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Regio- and stereo-selective synthesis of carbohydrate isoxazolidines by 1,3-dipolar cycloaddition of nitrones to 5,6-dideoxy-1,2-*O*-isopropylidene-α-D-*xylo*-hex-5-enofuranose

Usama A. R. Al-Timari*,[1], Ľubor Fišera†,[1], and Igor Goljer[2],
[1]*Department of Organic Chemistry and* [2]*Central Laboratory of Chemical Techniques, Slovak Technical University, CS-81237 Bratislava (Czechoslovakia)*

and Peter Ertl
Chemical Institute, Comenius University, CS-84215 Bratislava (Czechoslovakia)

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ABSTRACT

The synthesis of 2-phenyl-3-aryl and 2-phenyl-3-aroyl derivatives 5-(1,2-*O*-isopropylidene-α-D-*xylo*-tetrofuranos-4-yl)isoxazolidine (**3**) from nitrones and 5,6-dideoxy-1,2-*O*-isopropylidene-α-D-*xylo*-hex-5-enofuranose (**1**) is described. The 1,3-dipolar cycloaddition reactions give mainly *anti* adducts **3** and **4** (≥95% π-facial stereoselectivity). The cycloadducts **3** with H-3,5 *cis* are formed either exclusively or preponderate over the *trans* diastereoisomers **4**.

INTRODUCTION

Naturally occurring *C*-nucleosides are antibiotics, and many also exhibit anticancer and antiviral activities[1]. Cyclic *C*-glycosyl compounds are important as enzyme inhibitors[2] and as chiral synthons suitable for the synthesis of many natural products[3]. These properties have stimulated interest in the synthesis of analogues. 1,3-Dipolar cycloaddition reactions can create several chiral centers in one step[4] and much effort has been devoted to studies of the cycloaddition of nitrones to alkenes to give isoxazolidines[4–8].

In using heterocyclic compounds as dipolarophile components in 1,3-dipolar cycloaddition reactions[9–11], we have demonstrated[12] that nitrile oxides react with 5,6-dideoxy-1,2-*O*-isopropylidene-α-D-*xylo*-hex-5-enofuranose (**1**) to produce mainly *anti* adducts with ≥95% π-facial stereoselectivity. The influence of stereocentres in either of the reactants has been studied widely, including those in sugar-derived nitrones[5]. However, little attention has been paid to the cycloadditions of achiral nitrones to chiral alkenes[5,6,8], and none to sugar-derived alkenes.

We now report on the regio- and stereo-chemical features associated with the cycloaddition of several nitrones to **1**, together with quantum mechanical calculations using the AM1 method.

* On leave from the Basra University, Technical University, P.O. Box 272, Basra, Iraq.
† Author for correspondence.

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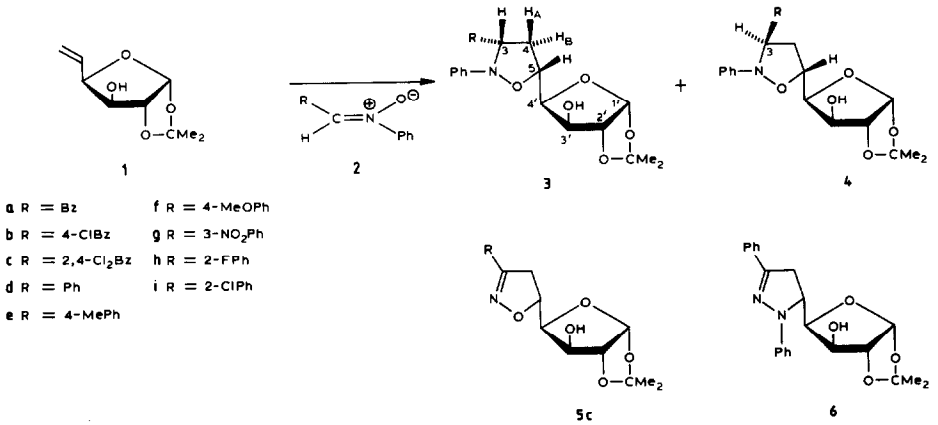
RESULTS AND DISCUSSION

Cycloaddition of the *C*-aryl-*N*-phenylnitrones **2** to **1** in toluene at 110° gave good yields of mixtures of the isoxazolidines **3** and **4** diastereoisomeric at C-3, in which the isomers **3** preponderated (**3d** 80:20, **3e** 73:27, **3f** 83:17, **3h** 75:25, based on n.m.r. data). Only the major adducts **3** could be isolated pure after column chromatography.

The cycloaddition to **1** of nitrones possessing an electron-withdrawing substituent, such as the *C*-aroyl-*N*-phenylnitrones **2a–2c** and the 3-nitrophenyl-substituted nitrone **2g**, gave only the isoxazolidines **3**. Two new asymmetric centres were generated in the cycloaddition and four diastereomeric cycloadducts are possible. There is strong evidence[13] that the nitrones **2** possess a *Z* configuration in which the *C*-aryl or *C*-aroyl groups are *trans* to the *N*-phenyl groups. Cycloaddition of the *Z*-nitrone **2** to **1** by way of an *endo* transition state yields the *trans*-isoxazolidine **4**, whereas the *exo* transition state yields the *cis* isomer **3** (*i.e.*, H-3,5 *cis*)[7]. However, since C-4′ in **1** is chiral, the alkene has diastereotopic faces, and two *trans* and two *cis* products can be formed[14].



The structures of **3** were determined by n.m.r. spectroscopy. In order to assign the signals, double-quantum-filtered ^1H–^1H correlation (DQF ^1H–^1H COSY)[15,16] and 2D n.O.e. spectroscopy were applied, and n.O.e. difference spectra[14,17] with multiple irradiation of proton multiplets without sample spinning were obtained. The assignment of the proton-coupling network in **3b** started from the signal for H-1′ (5.95 p.p.m.) which had a cross-peak with H-2′ at 4.53 p.p.m. The assignment of peaks was complicated by the overlap of the H-2′ signal with that assigned to H-5 of the isoxazolidine skeleton. The H-2′ signal exhibited two cross-peaks because of unresolved coupling with H-3′ (4.36 p.p.m.) and H-4′ (4.21 p.p.m.). The assignment of the isoxazolidine ring protons started from the signal for H-4A (2.53 p.p.m.) and H-4B (3.01 p.p.m.), which exhibited strong coupling to H-5 and H-3, resulting in four cross-signals.

The relative configuration of the substituents on the isoxazolidine ring was confirmed by n.O.e. difference spectroscopy. Irradiation of H-4B (3.01 p.p.m.) enhanced the signal for H-4′ by 6.9%, and irradiation of H-4A enhanced the signals of H-3

(7.8%) and H-5 (11.1%), thus indicating H-3,5 to be *cis*. The assignment of the ^{13}C resonances was based[18] on ^{1}H–^{13}C COSY (See Experimental). Some ambiguity remained in the assignment of the signals for C-5 and C-2′ because of overlap in the ^{1}H-n.m.r. spectra.

The relative stereochemistry of C-4′ and C-5 of isoxazolidines[7,14,19] cannot be determined by physical methods, but the anti C-4′,5 cycloadducts were produced stereoselectively. The 1,3-dipolar cycloaddition reactions of nitrile oxides to **1** proceeded with 78–95% π-facial stereoselectivity[12,20] and gave mainly *anti* adducts **5**. For comparison with the phenyl derivatives, the corresponding benzoyl-substituted isoxazoline **5c** were prepared, which were formed with >95% π-facial selectivity.

We supposed that the cycloadditions of the nitrones **2** to **1** are also *anti* selective and, therefore, that **3** has the *anti* C-4′,5 configuration. This result would be expected, since, in all published examples, the stereoselectivity of the cycloaddition of nitrones is slightly better than that of nitrile oxides[5].

The observed diastereofacial selectivity can be rationalised by assuming that there is a Houk-model transtion state[21,22] during cycloaddition. De Micheli *et al.*[20] suggested a transition-state structure for the cycloaddition of the parent nitrile oxide HCNO to **1** possessing the allylic oxygen "inside" (A) and *anti* (B) as shown in Fig. 1 for nitrone cycloaddition. Assuming an *anti* attack, both conformations A and B yield the major isomer **3** by way of a transition state with an *exo* arrangement of the nitrone **2**. *endo*-Cycloaddition, which yields the isoxazolidine **4** (3-epimer of **3**), is disfavoured due to greater steric repulsion between N–Ph and H-4′ in the *endo* transition state in comparison with the repulsion between C-aryl and H-4′ in the *exo* transition state. From the relevant signals in the n.m.r. spectra corresponding to the minor isomers **4d–4f** and **4h** in crude reaction mixtures, structure **4** of the *anti* adduct with H-3,5 *trans* can be proposed.

The relative stabilities of products with *cis* (**3**) and *trans* (**4**) configuration were assessed by semi-empirical quantum chemical calculations[23] (AM1 method) and the optimised geometries are shown in Fig. 2. Subsequent AM1 calculations showed the *cis* isomer **3** to be more stable by 9.5 kJ/mol, a fact that can be accounted for mainly on steric considerations. In the *cis* isomer, the two aryl groups can be better accommodated (Fig. 2A) than in the *trans* isomer **4** where their steric interaction forces the isoxazolidine ring to adopt a partial envelope configuration (Fig. 2B). Furthermore, for the *cis* isomer

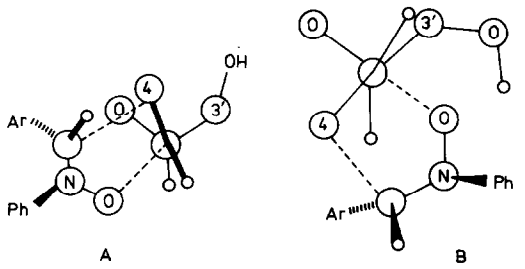


Fig. 1. The transition state of the cycloaddition of nitrone **2** to **1**.

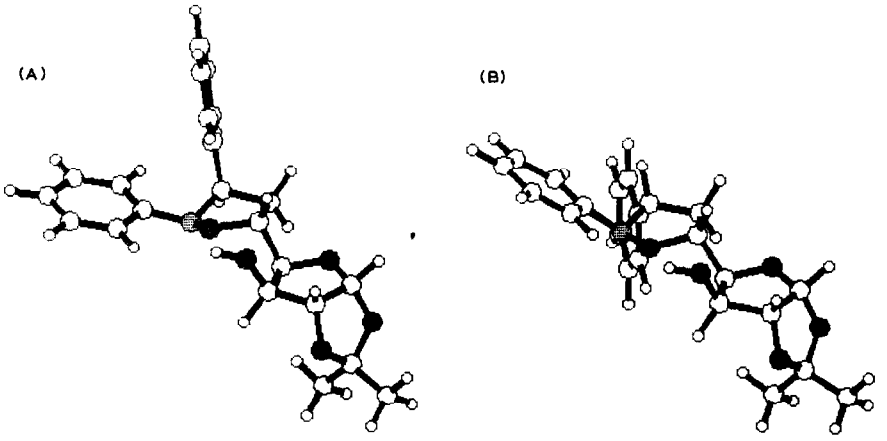


Fig. 2. Optimised geometries of *cis* cycloadduct **3** (A) and *trans* cycloadduct **4** (B).

3, there is additional stabilisation due to conjugation between the NPh group and N–O–C of the isoxazolidine. In each isomer, the phenyl ring is out of the plane of the isoxazolidine ring (20.2° in the *cis* isomer, 32.7° in the *trans* isomer) and, in each isomer, there is an intramolecular hydrogen bond (2.25 Å) between the pentose hydroxyl group and the oxygen atom of the isoxazolidine.

C,N-Diphenylnitrilimine cycloadded to **1** to give the *anti* pyrazoline derivative **6**. The preponderance of the *anti* isomers in the reaction of nitrile oxides, nitrones, and nitrile imines to **1** suggest that the high diastereofacial selectivity of dipolar cycloaddition to **1** is a general phenomenon.

EXPERIMENTAL

General methods. — Melting points were determined on a Kofler hot-plate apparatus and are uncorrected. Optical rotations were measured at 20° with a Perkin–Elmer 141 polarimeter. Reactions were monitored by t.l.c. on Silica Gel F_{254} (Lachema) with 9:1 $CHCl_3$–MeOH and detection by u.v. light and/or by exposure to iodine vapour. Column chromatography was performed on silica gel (Lachema, 230–400 mesh). All solvents were distilled from appropriate drying agents.

N.m.r. spectra were obtained with a Varian VXR 300 spectrometer for solutions in $CDCl_3$ (internal Me_4Si). For the ^1H measurements, a spectral width of 3000 Hz and a 45° pulse width were used; for the ^{13}C measurements, a 16-kHz spectral width and a 40° pulse width were used.

A spectral width of 2158 Hz was used for the DQF H^1–H^1 COSY spectrum with 1024 sample points in the F2 dimension and 256 increments in the F1 dimension with zero filling to 1024 Fourier-transform points. Gaussian weighting in both dimensions was used. The same spectral width was used for phase-sensitive NOESY with 512 data points in F2 and 512 increments in F1. The data were zero-filled to 1024 points before

2D phase-sensitive Fourier transformation. Lorentzian weighting was used in both dimensions prior to 2D Fourier transformation. A mixing delay of 0.2 s was used. In order to avoid misinterpretations of the phase-sensitive NOESY spectra, the spatial proximity of selected protons was confirmed with the help of ^{1}H n.O.e. difference spectroscopy.

5,6-Dideoxy-1,2-*O*-isopropylidene-α-D-*xylo*-hex-5-enofuranose (**1**) was prepared by the established procedure[24], *C*-aroyl-*N*-phenylnitrones **2a–2c** were prepared[25] from nitrosobenzene and the corresponding phenacylpyridinium bromide, and *C*-aryl-*N*-phenylnitrones **2d–2i** were prepared[26] from the respective benzaldehyde and phenylhydroxylamine.

Preparation of the isoxazolidines **3**. — A mixture of *C*-aryl-*N*-phenylnitrones (**2**, 10 mmol) and **1** (1.86 g, 10 mmol) in dry toluene (50 mL) was boiled under reflux for 2–4 h, then concentrated under reduced pressure. Column chromatography of the residue and crystallisation from MeOH then gave **3**. The cycloaddition of *C*-aroyl-*N*-phenylnitrones (**2**) involved stirring at room temperature for 24 h.

The following compounds were prepared in this manner.

3-Benzoyl-5-(1,2-*O*-isopropylidene-α-D-*xylo*-tetrofuranos-4-yl)-2-phenylisoxazolidine (**3a**, 60%), m.p. 168–170°, $[\alpha]_D^{20}$ − 52° (*c* 0.5, $CHCl_3$), R_F 0.66. N.m.r. data: ^{1}H, δ 7.04–8.03 (m, 9 H, arom.), 5.94 (d, 1 H, $J_{1',2'}$ 4.0 Hz, H-1'), 5.13 (dd, 1 H, $J_{3,4A}$ 9.0, $J_{3,4B}$ 4.0 Hz, H-3), 4.57 (dd, 1 H, $J_{4A,5}$ 2.7 Hz, H-5), 4.55 (d, 1 H, H-2'), 4.40 (d, 1 H, $J_{3',4'}$ 2.6 Hz, H-3'), 4.26 (dd, 1 H, $J_{4',5}$ 7.6 Hz, H-4'), 2.85 (ddd, 1 H, H-4B), 2.71 (dd, 1 H, $J_{4A,4B}$ 13.3 Hz, H-4A), 1.32 and 1.52 (2 s, each 3 H, CMe_2); ^{13}C, δ 195.07 (s, C = O), 149.46, 140.04, 133.26, 131.57, 130.49, 129.38, 129.01, 128.84, 123.26, 114.95 (arom. C), 112.01 (s, CMe_2), 104.88 (d, C-1'), 85.30 (d, C-5), 80.85 (d, C-4'), 75.68 (d, C-2'), 74.65 (d, C-3'), 70.26 (d, C-3), 34.62 (t, C-4), 26.86 and 26.28 (2 q, CMe_2).

Anal. Calc. for $C_{23}H_{25}NO_6$: C, 67.1; H, 6.1; N, 3.4. Found: C, 66.9; H, 6.2; N, 3.3.

3-(4-Chlorobenzoyl)-5-(1,2-*O*-isopropylidene-α-D-*xylo*-tetrofuranos-4-yl)-2-phenylisoxazolidine (**3b**, 66%), m.p. 184–186°, $[\alpha]_D^{20}$ − 97° (c 0.5, $CHCl_3$), R_F 0.68. N.m.r. data: ^{1}H, δ 6.99–7.44 (m, 9 H, arom.), 5.95 (d, 1 H, $J_{1',2'}$ 4.0 Hz, H-1'), 5.14 (dd, 1 H, $J_{3,4A}$ 9.6, $J_{3,4B}$ 2.6 Hz, H-3), 4.55 (dd, 1 H, $J_{4A,5}$ 2.3 Hz, H-5), 4.53 (d, 1 H, H-2'), 4.36 (d, 1 H, $J_{3',4'}$ 2.6 Hz, H-3'), 4.21 (dd, 1 H, $J_{4',5}$ 7.3 Hz, H-4'), 3.01 (ddd, 1 H, H-4B), 2.53 (dd, 1 H, $J_{4A,4B}$ 13 Hz, H-4A), 1.33 and 1.53 (2 s, each 3 H, CMe_2); ^{13}C, δ 201.10 (s, C = O), 149.34, 137.02, 136.64, 131.02, 130.38, 129.69, 129.27, 127.38, 123.03, 114.59 (arom. C), 112.18 (s, CMe_2), 105.03 (d, C-1'), 85.38 (d, C-5), 80.80 (d, C-4'), 75.91 (d, C-2'), 74.95 (d, C-3'), 73.32 (d, C-3), 33.04 (t, C-4), 27.00 and 26.43 (2 q, CMe_2).

Anal. Calc. for $C_{23}H_{24}ClNO_6$: C, 61.9; H, 5.3; N, 3.1. Found: C, 61.6; H, 4.9; N, 3.8.

3-(2,4-Dichlorobenzoyl)-5-(1,2-*O*-isopropylidene-α-D-*xylo*-tetrofuranos-4-yl)-2-phenylisoxazolidine (**3c**, 65%), m.p. 163–165°, $[\alpha]_D^{20}$ − 56° (*c* 0.5, $CHCl_3$), R_F 0.68. N.m.r. data: ^{1}H, δ 6.97–7.44 (m, 8 H, arom.), 5.95 (d, 1 H, $J_{1',2'}$ 4.0 Hz, H-1'), 5.14 (dd, 1 H, $J_{3,4A}$ 9.3, $J_{3,4B}$ 2.6 Hz, H-3), 4.55 (dd, 1 H, $J_{4A,5}$ 2.0 Hz, H-5), 4.53 (d, 1 H, H-2'), 4.36 (d, $J_{3',4'}$ 3.0 Hz, H-3'), 4.22 (dd, 1 H, $J_{4',5}$ 7.3 Hz, H-4'), 2.98 (ddd, 1 H, H-4B), 2.53 (dd, 1 , $J_{4A,4B}$ 13.0 Hz, H-4A), 1.33 and 1.54 (2 s, each 3 H, CMe_2); ^{13}C, δ 200.81 (s, C = O), 149.38, 137.03,

136.66, 131.04, 130.40, 129.70, 129.28, 127.39, 123.04, 114.61 (arom. C), 112.09 (s, CMe_2), 104.93 (d, C-1′), 85.29 (d, C-5), 80.69 (d, C-4′), 75.81 (d, C-2′), 74.84 (d, C-3′), 73.24 (d, C-3), 32.95 (t, C-4), 26.91 and 26.34 (2 q, CMe_2).

Anal. Calc. for $C_{23}H_{23}Cl_2NO_6$: C, 57.5; H, 4.8; N, 2.9. Found: C, 57.1; H, 4.7; N, 3.0.

5-(1,2-*O*-Isopropylidene-α-D-*xylo*-tetrofuranos-4-yl)-2,3-diphenylisoxazolidine (**3d**, 60%), m.p. 150–151°, $[\alpha]_D^{20}$ −14° (*c* 0.6, $CHCl_3$), R_F 0.65. N.m.r. data: ^1H, δ 7.00–7.45 (m, 10 H, 2 Ph), 5.99 (d, 1 H, $J_{1',2'}$ 3.7 Hz, H-1′), 4.74 (dd, 1 H, $J_{4',5}$ 9.6, $J_{4,5}$ 8.0 Hz, H-5), 4.63 (d, 1 H, $J_{3,4A}$ 8.6 Hz, H-3), 4.57 (d, 1 H, H-2′), 4.44 (d, 1 H, $J_{3',4'}$ 2.3 Hz, H-3′), 4.10 (d, 1 H. H-4′), 3.03 (ddd, 1 H, H-4B), 2.45 (dd, 1 H, $J_{4A,4B}$ 13.0 Hz, H-4A), 1.31 and 1.42 (2 s, each 3 H, CMe_2); ^{13}C, δ 149.94, 140.23, 129.12, 128.90, 128.21, 126.66, 123.54, 116.82 (arom. C), 111.67 (s, CMe_2), 104.85 (d, C-1′), 85.15 (d, C-5), 81.29 (d, C-4′), 75.59 (d, C-2′), 74.35 (d, C-3′), 71.07 (d, C-3), 42.61 (t, C-4), 26.72 and 26.20 (2q, CMe_2).

Anal. Calc. for $C_{22}H_{25}NO_5$: C, 68.9; H, 6.5; N, 3.6. Found: C, 69.0; H, 6.3; N, 3.7.

5-(1,2-*O*-Isopropylidene-α-D-*xylo*-tetrofuranos-4-yl)-2-phenyl-3-(*p*-tolyl)isoxazolidine (**3e**, 41%), m.p. 164–166°, $[\alpha]_D^{20}$ −157° (*c* 0.5, $CHCl_3$), R_F 0.66. N.m.r. data: ^1H, δ 6.93–8.30 (m, 9 H, arom.), 5.89 (d, 1 H, $J_{1',2'}$ 4.0 Hz, H-1′), 5.04 (dd, 1 H, $J_{4',5}$ 9.0, $J_{4,5}$ 8.0 Hz, H-5), 4.48 (d, 1 H, $J_{3,4A}$ 8.0 Hz, H-3), 4.46 (d, 1 H, H-2′), 4.25 (d, 1 H, $J_{3',4'}$ 2.5 Hz, H-3′, 4.18 (d, 1 H, H-4′), 2.85 (ddd, 1 H, H-4B), 2.53 (dd, 1 H, $J_{4A,4B}$ 13.3 Hz, H-4A), 2.42 (s, 3 H, CH_3), 1.31 and 1.50 (2 s, each 3 H, CMe_2).

Anal. Calc. for $C_{23}H_{27}NO_5$: C, 69.5; H, 6.8; N, 3.5. Found: C, 69.2; H, 7.1; N, 3.2.

5-(1,2-*O*-Isopropylidene-α-D-*xylo*-tetrofuranos-4-yl)-3-(4-methoxyphenyl)-2-phenylisoxazolidine (**3f**, 45%), m.p. 150°, $[\alpha]_D^{20}$ −121° (*c* 0.5, $CHCl_3$), R_F 0.66. N.m.r. data: ^1H, δ 6.90–8.43 (m, 9 H, arom.), 5.93 (d, 1 H, $J_{1',2'}$ 4.0 Hz, H-1′), 5.00 (dd, 1 H, $J_{4',5}$ 9.0, $J_{4,5}$ 8.0 Hz, H-5), 4.60 (d, 1 H, H-2′), 4.37 (d, 1 H, $J_{3,4A}$ 8.7 Hz, H-3), 4.29 (d, 1 H, $J_{3',4'}$ 3.0 Hz, H-3′), 4.17 (dd, 1 H, H-4′), 3.87 (s, 3 H, OMe), 3.09 (m, 2 H, H-4,4), 1.31 and 1.60 (2 s, each 3 H, CMe_2); ^{13}C, δ 161.70, 150.20, 134.85, 131.38, 129.71, 127.92, 121.66, 116.97, 114.21 (arom. C), 111.61 (s, CMe_2), 104.84 (d, C-1′), 85.23 (d, C-5), 81.37 (d, C-4′), 75.69 (d, C-2′), 74.17 (d, C-3′), 70.83 (d, C-3), 55.41 (q, OCH_3), 42.46 (t, C-4), 26.72 and 26.16 (2 q, CMe_2).

Anal. Calc. for $C_{23}H_{27}NO_6$: C, 66.8; H, 6.5; N, 3.4. Found: C, 66.5; H, 6.8; N, 3.6.

5-(1,2-*O*-Isopropylidene-α-D-*xylo*-tetrofuranos-4-yl)-3-(3-nitrophenyl)-2-phenylisoxazolidine (**3g**, 55%), m.p. 160–161°, $[\alpha]_D^{20}$ −59° (*c* 0.4, $CHCl_3$), R_F 0.60. N.m.r. data: ^1H, δ 7.12–8.06 (m, 9 H, arom.), 5.87 (d, 1 H, $J_{1',2'}$ 4.0 Hz, H-1′), 4.92 (dd, 1 H, $J_{4',5}$ 9.3 Hz, $J_{4A,5}$ 6.0 Hz, H-5), 4.49 (d, 1 H, H-2′), 4.33 (d, 1 H, $J_{3',4'}$ 3.0 Hz, H-3′), 4.08 (dd, 1 H, H-4′), 3.02 (ddd, 1 H, H-4B), 2.30 (dd, 1 H, $J_{4A,4B}$ 13.3 Hz, H-4A), 1.27 and 1.36 (2 s, each 3 H, CMe_2); ^{13}C, δ 157.22, 130.34, 129.68, 129.58, 129.46, 129.40, 129.13, 126.82 (arom. C), 111.93 (s, CMe_2), 105.19 (d, C-1′), 85.47 (d, C-5), 81.22 (d, C-4′), 77.60 (d, C-3), 74.53 (d, C-3′), 38.71 (t, C-4), 26.82 and 26.17 (2 q, CMe_2).

Anal. Calc. for $C_{22}H_{24}N_2O_7$: C, 61.6; H, 5.6; N, 6.5. Found: C, 61.3; H, 5.9; N, 6.2.

3-(2-Fluorophenyl)-5-(1,2-*O*-isopropylidene-α-D-*xylo*-tetrofuranos-4-yl)-2-phenylisoxazolidine (**3h**, 45%), m.p. 188–189°, $[\alpha]_D^{20}$ −35° (*c* 0.4, $CHCl_3$), R_F 0.65. N.m.r.

data: ^{1}H, δ 6.97–7.55 (m, 9 H, arom.), 5.97 (d, 1 H, $J_{1',2'}$ 3.6 Hz, H-1'), 4.70 (dd, 1 H, $J_{4A,5}$ 6.0 Hz, H-5), 4.64 (d, 1 H, $J_{3,4A}$ 8.0 Hz, H-3), 4.56 (d, 1 H, H-2'), 4.41 (d, 1 H, $J_{3',4'}$ 2.4 Hz, H-3'), 4.08 (dd, 1 H, $J_{4',5}$ 8.7 Hz, H-4'), 3.01 (ddd, 1 H, H-4B), 2.44 (dd, 1 H, $J_{4A,4B}$ 13.3 Hz, H-4A), 1.25 and 1.31 (2 s, each 3 H, CMe_2); ^{13}C, δ 131.60, 129.62, 129.03, 128.93, 128.80, 128.00, 125.52, 116.46, 115.34 (arom. C), 111.77 (s, CMe_2), 104.85 (d, C-1'), 85.16 (d, C-5), 81.14 (d, C-4'), 76.41 (d, C-2'), 74.43 (d, C-3'), 70.34 (d, C-3), 42.40 (t, C-4), 26.72 and 26.61 (2 q, CMe_2).

Anal. Calc. for $C_{22}H_{24}FNO_5$: C, 65.8; H, 6.0; N, 3.4. Found: C, 66.4; H, 6.3; N, 3.1.

3-(2-Chlorophenyl)-5-(1,2-*O*-isopropylidene-α-D-*xylo*-tetrofuranos-4-yl)-2-phenylisoxazolidine (**3i**, 40%), m.p. 160–161°, $[\alpha]_D^{20}$ −41° (*c* 0.4, $CHCl_3$), R_F 0.60. N.m.r. data: ^{1}H, δ 7.39–8.15 (m, 9 H, arom.), 5.96 (d, 1 H, $J_{1',2'}$ 3.7 Hz, H-1'), 5.02 (dd, 1 H, $J_{4',5}$ 9.3, $J_{4,5}$ 8.0 Hz, H-5), 4.58 (d, 1 H, H-2'), 4.42 (d, 1 H, $J_{3',4'}$ 3.0 Hz, H-3'), 4.18 (d, 1 H, H-4'), 3.52 (m, 2 H, H-4,4), 1.30 and 1.46 (2 s, each 3 H, CMe_2); ^{13}C, δ 157.04, 130.83, 130.40, 130.15, 128.96, 128.86, 126.69, 122.70 (arom. C), 111.74 (s, CMe_2), 105.00 (d, C-1'), 85.29 (d, C-5), 81.01 (d, C-4'), 77.42 (d, C-3), 74.31 (d, C-3'), 38.49 (t, C-4), 26.65 and 25.99 (2 q, CMe_2).

Anal. Calc. for $C_{22}H_{24}ClNO_5$: C, 63.3; H, 5.7; N, 3.4. Found: C, 63.8; H, 6.1; N, 3.7.

3-(2,4-Dichlorobenzoyl)-5-(1,2-*O*-isopropylidene-α-D-*xylo*-tetrofuranos-4-yl)-2-isoxazoline (**5**, 66%); prepared from **1** and 2,4-dichlorobenzoylnitrile oxide, which was generated[27] *in situ* from 2,4-dichlorophenylglyoxylhydroximoyl chloride and triethylamine; m.p. 177–178°, $[\alpha]_D^{20}$ +22° (*c* 0.5, $CHCl_3$), R_F 0.55; λ_{max} 252 nm (log ε 2.77). N.m.r. data: ^{1}H, δ 7.26–7.65 (m, 3 H, arom.), 5.92 (d, 1 H, $J_{1',2'}$ 4.0 Hz, H-1'), 4.97 (dd, 1 H, $J_{4',5}$ 9.0, $J_{4,5}$ 8.0 Hz, H-5), 4.55 (d, 1 H, H-2'), 4.38 (d, 1 H, $J_{3',4'}$ 2.6 Hz, H-3'), 4.15 (dd, 1 H, H-4'), 3.48 (dd, 2 H, H-4), 1.29 and 1.43 (2 s, each 3 H, CMe_2); ^{13}C, δ 184.25 (s, C=O), 157.85 (s, C=N), 137.60, 135.05, 132.87, 130.65, 128.98, 126.94 (arom. C), 112.13 (s, CMe_2), 105.12 (d, C-1'), 85.32 (d, C-5), 81.12 (d, C-4'), 77.52 (d, C-2'), 74.55 (d, C-3'), 38.79 (t, C-4), 26.70 and 26.07 (2 q, CMe_2).

Anal. Calc. for $C_{17}H_{17}Cl_2NO_6$: C, 50.7; H, 4.2; N, 3.4. Found: C, 51.0; H, 4.6; N, 2.9.

5-(1,2-*O*-Isopropylidene-α-D-*xylo*-tetrofuranos-4-yl)-1,3-diphenyl-2-pyrazoline (**6**, 60%); prepared from **1** and diphenylnitrilimine, which was generated[28] *in situ* from *N*-phenylbenzhydrazonyl chloride and triethylamine; m.p. 249–250°, $[\alpha]_D^{20}$ −21° (*c* 0.7, $CHCl_3$), R_F 0.65. N.m.r. data: ^{1}H, δ 6.78–8.74 (m, 10 H, 2 Ph), 6.05 (d, 1 H, $J_{1',2'}$ 4.0 Hz, H-1'), 4.71 (dd, 1 H, $J_{4',5}$ 8.0, $J_{4,5}$ 8.5 Hz, H-5), 4.52 (dd, 1 H, $J_{3',4'}$ 3.0 Hz, H-4'), 4.44 (d, 1 H, H-2'), 4.24 (d, 1 H, H-3'), 3.45 (s, 1 H, H-4A), 3.41 (d, 1 H, H-4B), 1.28 and 1.46 (2 s, each 3 H, CMe_2); ^{13}C, δ 150.29, 146.30, 132.34, 129.60, 129.00, 128.51, 126.18, 120.55, 119.92, 115.31, 114.27, (arom. C), 111.75 (s, CMe_2), 105.13 (d, C-1'), 84.92 (d, C-4'), 80.45 (d, C-2'), 75.79 (d, C-3'), 60.27 (d, C-5), 36.20 (t, C-4), 26.72 and 26.15 (2 q, CMe_2).

Anal. Calc. for $C_{22}H_{24}N_2O_4$: C, 69.5; H, 6.3; N, 7.4. Found: C, 69.2; H, 6.7; N, 7.3.

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