Pergamon

Tetrahedron, Vol. 52, No. 1, pp. 143-148, 1996

0040-4020/96 $15.00 + 0.00

0040-4020(95)00888-8

2-*C*-Trifluoromethyl Substituted 3-Deoxypentoses

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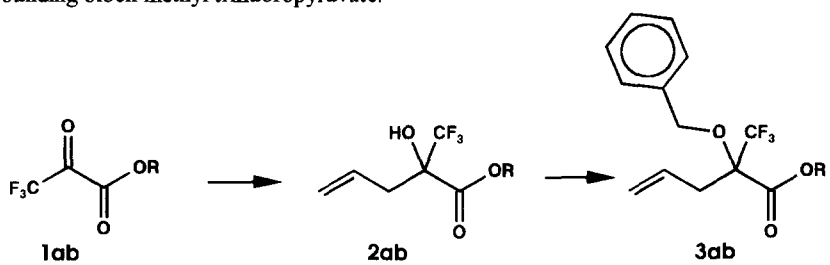
Abstract: *An efficient synthesis of 2-C-trifluoromethyl substituted 3-deoxypentoses starting from trifluoropyruvates is described.*

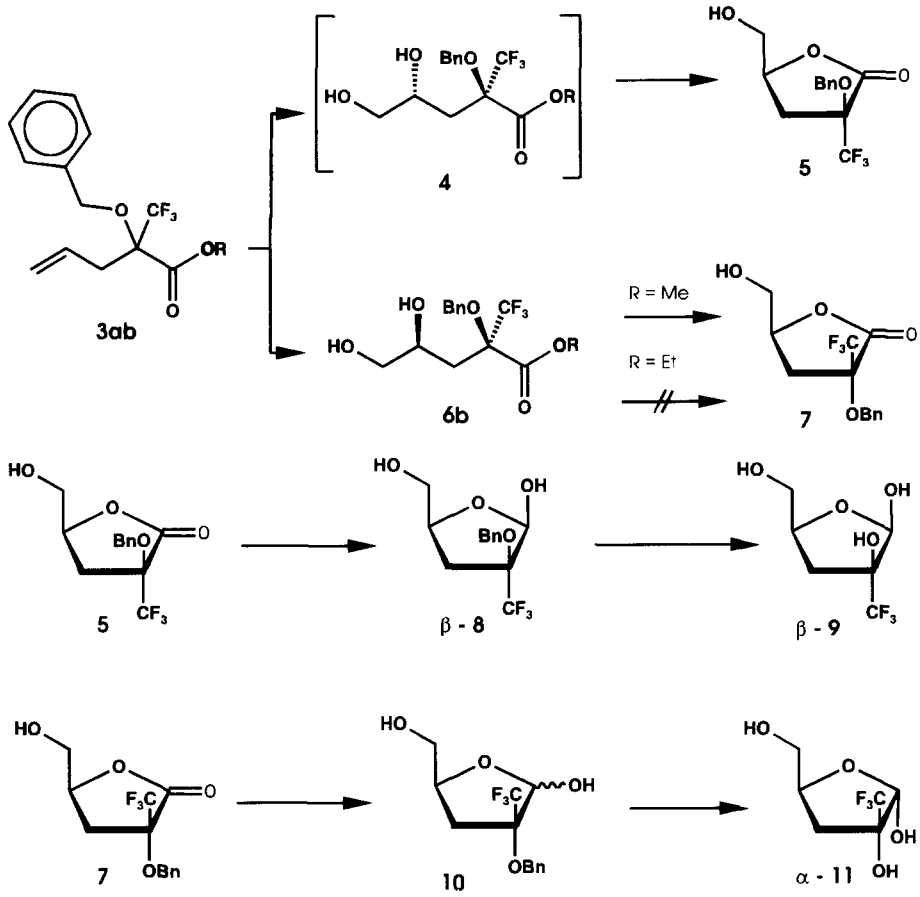
Cordycepin (3'-deoxyadenosine) is the first naturally occuring potent nucleoside antibiotic isolated from the fungus *Cordyceps militaris*.[1] Its cytostatic activity is derived from the chain terminating ability at the 3'-terminus during RNA synthesis. This is due to the lack of a 3'-hydroxy group in the sugar moiety.[2] Since, a large number of nucleosides derived from 3-deoxy sugars were found to possess antitumor or antiviral activity[3], like 3'-azido-3'-deoxythymidine (AZT)[4], 2',3'-dideoxyinosine (Didanosine, ddI)[5,6] and 2',3'-dideoxycytidine (ddC)[6] which have received much attention as potential drugs for HIV therapy. In this context, the development of nucleosides derived from unnatural carbohydrates, especially of the 3-deoxy- and 2,3-dideoxy-type as well as trifluoromethylated sugars[7] are of current interest.

The replacement of hydrogen atoms in strategical positions of target molecules by fluorine or trifluoromethyl groups results in various changes of chemical and biological properties.[8] Herein we wish to report on the synthesis of 2-*C*-trifluoromethyl substituted 3-deoxypentoses[9] from the readily available trifluoromethyl containing building block methyl trifluoropyruvate.



1ab **2ab** **3ab**

a: R = CH_3 b: R = C_2H_5



Reaction of allyl magnesium bromide and methyl 3,3,3-trifluoropyruvate[10] **1a** results in a regioselective addition to give methyl 2-hydroxy-2-trifluoromethyl-4-pentenoate **2a**. In contrast to the readily achieved *O*-benzylation of the unfluorinated analogue methyl 2-hydroxy-2-methyl-4-pentenoate described by Sugai *et al*[11], protection of the 2-hydroxy group of compound **2** turned out to be problematic. Because of the electron withdrawing inductive effect of the geminal trifluoromethyl group, which considerably decreases the nucleophilic capacity of the hydroxy function, the reaction even in the presence of catalytic amounts of tetrabutylammonium iodide is only achieved at elevated temperatures. Dihydroxylation with OsO_4 of **3a** yields a diastereomeric mixture of γ-lactones **5/7** in a 1:1 ratio. As shown by ^{19}F-NMR analysis, lactonization of the initially formed 4,5-dihydroxy esters occurs much slower with the erythro-configurated species **6** than with the threo-configurated **4**. In the case of the erythro ethylester **6b** no lactonization at all was observed under the reaction conditions applied. Reduction of the chromatographically separated diastereomeric lactones **5** and **7** with DIBAH provides the lactoles **8** and **10**, respectively. While **10** was isolated only as an oily mixture of anomers, **8** crystallized to give exclusively the β-anomer. After hydrogenolytic deprotection of **β-8** the *rac*-β-3-deoxy-2-*C*-trifluoromethyl arabinose **β-9** is obtained. From the anomeric mixture **10**, crystallizes to give pure *rac*-α-3-deoxy-2-*C*-trifluoromethyl ribose **α-11**.

Since, the protected lactoles **8** and **10** were shown to be tautomerically stable in $CDCl_3$, their relative configuration was determined by two dimensional hetero NOE NMR experiments (^{19}F-^1H-HOESY). The structural assignment is based on the NOE effect between the fluorine atoms of the trifluoromethyl group and the methine proton at C-4 (no cross peak for compound **10**) and the intensity of the cross peaks between the trifluoromethyl group and the anomeric protons (strong correlation for β-**8** and α-**10**). The β-configuration of **9** was proved further by a NOE correlation of the anomeric C(1)-H and the methine protone C(4)-H in a NOESY experiment. The different relative configurations of the anomeric carbon atoms can also be determined from the large differences of the chemical shift values of the trifluoromethyl groups. Based on this results the position of the anomeric hydroxy groups in **9** and **11** can be identified. The assigned configuration was confirmed by the ^1H- and ^{13}C-NMR data. Especially the chemical shift values of the anomeric carbon atoms[12] and of the protons[13] C(3)-H and C(4)-H are reliable indicators.

On the tautomeric and anomeric stabilities of the new trifluoromethylated sugars we report elsewhere.

Experimental

General.

Microanalyses were carried out with a Heraeus CHN-apparatus EA 415/0, Monar System. Melting points are determined on a Büchi SMP-20 apparatus (Tottoli) and are not corrected. Mass spectra were obtained with a Varian MAT CH5 (EI, 70eV) and Varian MAT M112S instruments (CI, Isobutane). IR spectra were mesured with Perkin-Elmer 157G and Perkin-Elmer 257 instruments. NMR spectra were recorded on Bruker AM 360, AC 250 and AC 200 instruments. Chemical shifts are reported in ppm relative to tetramethylsilane. For ^{19}F spectra external trifluoroacetic acid is used as reference. All solvents were dried by standard methods. Reactions were carried out under dry nitrogen or argon if necessary.

***(±)-Methyl 2-hydroxy-2-trifluoromethyl-4-pentenoate* 2a.**

Under a dry nitrogen atmosphere a solution of allyl magnesium bromide (209 mmol) in 230 ml Et_2O is slowly added at -50 °C to a solution of methyl trifluoromethyl pyruvate (209 mmol, 23.9 ml) in 200 ml Et_2O. After warming up to room temperature the reaction mixture is poored onto a suspension of ice and 1N HCl and the organic layer separated. The aqueous layer is extracted twice with Et_2O, then the combined organic layers are dried over $MgSO_4$. After solvent evaporation the residue is purified by distillation. Yield: 22.4 g (54 %).

Bp. 56 °C / 19 torr. ^1H-NMR ($CDCl_3$, 360 MHz): δ = 2.68 (m, 2H, 3-H), 3.88 (s, 3H, OCH_3), 4.14 (s, 1H, 2-OH), 5.20 (m, 2H, 5-H), 5.72 (dddd, *J* = 18.8, 10.2, 7.9, 6.4 Hz, 1H, 4-H). ^{13}C-NMR ($CDCl_3$, 90 MHz): δ = 36.45 (q, *J* = 1.2 Hz, C-3), 54.17 (OCH_3), 77.97 (q, *J* = 29.1 Hz, C-2), 120.74 (C-5), 123.45 (q, *J* = 286.1 Hz, CF_3), 129.54 (C-4), 169.99 (C-1). ^{19}F-NMR ($CDCl_3$, 60 MHz): δ = 0.2 (s, CF_3). MS (EI): m/z (%) = 180 (53), 166 (2), 165 (18), 157 (6), 139 (14), 129 (7), 91 (32), 69 (100), 59 (54), 41 (97). IR (film) $\upsilon_{max}(cm^{-1})$ = 1746, 1644. Anal. Calcd. for $C_7H_9F_3O_3$: C 42.43, H 4.58. Found: C 42.51, H 4.76.

***(±)-Methyl 2-benzyloxy-2-trifluoromethyl-4-pentenoate* 3a.**

To a solution of sodium hydride (1.58 g, 66 mmol) in 130 ml THF at -50 °C under a dry nitrogen atmosphere a solution of **2** (8.71 g, 44 mmol) in 50 ml THF is added. After 30 min of vigorous stirring benzyl bromide (11.22 ml, 66 mmol) and tetrabutyl ammonium iodide (3.25 g, 8.8 mmol) are added and the mixture is refluxed for 3 h. Then after cooling down to room temperature the reaction mixture is quenched with 1N HCl and extracted thrice with Et_2O. The combined organic phases are dried over $MgSO_4$ and evaporated. Purification by distillation yields **3a** (7.1 g, 56.3 %).

Bp. 89-91 °C / 0.8 torr. ^1H-NMR ($CDCl_3$, 360 MHz): δ = 2.80 (d, *J* = 7.0 Hz, 2H, 3-H), 3.84 (s, 3H, OCH_3), 4.67 (d, *J* = 10.7 Hz, 1H, OCH_2), 4.83 (d, *J* = 10.7 Hz, 1H, OCH_2), 5.18 (m, 2H, 5-H), 5.86 (m, 1H, 4-H), 7.36 (m, 5H, aromatic-H). ^{13}C-NMR ($CDCl_3$, 90 MHz): δ = 38.19 (C-3), 52.77 (OCH_3), 69.06

(OCH_2), 83.12 (q, J = 26.9 Hz, C-2), 119.71 (C-5), 123.81 (q, J = 289.6 Hz, CF_3), 127.65, 127.86, 128.35, 137.38 (aromatic-C), 130.18 (C-4), 167.23 (C-1). ^{19}F-NMR ($CDCl_3$, 235 MHz): δ = 6.90 (s, CF_3). MS (EI): m/z (%) = 181 (<0.1), 107 (42), 91 (100), 65 (23). IR (film) υ_{max}(cm^{-1}) = 1750, 1635. Anal. Calcd. for $C_{14}H_{15}F_3O_3$: C 58.33, H 5.25. Found: C 58.81, H 5.59.

***(±)-Ethyl 2-benzyloxy-2-trifluoromethyl-4-pentenoate* 3b.**

In a procedure analogous to that described above, sodium hydride (0.28 g, 6.0 mmol), ethyl 2-hydroxy-2-trifluoromethyl-4-pentenoate (0.79 g, 3.7 mmol), benzyl bromide (0.66 ml, 6.0 mmol) and tetrabutyl ammonium iodide (0.19 g 0.5 mmol) are reacted to yield **3b** (0.57 g, 51 %).

Bp. 115 °C / 0.8 torr. ^{1}H-NMR ($CDCl_3$, 360 MHz): δ = 1.32 (t, J = 7.1 Hz, 3H, OCH_2CH_3), 2.80 (d, J = 7.1 Hz, 2H, 3-H), 4.31 (q, J = 7.1 Hz, 2H, OCH_2CH_3), 4.68 (d, J = 10.6 Hz, 1H, OCH_2), 4.85 (d, J = 10.7 Hz, 1H, OCH_2), 5.18 (m, 2H, 5-H), 5.88 (ddt, J = 16.9, 10.2, 7.1 Hz, 1H, 4-H), 7.32 (m, 3H, aromatic-H), 7.43 (m, 2H, aromatic-H). ^{13}C-NMR ($CDCl_3$, 90 MHz): δ = 14.10 (OCH_2CH_3), 38.28 (C-3), 62.22 (OCH_2CH_3), 69.09 (OCH_2), 82.97 (q, J = 26.5 Hz, C-2), 119.69 (C-5), 123.98 (q, J = 289.4 Hz, CF_3), 127.71, 128.37, 128.88, 137.58 (aromatic-C), 130.30 (C-4), 166.72 (C-1). ^{19}F-NMR ($CDCl_3$, 60 MHz): δ = 8.1 (s, CF_3). MS (EI): m/z (%) = 228 (0.1), 211 (0.3), 196 (10), 168 (13), 148 (8), 107 (57), 91 (100). IR (film) υ_{max}(cm^{-1}) = 1745, 1640. Anal. Calcd. for $C_{15}H_{17}F_3O_3$: C 59.60, H 5.67. Found: C 59.73, H 5.57.

***(±)-2-Benzyloxy-4,5-dihydroxy-2-trifluoromethylpentanoic acid-γ-lactone* 5** (threo-isomer).

***(±)-2-Benzyloxy-4,5-dihydroxy-2-trifluoromethylpentanoic acid-γ-lactone* 7** (erythro-isomer).

***(±)-Ethyl 2-benzyloxy-4,5-dihydroxy-2-trifluoromethylpentanoate* 6b** (erythro-isomer).

A mixture of *N*-methyl morpholine *N*-oxid (1.8 g, 13 mmol), OsO_4-solution in toluene (5 mg, 0.02 mmol) and 2-benzyloxy-2-trifluoromethyl-4-pentenoic acid ester (8.7 mmol) in 9 ml acetone and 1 ml *aqua dest.* are stirred for 16 h. Then 1 g $NaHSO_3$ is added with vigorous stirring. After 10 min 10 ml CH_2Cl_2 and 2 g $MgSO_4$ are added and the suspension is stirred further 10 min. After separation and washing the residue thrice with CH_2Cl_2 the solvents are evaporated. The residue is taken up in ethyl acetate and washed twice with 1N HCl before drying the organic phase with $MgSO_4$ and evaporating the solvent. The oily products are separated and purified by flash-chromatography (eluent: ethyl acetate / hexane 3:2).

In the case of the methyl ester **3a** the compounds **5** and **7** are obtained (yield: 1.6 g, 63 %).

On using ethyl ester **3b** the resulting products are **5** and **6b** (yield: 2.1 g, 76 %).

Spectroscopic and analytical data:

5: R_f = 0.38 (ethyl acetate / hexane 3:2). ^{1}H-NMR ($CDCl_3$, 360 MHz): δ = 2.60 (dd, J = 14.6, 7.3 Hz, 1H, 3-H), 2.68 (dd, J = 14.6, 7.7 Hz, 1H, 3-H), 3.28 (s, 1H, 5-OH), 3.57 (dd, J = 12.9, 3.9 Hz, 1H, 5-H), 3.90 (dd, J = 12.9, 2.7 Hz, 1H, 5-H), 4.56 (dddd, J = 7.4, 7.4, 3.3, 3.3 Hz, 1H, 4-H), 4.66 (d, J = 10.9 Hz, 1H, OCH_2), 4.75 (d, J = 10.9 Hz, 1H, OCH_2), 7.30 (m, 5H, aromatic-H). ^{13}C-NMR ($CDCl_3$, 90 MHz): δ = 28.73 (C-3), 62.41 (C-5), 68.75 (OCH_2), 77.54 (C-4), 81.27 (q, J = 30.6 Hz, C-2), 123.19 (q, J = 285.8 Hz, CF_3), 127.86, 128.34, 128.58, 136.17 (aromatic-C), 168.93 (C-1). ^{19}F-NMR ($CDCl_3$, 60 MHz): δ = 1.4 (s, CF_3). MS (EI): m/z (%) = 290 (0.9), 259 (0.5), 213 (0.2), 184 (18), 166 (3), 138 (5), 128 (5), 107 (91), 91 (100), 44 (23). IR (film) υ_{max}(cm^{-1}) = 3400, 1775. Anal. Calcd. for $C_{13}H_{13}F_3O_4$: C 53.80, H 4.52. Found: C 53.93, H 4.69.

6b: ^{1}H-NMR ($CDCl_3$, 360 MHz): δ = 1.20 (t, J = 7.1 Hz, 3H, OCH_2CH_3), 1.94 (dd, J = 14.4, 2.2 Hz, 1H, 3-H), 2.21 (dd, J = 14.4, 9.6 Hz, 1H, 3-H), 3.00 (s, br, 2H, 4-OH, 5-OH), 3.33 (dd, J = 11.3, 6.7 Hz, 1H, 5-H), 3.47 (dd, J = 11.3, 3.3 Hz, 1H, 5-H), 4.04 (m, 1H, 4-H), 4.28 (m, 2H, OCH_2CH_3), 4.62 (d, J = 10.5 Hz, 1H, OCH_2), 4.98 (d, J = 10.5 Hz, 1H, OCH_2), 7.32 (m, 5H, aromatic-H). ^{13}C-NMR and 135°-DEPT ($CDCl_3$, 90 MHz): δ = 13.86 (OCH_2CH_3), 37.53 (C-3), 62.56 (OCH_2CH_3), 66.55 (C-5), 66.92 (C-4), 69.45 (OCH_2), 81.14 (q, J = 26.8 Hz, C-2), 124.15 (q, J = 290.1 Hz, CF_3), 128.05, 128.10, 128.47, 137.41 (aromatic-C), 167.58 (C-1). ^{19}F-NMR ($CDCl_3$, 60 MHz): δ = 8.5 (s, CF_3).

7: R_f = 0.43 (ethyl acetate / hexane 3:2). ^{1}H-NMR ($CDCl_3$, 360 MHz): δ = 2.40 (dd, J = 14.1, 5.7 Hz, 1H, 3-H), 2.59 (dd, J = 14.1, 9.6 Hz, 1H, 3-H), 3.48 (s, 1H, 5-OH), 3.58 (dd, J = 13.0, 4.2 Hz, 1H, 5-H), 3.92

(dd, *J* = 13.0, 2.7 Hz, 1H, 5-H), 4.68 (m, 1H, 4-H), 4.72 (d, *J* = 11.0 Hz, 1H, OCH_2), 4.89 (d, *J* = 11.0 Hz, 1H, OCH_2), 7.32 (m, 5H, aromatic-H). ^{13}C-NMR ($CDCl_3$, 90 MHz): δ = 32.44 (C-3), 61.95 (C-5), 70.37 (q, *J* = 1.2 Hz, OCH_2CH_3), 78.57 (C-4), 80.41 (q, *J* = 31.2 Hz, C-2), 123.17 (q, *J* = 285.0 Hz, CF_3), 127.99, 128.50, 128.65, 136.12 (aromatic-C), 167.96 (C-1). ^{19}F-NMR ($CDCl_3$, 60 MHz): δ = 3.1 (s, CF_3). MS (EI): m/z (%) = 290 (0.6), 259 (0.8), 184 (19), 166 (3), 138 (4), 128 (4), 107 (82), 91 (100), 44 (19). IR (film) υ_{max}(cm^{-1}) = 3400, 1775. Anal. Calcd. for $C_{13}H_{13}F_3O_4$: C 53.80, H 4.52. Found: C 53.94, H 4.69.

***(±)-2-O-Benzyl-3-deoxy-2-C-trifluoromethylarabinose* β-8.**

To a solution of **5** (850 mg, 2.9 mmol) in 80 ml dry toluene at -70 °C under an argon atmosphere diisobutyl aluminium hydride (1.57 ml, 8.7 mmol) is added. After stirring 1 h at -70 °C the mixture is poored into 150 ml 1N HCl and extracted thrice with Et_2O. The combined organic phases are washed with saturated $NaHCO_3$ solution, dried over $MgSO_4$ and evaporated. The crude product is purified by flash-chromatography (eluent: Et_2O). The resulting oil crystallizes within one week. Recrystallization ($CHCl_3$ / hexane) yields **β-8.**

Mp. 79-81 °C. ^{1}H-NMR ($CDCl_3$, 360 MHz): δ = 2.39 (dd, *J* = 13.9, 7.8 Hz, 1H, 3-H), 2.49 (dd, *J* = 13.9, 7.7 Hz, 1H, 3-H), 3.20 (s, br, 2H, 1-OH, 5-OH), 3.50 (dd, *J* = 12.2, 3.0 Hz, 1H, 5-H), 3.82 (dd, *J* = 12.2, 2.5 Hz, 1H, 5-H), 4.69 (d, *J* = 10.6 Hz, 1H, OCH_2), 4.80 (d, *J* = 10.6 Hz, 1H, OCH_2), 5.36 (s, 1H, 1-H), 7.34 (m, 5H, aromatic-H). ^{13}C-NMR ($CDCl_3$, 90 MHz): δ = 29.10 (C-3), 63.04 (C-5), 69.59 (OCH_2), 77.90 (C-4), 85.21 (q, *J* = 27.1 Hz, C-2), 96.24 (q, *J* = 1.8 Hz, C-1), 125.29 (q, *J* = 287.8 Hz, CF_3), 127.96, 128.28, 128.60, 136.80 (aromatic-C). ^{19}F-NMR ($CDCl_3$, 340 MHz): δ = 2.07 (s, CF_3). MS (EI): m/z (%) = 292 (0.2), 274 (0.2), 244 (0.1), 243 (0.8), 228 (0.2), 201 (0.4), 183 (2), 168 (4), 155 (3), 150 (5), 137 (8), 107 (18), 91 (100). IR (film) υ_{max}(cm^{-1}) = 3550-3150. Anal. Calcd. for $C_{13}H_{15}F_3O_4$: C 53.43, H 5.17. Found: C 53.44, H 4.94.

***(±)-2-O-Benzyl-3-deoxy-2-C-trifluoromethylribose* 10.**

7 (940 mg, 3.2 mmol) is reduced with DIBAH (1.73 ml, 9.6 mmol) to yield **10** (840 mg, 90 %) as oily mixture of both anomers.

^{1}H-NMR ($CDCl_3$, 360 MHz): δ = 2.20 (dd, *J* = 14.2, 10.3 Hz, 3-H), 2.20 (dd, *J* = 13.9, 6.7 Hz, 3-H) overlapping peaks, integral: 2H, 2.42 (dd, *J* = 14.2, 5.7 Hz, 3-H), 2.52 (dd, *J* = 13.9, 8.9 Hz, 3-H) overlapping peaks, integral: 2H, 3.48 (m, 2H, 5-H), 3.75 (m, 2H, 5-H), 4.37 (m, 2H, 4-H), δ = 4.64 (d, *J* = 11.1 Hz, OCH_2), 4.68 (d, *J* = 10.8 Hz, OCH_2), 4.69 (d, *J* = 11.1 Hz, OCH_2), 4.78 (d, *J* = 10.8 Hz, OCH_2) overlapping peaks, integral: 4H, 5.43 (s, 1H, 1-H), 5.49 (s, 1H, 1-H), 7.31 (m, 5H, aromatic-H). ^{13}C-NMR ($CDCl_3$, 90 MHz): δ = 28.34, 29.66 (C-3), 62.70, 63.20 (C-5), 67.59, 68.75 (OCH_2), 77.05, 79.58 (C-4), 83.58 (q, *J* = 27.9 Hz, C-2), 87.07 (q, *J* = 26.9 Hz, C-2), 98.05 (q, *J* = 2.1 Hz, C-1), 98.30 (C-1), 124.52 (q, *J* = 285.5 Hz, CF_3), 124.62 (q, *J* = 286.2 Hz, CF_3), 127.44, 127.83, 127.96, 128.46, 128.51, 128.72, 136.37, 137.29 (aromatic-C). ^{19}F-NMR ($CDCl_3$, 60 MHz): δ = 4.0, 8.9 (s, 2x CF_3). MS (EI): m/z (%) = 292 (0.1), 274 (<0.1), 244 (0.1), 243 (0.7), 228 (0.5), 201 (0.6), 183 (3), 168 (2), 155 (3), 150 (2), 137 (7), 107 (9), 91 (100). IR (film) υ_{max}(cm^{-1}) = 3550, 3550-3150. Anal. Calcd. for $C_{13}H_{15}F_3O_4$: C 53.43, H 5.17. Found: C 53.09, H 5.28.

***(±)-3-Deoxy-2-C-trifluoromethylarabinose* β-9.**

β-8 (403 mg, 1.38 mmol) and 100 mg 10% Pd/C are suspended in 40 ml of abs. MeOH. The mixture is vigorously stirred for 4 h under a hydrogen atmosphere. Before evaporation of the solvent the suspension is filtered. Distillation *in vacuo* yields 186 mg (67 %) of an oily product, which crystallizes after addition of a few drops of $CHCl_3$. Recrystallization is achieved from $CHCl_3$.

Mp. 75 °C. ^{1}H-NMR ([D_6]DMSO, 360 MHz): δ = 1.87 (dd, *J* = 14.0, 7.7 Hz, 1H, 3-H), 2.31 (dd, *J* = 14.0, 7.6 Hz, 1H, 3-H), 3.42 (m, 2H, 5-H), 3.91 (m, 1H, 4-H), 4.85 (dd, *J* = 5.4, 5.4 Hz, 1H, 5-OH), 5.09 (d, *J* = 6.6 Hz, 1H, 1-H), 6.00 (s, 1H, 2-OH), 6.87 (d, *J* = 6.6 Hz, 1H, 1-OH). ^{13}C-NMR ([D_6]acetone, 90 MHz): δ = 34.62 (C-3), 64.63 (C-5), 78.01 (C-4), 80.72 (q, *J* = 28.1 Hz, C-2), 96.91 (C-1), 126.40 (q, *J* = 282.6 Hz, CF_3). ^{19}F-NMR (D_2O, 235 MHz): δ = -2.67 (s, CF_3). MS (EI): m/z (%) = 203 (<1), 185 (1), 171 (52),

153 (45), 138 (24), 133 (9), 125 (7), 118 (7), 106 (14), 105 (26), 89 (21), 77 (20), 69 (53), 44 (100), 43 (54), 41 (36), 31 (54), 29 (43). IR (KBr) $\upsilon_{max}(cm^{-1})$ = 3600-3200. Anal. Calcd. for $C_6H_9F_3O_4$: C 35.64, H 4.49. Found: C 36.20, H 4.90.

***(±)-3-Deoxy-2-C-trifluoromethylribose* α-11.**

Deprotection is carried out under similar conditions as described above. (502 mg, 1.73 mmol) **10** and 60 mg catalyst are stirred in 20 ml MeOH for 5 h under a hydrogen atmosphere. The oily product is purified as described above to yield 350 mg (100 %) crystalline **α-11**.

Mp. 106 °C. ^{1}H-NMR ([D_6]DMSO, 360 MHz): δ = 1.95 (m, 2H, 3-H), 3.40 (m, 2H, 5-H), 4.22 (m, 1H, 4-H), 4.78 (dd, *J* = 5.8, 5.8 Hz, 1H, 5-OH), 5.25 (d, *J* = 6.4 Hz, 1H, 1-H), 5.89 (s, 1H, 2-OH), 6.93 (d, *J* = 6.4 Hz, 1H, 1-OH). ^{13}C-NMR ([D_6]acetone, 90 MHz): δ = 36.27 (C-3), 63.72 (C-5), 78.47 (C-4), 80.92 (q, *J* = 28.8 Hz, C-2), 96.84 (C-1), 126.26 (q, *J* = 282.5 Hz, CF_3). ^{19}F-NMR (D_2O, 235 MHz): δ = -2.46 (s, CF_3). MS (EI): m/z (%) = 185 (1), 172 (6), 171 (100), 154 (11), 153 (71), 138 (28), 133 (12), 125 (7), 118 (6), 106 (15), 105 (25), 89 (24), 77 (13), 69 (37), 44 (64), 43 (31), 41 (17), 31 (24), 29 (15). IR (KBr) $\upsilon_{max}(cm^{-1})$ = 3550-3100. Anal. Calcd. for $C_6H_9F_3O_4$: C 35.64, H 4.49. Found: C 35.33, H 4.33.

Acknowledgements

The authors thank DFG, Fonds der Chemischen Industrie for financial support and Hoechst AG, Frankfurt/Main, for generous supply with chemicals. This project is associated to a COST D-2 program.

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(*Received* 19 *June* 1995)