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A new synthetic approach to mycobacterial cell wall α-(1→5)-D-arabinofuranosyl *C*-oligosaccharides

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Abstract—Three designed arabinofuranose building blocks allowed the diastereoselective synthesis of a *C*-disaccharide and a *C*-trisaccharide by Wittig olefination. The latter compound represents the first example of all-carbon linked arabinofuranotriose analogue.

The polysaccharidic chains which form the cell wall of mycobacteria are constituted mainly by D-arabinofuranose units connected through α-1,5-*O*-glycosidic linkages.[1] Since these pentofuranoses and the corresponding glycoconjugates are xenobiotic to humans, inhibitors of their biosynthesis are potential therapeutic agents against mycobacterial infections such as tuberculosis and leprosy.[2] Thus, over the past few years, many efforts have been devoted toward the preparation of *O*-oligoarabinofuranosides **A** (Fig. 1) in order to elucidate the biosynthesis and evaluate the immunological properties of the naturally occurring arabinose-based polysaccharides.[3] On the other hand, despite a large body of knowledge on *C*-glycoside synthesis,[4] the preparation of hydrolytically and enzymatically resistant analogues, i.e. carbon-linked arabinofuranosyl oligosaccharides **B** (Fig. 1), has not been described until a few months ago. The recent paper[5] by Gurjar et al. dealing with the synthesis of a single compound, the methyl 5-(α-D-*C*-arabinofuranosyl)-α-D-*O*-arabinofuranoside, via nitro-aldol condensation prompted us to report on our alternative synthetic approach to oligoarabinofuranoside methylene isosteres.

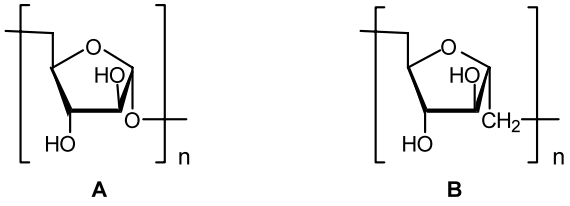

Figure 1. Natural α-(1→5)-D-arabinofuranosyl oligosaccharide (**A**) and its methylene isostere (**B**).

Taking advantage of our experience on the stereoselective synthesis of *C*-oligosaccharides by iterative Wittig olefination,[6] we developed new building blocks and a modified protocol for the straightforward assembly of *C*-oligoarabinofuranosides **1** (Scheme 1). While the two monofunctionalized sugar moieties **2** and **4** were suitable precursors to the head and tail of the oligosaccharidic chain, the difunctionalized compound **3** was envisaged as repeating unit. In particular, the building block **3** was designed to allow, after the Wittig coupling, the regeneration of the formyl group in a single step under conditions which do not affect the chemical and stereochemical integrity of the growing saccharidic chain. Interestingly, all *C*-monosaccharides **2**–**4** appeared to be accessible in a multigram scale from the same perbenzylated thiazolyl *C*-arabinoside **5** exploiting the well established thiazole-to-formyl conversion.[7] Moreover, di- and oligosaccharide derivatives originated from the Wittig carbon–carbon bond formation reaction could be readily converted into the target compounds **1** by hydrogenation without any other manipulation of the functional groups.

The addition at low temperature of 2-lithiothiazole, prepared in situ from 2-bromothiazole and butyllithium, to the lactone[8] **6** (9.6 g, 23 mmol), followed by the acetylation of the crude thiazolylketose, gave the 1-*O*-acetyl derivative[9] **7** as a 4:1 mixture of anomers in 84% overall yield after column chromatography (Scheme 2). The deoxygenation of **7** was carried out

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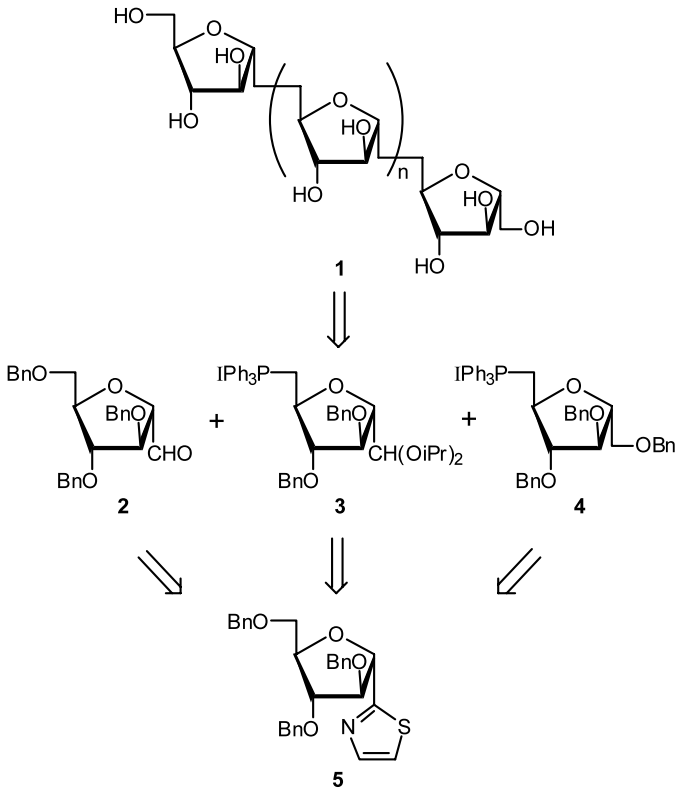
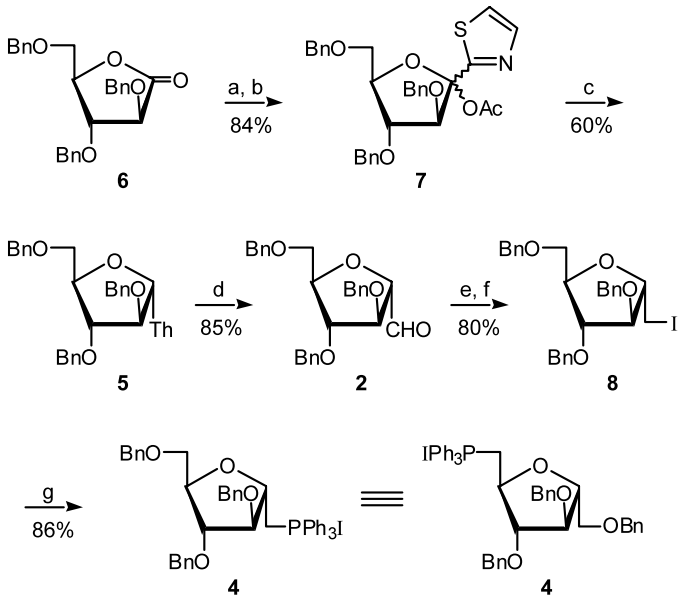


Scheme 1. Retrosynthetic approach to 1,5-*C*-oligoarabinofuranosides.

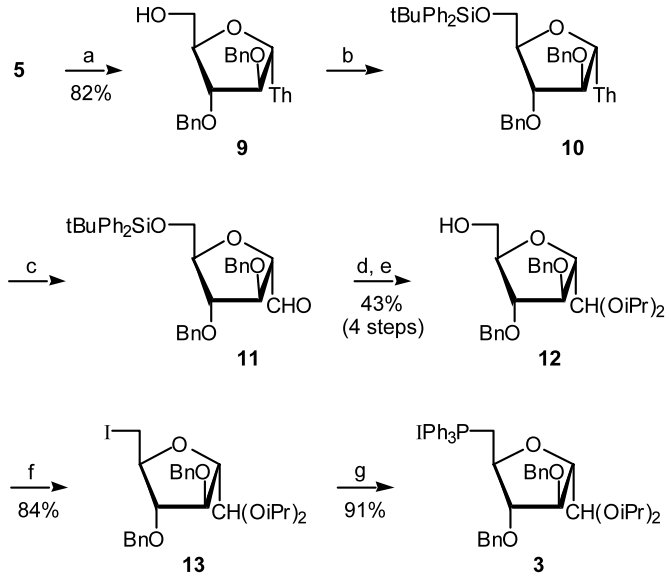
with samarium(II) iodide[6f] in the presence of ethylene glycol to afford the desired α-D-*C*-glycoside[10] **5** (60%) which was easily separated from the β-anomer (16%). The anomeric configuration of the latter compounds was assigned by NOE difference experiments. Upon irradiation of the H-1 proton of both anomers, a significant NOE with H-3 was observed only for **5**, thus indicating a *cis*-relationship between these protons. The key intermediate **5** was then submitted to the usual unmasking sequence[7,11] involving *N*-methylation, hydride reduction, and silver-assisted hydrolysis of the thiazolidine intermediate to give, without any epimerization, the α-linked formyl *C*-arabinoside[12] **2** in good yield (85%). The second monofunctionalized building block, i.e. the tribenzylated phosphonium salt[13] **4**, was obtained from the aldehyde **2** by reduction to alcohol, iodination[14] to **8**, and treatment of the latter with neat triphenylphosphine at 120°C (69%, three steps).

The preparation of the third building block **3** from the thiazolyl *C*-glycoside **5** required a longer reaction sequence, although each step involved high-yielding transformations of the functional groups and no purification of some intermediates was necessary (Scheme 3). Selective removal of the 5-*O*-benzyl group by acetolysis gave the alcohol **9** (82%) which was silylated to **10** and this converted into the formyl *C*-arabinofuranoside **11**. This crude aldehyde was protected as diisopropyl acetal and desilylated to give pure[15] **12** in 43% overall yield from **10**. The alcohol **12** was finally transformed into the target phosphonium salt[16] **3** via the iodide derivative **13** by the above mentioned iodination and phosphanation reactions (76%, two steps).

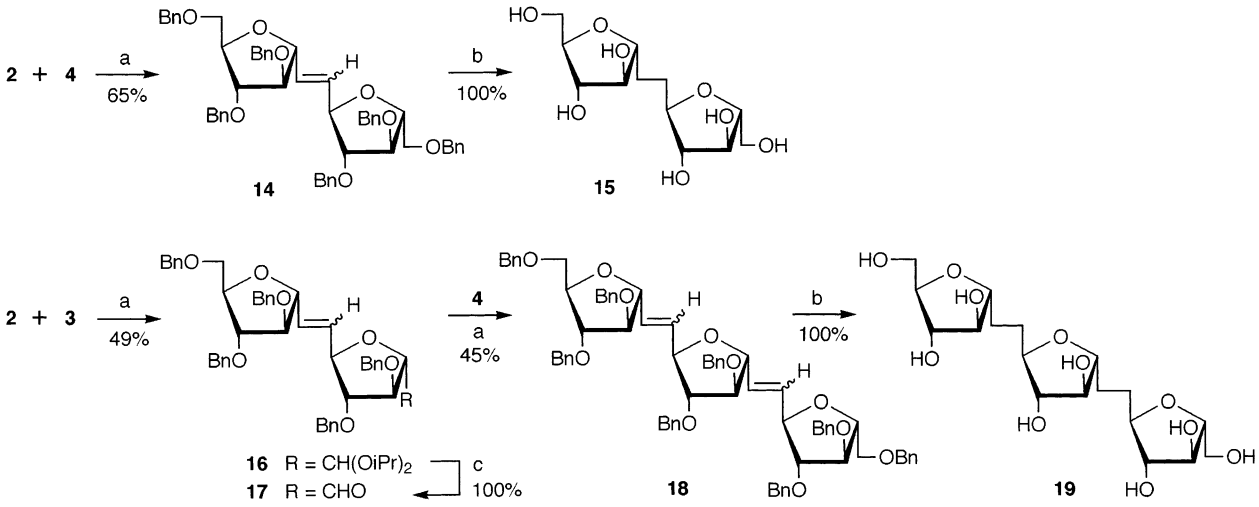


Scheme 2. Th = 2-thiazolyl. *Reagents and conditions*: (a) 2-lithiothiazole, dry Et_2O, −75°C, 1 h; (b) Ac_2O, Et_3N, CH_2Cl_2, rt, 48 h; (c) 0.1 M SmI_2, $(CH_2OH)_2$, dry THF, rt, 30 min; (d) MeOTf, CH_3CN, rt, 15 min; then $NaBH_4$, MeOH, rt, 5 min; then $AgNO_3$, CH_3CN, H_2O, rt, 10 min; (e) $NaBH_4$, Et_2O, MeOH, rt, 15 min; (f) I_2, PPh_3, imidazole, toluene, 80°C, 1 h; (g) neat PPh_3, 120°C, 4 h.

Aiming at preparing the all-carbon linked diarabinofuranoside **15** (Scheme 4), the formyl *C*-glycoside **2** was



Scheme 3. Th = 2-thiazolyl. *Reagents and conditions*: (a) Ac_2O, AcOH, H_2SO_4, rt, 1 h; then Et_3N, MeOH, H_2O, rt, 18 h; (b) *t*-$BuPh_2SiCl$, Py, DMAP, rt, 24 h; (c) MeOTf, CH_3CN, rt, 15 min; then $NaBH_4$, MeOH, rt, 5 min; then $AgNO_3$, CH_3CN, H_2O, rt, 10 min; (d) $CH(Oi\text{-}Pr)_3$, $BF_3{\cdot}Et_2O$, dry CH_2Cl_2, rt, 45 min; (e) Bu_4NF, THF, rt, 2 h; (f) I_2, PPh_3, imidazole, toluene, 80°C, 1 h; (g) neat PPh_3, 120°C, 4 h.



Scheme 4. *Reagents and conditions*: (a) BuLi, 3:1 dry THF–HMPA, 4 Å MS, –20°C, 2 h; (b) H_2, $Pd(OH)_2$/C, AcOEt–MeOH, rt, 3 h; (c) TFA, H_2O, THF, rt, 2 h.

allowed to react at –20°C with an equimolar amount of the phosphorane generated from **4** and butyllithium. The Wittig coupling was performed in the presence of activated 4 Å molecular sieves using a 3:1 mixture of anhydrous THF and HMPA as the solvent to give a *Z*,*E* mixture of *C*-disaccharide **14** in 65% isolated yield. The reduction of the double bond and the removal of the benzyl groups was quantitatively accomplished by hydrogenation over $Pd(OH)_2$ to afford the polyol **15** which was fully characterized as perbenzoate.[17] The ^1H NMR spectrum of the latter compound clearly showed a C_2 symmetric structure, therefore proving that the α-D configuration of both monosaccharidic reagents **2** and **4** was retained during the Wittig reaction.

Targeting a higher *C*-oligoarabinoside homologue, the aldehyde **2** was coupled with the phosphorane derived from **3** as described above (Scheme 4). The (*Z*,*E*)-*C*-disaccharide[18] **16**, isolated in 49% yield, upon treatment with aqueous trifluoroacetic acid at rt nicely gave almost pure aldehyde[18] **17** which was used for the following step without further purification. When **17** was coupled with the tribenzylated phosphorane prepared from **4**, the bisalkene **18** and the unreacted aldehyde **17** were recovered by column chromatography in 45 and 25% yield, respectively. Then the *C*-trisaccharide **18** was hydrogenated over $Pd(OH)_2$ to afford quantitatively the α-D-arabinotriose methylene isostere **19**, characterized as perbenzoate derivative.[18] The C_2 symmetry of the final product was substantiated by the NMR spectra, therefore the configuration of the stereocenters next to the reactive functionalities was not modified through the chain elongation sequence.

In conclusion, our approach to totally carbon-linked oligoarabinofuranosides appears to be more efficient than that of Gurjar[5] because it requires less steps for the elaboration of the coupling product and because it is iteratively repeatable. Although only a *C*-trisaccharide has been prepared, the method is suitable for the construction of higher oligomers by the use of several units of the difunctionalized building block **3**. Hence the synthesis of other *C*-oligosaccharides is currently underway in our laboratory.

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7. For recent reviews, see: (a) Dondoni, A., Marra, A. In *Preparative Carbohydrate Chemistry*; Hanessian, S., Ed.; Marcel Dekker: New York, 1997; pp. 173–205; (b) Dondoni, A. *Synthesis* **1998**, 1681–1706; (c) Dondoni, A. *Pure Appl. Chem*. **2000**, *72*, 1577–1588.
8. Known lactone **6** (Meng, Q.; Hesse, M. *Helv. Chim. Acta* **1991**, *74*, 445–449) was prepared on a 5–10 g scale in quantitative yield by oxidation of commercially available 2,3,5-tri-*O*-benzyl-D-arabinose (Sigma) with pyridinium chlorochromate (Corey, E. J.; Suggs, J. W. *Tetrahedron Lett*. **1975**, *16*, 2647–2650).
9. Compound **α7**. $[\alpha]_D=+43.9$ (*c* 1, $CHCl_3$). ^1H NMR (300 MHz, $CDCl_3$): δ 7.82 and 7.39 (2 d, 2H, $J=3.1$ Hz, Th), 7.36–7.26 and 7.04–7.00 (2 m, 15 H, 3 Ph), 4.66 and 4.61 (2 d, 2H, $J=12.0$ Hz, PhCH_2), 4.54 and 4.49 (2 d, 2H, $J=11.7$ Hz, PhCH_2), 4.53 (d, 1H, $J_{2,3}=2.5$ Hz, H-2), 4.50 (ddd, 1H, $J_{3,4}=4.6$, $J_{4,5a}=4.7$, $J_{4,5b}=5.5$ Hz, H-4), 4.35 and 4.28 (2 d, 2H, $J=11.6$ Hz, PhCH_2), 4.18 (dd, 1H, H-3), 3.82 (dd, 1H, $J_{5a,5b}=10.8$ Hz, H-5a), 3.75 (dd, 1H, H-5b), 2.15 (s, 3 H, Ac). ^{13}C NMR (75 MHz, $CDCl_3$): δ 107.9 (C-1). Compound **β7**. $[\alpha]_D=-35.6$ (*c* 0.5, $CHCl_3$). ^1H NMR (300 MHz, $CDCl_3$): δ 7.82 and 7.38 (2 d, 2H, $J=3.1$ Hz, Th), 7.37–7.23 (m, 15 H, 3 Ph), 4.89 and 4.61 (2 d, 2H, $J=11.8$ Hz, PhCH_2), 4.68 and 4.58 (2 d, 2H, $J=11.6$ Hz, PhCH_2), 4.54 (s, 2H, PhCH_2), 4.53 (dd, 1H, $J_{2,3}=7.1$, $J_{3,4}=6.8$ Hz, H-3), 4.40 (d, 1H, H-2), 4.35 (ddd, 1H, $J_{4,5a}=4.1$, $J_{4,5b}=4.5$ Hz, H-4), 3.71 (dd, 1H, $J_{5a,5b}=10.7$ Hz, H-5a), 3.62 (dd, 1H, H-5b), 1.99 (s, 3 H, Ac). ^{13}C NMR (75 MHz, $CDCl_3$): δ 103.2 (C-1).
10. Compound **α5**. $[\alpha]_D=+34.4$ (*c* 0.7, $CHCl_3$). ^1H NMR (400 MHz, $CDCl_3$): δ 7.78 (d, 1H, $J=3.3$ Hz, Th), 7.35–7.24 and 7.13–6.99 (2 m, 16 H, 3 Ph, Th), 5.43 (d, 1H, $J_{1,2}=3.1$ Hz, H-1), 4.74 and 4.59 (2 d, 2H, $J=11.8$ Hz, PhCH_2), 4.61 and 4.57 (2 d, 2H, $J=12.1$ Hz, PhCH_2), 4.54 (dd, 1H, $J_{2,3}=2.7$ Hz, H-2), 4.47 and 4.43 (2 d, 2H, $J=12.0$ Hz, PhCH_2), 4.45 (ddd, 1H, $J_{3,4}=4.3$, $J_{4,5a}=5.8$, $J_{4,5b}=5.5$ Hz, H-4), 4.14 (dd, 1H, H-3), 3.68 (dd, 1H, $J_{5a,5b}=10.3$ Hz, H-5a), 3.65 (dd, 1H, H-5b). Compound **β5**. $[\alpha]_D=+2.4$ (*c* 1, $CHCl_3$). ^1H NMR (300 MHz, $CDCl_3$): δ 7.84 (d, 1H, $J=3.2$ Hz, Th), 7.40–7.24 and 7.04–6.99 (2 m, 16 H, 3 Ph, Th), 5.58 (d, 1H, $J_{1,2}=3.8$ Hz, H-1), 4.66 and 4.60 (2 d, 2H, $J=12.0$ Hz, PhCH_2), 4.53 (s, 2H, PhCH_2), 4.31 (ddd, 1H, $J_{3,4}=2.7$, $J_{4,5a}=6.0$, $J_{4,5b}=6.6$ Hz, H-4), 4.29 (dd, 1H, $J_{2,3}=1.0$ Hz, H-2), 4.23 and 4.18 (2 d, 2H, $J=12.0$ Hz, PhCH_2), 4.08 (dd, 1H, H-3), 3.80 (dd, 1H, $J_{5a,5b}=10.0$ Hz, H-5a), 3.69 (dd, 1H, H-5b).
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12. Crude aldehyde **2** was previously obtained by oxidative ring contraction of the tri-*O*-benzyl-D-glucal (Kaye, A.; Neidle, S.; Reese, C. B. *Tetrahedron Lett*. **1988**, *29*, 1841–1844; Bettelli, E.; D'Andrea, P.; Mascanzoni, S.; Passacantilli, P.; Piancatelli, G. *Carbohydr. Res*. **1998**, *306*, 221–230) but no physical and spectroscopic data were provided for this product. The synthesis of this aldehyde from tetra-*O*-benzyl-D-mannopyranose (six steps, 15% overall yield) and its spectroscopic characterization have been recently described, see: Persky, R.; Albeck, A. *J. Org. Chem*. **2000**, *65*, 5632–5638. The NMR data of **2**, prepared by us as shown in Scheme 2, are in agreement with those reported by Persky and Albeck. Gurjar and co-workers (see Ref. 5) prepared the same aldehyde from D-glucosamine hydrochloride (seven steps, 22%) but no reference to previous syntheses was given in their paper.
13. Compound **4**. ^1H NMR (400 MHz, $CDCl_3$): δ 7.82–7.71, 7.63–7.57, and 7.36–7.16 (3 m, 30 H, 6 Ph), 4.96 (ddd, 1H, $J_{1a,2}=3.0$, $J_{1a,1b}=15.5$, $J_{1a,P}=13.6$ Hz, H-1a), 4.84 (bs, 1H, H-3), 4.81 and 4.74 (2 d, 2H, $J=11.9$ Hz, PhCH_2), 4.71 and 4.49 (2 d, 2H, $J=11.9$ Hz, PhCH_2), 4.58 (ddd, 1H, $J_{1b,2}=11.3$, $J_{2,P}=6.0$ Hz, H-2), 4.37 and 4.34 (2 d, 2H, $J=11.5$ Hz, PhCH_2), 3.96 (bd, 1H, $J_{4,5}=1.6$ Hz, H-4), 3.86 (ddd, 1H, $J_{5,6a}=6.9$, $J_{5,6b}=6.4$ Hz, H-5), 3.77 (ddd, 1H, $J_{1b,P}=11.3$ Hz, H-1b), 3.38 (dd, 1H, $J_{6a,6b}=9.6$ Hz, H-6a), 3.32 (dd, 1H, H-6b). ^{31}P NMR (121 MHz, $CDCl_3$): δ 24.6.
14. Compound **8**. $[\alpha]_D=-10.0$ (*c* 0.9, $CHCl_3$). ^1H NMR (300 MHz, $CDCl_3$): δ 7.40–7.24 (m, 15 H, 3 Ph), 4.60 and 4.55 (2 d, 2H, $J=12.0$ Hz, PhCH_2), 4.58 (s, 2H, PhCH_2), 4.55 and 4.50 (2 d, 2H, $J=12.0$ Hz, PhCH_2), 4.35 (ddd, 1H, $J_{1a,2}=J_{1b,2}=6.0$, $J_{2,3}=3.3$ Hz, H-2), 4.24 (ddd, 1H, $J_{4,5}=3.0$, $J_{5,6a}=8.2$, $J_{5,6b}=5.5$ Hz, H-5), 4.12 (dd, 1H, $J_{3,4}=2.0$ Hz, H-4), 4.08 (dd, 1H, H-3), 3.61 (dd, 1H, $J_{1a,1b}=10.0$ Hz, H-1a), 3.56 (dd, 1H, H-1b), 3.38 (dd, 1H, $J_{6a,6b}=10.1$ Hz, H-6a), 3.30 (dd, 1H, H-6b). This compound has been previously obtained as a diastereomeric mixture (Reitz, A. B.; Nortey, S. O.; Maryanoff, B. E.; Liotta, D.; Monahan, R. *J. Org. Chem*. **1987**, *52*, 4191–4202) and as a pure product (McGurk, P.; Chang, G. X.; Lowary, T. L.; McNeil, M.; Field, R. A. *Tetrahedron Lett*. **2001**, *42*, 2231–2234) but no physical and spectroscopic data were reported.
15. A strong NOE between the C*H*(O*i*-Pr)$_2$ (H-1) and H-3 protons confirmed the α-D configuration of the *C*-arabinofuranoside derivative **12**. $[\alpha]_D=+14.1$ (*c* 0.9, $CHCl_3$). ^1H NMR (400 MHz, $CDCl_3$): δ 7.39–7.28 (m, 10 H, 2 Ph), 4.67 (d, 1H, $J_{1,2}=5.8$ Hz, H-1), 4.65 and 4.50 (2 d, 2H, $J=11.7$ Hz, PhCH_2), 4.56 and 4.49 (2 d, 2H, $J=11.8$ Hz, PhCH_2), 4.24 (dd, 1H, $J_{2,3}=2.6$, $J_{3,4}=2.8$ Hz, H-3), 4.13 (ddd, 1H, $J_{4,5}=5.2$, $J_{5,6a}=3.3$, $J_{5,6b}=5.1$ Hz, H-5), 4.04 (dd, 1H, H-2), 4.02 (dd, 1H, H-4), 3.94 (qq, 1H, $J=6.2$ Hz, C*H*Me$_2$), 3.90 (qq, 1H, $J=6.2$ Hz, C*H*Me$_2$), 3.75 (ddd, 1H, $J_{6a,6b}=11.8$, $J_{6a,OH}=5.7$ Hz, H-6a), 3.65 (ddd, 1H, $J_{6b,OH}=6.6$ Hz, H-6b), 1.99 (dd, 1H, OH), 1.23, 1.22, 1.19, and 1.08 (4 d, 12 H, 4 Me).
16. Compound **3**. ^1H NMR (400 MHz, C_6D_6): δ 7.77–7.63, 7.38–7.30, and 7.18–6.92 (3 m, 25 H, 5 Ph), 6.31 (ddd, 1H, $J_{5,6a}=3.0$, $J_{6a,6b}=J_{6a,P}=15.0$ Hz, H-6a), 5.25 and 5.15 (2 d, 2H, $J=12.1$ Hz, PhCH_2), 5.21 (bs, 1H, H-4), 5.04 (ddd, 1H, $J_{5,6b}=11.0$, $J_{5,P}=6.2$ Hz, H-5), 4.72 (d, 1H, $J_{1,2}=8.0$ Hz, H-1), 4.59 and 4.34 (2 d, 2H, $J=11.9$ Hz, PhCH_2), 4.18 (bs, 1H, H-3), 3.86 (bd, 1H, H-2), 3.74 (qq, 1H, $J=6.1$ Hz, C*H*Me$_2$), 3.69 (ddd, 1H, $J_{6b,P}=11.0$ Hz, H-6b), 3.57 (qq, 1H, $J=6.1$ Hz, C*H*Me$_2$), 1.05, 0.92, 0.87, and 0.86 (4 d, 12 H, 4 Me). ^{31}P NMR (121 MHz, $CDCl_3$): δ 24.7.
17. Compound **15Bz**. $[\alpha]_D=-27.8$ (*c* 0.4, $CHCl_3$). ^1H NMR (400 MHz, $CDCl_3$): δ 8.08–7.99, 7.60–7.50, 7.44–7.39, and 7.36–7.32 (4 m, 30 H, 6 Ph), 5.67 (dd, 2H, $J_{2,3}=$

$J_{10,11}=3.4$, $J_{3,4}=J_{9,10}=2.1$ Hz, H-3, H-10), 5.51 (dd, 2H, $J_{4,5}=J_{8,9}=3.6$ Hz, H-4, H-9), 4.70 (dd, 2H, $J_{1a,2}=J_{11,12a}=5.8$, $J_{1a,1b}=J_{12a,12b}=11.8$ Hz, H-1a, H-12a), 4.65 (dd, 2H, $J_{1b,2}=J_{11,12b}=4.5$ Hz, H-1b, H-12b), 4.53 (ddd, 2H, H-2, H-11), 4.46–4.41 (m, 2H, H-5, H-8), 2.19–2.02 (m, 4 H, 2 H-6, 2 H-7). MALDI-TOF (918.96): 919.7 (M+H), 941.4 (M+Na), 957.5 (M+K).

18. Compound *Z*-**16**. ^{1}H NMR (400 MHz, C_6D_6): δ 7.36–7.00 (m, 25 H, 5 Ph), 5.89 (dd, 1H, $J_{5,6}=7.7$, $J_{6,7}=11.3$ Hz, H-6), 5.85 (dd, 1H, $J_{7,8}=8.0$ Hz, H-7), 5.31 (dd, 1H, $J_{4,5}=5.5$ Hz, H-5), 5.26 (dd, 1H, $J_{8,9}=4.8$ Hz, H-8), 4.72 (d, 1H, $J_{1,2}=5.2$ Hz, H-1), 4.64 and 4.51 (2 d, 2H, $J=11.9$ Hz, PhCH_2), 4.62 and 4.47 (2 d, 2H, $J=12.0$ Hz, PhCH_2), 4.61 and 4.42 (2 d, 2H, $J=12.0$ Hz, PhCH_2), 4.53 (dd, 1H, $J_{2,3}=3.0$, $J_{3,4}=3.3$ Hz, H-3), 4.43 (s, 2H, PhCH_2), 4.42 (ddd, 1H, $J_{10,11}=4.0$, $J_{11,12a}=J_{11,12b}=6.2$ Hz, H-11), 4.33 (dd, 1H, H-2), 4.25 (s, 2H, PhCH_2), 4.25 (dd, 1H, $J_{9,10}=3.3$ Hz, H-10), 4.12 (dd, 1H, H-4), 4.07 (dd, 1H, H-9), 3.78 (qq, 1H, $J=6.1$ Hz, CHMe$_2$), 3.76 (qq, 1H, $J=6.1$ Hz, CHMe$_2$), 3.54 (dd, 1H, $J_{12a,12b}=9.8$ Hz, H-12a), 3.50 (dd, 1H, H-12b), 1.09, 1.08, 1.04, and 0.99 (4 d, 12 H, 4 Me). Compound *Z*-**17**. ^{1}H NMR (400 MHz, $CDCl_3$): δ 9.57 (d, 1H, $J_{1,2}=1.0$ Hz, H-1), 7.39–7.17 (m, 25 H, 5 Ph), 5.81 (dd, 1H, $J_{5,6}=8.5$, $J_{6,7}=11.3$ Hz, H-6), 5.74 (dd, 1H, $J_{7,8}=8.0$ Hz, H-7), 5.12 (dd, 1H, $J_{4,5}=2.0$ Hz, H-5), 4.91 (dd, 1H, $J_{8,9}=4.8$ Hz, H-8), 4.62 and 4.52 (2 d, 2H, $J=11.8$ Hz, PhCH_2), 4.58 and 4.51 (2 d, 2H, $J=11.9$ Hz, PhCH_2), 4.54 (s, 2H, PhCH_2), 4.51 (s, 2H, PhCH_2), 4.47 and 4.41 (2 d, 2H, $J=11.5$ Hz, PhCH_2), 4.46 (dd, 1H, $J_{2,3}=1.8$ Hz, H-2), 4.24 (ddd, 1H, $J_{10,11}=4.0$, $J_{11,12a}=5.6$, $J_{11,12b}=5.8$ Hz, H-11), 4.20 (dd, 1H, $J_{3,4}=1.5$ Hz, H-3), 4.08 (dd, 1H, $J_{9,10}=3.3$ Hz, H-10), 3.99 (dd, 1H, H-9), 3.98 (dd, 1H, H-4), 3.57 (dd, 1H, $J_{12a,12b}=10.0$ Hz, H-12a), 3.54 (dd, 1H, H-12b). Compound **19Bz**. $[\alpha]_D=-25.6$ (*c* 0.9, $CHCl_3$). ^{1}H NMR (400 MHz, C_6D_6): δ 8.20–8.16, 8.10–8.03, and 7.10–6.92 (3 m, 40 H, 8 Ph), 5.76 (dd, 2H, $J_{2,3}=3.2$, $J_{3,4}=1.9$ Hz, H-3, H-16), 5.60 (dd, 2H, $J_{4,5}=3.3$ Hz, H-4, H-15), 5.56–5.54 (m, 2H, H-9, H-10), 4.64 (d, 4 H, $J_{1,2}=5.6$ Hz, 2 H-1, 2 H-18), 4.39 (dt, 2H, H-2, H-17), 4.34–4.29 (m, 2H, H-5, H-14), 4.25–4.20 (m, 2H, H-8, H-11), 2.23–2.12 and 2.02–1.92 (2 m, 8 H, 2 H-6, 2 H-7, 2 H-12, 2 H-13). MALDI-TOF (1257.33): 1279.9 (M+Na), 1295.9 (M+K).