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Synthesis of *D*-Apio-β-*D*-furanosyl Maleimide, an Analogue of Showdomycin with Transposed Hydroxymethyl Group

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Summary. Apioshowdomycin (3-(*D*-apio-β-*D*-furanosyl)-1*H*-pyrrole-2,5-dione, **2**) has been prepared as an analogue of the C-nucleoside showdomycin (**1**) in eight steps and with 5% overall yield, starting from 2,3-O-isopropylidene-*D*-apio-β-*D*-furanose (**3**).

Keywords. Showdomycin; Apioshowdomycin; C-Nucleoside; 2,3-O-Isopropylidene-*D*-apio-β-*D*-furanose.

Synthese von *D*-Apio-β-*D*-furanosyl-maleinsäureimid, einem Showdomycinanalogen mit verschobener Hydroxymethylgruppe

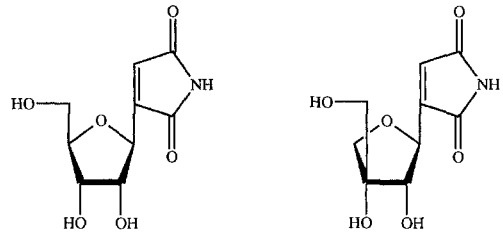
Zusammenfassung. Ausgehend von 2,3-O-Isopropyliden-*D*-apio-β-*D*-furanose (**3**) wurde in acht Stufen und 5% Gesamtausbeute Apioshowdomycin (3-(*D*-Apio-β-*D*-furanosyl)-1*H*-pyrrol-2,5-dion, **2**), ein Analoges des C-Nucleosids Showdomycin (**1**), hergestellt.

Introduction

Since the first isolation of showdomycin (**1**) from *Streptomyces showdoensis* [1], this C-nucleoside antibiotic has attracted considerable attention because of its antibacterial activity, especially against *Streptococcus hemolyticus* [1], its antitumor activity [2], and its enzyme inhibitory abilities [3, 4]. Numerous syntheses of the natural compound have been reported [5], as well as syntheses of analogues of **1** with modified sugar moiety, exemplified by 2′-deoxyshowdomycin [6, 7], 2′,3′-dideoxyshowdomycin [8], a carbocyclic analogue of **1** [9], homoshowdomycin (with an additional methylene group between the nitrogen base and carbon C-1 of *D*-ribose) [10], and an analogue linking the four membered sugar moiety of oxetanocin with the maleimide unit of showdomycin [11]. A close analogue of **1** with modified nucleobase in which the C=C double bond has been exchanged for a C–N single bond has recently been obtained by adding a hydantoin moiety to the ribosyl unit [12].

In continuation of a program addressing the synthesis and biological evaluation of nucleoside analogues containing the naturally occuring branched chain sugar *D*-apiose [13–15], we describe in this paper our first approach to the analogue **2** of

showdomycin [16] in which the β-*D*-ribosyl unit is exchanged for a *D*-apio-β-*D*-furanosyl part.



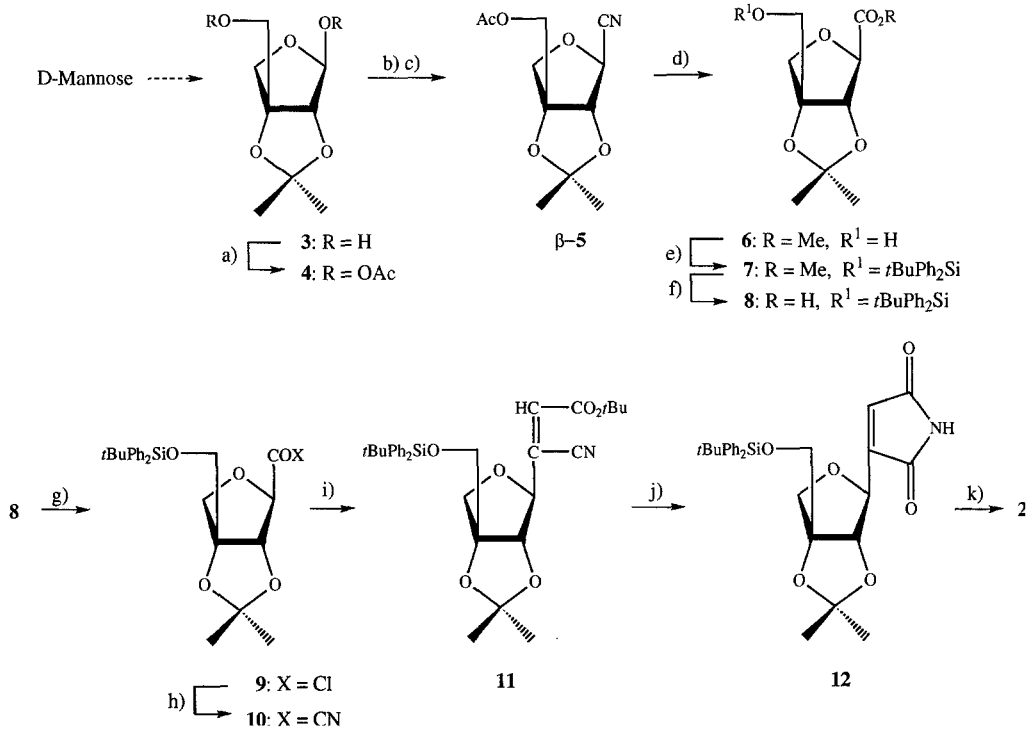
Scheme 1.

D-Apio-β-*D*-furanosyl nucleosides differ structurally from ribosyl nucleosides only in the location of the hydroxymethyl group which is shifted from C-4′ to C-3′ (Scheme 1). During the last years, interesting biological activities have been observed on several C-3′ branched nucleoside analogues or the corresponding deoxy compounds [17].

Results and Discussion

The synthesis depicted in Scheme 2 is an extension of the method used by *Kalvoda* [18] for the parent C-nucleoside. 2,3-O-Isopropylidene-*D*-apio-β-*D*-furanose (**3**), obtained from D-mannose in 4 steps in 20–30 g quantities and in 40–50% overall yield by modified literature procedures [19], was diacetylated and then converted in 82% yield to a 7:1 mixture of the anomeric apiosyl cyanides β- and α-**5** from which the slightly less polar main product was separated by flash chromatography on silica gel. Acid catalyzed hydrolysis of the nitrile group as reported for a perbenzoylated ribosyl cyanide [18] was found to be incompatible with nitrile β-**5**. However, treatment of the latter with sodium methoxide in methanol [20], followed by acidic work up, provided – with simultaneous loss of the 3′-acetyl group – readily the methyl ester derivative **6** in 88% yield. After the introduction of a *tert*-butyldiphenylsilyl protecting group, carboxylic acid **8** was obtained from the corresponding methyl ester **7** with lithium iodide in refluxing pyridine in 90% yield [21].

Acid **8** was converted to the acyl chloride **9** with thionyl chloride in diethyl ether in the presence of a small amount of dimethyl formamide. Treatment of **9** with trimethylsilyl cyanide afforded the unstable α-oxonitrile **10** which was reacted *in situ* with *tert*-butyl triphenylphosphoranylidene acetate. This three-step sequence provided, without isolation of the intermediates **9** and **10**, the stereochemically desired cyano-substituted (*E*)-acrylester derivative **11** as the sole reaction product in 52% overall yield from **8** [22]. Cyclization of the conjugate nitrile ester functionality to maleimide was achieved by exposure of the acrylate **11** to a mixture of trifluoroacetic acid and trifluoroacetic anhydride to provide the protected C-nucleoside **12** as a crystalline compound in 42% yield. Finally, complete



Scheme 2. a) Ac_2O/pyridine, r.t., 16 h, 98%; b) *TMS*CN*TMSOTf*, r.t., 48 h, 82%; c) chromatography on silica gel (*β*-**5**: 71% *α*-**5**: 11%); d) NaOMe/MeOH, r.t. 1.5 h, then $H_3O_I^+$ 88%; e) *t*$BuPh_2SiCl$/imidazole/*DMAP*/*DMF*; r.t., 1.5 h, 83%; f) 1. LiI/pyridine, reflux, 16 h, 2. H_3O^+; 90%; g) $SOCl_2/Et_2O$/*DMF*, r.t., 45 min; h) *TMS*CN/CH_2Cl_2, −78°C to r.t., 16 h, 52% based on **8**; j) $(CF_3CO)_2O$/*TFA*, 40°C, 6 h, 42%; k) *TFA*/H_2O, r.t., 2 h, 51%

deprotection with 40% aqueous *TFA* afforded the target apiosyl nucleoside **2** in 51% yield from **12**, and with 5% overall yield from the precursor **3**.

Significant NMR data of the sugar skeletons of compounds **2**–**12** are collected in Tables 1 and 2. Assignment of the anomeric configuration of the bicyclic intermediates **3**–**12** is based on the coupling constants between 1-H and 2-H, which – in accordance with other protected apiofuranosyl derivatives [13, 15] – is missing or very small for compounds with *β*-configuration ($J_{1,2}$ = 0–2 Hz), and amounts to $J_{1,2}$ = 3.9 Hz for the *α*-anomeric cyanide *α*-**5**. Consequently, 1-H and 2-H signals are found as singlets for compounds **3**, **4**, *β*-**5**, **6**, and **7**, and as a doublet with $J_{1,2}$ = 1 Hz for compound **8**, respectively, whereas in the ^{1}H NMR spectra of the vinyl substituted derivatives **11** and **12** an additional long range coupling with the vinylic proton (^4J = 1.5–2 Hz) is typical for the anomeric hydrogen [23].

The large vicinal 1′-H–2′-H coupling observed in the ^{1}H NMR spectrum of the target compound **2** ($J_{1',2'}$ = 7.4 Hz) arises from a conformational change which occurs upon deprotection and parallels the values reported for *D*-apio-*β*-*D*-furanosyl nucleosides with adenosine [24, 25], thymine [13], uracil [13], and cytosine [13] nucleobases, and also for 1-(*D*-apio-*β*-*D*-furanosyl)-1,2,3-triazoles [15].

According to the investigations to *Tronchet* [24], the conformation of unprotected apiosyl nucleosides depends on the stereochemistry at carbon C-3′ which is substituted by the side chain. Thus, for *D*-apio-*β*-*D*-furanosyl nucleosides a con-

Table 1. ^{1}H NMR data of the sugar skeletons of compounds **2**–**12** (**3**–**12**: $CDCl_3$; **2**: acetone-d_6; δ (ppm), J (Hz))

	1-H	2-H	$J_{1,2}$	3′-H_a	3′-H_b	$J_{a,b}$	4-H_a	4-H_b	$J_{a,b}$
3	5.45	4.35	0	3.82	3.82	0	3.98	4.05	10.0
4	6.20	4.50	0	4.25	4.40	11.8	3.95	4.10	10.3
β-**5**	4.73	4.73	0	4.20	4.30	11.8	3.87	4.07	10.8
α-**5**	4.68[a]	4.38[a]	3.9	4.18	4.25	11.8	3.58	4.03	10.8
6	4.64[a]	4.75[a]	0	3.68[e]	3.76[f]	11.8	4.02	4.07	10.3
7	4.61[a]	4.90[a]	0	3.68	3.74	10.8	4.02	4.17	10.3
8	4.58[a]	4.89[a]	1	3.62	3.68	10.8	3.98	4.10	10.3
11	4.71[b]	4.88	≈ 2	3.62	3.72	10.8	3.97	4.00	10.8
12	5.00[c]	4.83	1.5	3.65	3.75	10.8	4.00	4.00	0
2	4.53[d]	4.05	7.4	3.43	3.47	11.8	3.68	3.98	9.4

[a] assignment may be interchanged; [b] br t, $J_{1,2} \approx {}^4J_{1,H} \approx 2$ Hz; [c] dd, ${}^4J_{1,H} = 2.5$ Hz; [d] dd, ${}^4J_{1',4} = 1.5$ Hz; [e] dd, $J_{3'a,OH} = 7.5$ Hz; [f] dd, $J_{3'b,OH} = 5.4$ Hz

Table 2. ^{13}C NMR data of the sugar skeletons of compounds **2**–**12** (**3**–**12**: $CDCl_3$; **2**: acetone-d_6; δ (ppm))

	C-1	C-2	C-3	C-3′	C-4
3	101.8	87.2	91.9	64.4	74.5
4	101.3	86.5	89.7	65.1	75.8
β-**5**	73.4	86.8	90.3	63.5	75.5
α-**5**	71.6	83.3	90.5	64.0	75.3
7	84.2[a]	86.2[a]	92.9	64.3	75.6
8	83.9[a]	86.2[a]	92.7	64.3	75.7
11	85.6[a]	86.1[a]	92.7	64.0	75.1
12	81.3[a]	85.9[a]	92.8	64.2	74.8
2	79.4[a]	77.9[a]	80.9	65.6	76.1

[a] assignment may be interchanged

formation with C-3′ below the plane of the four other atoms of the furanose ring is assumed [24]. Contrastingly, for peracylated apioses the conformation is determined by the configuration at C-1.

Experimental

Melting points: Reichert Thermovar Instrument, uncorrected; ^{1}H and J-modulated ^{13}C NMR spectra: Bruker AM 400 WB; IR spectra: film on Si-plates [26], recorded on a Perkin Elmer FT 1600 infrared spectrophotometer; optical rotations: Perkin Elmer polarimeter 241 with solvents of Uvasol quality; TLC: Merck silica gel 60 F_{254} plates, visualization by UV light (254 nm) and/or spraying with 2% $Ce(SO_4)_2 \cdot 4H_2O$ in 1 *M* H_2SO_4 and subsequent charring on a hot plate; flash chromatography: glass columns packed with Merck silica gel 60 (230–400 mesh).

Abbreviations: *DMAP* = 4-Dimethylaminopyridine; *TFA* = trifluoroacetic acid; *TMS* = trimethylsilyl; *TMSOTf* = trimethylsilyl trifluoromethanesulfonate.

1,3'-Di-O-acetyl-2,3-O-isopropylidene-D-apio-β-D-ribofuranose (**4**)

To a solution of **3** ([27]; 1.0 g, 5.26 mmol) in dry pyridine (2 ml), Ac_2O (1.23 g, 11.6 mmol) was added at room temp. After 16 h the mixture was poured into ice/water. The product was extracted with dichloromethane (4 × 15 ml). The combined organic solutions were washed sequentially with 10% HCl, water, and sat. aq. $NaHCO_3$, dried (Na_2SO_4), and concentrated *in vacuo*. The residue was purified by flash chromatography (100 g silica gel, hexanes/EtOAc, 7:3) to yield **4** (1.41 g, 98%) as a colourless viscous oil (Ref. [28]: m.p.: 30–32°C). On the basis of the ^1H NMR data, the substance corresponds to the compound described in Ref. [28].

^1H NMR ($CDCl_3$): $\delta = 1.43, 1.50$ (2 s, each 3H, $C(CH_3)_2$), 2.08, 2.13 (2 s, each 3H, $COCH_3$) ppm; for other data see Table 1; ^{13}C NMR ($CDCl_3$): $\delta = 20.7, 20.9$ ($COCH_3$), 27.3, 27.5 ($C(CH_3)_2$), 114.4 (CMe_2), 169.2, 170.4 ($COCH_3$) ppm; for other data see Table 2.

3'-O-Acetyl-2,3-O-isopropylidene-D-apio-β-D-furanosyl cyanide (*β*-**5**)

Compound **4** (1.37 g, 5.0 mmol) was dried by repeated coevaporation with dry toluene and then dissolved under Ar in *TMS*CN (2.5 ml). To this solution, *TMSOTf* (0.27 ml, 1.5 mmol) was added with stirring at room temp. After 48 h, the solution was poured into sat. aq. $NaHCO_3$ (50 ml) and extracted with dichloromethane (5 × 10 ml). The combined extracts were dried ($MgSO_4$) and concentrated *in vacuo*. The residue was flash chromatographed (50 g silica gel, hexanes/EtOAc, 7:1) to afford sequentially *β*-**5** (856 mg, 71%) and *α*-**5** (132 mg, 11%) contaminated with traces of the *β*-anomer, both as colourless viscous oils (*β*-**5**: $R_f = 0.61$, *α*-**5**: $R_f = 0.58$; hexanes/EtOAc, 7:3).

β-**5**: $[\alpha]_D^{20} = -40.69$ ($c = 0.43$, $CHCl_3$); IR (film): $\nu = 1750, 1458, 1374, 1185, 1084, 927\ cm^{-1}$; ^1H NMR ($CDCl_3$): $\delta = 1.30, 1.40$ (2 s, each 3H, $C(CH_3)_2$), 2.05 (s, 3H, $COCH_3$) ppm; for other data see Table 1; ^{13}C NMR ($CDCl_3$): $\delta = 20.7$ ($COCH_3$), 27.2, 27.4 ($C(CH_3)_2$) 115.0, 115.6 (CMe_2, CN), 170.3 (CO) ppm; for other data see Table 2; $C_{11}H_{15}NO_5$ (241.3); calc.: C 54.77, H 6.22, N 5.81; found: C 55.05, H 6.10, N 5.70.

α-**5**: ^1H NMR ($CDCl_3$): $\delta = 1.42, 1.55$ (2 s, each 3H, $C(CH_3)_2$), 2.08 (s, 3H, $COCH_3$) ppm; for other data see Table 1; ^{13}C NMR ($CDCl_3$): $\delta = 20.6$ ($COCH_3$), 27.4, 27.5 ($C(CH_3)_2$), 114.1, 115.9 (CMe_2, CN), 170.1 (CO) ppm; for other data see Table 2.

Methyl 2,3-O-isopropylidene-D-apio-β-D-furanosyl carboxylate (**6**)

To a solution of *β*-**5** (650 mg, 2.70 mmol) in dry MeOH, a solution of $NaOCH_3$ in MeOH (0.3 ml) was added dropwise with stirring at room temperature. After consumption of *β*-**5** (1.5 h, TLC control with hexanes/EtOAc, 1:1) the mixture was poured into ice/water (20 ml), brought to $pH \approx 6$ by the dropwise addition of 10% HCl, and finally extracted with ethyl acetate (3×10 ml). The combined extracts were dried (Na_2SO_4), concentrated, and the residue was purified by flash chromatography (30 g silica gel, hexanes/EtOAc, 3:2) to afford **6** (550 mg, 88%) as a colourless viscous oil with $R_f = 0.40$ (hexanes/EtOAc, 1:1).

^1H NMR ($CDCl_3$): $\delta = 1.44$, 1.54 (2 s, each 3H, $C(CH_3)_2$), 2.02 (dd, $J_{H,3'a} = 7.4, J_{H,3'b} = 5.4$ Hz, 1H, OH), 3.77 (s, 3H, CO_2CH_3) ppm; for other data see Table 1.

Methyl 3'-O-tert-butyldiphenylsilyl-2,3-O-isopropylidene-D-apio-β-D-furanosyl carboxylate (**7**)

To a solution of **6** (550 mg, 2.37 mmol) in dry *DMF* (6 ml), imidazole (550 mg, 8.09 mmol), *DMAP* (5 mg), and then dropwise *tert*-butyldiphenylsilyl chloride (1.08 ml, 4.04 mmol) were added sequentially with stirring at room temperature. Stirring was continued for 1.5 h, and then the mixture was concentrated *in vacuo* at 0.01 torr. Water (20 ml) was added to the residue, and the mixture was extracted with dichloromethane (6 × 10 ml). The combined extracts were dried (Na_2SO_4), concentrated at reduced pressure, and the residue was purified by flash chromatography (30 g

silica gel, hexanes/EtOAc, 16:1) to provide **7** (920 mg, 83%) as a colourless viscous oil with $R_f = 0.32$ (hexanes/EtOAc, 10:1).

$[\alpha]_D^{20} = -36.52$ ($c = 0.57$, $CHCl_3$); IR (film): $\nu = 2933$, 2859, 1757, 1428, 1245, 1209, 1098 cm^{-1}; ^1H NMR ($CDCl_3$): $\delta = 1.03$ (s, 9H, $C(CH_3)_3$), 1.34, 1.51 (2s, each 3H, $C(CH_3)_2$), 3.69 (s, 3H, CO_2CH_3), 7.35–7.47 (m, 6H, H_{arom}), 7.64 (m_c, 4H, H_{arom}) ppm; for other data see Table 1; ^{13}C NMR ($CDCl_3$): $\delta = 19.2$ (CMe_3), 26.7 ($C(CH_3)_3$), 27.7, 28.0 ($C(CH_3)_2$), 52.2 (CO_2CH_3), 113.9 (CMe_2), 127.8 (4C, CH_{arom}), 129.85, 129.90 (each 1C, CH_{arom}), 132.6, 132.8 (*i*-C), 135.56, 135.64 (each 2C, CH_{arom}), 170.5 (CO) ppm; for other data see Table 2; $C_{26}H_{34}O_7Si$ (470.4); calc.: C 66.38, H 7.23; found: C 66.63, H 7.47.

3′-O-tert-Butyldiphenylsilyl-2,3-O-isopropylidene-D-apio-β-D-furanosyl carboxylic acid (**8**)

A solution of **7** (920 mg, 1.96 mmol) and anhydrous LiI (1.04 g, 7.83 mmol) in dry pyridine (15 ml) was refluxed for 16 h under an Ar atmosphere. Then the solvent was evaporated at reduced pressure. The residue was redissolved in H_2O (20 ml), the solution brought to $pH = 6$ with hydrochloric acid (*6N*), and extracted with diethyl ether (6 × 10 ml). The dried (Na_2SO_4) extracts were concentrated *in vacuo* and the residue was purified by flash chromatography (20 g silica gel, hexanes/EtOAc, 7:3) to provide **8** (800 mg, 90%) as a colourless, viscous oil with $R_f = 0.16$ which was used for the conversion to **11** without further purification.

^1H NMR ($CDCl_3$): $\delta = 0.97$ (s, 9H, $C(CH_3)_3$), 1.27, 1.45 (2 s, each 3H, $C(CH_3)_2$), 7.28–7.40 (m, 6H, H_{arom}), 7.57 (m_c, 4H, H_{arom}) ppm; for other data see Table 1; ^{13}C NMR ($CDCl_3$): $\delta = 19.1$ (CMe_3), 26.7 ($C(CH_3)_3$), 27.6, 27.9 ($C(CH_3)_2$), 114.0 (CMe_2), 127.81, 127.82 (each 2C, CH_{arom}), 129.90, 129.93 (each 1C, CH_{arom}), 132.4, 132.6 (*i*-C), 135.55, 135.64 (each 2C, CH_{arom}), 174.9 (CO) ppm; for other data see Table 2.

tert-Butyl (E)-3-(3″-O-tert-butyldiphenylsilyl-2′,3′-O-isopropylidene-D-apio-β-D-furanosyl)-3-cyano-2-propenoate (**11**) *from* **8**

A stirred suspension of **8** (800 mg, 1.75 mmol) in dry diethyl ether (6 ml) was brought to solution with the minimum amount of dry *DMF*. Then thionyl chloride (0.5 ml, 6.85 mmol) was added dropwise at room temperature, and stirring was continued for 45 min. Volatiles were removed at reduced pressure, and the residue was dried by repeated coevaporation with dry toluene. To a cooled (−78°C) solution of the crude acyl chloride **9** in anhydrous dichloromethane (6 ml), *TMS*CN (0.65 ml, 5.26 mmol) was added dropwise with stirring, and stirring was continued for 2.5 h at the same temperature. Then a solution of *tert*-butyl triphenylphosphoranylidene acetate ([29]; 1.659 g, 4.4 mmol) in dry dichloromethane (6 ml) was added dropwise at −78°C to the solution of the α-oxonitrile **10** intermediately formed. Stirring was continued for 16 h; during this time, the mixture was allowed to reach room temperature. Then the solvent was removed at reduced pressure. Water (35 ml) was added to the residue, the mixture was neutralized by the dropwise addition of HCl (10%), and extracted with diethyl ether (3 × 35 ml). The combined extracts were dried ($MgSO_4$), concentrated *in vacuo*, and the residue was purified by flash chromatography (45 g silica gel, hexanes/EtOAc, 16:1) to provide cyanoacrylate **11** ([22]; 510 mg, 52% from **8**) as a colourless, viscous oil with $R_f = 0.34$ (hexanes/EtOAc, 9:1).

$[\alpha]_D^{20} = -56.52$ ($c = 0.69$, $CHCl_3$); IR (film): $\nu = 2932$, 1719, 1371, 1245, 1156, 1087 cm^{-1}; ^1H NMR ($CDCl_3$): $\delta = 1.02$ (s, 9H, $C(CH_3)_3$), 1.06, 1.33 (2 s, each 3H, $C(CH_3)_2$), 1.51 (s, 9H, $CO_2C(CH_3)_3$), 6.52 (d, $^4J = 2.5$ Hz, 1H, CH=), 7.33–7.45 (m, 6H, H_{arom}), 7.58–7.72 (m, 4H, H_{arom}) ppm; for other data see Table 1; ^{13}C NMR ($CDCl_3$) $\delta = 19.1$ ($SiCMe_3$), 26.8 ($SiC(CH_3)_3$), 27.8, 28.0 ($C(CH_3)_2$), 27.9 ($OC(CH_3)_3$), 83.3 ($OCMe_3$), 114.34, 114.36 (CMe_2, CN), 124.27 (*C*–CN), 127.88, 127.92 (each 2C, CH_{arom}), 129.92 (2C, CH_{arom}), 132.36, 132.42 (*i*-C), 134.0

($CHCO_2$), 135.52, 135.60 (each 2C, CH_{arom}), 161.5 (CO) ppm; for other data see Table 2; $C_{32}H_{41}NO_6Si$ (563.4); calc.: C 68.21, H 7.28, N 2.49; found: C 68.45, H 7.31, N 2.23.

3-(3''-O-tert-Butyldiphenylsilyl-2',3'-O-isopropylidene-D-apio-β-D-furanosyl)-1H-pyrrole-2,5-dione (**12**)

A solution of **11** (360 mg, 0.639 mmol) in *TFA* (1 ml) and trifluoroacetic anhydride (2 ml) was stirred at 40°C until consumption of **11** (6 h, TLC control with hexanes/EtOAc, 5:1). The solution was concentrated at reduced pressure, water (10 ml) was added to the residue, and the mixture was neutralized carefully with solid $NaHCO_3$. Then the aqueous solution was extracted with dichloromethane (3 × 10 ml), the extracts were dried (Na_2SO_4), concentrated *in vacuo*, and the residue was purified by flash chromatography (30 g silica gel, hexanes/EtOAc, 7:1) to provide maleimide derivative **12** (142 mg, 42%) as colourless crystals with a m.p. of 113°C (Et_2O/hexanes) and $R_f = 0.35$ (hexanes/EtOAc, 5:1).

$[\alpha]_D^{20} = -21.28\,(c = 0.39, CHCl_3)$; IR (film): $\nu = 1770,\ 1715, 1345, 1247, 1083, 950\,cm^{-1}$; ^1H NMR ($CDCl_3$) : $\delta = 1.01$ (s, 9H, $C(CH_3)_3$), 1.37, 1.56 (2s, each 3H, $C(CH_3)_2$), 6.42 (dd, $^4J_{H,1'} = 2.5$, $^4J_{H,NH} \approx 1$Hz, 1H, 4-H), 7.28 (br s, 1H, NH), 7.33–7.46 (m, 6H, H_{arom}), 7.56–7.62 (m, 4H, H_{arom}) ppm; for other data see Table 1; ^{13}C NMR ($CDCl_3$) : $\delta = 19.1$ (CMe_3), 26.7 ($C(CH_3)_3$), 27.8, 28.0 ($C(CH_3)_2$), 114.2 (CMe_2), 127.87, 127.89 (each 2C, CH_{arom}), 130.02, 130.07 (each 1C, CH_{arom}), 128.45 (C-4), 132.37, 132.45 (*i*-C), 135.47, 135.55 (each 2C, CH_{arom}), 147.25 (C-3), 168.85, 169.52 (CO) ppm; for other data see Table 2; $C_{28}H_{33}NO_6Si$ (507.4) calcd.: C 66.27, H, 6.51, N 2.76; found: C 66.74, H 6.62, N 2.44.

3-(D-Apio-β-D-furanosyl)-1H-pyrrole-2,5-dione (**2**)

A solution of **12** (55 mg, 0.108 mmol) in *TFA* (2 ml) and water (0.5 ml) was stirred at room temperature until completion of reaction (2 h, TLC control with hexanes/EtOAc, 3:1). Then the solvents were removed at reduced pressure. The residue was dried at 0.01 torr for 1 h and then purified by flash chromatography (3 g silica gel, hexanes/EtOAc, 2:1) to afford **2** (13 mg, 51%) with $R_f = 0.55$ (EtOAc/MeOH, 10:1) as colourless crystals, m.p.: 92–94°C (acetone/hexanes).

IR (film): $\nu = 3357, 2927, 1771, 1714, 1355, 1204, 1183, 1096, 1049\ cm^{-1}$; ^1H NMR (acetone-d_6) : $\delta = 2.75$ (br s, OH), 4.25 (br s, OH), 4.85 (br s, OH), 6.45 (t, $^4J = 1.5$ Hz, 1H, 4-H), 9.59 (br s, 1H, NH) ppm; for other data see Table 1; ^{13}C NMR(acetone-d_6) : $\delta = 129.9$ (C-4), 150.4 (C-3), 172.2, 172.8 (CO) ppm; for other data see Table 2; high resolution MS with methane-DCl with PFK as reference: $m/z = 230.0663 \pm 0.4$ mmu (100%, $(M+H)^+$, $C_9H_{12}NO_6$; calc.: 230.0665), 212.0555 ± 0.4 mmu (18%, $(M+H)^+ - H_2O$, $C_9H_{10}NO_5$; calc.: 212.0559), 194.0451 ± 0.4 mmu (91%, $(M+H)^+ - 2\ H_2O$, $C_9H_8NO_4$; calc.: 194.0453), 182.0452 ± 0.4 mmu (14%, $(M+H)^+ - CHOH - H_2O$, $C_8H_8NO_4$; calc.: 182.0453).

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