the equatorial position.

EXPERIMENTAL

Melting points are uncorrected. Nmr spectra were determined at 60 MHz with a Perkin-Elmer R-10 or R-12 spectrometer using TMS as the internal standard. Optical rotations were determined on a Perkin-Elmer 141 polarimeter. Preparative layer chromatography (20 x 20 cm, 2 mm thickness) was performed on PF_{254} silica gel (Merck); silica gel GF_{254} (Merck) was used for analytical tlc. Spots were observed with uv light (254 mμ).

General Procedure for the Hydrogenation of the *N*-(Pent-2-enopyranosyl)benzotriazoles.

A solution of 0.12 g. of unsaturated compound in 10 ml. of ethyl acetate (purified by distillation and passage through a column of anhydrous sodium carbonate) was hydrogenated with platinum oxide at room temperature and ~3 atmospheres. Hydrogen uptake was rapid; after 4-7 minutes the catalyst was filtered off and the filtrate was evaporated. The resulting crude product was purified by thick-layer chromatography as indicated in each case.

Hydrogenation of 1-(4-*O*-Acetyl-2,3-dideoxy-β-D- and L-*glycero*-pent-2-enopyranosyl)benzotriazole (Ia and IIIa). Preparation of 1-(4-*O*-Acetyl-2,3-dideoxy-β-D- and L-*glycero*pentopyranosyl)-benzotriazole. (IIa and IVa).

The residue from the hydrogenation of Ia was purified by preparative tlc with ethyl acetate-petroleum ether 1:2 as the developer. The solid obtained from the major band was recrystallized from ethyl acetate-petroleum ether to give 0.08 g. of IIa, m.p. 82-83°; $[\alpha]_D$ -109.8° (c 0.75, chloroform).

Anal. Calcd. for $C_{13}H_{15}N_3O_3$: C, 59.75; H, 5.74; N, 16.09. Found: C, 59.65; H, 5.73; N, 16.16.

Reduction of IIIa and work-up as above afforded 0.09 g. of IVa m.p. 82-83° (from ethyl acetate-petroleum ether); $[\alpha]_D$ + 112.5° (c 1, chloroform).

Anal. Calcd. for $C_{13}H_{15}N_3O_3$: C, 59.75; H, 5.74; N, 16.09. Found: C, 59.62; H, 5.81; N, 16.06.

Hydrogenation of 1-(4-*O*-Acetyl-2,3-dideoxy-α-D-*glycero*pent-2-enopyranosyl)-5,6-dimethylbenzotriazole (V). Preparation of 1-(4-*O*-Acetyl-2,3-dideoxy-α-D-*glycero*pentopyranosyl)-5,6-dimethylbenzotriazole (VI).

The crude reaction product was separated into 3 fractions by preparative tlc using ethyl acetate-chloroform 1:3 as developer system. The fastest moving band gave 0.032 g. of (+)-1-(tetrahydropyran-2-yl)-5,6-dimethylbenzotriazole, m.p. 123-124° (from ethyl acetate-petroleum ether); $[\alpha]_D$ + 71.9° (c 1, chloroform).

Anal. Calcd. for $C_{13}H_{17}N_3O$: C, 67.53; H, 7.40; N, 18.22. Found: C, 67.45; H, 7.29; N, 18.17.

The second band gave 0.05 g. of VIc, m.p. 144-145° (from ethyl acetate-petroleum ether); $[\alpha]_D$ + 58.8° (c 1, $CHCl_3$).

Anal. Calcd. for $C_{15}H_{19}N_3O_3$: C, 62.28; H, 6.57; N, 14.53. Found: C, 62.17; H, 6.48; N, 14.44.

The slowest moving band afforded 5,6-dimethylbenzotriazole.

Hydrogenation of 1-(4-*O*-Acetyl-2,3-dideoxy-α-L-*glycero*pent-2-enopyranosyl)-5,6-dimethylbenzotriazole (VIIa). Preparation of 1-(4-*O*-acetyl-2,3-dideoxy-α-L-*glycero*pentopyranosyl)-5,6-dimethylbenzotriazole (VIIIa).

Work-up as above gave 0.027 g. of (-)-1-(tetrahydropyran-2-yl)-5,6-dimethylbenzotriazole, m.p. 123-124° (from ethyl acetate-petroleum ether); $[\alpha]_D$ -70° (c 1, chloroform).

Anal. Calcd. for $C_{13}H_{17}N_3O$: C, 67.53; H, 7.40; N, 18.22. Found: C, 67.43; H, 7.32; N, 18.30.

Also obtained was 0.05 g. of VIIIa, m.p. 144-145° (from ethyl acetate-petroleum ether); $[\alpha]_D$ -58.4° (c 1, chloroform).

Anal. Calcd. for $C_{15}H_{19}N_3O_3$: C, 62.28; H, 6.57; N, 14.53. Found: C, 62.36; H, 6.45; N, 14.49.

Hydrogenation of 1-(4-*O*-Acetyl-2,3-dideoxy-β-D- and L-*glycero*-pent-2-enopyranosyl)-5,6-dichlorobenzotriazole (Ib and IIIb). Preparation of 1-(4-*O*-Acetyl-2,3-dideoxy-β-D- and L-*glycero*pentopyranosyl)-5,6-dichlorobenzotriazole (IIb and IVb).

The crude product from the reduction of Ib was purified by preparative tlc using ethyl acetate-petroleum ether 1:2 as developer system. The major band gave 0.07 g. of IIb, m.p. 135-136° (from ethyl acetate-petroleum ether); $[\alpha]_D$ -130.5° (c 1, chloroform).

Anal. Calcd. for $C_{13}H_{13}Cl_2N_3O_3$: C, 47.27; H, 3.94; N, 12.72. Found: C, 47.35; H, 4.07; N, 12.63.

Similarly, reduction of IIIb and work-up as above afforded 0.07 g. of IVb, m.p. 135-136° (from ethyl acetate-petroleum ether); $[\alpha]_D$ + 129° (c 1, chloroform).

Anal. Calcd. for $C_{13}H_{13}Cl_2N_3O_3$: C, 47.27; H, 3.94; N, 12.72. Found: C, 47.09; H, 3.99; N, 12.85.

Hydrogenation of 2-(4-*O*-Acetyl-2,3-dideoxy-β-L-*glycero*pent-2-enopyranosyl)-5,6-dichlorobenzotriazole (IIIc). Preparation of 2-(4-*O*-acetyl-2,3-dideoxy-β-L-*glycero*pentopyranosyl)-5,6-dichlorobenzotriazole (IVc).

Preparative tlc of the crude reaction product using ether-petroleum ether 1:1 afforded 0.05 g. of IVc m.p. 133-134° (from ethyl acetate-petroleum ether); $[\alpha]_D$ + 50° (c 0.8, chloroform).

Anal. Calcd. for $C_{13}H_{13}Cl_2N_3O_3$: C, 47.27; H, 3.94; N, 12.72. Found: C, 47.41; H, 3.82; N, 12.79.

Hydrogenation of 1-(4-*O*-Acetyl-2,3-dideoxy-α-L-*glycero*pent-2-enopyranosyl)-5,6-dichlorobenzotriazole (VIIb). Preparation of 1-(4-*O*-Acetyl-2,3-dideoxy-α-L-*glycero*pentopyranosyl)-5,6-dichlorobenzotriazole (VIIIb).

Preparative tlc of the crude reduction product using ethyl acetate-petroleum ether 1:3 resulted in the separation of 0.065 g. of VIIIb m.p. 140-141° (from ethyl acetate-petroleum ether); $[\alpha]_D$ -68.2° (c 0.6, chloroform).

Anal. Calcd. for $C_{13}H_{13}Cl_2N_3O_3$: C, 47.27; H, 3.94; N, 12.72. Found: C, 47.15; H, 3.88; N, 12.80.

General Procedure for the Hydrogenation of the *N*-(Hex-2-enopyranosyl)benzotriazoles.

A solution of 0.3 g. of unsaturated derivative in 20 ml. of ethyl acetate was hydrogenated at room temperature and ~3 atmospheres for 10-12 minutes using platinum oxide as catalyst. The resulting crude product was purified by preparative tlc as indicated in each case. The benzotriazole derivatives IXa, XIa and XIb were hydrogenated at -18° and 1 atmosphere for 4-5 hours. Reduction of the 5,6-dimethylbenzotriazole derivative Vc was effected at 0° and 3 atmospheres for 6 minutes.

Hydrogenation of 1-(4,6-Di-*O*-acetyl-2,3-dideoxy-β-D-*erythro*hex-2-enopyranosyl)benzotriazole (IXa). Preparation of 1-(4,6-Di-*O*-acetyl-2,3-dideoxy-β-D-*erythro*hexopyranosyl)benzotriazole (Xa).

The crude product was purified by preparative tlc using ethyl acetate-chloroform-petroleum ether 1:1:2 as developer system (9 consecutive developments). The major band afforded 0.16 g. of Xa m.p. 102-103° (from ethyl acetate-petroleum ether); $[\alpha]_D$ + 1.5° (c 1, chloroform).

Anal. Calcd. for $C_{16}H_{19}N_3O_5$: C, 57.65; H, 5.74; N, 12.60. Found: C, 57.47; H, 5.66; N, 12.60.

Hydrogenation of 1-(4,6-Di-*O*-acetyl-2,3-dideoxy-α-D-*erythro*hex-2-enopyranosyl)benzotriazole (XIa). Preparation of 1-(4,6-di-*O*-acetyl-2,3-dideoxy-α-D-*erythro*hexopyranosyl)benzotriazole (XIIa).

Work-up as above afforded 0.16 g. of XIIa, m.p. 72-73° (from ethyl acetate-petroleum ether); $[\alpha]_D$ + 166.2° (c 0.6, chloroform).

Anal. Calcd. for $C_{16}H_{19}N_3O_5$: C, 57.65; H, 5.74; N, 12.60. Found: C, 57.51; H, 5.69; N, 12.54.

Hydrogenation of 2-(4,6-Di-*O*-acetyl-2,3-dideoxy-α-D-*erythro*hex-2-enopyranosyl)benzotriazole (XIb). Preparation of 2-(4,6-Di-*O*-acetyl-2,3-dideoxy-α-D-*erythro*hexopyranosyl)benzotriazole (XIIb).

The oily residue was purified by preparative tlc using ethyl acetate-chloroform-petroleum ether 1:1:3 as developer (3 consecutive developments). The major band afforded 0.19 g. of XIIb as a chromatographically homogeneous syrup, $[\alpha]_D$ + 78.2° (c 0.3, chloroform).

Anal. Calcd. for $C_{16}H_{19}N_3O_5$: C, 57.65; H, 5.74; N, 12.60. Found: C, 57.68; H, 5.63; N, 12.83.

Hydrogenation of 1-(4,6-Di-*O*-acetyl-2,3-dideoxy-β-D-*erythro*hex-2-enopyranosyl)-5,6-dimethylbenzotriazole (IXb). Preparation of 1-(4,6-Di-*O*-acetyl-2,3-dideoxy-β-D-*erythro*hexopyranosyl)-5,6-dimethylbenzotriazole (Xb).

Preparative tlc (ethyl acetate-chloroform-petroleum ether 1:1:8, 15 consecutive developments) yielded as the major fraction (slowest moving band), 0.12 g. of Xb, m.p. 139-140° (from ethyl acetate-petroleum ether); $[\alpha]_D$ + 9.9° (c 0.5, chloroform).

Anal. Calcd. for $C_{18}H_{23}N_3O_5$: C, 59.82; H, 6.41; N, 11.62. Found: C, 59.56; H, 6.42; N, 11.69.

Hydrogenation of 1-(4,6-Di-*O*-acetyl-2,3-dideoxy-α-D-*erythro*hex-2-enopyranosyl)-5,6-dimethylbenzotriazole (XIc). Preparation of 1-(4,6-Di-*O*-acetyl-2,3-dideoxy-α-D-*erythro*hexopyranosyl)-5,6-dimethylbenzotriazole (XIIc).

The crude product was purified by preparative tlc (ether-petroleum ether 1:1, 12 consecutive developments). The major band (fastest band) gave 0.18 g. of XIIc, m.p. 115-116° (from ethyl ethyl acetate-petroleum ether); $[\alpha]_D$ + 193.8° (c 0.6, chloroform).

Anal. Calcd. for $C_{18}H_{23}N_3O_5$: C, 59.82; H, 6.41; N, 11.62. Found: C, 59.70; H, 6.39; N, 11.49.

Hydrogenation of 2-(4,6-Di-*O*-acetyl-2,3-dideoxy-β-D-*erythro*hex-2-enopyranosyl)-5,6-dimethylbenzotriazole (IXc). Preparation of 2-(4,6-Di-*O*-acetyl-2,3-dideoxy-β-D-*erythro*hexopyranosyl)-5,6-dimethylbenzotriazole (Xc).

The crude product was purified by preparative tlc (ethyl acetate-chloroform-petroleum ether 1:1:3; 5 consecutive developments). The major band (fastest band) afforded 0.15 g. of Xc, m.p. 157-158° from ethyl acetate-petroleum ether); $[\alpha]_D$ + 38.7° (c 0.7, chloroform).

Anal. Calcd. for $C_{18}H_{23}N_3O_5$: C, 59.82; H, 6.41; N, 11.62. Found: C, 60.08; H, 6.46; N, 11.76.

Hydrogenation of 2-(4,6-Di-*O*-acetyl-2,3-dideoxy-α-D-*erythro*hex-2-enopyranosyl)-5,6-dimethylbenzotriazole (XId). Preparation of 2-(4,6-Di-*O*-acetyl-2,3-dideoxy-α-D-*erythro*hexopyranosyl)-5,6-dimethylbenzotriazole (XIId).

Purification of the crude product was effected by preparative tlc (ethyl acetate-chloroform 1:3, 2 consecutive developments). The major band afforded 0.17 g. of XIId, m.p. 100-101° (from ethyl acetate-petroleum ether); $[\alpha]_D$ + 50.5° (c 0.5, chloroform).

Anal. Calcd. for $C_{18}H_{23}N_3O_5$: C, 59.82; H, 6.41; N, 11.62. Found: C, 60.08; H, 6.39; N, 11.40.

Hydrogenation of 1-(4,6-Di-*O*-acetyl-2,3-dideoxy-β-D-*erythro*hex-2-enopyranosyl)-5,6-dichlorobenzotriazole (IXd). Preparation of 1-(4,6-Di-*O*-acetyl-2,3-dideoxy-β-D-*erythro*hexopyranosyl)-5,6-dichlorobenzotriazole (Xd).

The syrupy residue was purified by preparative tlc (ethyl acetate-chloroform 1:1, 2 developments). The major fraction (fastest moving band) gave 0.18 g. of Xd, m.p. 153-154° (from ethyl acetate-petroleum ether); $[\alpha]_D$ + 4.0° (c 0.7, chloroform).

Anal. Calcd. for $C_{16}H_{17}Cl_2N_3O_5$: C, 47.76; H, 4.22; N, 10.44. Found: C, 47.49; H, 4.34; N, 10.16.

Hydrogenation of 1-(4,6-Di-*O*-acetyl-2,3-dideoxy-α-D-*erythro*hex-2-enopyranosyl)-5,6-dichlorobenzotriazole (XIe). Preparation of 1-(4,6-Di-*O*-acetyl-2,3-dideoxy-α-D-*erythro*hexopyranosyl)-5,6-dichlorobenzotriazole (XIIe).

Work-up exactly as before afforded 0.19 g. of XIIe, m.p. 109-110° (from ethyl acetate-petroleum ether); $[\alpha]_D$ + 198° (c 0.4, chloroform).

Anal. Calcd. for $C_{16}H_{17}Cl_2N_3O_5$: C, 47.76; H, 4.22; N, 10.44. Found: C, 47.72; H, 4.02; N, 10.25.

Hydrogenation of 2-(4,6-Di-*O*-acetyl-2,3-dideoxy-α-D-*erythro*hex-2-enopyranosyl)-5,6-dichlorobenzotriazole (XIf). Preparation of 2-(4,6-Di-*O*-acetyl-2,3-dideoxy-α-D-*erythro*hexopyranosyl)-5,6-dichlorobenzotriazole (XIIf).

Work-up as described above gave 0.15 g. of XIIf as a chromatographically homogeneous syrup, $[\alpha]_D$ + 50.7° (c 0.4, chloroform).

Anal. Calcd. for $C_{16}H_{17}Cl_2N_3O_5$: C, 47.76; H, 4.22; N, 10.44. Found: C, 47.91; H, 4.28; N, 10.27.

Hydrogenation of 1-(4-*O*-Acetyl-2,3-dideoxy-β-D-*glycero*pentopyranosyl)benzotriazole (IIa). Preparation of 1-(4-*O*-Acetyl-2,3-dideoxy-β-D-*glycero*pentopyranosyl)-4,5,6,7-tetrahydrobenzotriazole.

A solution of 0.33 g. of IIa in 20 ml. of acetic acid was hydrogenated at room temperature and ~3 atmospheres for 2.5 hours over platinum oxide. The catalyst was separated by filtration and the filtrate evaporated to yield a syrup, which was purified by preparative tlc (ethyl acetate-petroleum ether 1:1) to give 0.28 g. of the tetrahydrobenzotriazole derivative, m.p. 75-76° (from ethyl acetate-petroleum ether); $[\alpha]_D$ -73.8° (c 1, chloroform). Nmr (deuteriochloroform, τ), 4.30 (H-1′), 5.13 (H-4′), 6.39 (H-5′a), 6.22 (H-5′e). Coupling constants (Hz) ($J_{1',2'a}$ + $J_{1',2'e}$) = 8.9, ($J_{4',5'a}$ + $J_{4',5'e}$) = 7.6, $J_{5'a,5'e}$ = -12.0.

Anal. Calcd. for $C_{13}H_{19}N_3O_3$: C, 58.86; H, 7.16; N, 15.84. Found: C, 58.75; H, 7.43; N, 16.05.

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