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Tetrahedron 64 (2008) 3381–3391
Tetrahedron
www.elsevier.com/locate/tet

A new, improved synthesis of the trisaccharide repeating unit of the *O*-antigen from *Xanthomonas campestris* pv. *campestris* 8004

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Received 15 November 2007; received in revised form 7 January 2008; accepted 24 January 2008
Available online 31 January 2008

Dedicated to Professor Matteo Adinolfi on the occasion of his 70th birthday

Abstract

Recent studies have revealed that lipid-A and core fragments of the lipopolysaccharide from *Xanthomonas campestris* pv. *campestris* 8004 (*Xcc*), a phytopathogenic Gram-negative bacterium, are able to elicit plant immunity with two independent mechanisms. To date, nothing is known about the effect of the *O*-antigen portion. Since its separation from the core region by selective chemical degradation is very difficult, the chemical synthesis of related oligosaccharides is strictly necessary. In this paper a new, improved synthesis of the *O*-antigen repeating unit is presented. The main improvements in the synthesis are: (1) a shorter, high-yielding preparation of an efficient glycosyl donor of the rare sugar 3-acetamido-3,6-dideoxy-D-galactopyranose (3-acetamido-D-fucose, D-Fuc*p*3NAc); (2) a new protecting group pattern, which is demonstrated to open a path to the future synthesis of higher oligomers.

Keywords: 3-Acetamido-D-fucose; D-Rhamnose; Glycosylation; *Xanthomonas*

1. Introduction

The principal components of the Gram-negative outer membrane cell surface are the lipopolysaccharides (LPSs), amphiphilic macromolecules usually consisting of three different domains: a lipid part (lipid-A), an oligosaccharide region (core) and a long-chain polysaccharide portion (*O*-chain, *O*-antigen). LPSs are highly involved in bacterial pathogenesis both in animals and plants.

The mechanism of interaction between eukaryotic cells and Gram-negative bacteria, which are pathogenic to humans and animals, has been studied in great extent,[1] whereas only a few, non-exhaustive studies have been accomplished about plant–bacteria interactions.[2] Indeed, to date, very little is known about LPS perception by plants. It has been suggested recently that the recognition mechanism works analogously to the innate immunity system of animals, which is based on the perception of pathogen-associated molecular patterns (PAMPs),[3] characteristic structures of the pathogen indispensable for its growth within the host.[4] Since LPSs cover a wide part of the outer bacterial membrane, they might be a group of general elicitors that can be recognized by plants to trigger a defence response. Actually, it was shown that the lipid-A moiety acts as PAMP in plants;[5] recently, the core moiety was recognized to elicit plant innate immunity too. This study revealed that, when *Arapidopsis thaliana* leaves were inoculated with the core or the lipid-A from the phytopathogenic bacterium *Xanthomonas campestris* pv. *campestris* 8004 (*Xcc*), a noteworthy up-regulation of defense-related genes was observed. In addition, the transcript levels showed an accumulation after 12 h in response to the core and after 24 h in response to the lipid-A, which highly resembled the values obtained in an experiment where the leaves were inoculated with the whole lipooligosaccharide.[6] These data strongly suggested for the first time that

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doi:10.1016/j.tet.2008.01.093

two distinct and independent mechanisms are involved in the perception of the core and lipid-A, even if the receptor components involved in recognition and transmembrane signalling still remain unknown.[7] The role of the *O*-antigen portion of the *Xcc* lipopolysaccharide was not elucidated since its separation from the core region by selective chemical degradation is very difficult. The chemical structure of this *O*-antigen consists of a trisaccharide repeating unit, that has a D-rhamnose disaccharide backbone with a 3-acetamido-3,6-dideoxy-D-galactopyranose (3-acetamido-D-fucose, D-Fuc*p*3NAc) as branch (Fig. 1).[8]

We have recently demonstrated that synthetic oligorhamnans, which resemble the most general structure of *O*-antigen backbones from phytopathogenic bacteria,[9] are recognized by plant cells and elicit plant innate immunity.[10] From this result one could hypothesize that the 'rhamnose-rich' *Xcc O*-antigen could be involved in the mechanisms of elicitation of plant innate immunity. This could be proved by synthesizing the repeating unit of this *O*-antigen as well as its higher oligomers and then testing them in *Arabidopsis thaliana* defense-related genes up-regulation experiments. En route to this goal, we present here a new synthesis of the trisaccharide repeating unit. The synthetic strategy was carefully planned in order to use a protecting group pattern, which will enable the oligomerization of the repeating unit.

2. Results and discussion

The chemical synthesis of the *Xcc O*-antigen trisaccharide repeating unit was challenging owing to two features: (1) its monosaccharide constituents—D-rhamnose and D-Fuc*p*3NAc—are rather unusual and therefore not commercially available: they had to be synthesized from other sugar precursors; (2) two of the three linkages present in the repeating unit are cis-configured and one of these has a β-*manno* configuration, which is the most difficult to synthesize stereoselectively.[11,12] The synthesis of this trisaccharide repeating unit as the methyl glycoside **1** was already reported by us (Scheme 1).[13] Unfortunately, the overall yield of the synthesis was not high enough to allow further manipulation of the trisaccharide towards higher oligomers. Actually, the 'Achilles heel' of that synthesis was the overly long and low-yielding path (3% overall yield) for the conversion of commercially available D-fucose into the D-Fuc*p*3NAc donor **5**. The synthetic strategy required 15 reactions, with the intramolecular cyclization of the α,β-epoxytrichloroacetimidate **10** as key step for the introduction of the nitrogen moiety at position *O*-3 (Scheme 2, route A).[14] Besides, the coupling of **5** with the sterically crowded D-rhamnose disaccharide **23** (see Scheme 3) gave trisaccharide **3** in only 40% yield. Therefore, we looked for a high-yielding synthesis of a new, more efficient D-Fuc*p*3NAc donor.

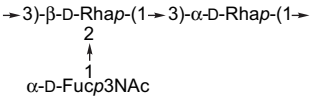
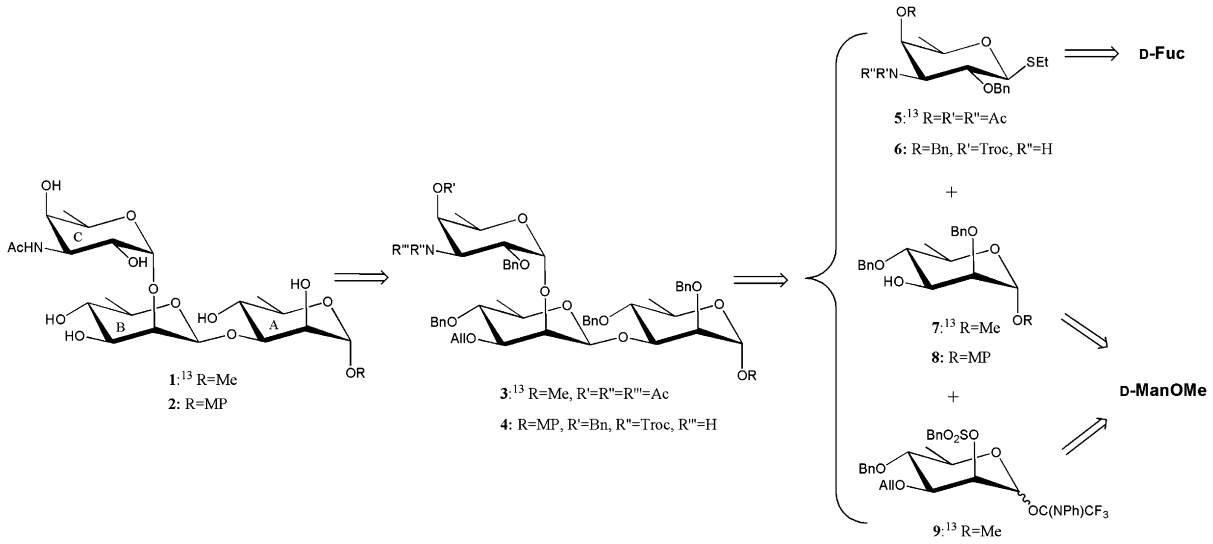


Figure 1. Repeating unit of the *O*-antigen from *Xanthomonas campestris* pv. *campestris* 8004.

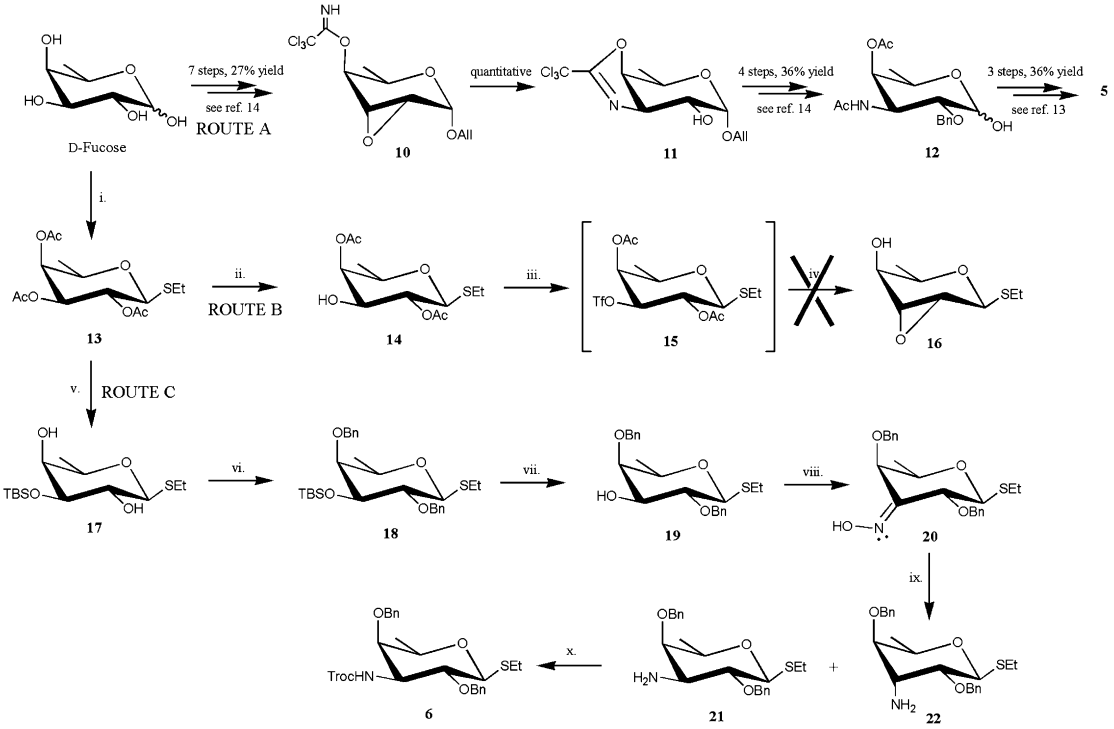
Firstly, we planned to perform the α,β-epoxytrichloroacetimidate intramolecular cyclization on a compound with a β-configured thioalkyl group already installed at the anomeric position, to avoid the low β-stereoselectivity in the conversion of hemiacetal **12** to thioglycoside **5** (Scheme 2, route A).[13] Thus, β-thioglycoside **13** was obtained in high yield (78%) and excellent stereoselectivity (β/α=19:1) from D-fucose via a thiouronium intermediate generated from fucosyl iodide.[15] Compound **13** was then deacetylated and regioselectively protected at positions *O*-2 and *O*-4 in four steps one-pot (Zemplén deacylation, orthoesterification, acetylation, orthoester hydrolysis) to afford alcohol **14** (71% over four steps from **13**) (Scheme 2, route B). Unfortunately, treatment of triflate derivative **15** with sodium methoxide did not afford the desired 2,3-epoxide derivative **16**. Instead a complex mixture was obtained probably due to the trans-configuration of a good leaving group at position *O*-2 and the adjacent thioalkyl moiety that was prone to give an intramolecular displacement of the epoxide.[16] This generated a glycosyl oxonium ion, whose uncontrollable reactivity could explain the complex mixture of products obtained in this reaction. Alternatively, the introduction of a nitrogen function at position *O*-3 was planned via a Lattrell-Dax[17,18] epimerization followed by an S_N2 azide displacement. However, the treatment of triflate **15** with KNO_2 in strictly anhydrous DMF at 50 °C[19] afforded the desired 6-deoxy-gulose (antiarose) derivative in only moderate yield (57%); therefore, this route was not further developed. Inspired by the recent synthesis of ravidosamine (L-Fuc*p*3NMe$_2$)[20] and by the synthesis of the unnatural 3-acetamido-3,6-dideoxy-L-galactopyranose (L-Fuc*p*3NAc),[21] we planned to insert the nitrogen function at position *O*-3 by oxime reduction. Thus, thioglycoside **13** was deacetylated and the resulting triol was regioselectively silylated at position *O*-3[22] to give diol **17** (79%) (Scheme 2, route C). Benzylation (93%) and subsequent cleavage of TBS group (98%) afforded **19** that gave in turn compound **20** (78%) after oxidation of the alcohol and oximation of the resulting ketone. Several reduction conditions were screened on oxime **20**. Red-Al® in THF at 0 °C was found to give best yield and stereoselectivity, affording the desired *galacto*-configured amine **21** together with the *gulo*-configured compound **22** in 88% yield (**21**/**22**=10:1). After separation of the two epimers by column chromatography, the amino moiety of **21** was protected as Troc to give the D-Fuc*p*3NAc donor **6**. The overall yield of the new synthetic path (route C) was 27% over 11 steps, which was much better than the former one (route A, 3% over 15 steps). Besides, the coupling of the new donor **6** with the rhamnose disaccharide **23** proceeded smoothly and in better yield than coupling of donor **5** with acceptor **23** (Scheme 3). Actually, in the latter case trisaccharide **3** was obtained in modest yield (40%) together with unreacted acceptor recovered in 27% yield: the separation of disaccharide **23** and trisaccharide **3** was not easily achievable and required HPLC.[13] Difficulties in introducing an amino-fucose residue on a sterically crowded acceptor was already reported in literature.[23] Nevertheless the coupling between the new D-Fuc*p*3NAc donor **6** and **23** under



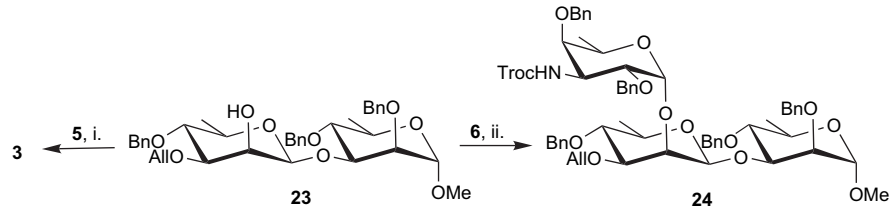
Scheme 1. Former[13] and new retrosynthetic analysis for the target trisaccharide.

NIS/AgOTf activation at −20 °C in 1:1 v/v CH_2Cl_2/Et_2O proceeded in good yield (77%) and pure trisaccharide **24** was obtained simply by column chromatography. The α-configuration of the new glycosidic bond was ascertained by a $^1J_{H\text{-}1,H\text{-}2}$ value of 3.3 Hz, typical of a 1,2-cis-configuration in the case of a *galacto*-configured residue. In conclusion, a new, high-yielding synthetic path to a protected form of the trisaccharide repeating unit of the *Xcc O*-antigen has been accomplished.

A further goal was to open a synthetic way towards *O*-antigen higher oligomers. For this purpose, we had to test if the trisaccharide building block **24** could be transformed into both a glycosyl donor and a glycosyl acceptor. As first step towards a glycosyl donor, we planned the conversion of the anomeric methoxy group into an acetate by acetolysis. Even when it was conducted in mild conditions (1:1:0.05 v/v/v AcOH/Ac_2O/TFA at 70 °C) as recently reported on a disaccharide case,[24] a complex mixture of mono-, di- and trisaccharides

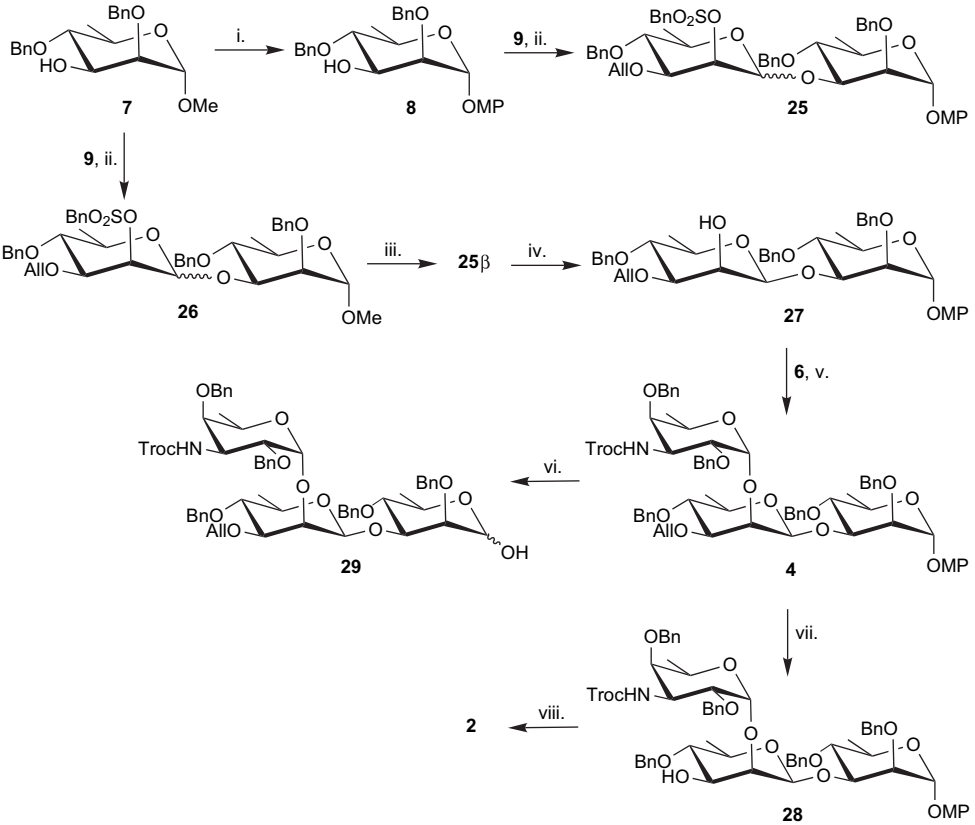


Scheme 2. Synthesis of D-Fuc*p*3NAc donors **5**[13] and **6**. Reagents and conditions: i: (a) Ac_2O, py, rt, (b) I_2, Et_3SiH, CH_2Cl_2, reflux, (c) thiourea, CH_3CN, 60 °C then EtI, Et_3N, rt, 74% over three steps; ii: (a) *t*-BuOK, MeOH, 0 °C, (b) CSA, 7:2 v/v $MeC(OMe)_3$/DMF, 100 mbar, rt, (c) Ac_2O, py, rt, (d) 80% AcOH, rt, 82% over four steps; iii: Tf_2O, 1:1 v/v py/CH_2Cl_2, 0 °C; iv: Na, 1:1 v/v MeOH/CH_2Cl_2, 0 °C; v: (a) *t*-BuOK, MeOH, 0 °C, (b) TBSCl, ImH, DMF, 0 °C, 79% over two steps; vi: BnBr, NaH, DMF, 0 °C, 93%; vii: TBAF, THF, rt, 98%; viii: (a) 2:1 v/v DMSO/Ac_2O, rt, (b) $NH_2OH\cdot HCl$, NaOAc, MeOH, rt, 78% over two steps; ix: Red-Al®, THF, 0 °C, **21**: 80%, **22**: 8%; x: TrocCl, py, 82%.



Scheme 3. Glycosylation reactions of D-Fuc*p*3NAc donors **5**[13] and **6** with rhamnose disaccharide **23**. Reagents and conditions: i: 40%: see Ref. 13; ii: NIS, AgOTf, AW-300 4 Å MS, 1:1 v/v CH_2Cl_2/Et_2O, −20 °C, 77%.

was obtained, due to the simultaneous cleavage of the interglycosidic bonds. The explanation is that in our case both the two glycosidic linkages and the methoxy group are rather activated towards acid-mediated cleavage due to the electron-donating protecting groups at position *O*-2 of all three residues. The mild acetolysis reaction was unable to select between the three similarly activated linkages; a non-regioselective cleavage was observed.[25] At this point, the synthesis of a new trisaccharide building block, possessing an orthogonal protecting group at the anomeric position, was mandatory. We chose a *p*-methoxyphenyl (MP) as new anomeric protecting group: its use as an effective anomeric protecting group in D-rhamnose oligosaccharide synthesis was very recently reported.[26,27] Thus, the new D-rhamnose acceptor **8** was obtained from the former one **7**[13] by acetolysis, *p*-methoxyphenylation and Zemplén deacetylation (62% yield over three steps) (Scheme 4). *N*-Phenyl trifluoroacetimidate **9**[13] was used as D-rhamnose donor to have a β>α stereoselectivity in the glycosylation, since the benzylsulfonyl group at 2-*O*-atom was already exploited in β-stereoselective mannosylations.[28] Unfortunately, the coupling between **8** and **9** afforded disaccharide **25** in high yield (88%) but without the desired stereoselectivity (α/β=3:2). Since the coupling between **9** and the former acceptor **7** gave disaccharide **26** in quantitative yield (99%) and higher β-stereoselectivity,[13] we decided to insert the MP group at the 'disaccharide level'. Mild acetolysis of **26b** proceeded smoothly to give the disaccharide with an acetyl group at the anomeric position. This result was explained by the strong



Scheme 4. Completion of the synthesis. Reagents and conditions: i: (a) 1:1:0.1 v/v/v Ac_2O/AcOH/TFA, 70 °C, (b) *p*-methoxyphenol, $BF_3{\cdot}OEt_2$, CH_2Cl_2, 0 °C, (c) *t*-BuOK, MeOH, rt, 62% over three steps; ii: TMSOTf, AW-300 4 Å MS, CH_2Cl_2, −50 °C to −25 °C, **25**: 88% (α/β=3:2), **26** (see Ref. 13): 99% (α/β=2:3); iii: (a) 1:1:0.1 v/v/v Ac_2O/AcOH/TFA, 70 °C, (b) *p*-methoxyphenol, $BF_3{\cdot}OEt_2$, CH_2Cl_2, 0 °C, 65% over two steps; iv: $NaNH_2$, DMF, rt, 52%; v: NIS, AgOTf, AW-300 4 Å MS, 1:1 v/v CH_2Cl_2/Et_2O, −20 °C, 65%; vi: CAN, 2:2:1 v/v/v toluene/CH_3CN/H_2O, rt, 68% (α/β=4.5:1); vii: $PdCl_2$, 2:1 v/v MeOH/CH_2Cl_2, rt, 86%; viii: (a) Zn/Cu, 2:1 v/v AcOH, Ac_2O, rt, (b) Pd/C, 9:1 v/v MeOH/HCOOH, ultrasound bath, 55% over two steps.

electron-withdrawing character of the benzylsulfonyl group, which disfavoured the acid-catalyzed cleavage of the interglycosidic bond; on the contrary the electron-donating benzyl group at position O-2_A activated the anomeric methoxy group towards acetolysis.[25] After subsequent *p*-methoxyphenylation, disaccharide **25β** was obtained in good yield (65% after two steps). Cleavage of the benzylsulfonyl group on **25β** with sodium amide in DMF for 48 h proceeded in 52% yield. Attempts to shorten the reaction time by using microwave irradiation[29] considerably lowered the yield. In this case, β-elimination of $PhCH_2SO_2H$ competed with benzylsulfonyl cleavage, as observed by MALDI mass spectrum of the crude reaction mixture. Disaccharide acceptor **27** was coupled with donor **6** under reaction conditions already used for the synthesis of **24**. Glycosylation proceeded uneventfully to give trisaccharide **4** in 65% yield. The α-configuration of the new glycosidic bond was ascertained by a $^1J_{H\text{-}1,H\text{-}2}$ value of 3.2 Hz, typical of a 1,2-cis-configuration in the case of a *galacto*-configured residue. The protecting group pattern on **4** was demonstrated to be orthogonal enough to open a path towards higher oligomers of the repeating unit of *Xcc O*-antigen. Actually, compound **4** was smoothly transformed into trisaccharide acceptor **28** (86%) by chemoselective de-O-allylation with $PdCl_2$ in 2:1 v/v $MeOH/CH_2Cl_2$. Selective deprotection of the anomeric MP group was accomplished by treating **4** with CAN in 2:2:1 toluene/CH_3CN/water: hemiacetal **29** was obtained in 68% yield (α/β=4.5:1) and can be activated as a trisaccharide donor. The optimization of the [3+3] glycosylation is currently underway and the synthesis of higher oligomers of the repeating unit of *Xcc O*-antigen will be reported elsewhere. Finally, global deprotection of trisaccharide **28** was accomplished in two steps: firstly, the NHTroc group was converted into an acetamido group by treatment with Zn/Cu in 2:1 v/v $AcOH/Ac_2O$, then de-O-benzylation was performed by transfer hydrogenation under Perlin conditions[30] to give deprotected trisaccharide **2**. ^1H and ^{13}C NMR data of the target compound **2** are reported in Table 1.

3. Conclusions

In conclusion, a new, improved synthesis of the trisaccharide repeating unit of the *O*-antigen from *Xanthomonas campestris* pv. *campestris* 8004 was accomplished. The main improvements are: (1) a shorter, high-yielding synthesis of a very efficient D-Fuc*p*3NAc donor; (2) the choice of a new protecting group pattern, which was demonstrated to be orthogonal enough to open a path to both a trisaccharide acceptor and a trisaccharide donor. This will enable the synthesis of higher oligomers of the repeating unit of *Xcc O*-antigen. To this purpose, work is currently underway.

4. Experimental section

4.1. General methods

^1H and ^{13}C NMR spectra were recorded on Varian XL-200 (^1H: 200 MHz, ^{13}C: 50 MHz), Varian Gemini-300 (^1H: 300 MHz, ^{13}C: 75 MHz), Bruker DRX-400 (^1H: 400 MHz, ^{13}C: 100 MHz) or Varian INOVA 500 (^1H: 300 MHz, ^{13}C: 125 MHz) instruments in $CDCl_3$ ($CHCl_3$ as internal standard, ^1H: C*H*Cl_3 at δ 7.26; ^{13}C: *C*DCl_3 at δ 77.0) and in D_2O (acetone as internal standard, ^1H: $(CH_3)_2CO$ at δ 2.22; ^{13}C: $(CH_3)_2CO$ at δ 31.5). Assignment of proton chemical shifts were based on 1D HOHAHA and COSY experiments. Assignment of proton and carbon chemical shifts of the deprotected trisaccharide **2** was based on 2D NMR experiments such as COSY, TOCSY and HSQC. Positive ESI-MS spectra were recorded on a Finnigan LCQ-DECA ion trap mass spectrometer. Positive MALDI-MS spectra were recorded on a Applied Biosystem Voyager DE-PRO MALDI-TOF mass spectrometer in the positive mode: compounds were dissolved in the appropriate solvent at a concentration of 1 mg/mL and 1 μL of these solutions were mixed with 1 μL of a 20 mg/mL solution of 2,5-dihydroxybenzoic acid in 7:3 CH_3CN/water. Optical rotations were measured on a JASCO P-1010 polarimeter at 294 K. Analytical thin layer chromatography (TLC) was performed on aluminium plates precoated with Merck Silica Gel 60 F_{254} as the adsorbent. The plates were developed with 5% H_2SO_4 ethanolic solution and then heated to 130 °C. Column chromatography was performed on Merck Kieselgel 60 (63–200 mesh). Gel-filtration chromatography was performed on a Sephadex G-10 column (2.0×90 cm) with water as eluant.

4.1.1. Ethyl 2,3,4-tri-O-acetyl-1-thio-β-D-fucopyranoside[31] (13)

A solution of D-fucose (2.5 g, 15.3 mmol) in 1:1 v/v Ac_2O/pyridine (20 mL) was stirred overnight, after that, it was diluted with CH_2Cl_2 (200 mL) and washed with 1 M HCl (200 mL), 1 M $NaHCO_3$ (200 mL) and water (200 mL). The organic layer was collected, dried over anhydrous Na_2SO_4, filtered and concentrated. The obtained residue was dissolved in CH_2Cl_2 (20 mL) and treated with iodine (5.5 g, 21.7 mmol) and Et_3SiH (3.47 mL, 21.7 mmol). The mixture was heated at reflux for few minutes, then diluted with CH_2Cl_2 (200 mL) and washed with 1:1 v/v 1 M $NaHCO_3$/10% $Na_2S_2O_3$ (200 mL) and water (200 mL). The organic layer was collected, dried over anhydrous Na_2SO_4, filtered and

Table 1
^1H and ^{13}C NMR (*italic*) chemical shifts (δ in ppm) of target trisaccharide **2**

Sugar residue	H-1/*C-1*	H-2/*C-2*	H-3/*C-3*	H-4/*C-4*	H-5/*C-5*	H-6/*C-6*
A	5.57/*100.1*	4.44/*68.1*	4.22/*79.1*	3.68/*71.4*	3.94/*69.3*	1.32/*18.8*
B	4.96/*98.1*	4.24/*79.1*	3.78/*74.2*	3.58/*74.3*	3.54/*73.5*	1.44/*18.7*
C	5.28/*101.1*	3.94/*69.5*	4.36/*52.2*	3.82/*71.2*	4.64/*68.1*	1.28/*18.0*

concentrated. The residue was mixed with thiourea (1.75 g, 23.0 mmol), suspended in CH_3CN (20 mL) and then heated to 60 °C. After 20 min the reaction mixture was cooled to rt, and EtI (2.5 mL, 31.3 mmol) and Et_3N (8.5 mL, 61.0 mmol) were added. The mixture was stirred for additional 20 min and then concentrated. The residue was subjected to column chromatography (15–30% ethyl acetate in petroleum ether) to give **13**[31] (3.99 g, 74%). $[\alpha]_D^{21}$ −30 (*c* 0.5, CH_2Cl_2) [lit.:[31] −28 (*c* 1, $CHCl_3$)]. ^{1}H NMR ($CDCl_3$, 300 MHz) δ 5.28 (dd, $[\alpha]_D^{20}$ $J_{4,3}$=3.3 Hz, $J_{4,5}$=1.2 Hz, 1H, H-4), 5.22 (t, $J_{2,3}$=$J_{2,1}$=9.9 Hz, 1H, H-2), 5.06 (dd, $J_{3,2}$=9.9 Hz, $J_{3,4}$=3.3 Hz, 1H, H-3), 4.49 (d, $J_{1,2}$=9.9 Hz, 1H, H-1), 3.86 (dq, $J_{5,6}$=6.6 Hz, $J_{5,4}$=1.2 Hz, 1H, H-5), 2.81–2.67 (m, 2H, SCH_2CH$_3$), 2.19, 2.08, 1.99 (3s, 9H, 3Ac), 1.29 (t, J_{vic}=7.5 Hz, 3H, SCH$_2$CH_3), 1.23 (d, $J_{6,5}$=6.6 Hz, 3H, H-6); ^{13}C NMR ($CDCl_3$, 75 MHz) δ 170.4, 169.8, 169.4 (3CO), 83.2 (C_1), 72.9, 72.1, 70.2, 67.1 (C_2, C_3, C_4, C_5), 23.8 (SCH_2CH$_3$), 20.5, 20.3 (2COCH_3), 16.1 (C_6), 14.5 (SCH$_2$$CH_3$). ESI-MS for $C_{14}H_{22}O_7S$ (*m*/*z*): M_r (calcd) 334.11, M_r (found) 356.93 $(M+Na)^+$.

4.1.2. Ethyl 2,4-di-O-acetyl-1-thio-β-D-fucopyranoside (*14*)

A solution of **13** (0.512 g, 1.75 mmol) in MeOH (5.0 mL) was treated at 0 °C with *t*-BuOK until it was strongly basic. After 30 min stirring at rt, it was neutralized with Amberlyst-15 (H^+), then filtered and concentrated to give a residue that was dissolved in 7:2 v/v MeC(OMe)$_3$/DMF (9.0 mL). CSA (80 mg, 0.34 mmol) was then added and the solution was evacuated at 100 mbar for 20 min, after that pyridine (7.0 mL) and Ac_2O (7.0 mL) were sequentially added. The solution was stirred overnight at rt, then coevaporated four times with toluene (10 mL each). The residue was dissolved in 80% AcOH (10 mL) and the solution was stirred at rt for 10 min, after that it was coevaporated two times with toluene (5 mL each). The residue was subjected to column chromatography (40% ethyl acetate in petroleum ether) to give **14** (0.893 g, 82%) as a white solid. $[\alpha]_D^{21}$ −2.4 (*c* 1.0, CH_2Cl_2). Mp=120.4–121.3 °C. ^{1}H NMR ($CDCl_3$, 200 MHz) δ 5.17 (dd, $J_{4,3}$=3.2 Hz, $J_{4,5}$=0.8 Hz, 1H, H-4), 4.97 (t, $J_{2,3}$=$J_{2,1}$=9.6 Hz, 1H, H-2), 4.37 (d, $J_{1,2}$=10.0 Hz, 1H, H-1), 3.79 (dd, $J_{3,2}$=9.6 Hz, $J_{3,4}$=3.2 Hz, 1H, H-3), 3.71 (dq, $J_{5,6}$=6.4 Hz, $J_{5,4}$=0.8 Hz, 1H, H-5), 2.76–2.58 (m, 2H, SCH_2CH$_3$), 2.14, 2.07 (2s, 6H, 2Ac), 1.23 (t, J_{vic}=7.2 Hz, 3H, SCH$_2$CH_3), 1.16 (d, $J_{6,5}$=6.4 Hz, 3H, H-6); ^{13}C NMR ($CDCl_3$, 50 MHz) δ 171.3, 171.0 (2CO), 83.1 (C_1), 73.4, 73.1, 72.4, 71.0 (C_2, C_3, C_4, C_5), 24.1 (SCH_2CH$_3$), 20.9, 20.8 (2COCH_3), 16.6 (C_6), 14.7 (SCH$_2$$CH_3$). ESI-MS for $C_{12}H_{20}O_6S$ (*m*/*z*): M_r (calcd) 292.10, M_r (found) 315.21 $(M+Na)^+$. Anal. Calcd: C 49.30, H 6.90. Found: C 49.35, H 6.85.

4.1.3. Ethyl 3-O-tert-butyldimethylsilyl-1-thio-β-D-fucopyranoside (*17*)

To a solution of **13** (3.800 g, 11.4 mmol) in MeOH (25 mL) at 0 °C, *t*-BuOK was added until the solution was strongly basic. After 30 min stirring at rt, the mixture was neutralized with Amberlyst-15 (H^+), then filtered and concentrated to give a residue that was dissolved in DMF (7.0 mL), cooled to 0 °C and then treated with imidazole (2.04 g, 29.6 mmol) and TBSCl (2.25 g, 14.8 mmol). The mixture was stirred at 0 °C for 30 min and then diluted with ethyl acetate (200 mL) and washed with water (200 mL). The organic layer was collected, dried over anhydrous Na_2SO_4, filtered and concentrated to afford a residue that was subjected to a column chromatography (10–20% ethyl acetate in petroleum ether) to give **17** (2.888 g, 79%) as a yellowish oil. $[\alpha]_D^{21}$ −13 (*c* 1.0, CH_2Cl_2). ^{1}H NMR ($CDCl_3$, 200 MHz) δ 4.21 (d, $J_{1,2}$=8.4 Hz, 1H, H-1), 3.66–3.50 (m, 4H, H-2, H-3, H-4, H-5), 2.81–2.64 (m, 2H, SCH_2CH$_3$), 2.55 (br s, 1H, OH), 2.36 (br s, 1H, OH), 1.32 (d, $J_{6,5}$=6.6 Hz, 3H, H-6), 1.26 (t, J_{vic}=6.8 Hz, 3H, SCH$_2$CH_3), 0.87 (s, 9H, SiC(CH_3)$_3$), 0.12 (s, 3H, SiCH_3), 0.10 (s, 3H, SiCH_3); ^{13}C NMR ($CDCl_3$, 50 MHz) δ 85.8 (C_1), 75.9, 74.2, 72.3, 69.7 (C_2, C_3, C_4, C_5), 25.6 (SiC(CH$_3$)$_3$), 23.9 (SCH_2CH$_3$), 18.0 (C_6), 15.1 (SCH$_2$$CH_3$), −4.5, −5.1 (Si(C$H_3$)$_2$). ESI-MS for $C_{14}H_{30}O_4SSi$ (*m*/*z*): M_r (calcd) 322.16, M_r (found) 345.33 $(M+Na)^+$. Anal. Calcd: C 52.13, H 9.38. Found: C 52.26, H 9.28.

4.1.4. Ethyl 2,4-di-O-benzyl-3-O-tert-butyldimethylsilyl-1-thio-β-D-fucopyranoside (*18*)

A solution of **17** (2.888 g, 8.97 mmol) in DMF (10 mL) was cooled to 0 °C and then treated with BnBr (1.97 mL, 19.6 mmol) and NaH (60% oil suspension; 1.808 g, 53.8 mmol). The mixture was stirred at 0 °C for 1 h, after that water (10 mL) was carefully added. The mixture was diluted with ethyl acetate (200 mL) and washed with water (200 mL). The organic layer was collected, dried over anhydrous Na_2SO_4, filtered and concentrated to afford a residue, that was chromatographed (4% ethyl acetate in petroleum ether) to give **18** (4.188 g, 93%) as white amorphous crystals. $[\alpha]_D^{21}$ −14 (*c* 0.8, CH_2Cl_2). ^{1}H NMR ($CDCl_3$, 300 MHz) δ 7.47–7.24 (m, 10H, H-Ar), 5.15 (d, J_{gem}=11.7, 1H, OCHHPh), 4.94 (d, J_{gem}=10.5, 1H, OCHHPh), 4.80 (d, J_{gem}=10.5, 1H, OCHHPh), 4.68 (d, J_{gem}=11.7, 1H, OCHHPh), 4.44 (d, $J_{1,2}$=9.0 Hz, 1H, H-1), 3.81 (dd, $J_{3,2}$=9.3 Hz, $J_{3,4}$=3.0 Hz, 1H, H-3), 3.73 (t, $J_{2,3}$=$J_{2,1}$=9.3 Hz, 1H, H-2), 3.61 (q, $J_{5,6}$=6.6 Hz, 1H, H-5), 3.51 (d, $J_{4,3}$=3.0 Hz, 1H, H-4), 2.86–2.66 (m, 2H, SCH_2CH$_3$), 1.34 (t, J_{vic}=7.5 Hz, 3H, SCH$_2$CH_3), 1.29 (d, $J_{6,5}$=6.6 Hz, 3H, H-6), 1.02 (s, 9H, SiC(CH_3)$_3$), 0.19 (s, 3H, SiCH_3), 0.14 (s, 3H, SiCH_3); ^{13}C NMR ($CDCl_3$, 75 MHz) δ 138.8, 138.3 ($2C_{ipso}$), 128.3–127.2 (C-Ar), 84.8 (C_1), 80.6, 78.4 (C_2, C_4), 77.7, 75.3, 75.1, 74.2 (C_3, C_5, 2OCH_2Ph), 26.0 (SiC(CH$_3$)$_3$), 24.5 (SCH_2CH$_3$), 18.0 (C_6), 14.9 (SCH$_2$$CH_3$), −4.1, −4.6 (Si(C$H_3$)$_2$). ESI-MS for $C_{28}H_{42}O_4SSi$ (*m*/*z*): M_r (calcd) 502.26, M_r (found) 525.41 $(M+Na)^+$. Anal. Calcd: C 66.89, H 8.42. Found: C 66.76, H 8.68.

4.1.5. Ethyl 2,4-di-O-benzyl-1-thio-β-D-fucopyranoside (*19*)

A 1 M solution of TBAF in THF (20 mL, 20 mmol) was added to a solution of **18** (3.500 g, 6.97 mmol) in THF (20 mL), and the resulting solution was stirred at rt for 3 h. After concentration, column chromatography (10–30% ethyl acetate in petroleum ether) afforded **19** (2.650 g, 98%) as a yellowish oil. $[\alpha]_D^{21}$ +7 (*c* 0.7, CH_2Cl_2). ^{1}H NMR ($CDCl_3$, 300 MHz) δ 7.49–7.25 (m, 10H, H-Ar), 5.01 (d, J_{gem}=10.8, 1H, OCHHPh), 4.88–4.76 (m, 3H, 3OCHHPh), 4.44 (d,

$J_{1,2}$=9.0 Hz, 1H, H-1), 3.75 (dd, $J_{3,2}$=9.3 Hz, $J_{3,4}$=3.0 Hz, 1H, H-3), 3.63 (t, $J_{2,3}$=$J_{2,1}$=9.3 Hz, 1H, H-2), 3.57 (d, $J_{4,3}$=3.0 Hz, 1H, H-4), 3.54 (q, $J_{5,6}$=6.6 Hz, 1H, H-5), 2.91–2.78 (m, 3H, SCH_2CH$_3$, OH), 1.39 (t, J_{vic}=7.5 Hz, 3H, SCH$_2$CH_3), 1.33 (d, $J_{6,5}$=6.6 Hz, 3H, H-6); ^{13}C NMR ($CDCl_3$, 75 MHz) δ 138.1, 138.0 (2C$_{ipso}$), 128.0–127.4 (C-Ar), 84.3 (C$_1$), 79.0, 78.9 (C$_2$, C$_4$), 75.5, 75.1, 74.9, 74.3 (C$_3$, C$_5$, 2OCH$_2$Ph), 24.5 (SCH$_2$CH$_3$), 16.9 (C$_6$), 14.7 (SCH$_2$CH$_3$). ESI-MS for $C_{22}H_{28}O_4S$ (*m/z*): M_r (calcd) 388.17, M_r (found) 411.38 (M+Na)$^+$. Anal. Calcd: C 68.01, H 7.26. Found: C 68.36, H 7.20.

4.1.6. Ethyl 2,4-di-O-benzyl-6-deoxy-1-thio-β-D-xylo-hexopyranosid-3-ulose (E)-oxime (**20**)

Alcohol **19** (2.796 g, 7.20 mmol) was dissolved in 2:1 v/v DMSO/Ac_2O (15 mL) and stirred at rt for 3 h. The solution was then diluted with ethyl acetate (300 mL) and washed with water (300 mL). The organic layer was collected, dried over anhydrous Na_2SO_4, filtered and concentrated to afford a residue that was dissolved in MeOH (25 mL) and treated with NaOAc (847 mg, 10.1 mmol) and $NH_2OH\cdot HCl$ (750 mg, 10.1 mmol). After stirring at rt for 2 h, the solution was concentrated and the obtained residue was subjected to column chromatography (10–30% ethyl acetate in petroleum ether) to afford **20** (2.252 g, 78%) as a yellowish oil. $[\alpha]_D^{21}$ −38.8 (*c* 1.1, CH_2Cl_2). ^{1}H NMR ($CDCl_3$, 300 MHz) δ 7.36–7.20 (m, 10H, H-Ar), 4.83 (d, $J_{4,5}$=1.8 Hz, 1H, H-4), 4.81 (d, J_{gem}=11.2 Hz, 1H, OCHHPh), 4.71 (d, J_{gem}=11.2 Hz, 1H, OCHHPh), 4.54 (d, $J_{1,2}$=9.8 Hz, 1H, H-1), 4.51 (d, J_{gem}=12.2 Hz, 1H, OCHHPh), 4.34 (d, J_{gem}=12.2 Hz, 1H, OCHHPh), 4.27 (d, $J_{2,1}$=9.8 Hz, 1H, H-2), 3.58 (dq, $J_{5,6}$=6.6 Hz, $J_{5,4}$=1.8 Hz, 1H, H-5), 2.89–2.58 (m, 2H, SCH_2CH$_3$), 1.31 (d, $J_{6,5}$=6.6 Hz, 3H, H-6), 1.29 (t, J_{vic}=7.5 Hz, 3H, SCH$_2$CH_3); ^{13}C NMR ($CDCl_3$, 75 MHz) δ 154.8 (CN), 137.6, 137.1 (2C$_{ipso}$), 128.7–127.7 (C-Ar), 86.7 (C$_1$), 76.0, 74.7, 73.9, 71.2, 70.2 (C$_2$, C$_4$, C$_5$, 2OCH$_2$Ph), 24.4 (SCH$_2$CH$_3$), 16.4 (C$_6$), 14.8 (SCH$_2$CH$_3$). ESI-MS for $C_{22}H_{27}NO_4S$ (*m/z*): M_r (calcd) 401.17, M_r (found) 424.42 (M+Na)$^+$. Anal. Calcd: C 65.81, H 6.78, N 3.49. Found: C 65.95, H 6.59, N 3.43.

4.1.7. Ethyl 3-amino-2,4-di-O-benzyl-3-deoxy-1-thio-β-D-fucopyranoside (**21**) and ethyl 3-amino-2,4-di-O-benzyl-3,6-dideoxy-1-thio-β-D-gulopyranoside (**22**)

A solution of **20** (2.231 g, 5.56 mmol) in THF (25 mL) was cooled to 0 °C and then treated with a 70% solution of Red-Al® in toluene (7.16 mL, 27.8 mmol). The solution was stirred at 0 °C for 5 h, then water (10 mL) was added dropwise. The mixture was diluted with ethyl acetate (200 mL) and washed with water (200 mL). The organic layer was collected, dried over anhydrous Na_2SO_4, filtered and concentrated. The residue was subjected to column chromatography (1% methanol in dichloromethane) to afford **22** (168 mg, 8%) as a yellowish oil. $[\alpha]_D^{21}$ −12 (*c* 0.4, CH_2Cl_2). ^{1}H NMR ($CDCl_3$, 300 MHz) δ 7.36–7.25 (m, 10H, H-Ar), 4.90 (d, $J_{1,2}$=9.6 Hz, 1H, H-1), 4.71 (d, J_{gem}=11.6 Hz, 1H, OCHHPh), 4.55 (d, J_{gem}=11.6 Hz, 1H, OCHHPh), 4.53 (d, J_{gem}=12.0 Hz, 1H, OCHHPh), 4.49 (d, J_{gem}=12.0 Hz, 1H, OCHHPh), 4.57 (dq, $J_{5,6}$=6.4 Hz, $J_{5,4}$=2.0 Hz, 1H, H-5), 3.66 (dd, $J_{2,1}$=9.6 Hz, $J_{2,3}$=3.6 Hz, 1H, H-2), 3.64 (dd, $J_{4,3}$=3.6 Hz, $J_{4,5}$=2.0 Hz, 1H, H-4), 3.47 (t, $J_{3,4}$=$J_{3,2}$=3.6 Hz, 1H, H-3), 2.77–2.66 (m, 2H, SCH_2CH$_3$), 1.28 (t, J_{vic}=8.0 Hz, 3H, SCH$_2$CH_3), 1.20 (d, $J_{6,5}$=6.4 Hz, 3H, H-6); ^{13}C NMR ($CDCl_3$, 75 MHz) δ 138.3, 138.1 (2C$_{ipso}$), 128.4–127.7 (C-Ar), 80.6, 80.0, 75.6, 72.6, 70.6, 62.7 (C$_1$, C$_2$, C$_4$, C$_5$, 2OCH$_2$Ph), 49.3 (C$_3$), 24.4 (SCH$_2$CH$_3$), 16.5 (C$_6$), 14.9 (SCH$_2$CH$_3$). ESI-MS for $C_{22}H_{29}NO_3S$ (*m/z*): M_r (calcd) 387.19, M_r (found) 410.41 (M+Na)$^+$. Anal. Calcd: C 68.18, H 7.54, N 3.61. Found: C 68.06, H 7.66, N 3.57.

Second eluted compound **21** (1.726 g, 80%) was recovered as a yellowish oil. $[\alpha]_D^{21}$ +18 (*c* 0.3, CH_2Cl_2). ^{1}H NMR ($CDCl_3$, 300 MHz) δ 7.40–7.28 (m, 10H, H-Ar), 5.04 (d, J_{gem}=10.8 Hz, 1H, OCHHPh), 4.76 (d, J_{gem}=11.4 Hz, 1H, OCHHPh), 4.65 (d, J_{gem}=11.4 Hz, 1H, OCHHPh), 4.43 (d, J_{gem}=10.8 Hz, 1H, OCHHPh), 4.34 (d, $J_{1,2}$=9.6 Hz, 1H, H-1), 3.61–3.57 (m, 2H, H-4, H-5), 3.30 (t, $J_{2,3}$=$J_{2,1}$=9.6 Hz, 1H, H-2), 2.84–2.69 (m, 3H, H-3, SCH_2CH$_3$), 1.33 (t, J_{vic}=7.5 Hz, 3H, SCH$_2$CH_3), 1.31 (d, $J_{6,5}$=6.3 Hz, 3H, H-6); ^{13}C NMR ($CDCl_3$, 75 MHz) δ 138.2, 138.0 (2C$_{ipso}$), 128.5–127.7 (C-Ar), 85.5 (C$_1$), 81.0, 80.5 (C$_2$, C$_4$), 76.1, 76.0, 75.3 (C$_5$, 2OCH$_2$Ph), 58.0 (C$_3$), 24.9 (SCH$_2$CH$_3$), 17.2 (C$_6$), 14.9 (SCH$_2$CH$_3$). ESI-MS for $C_{22}H_{29}NO_3S$ (*m/z*): M_r (calcd) 387.19, M_r (found) 410.29 (M+Na)$^+$. Anal. Calcd: C 68.18, H 7.54, N 3.61. Found: C 68.00, H 7.58, N 3.55.

4.1.8. Ethyl 2,4-di-O-benzyl-3-deoxy-1-thio-3-(2,2,2-trichloroethoxycarbonylamino)-β-D-fucopyranoside (**6**)

A solution of **21** (138 mg, 0.356 mmol) in pyridine (2.0 mL) was treated with 2,2,2-trichloroethyl chloroformate (122 μL, 0.890 mmol) and stirred at rt for 2 h, after that MeOH (10 mL) was added and the solution was concentrated. The residue was subjected to a column chromatography (1% methanol in dichloromethane) to afford **6** (164 mg, 82%) as a yellowish powder. $[\alpha]_D^{21}$ +25 (*c* 0.8, CH_2Cl_2). ^{1}H NMR ($CDCl_3$, 300 MHz) δ 7.40–7.28 (m, 10H, H-Ar), 4.86 (d, J_{gem}=10.8 Hz, 1H, OCHHPh), 4.76 (d, J_{gem}=11.3 Hz, 1H, OCHHPh), 4.63 (s, 2H, OCH$_2$CCl$_3$), 4.58 (d, J_{gem}=11.3 Hz, 1H, OCHHPh), 4.48 (d, $J_{1,2}$=9.3 Hz, 1H, H-1), 4.44 (d, J_{gem}=10.8 Hz, 1H, OCHHPh), 3.84 (dt, $J_{3,2}$=$J_{3,NH}$=9.9 Hz, $J_{3,4}$=3.0 Hz, 1H, H-3), 3.66–3.57 (m, 2H, H-4, H-5), 3.42 (t, $J_{2,3}$=$J_{2,1}$=9.9 Hz, 1H, H-2), 2.84–2.71 (m, 2H, SCH_2CH$_3$), 1.37–1.32 (m, 6H, H-6, SCH$_2$CH_3); ^{13}C NMR ($CDCl_3$, 75 MHz) δ 154.0 (CO), 137.7, 137.5 (2C$_{ipso}$), 128.6–127.9 (C-Ar), 95.4 (CCl$_3$), 85.6 (C$_1$), 79.4, 76.3, 75.9, 75.0, 74.6, 74.3 (C$_2$, C$_4$, C$_5$, 2OCH$_2$Ph, OCH$_2$CCl$_3$), 57.1 (C$_3$), 25.0 (SCH$_2$CH$_3$), 17.1 (C$_6$), 14.9 (SCH$_2$CH$_3$). ESI-MS for $C_{25}H_{30}Cl_3NO_5S$ (*m/z*): M_r (calcd) 561.09, M_r (found) 584.29 (M+Na)$^+$. Anal. Calcd: C 53.34, H 5.37, N 2.49. Found: C 53.38, H 5.35, N 2.48.

4.1.9. Methyl 2,4-di-O-benzyl-3-deoxy-3-(2,2,2-trichloroethoxycarbonylamino)-α-D-fucopyranosyl-(1→2)-3-O-allyl-4-O-benzyl-β-D-rhamnopyranosyl-(1→3)-2,4-di-O-benzyl-α-D-rhamnopyranoside (**24**)

A mixture of acceptor **23** (34 mg, 0.054 mmol) and donor **6** (60 mg, 0.107 mmol) was coevaporated three times with toluene (2 mL). The residue was mixed with freshly activated AW-300

4 Å molecular sieves, cooled to −40 °C, suspended in 1:1 Et_2O/CH_2Cl_2 (2.0 mL) under Ar atmosphere and then treated with NIS (30 mg, 0.134 mmol) and AgOTf (12 mg, 0.047 mmol). The temperature was allowed to rise gradually to −20 °C. After 1 h stirring at −20 °C, the mixture was diluted with CH_2Cl_2 (30 mL) and washed with 10% $Na_2S_2O_3$ (30 mL) and then with 1 M $NaHCO_3$ (30 mL). The organic layer was collected, dried over anhydrous Na_2SO_4, filtered and concentrated to give a residue that, after column chromatography (10−30% ethyl acetate in petroleum ether), afforded **24** (47 mg, 77%) as a yellowish oil. $[\alpha]_D^{21}$ +145 (*c* 0.7, CH_2Cl_2). ^{1}H NMR ($CDCl_3$, 600 MHz) δ 7.49−7.18 (m, 25H, H-Ar), 5.98−5.92 (m, 1H, OCH_2CH=CH_2), 5.73 (d, $J_{1,2}$=3.3 Hz, 1H, H-1_C), 5.34 (d, *J*=16.8 Hz, 1H, trans OCH_2CH=C*H*H), 5.24 (d, *J*=10.3 Hz, 1H, cis OCH_2CH=C*H*H), 5.14 (d, *J*=10.3 Hz, 1H, OC*H*HPh), 5.07 (d, *J*=12.1 Hz, 1H, OC*H*HPh), 5.01 (d, $J_{H,NH}$=5.1 Hz, 1H, NH), 4.81−4.46 (m, 12H, H-1_A, H-5_C, OCH_2CCl_3, 8OC*H*HPh), 4.38 (br s, 1H, H-1_B), 4.26−4.20 (m, 3H, H-2_B, H-3_C, OC*H*HCH=CH_2), 4.17−4.11 (m, 3H, H-3_A, H-4_C, OC*H*HCH=CH_2), 3.78 (dd, $J_{2,3}$=11.1 Hz, $J_{2,1}$=3.3 Hz, 1H, H-2_C), 3.74−3.67 (m, 2H, H-2_A, H-5_A), 3.56 (t, $J_{4,5}$=$J_{4,3}$=8.8 Hz, 1H, H-4_A), 3.50 (t, $J_{4,5}$=$J_{4,3}$=9.3 Hz, 1H, H-4_B), 3.35 (s, 3H, OCH_3), 3.29 (dd, $J_{3,4}$=9.3 Hz, $J_{3,2}$=2.3 Hz, 1H, H-3_B), 3.21 (dq, $J_{5,4}$=9.3 Hz, $J_{5,6}$=6.0 Hz, 1H, H-5_B), 1.41 (d, $J_{6,5}$=6.2 Hz, 3H, H-6_A), 1.26−1.23 (m, 6H, H-6_B, H-6_C); ^{13}C NMR ($CDCl_3$, 150 MHz) δ 153.9 (CO), 138.9, 138.6, 138.5, 138.1, 138.0 (5C_{ipso}-Bn), 134.6 (OCH_2CH=CH_2), 128.5−126.8 (C-Ar), 117.2 (OCH_2CH=CH_2), 99.0, 97.8, 95.7, 95.1 (C_{1A}, C_{1B}, C_{1C}, CCl_3), 83.6, 80.4, 80.2, 78.9, 76.5, 76.3, 75.1, 74.8, 74.1, 73.5, 73.4, 72.4, 72.0, 71.7, 71.1, 69.9, 67.2, 66.0 (C_{2A}, C_{2B}, C_{2C}, C_{3A}, C_{3B}, C_{4A}, C_{4B}, C_{4C}, C_{5A}, C_{5B}, C_{5C}, 5OCH_2Ph, OCH_2CH=CH_2, OCH_2CCl_3), 54.6, 52.0 (C_{3C}, OCH_3), 18.5, 17.8, 16.8 (C_{6A}, C_{6B}, C_{6C}). MALDI-MS for $C_{60}H_{70}Cl_3NO_{14}$ (*m*/*z*): M_r (calcd) 1133.39, M_r (found) 1156.42 $(M+Na)^+$. Anal. Calcd: C 63.46, H 6.21, N 1.23. Found: C 63.30, H 6.30, N 1.21.

*4.1.10. 4-Methoxyphenyl 2,4-di-O-benzyl-α-D-rhamnopyranoside (**8**)*

Alcohol **7** (90 mg, 0.254 mmol) was dissolved in 1:1:0.1 v/v/v Ac_2OH/Ac_2O/TFA (2.2 mL). The yellow solution was stirred at 70 °C overnight, after that the solution was cooled to 0 °C and water (10 mL) was very carefully added. The solution was diluted with CH_2Cl_2 (50 mL) and washed twice with water (50 mL) and then with 0.1 M $NaHCO_3$ (50 mL). The organic layer was collected, dried over anhydrous Na_2SO_4, filtered and concentrated to give a residue that was mixed with *p*-methoxyphenol (63 mg, 0.508 mmol) and then dissolved at 0 °C in CH_2Cl_2 (2.5 mL) under Ar atmosphere. The solution was then treated with $BF_3\cdot OEt_2$ (9.4 μL, 76.2 μmol), stirred at 0 °C for 2 h, then diluted with CH_2Cl_2 (40 mL) and washed with 1 M $NaHCO_3$ (40 mL). The organic layer was collected, dried over anhydrous Na_2SO_4, filtered and concentrated to give a residue that was dissolved in MeOH (3.0 mL) and *t*-BuOK was added until the solution was strongly basic. The solution was stirred at rt for 40 min, then neutralized with Amberlyst-15 (H^+), filtered and concentrated. The residue was subjected to column chromatography (8−16% ethyl acetate in petroleum ether) to give **8** (56 mg, 62%) as a colourless oil. ^{1}H NMR ($CDCl_3$, 300 MHz) δ 7.42−7.29 (m, 10H, H-Ar), 6.97 (d, J_{ortho}=9.0 Hz, 2H, $C_6H_2H_2OCH_3$), 6.84 (d, J_{ortho}=9.0 Hz, 2H, $C_6H_2H_2OCH_3$), 5.45 (br s, 1H, H-1), 4.95 (d, J_{gem}=11.1 Hz, 1H, OC*H*HPh), 4.82 (d, J_{gem}=11.4 Hz, 1H, OC*H*HPh), 4.70 (d, J_{gem}=11.1 Hz, 1H, OC*H*HPh), 4.68 (d, J_{gem}=11.4 Hz, 1H, OC*H*HPh), 4.21−4.14 (m, 1H, H-3), 3.94 (dd, $J_{2,3}$=3.9 Hz, $J_{2,1}$=1.2 Hz, 1H, H-2), 3.84 (dq, $J_{5,4}$=9.3 Hz, $J_{5,6}$=6.3 Hz, 1H, H-5), 3.78 (s, 3H, $C_6H_4OCH_3$), 3.44 (t, $J_{4,5}$=$J_{4,3}$=9.3 Hz, 1H, H-4), 2.45 (d, $J_{H,OH}$=7.0 Hz, 1H, OH), 1.34 (d, $J_{6,5}$=6.3 Hz, 3H, H-6); ^{13}C NMR ($CDCl_3$, 75 MHz) δ 154.7, 150.2 (2C_{ipso}-MP), 138.3, 137.5 (2C_{ipso}-Bn), 128.5−127.6 (C-Ar), 117.4, 114.5 (C-Ar MP), 95.9 (C_1), 82.1, 78.3 (C_2, C_4), 75.0, 73.1, 71.4, 67.8 (C_3, C_5, 2OCH_2Ph), 55.6 (OCH_3), 18.0 (C_6). ESI-MS for $C_{27}H_{30}O_6$ (*m*/*z*): M_r (calcd) 450.20, M_r (found) 472.97 $(M+Na)^+$. Anal. Calcd: C 71.98, H 6.71. Found: C 71.66, H 6.61.

*4.1.11. 4-Methoxyphenyl 3-O-allyl-2-O-benzenesulfonyl-4-O-benzyl-D-rhamnopyranosyl-(1→3)-2,4-di-O-benzyl-α-D-rhamnopyranoside (**25**)*

From compounds **8** and **9**—a mixture of acceptor **8** (40 mg, 89.7 μmol) and donor **9** (89 mg, 143.5 μmol) was coevaporated three times with toluene (2 mL). The residue was mixed with freshly activated AW-300 4 Å molecular sieves, cooled to −50 °C and suspended in CH_2Cl_2 (3.0 mL) under Ar atmosphere. A 144 μM solution of TMSOTf in CH_2Cl_2 (70 μL, 9.9 μmol) was added. The temperature was allowed to rise gradually to −25 °C. After 2 h stirring at −25 °C, some drops of Et_3N were added. The mixture was filtered over a Celite pad, then concentrated to give a residue that was subjected to column chromatography (1−3% ethyl acetate in toluene) to afford **25α** (42 mg, 53%) as a yellowish oil. As second eluted compound **25β** (28 mg, 35%) was recovered as a yellowish oil.

From compound **26β**—compound **26β** (1.066 g, 1.35 mmol) was dissolved in 1:1:0.1 v/v/v AcOH/Ac_2O/TFA (42 mL). The yellow solution was heated to 70 °C and stirred overnight, after that it was cooled to 0 °C and water (40 mL) was very carefully added. The solution was diluted with CH_2Cl_2 (500 mL) and washed twice with water (500 mL) and then with 0.1 M $NaHCO_3$ (500 mL). The organic layer was collected, dried over anhydrous Na_2SO_4, filtered and concentrated to give a residue that was mixed with *p*-methoxyphenol (336 mg, 2.71 mmol) and then dissolved at 0 °C in CH_2Cl_2 (26 mL) under Ar atmosphere. The solution was then treated with $BF_3\cdot OEt_2$ (50 μL, 0.410 μmol), stirred at 0 °C for 2 h, then diluted with CH_2Cl_2 (200 mL) and washed with 1 M $NaHCO_3$ (200 mL). The organic layer was collected, dried over anhydrous Na_2SO_4, filtered and concentrated to give a residue that was subjected to a column chromatography (1−3% ethyl acetate in toluene) to afford **25β** (772 mg, 65%) as a yellowish oil.

25α: $[\alpha]_D^{21}$ +30 (*c* 0.7, CH_2Cl_2). ^{1}H NMR ($CDCl_3$, 400 MHz) δ 7.55−7.15 (m, 20H, H-Ar), 6.93 (d, J_{ortho}=9.2 Hz, 2H, $C_6H_2H_2OCH_3$), 6.80 (d, J_{ortho}=9.2 Hz, 2H, $C_6H_2H_2OCH_3$), 5.98−5.86 (m, 1H, OCH_2CH=CH_2), 5.35 (d, $J_{2,3}$=3.0 Hz, 1H, H-2_B), 5.28 (d, J_{vic}=17.2 Hz, 1H, trans OCH_2CH=C*H*H),

5.18–5.08 (m, 3H, H-1_A, H-1_B, cis $OCH_2CH{=}CHH$), 4.93 (d, J_{gem}=11.0 Hz, 1H, $OCHHPh$), 4.82 (d, J_{gem}=10.8 Hz, 1H, $OCHHPh$), 4.72 (s, 2H, $2OCHHPh$), 4.64 (d, J_{gem}=11.0 Hz, 1H, $OCHHPh$), 4.60 (d, J_{gem}=10.8 Hz, 1H, $OCHHPh$), 4.46 (d, J_{gem}=14.0 Hz, 1H, OSO_2CHHPh), 4.37 (d, J_{gem}=14.0 Hz, 1H, OSO_2CHHPh), 4.25–4.14 (m, 2H, H-3_A, $OCHHCH{=}CH_2$), 4.06 (dd, 1H, J_{gem}=12.6 Hz, J_{vic}=5.4 Hz, $OCHHCH{=}CH_2$), 3.91–3.76 (m, 7H, H-2_A, H-3_B, H-5_A, H-5_B, $C_6H_4OCH_3$), 3.63 (t, $J_{4,5}$=$J_{4,3}$=9.2 Hz, 1H, H-4_A), 3.39 (t, $J_{4,5}$=$J_{4,3}$=9.4 Hz, 1H, H-4_B), 1.28–1.24 (m, 6H, H-6_A, H-6_B); ^{13}C NMR ($CDCl_3$, 100 MHz) δ 154.9, 150.3 ($2C_{ipso}$-MP), 138.4, 137.9, 137.8 ($3C_{ipso}$-Bn), 134.3 ($OCH_2CH{=}CH_2$), 130.9 (C_{ipso}-SO_2Bn), 128.1–126.3 (C-Ar), 120.5, 117.8, 114.6 (C-Ar MP, $OCH_2CH{=}CH_2$), 99.2, 96.4 (C_{1A}, C_{1B}), 84.6, 80.4, 79.7, 78.2, 77.5, 76.3, 76.2, 75.3, 72.8, 71.4, 68.7, 68.6 (C_{2A}, C_{2B}, C_{3A}, C_{3B}, C_{4A}, C_{4B}, C_{5A}, C_{5B}, $3OCH_2Ph$, $OCH_2CH{=}CH_2$), 57.6, 55.6 (OCH_3, OSO_2CH_2Ph), 18.0, 17.9 (C_{6A}, C_{6B}). MALDI-MS for $C_{50}H_{56}O_{12}S$ (*m*/*z*): M_r (calcd) 880.35, M_r (found) 903.41 $(M+Na)^+$. Anal. Calcd: C 68.16, H 6.41. Found: C 68.04, H 6.38.

25β: $[\alpha]_D^{21}$ +2.8 (*c* 1.0, CH_2Cl_2). ^{1}H NMR ($CDCl_3$, 400 MHz) δ 7.39–7.10 (m, 20H, H-Ar), 6.91 (d, J_{ortho}=9.0 Hz, 2H, $C_6H_2H_2OCH_3$), 6.76 (d, J_{ortho}=9.0 Hz, 2H, $C_6H_2H_2OCH_3$), 6.01–5.89 (m, 1H, $OCH_2CH{=}CH_2$), 5.44 (d, $J_{2,3}$=2.9 Hz, 1H, H-2_B), 5.35 (d, J_{vic}=17.3 Hz, 1H, trans $OCH_2CH{=}CHH$), 5.19 (d, J_{vic}=11.2 Hz, 1H, cis $OCH_2CH{=}CHH$), 5.08 (d, $J_{1,2}$=2.2 Hz, 1H, H-1_A), 4.93 (d, J_{gem}=11.0 Hz, 1H, $OCHHPh$), 4.89 (d, J_{gem}=10.9 Hz, 1H, $OCHHPh$), 4.79 (d, J_{gem}=12.1 Hz, 1H, $OCHHPh$), 4.68 (d, J_{gem}=12.1 Hz, 1H, $OCHHPh$), 4.58 (d, J_{gem}=10.9 Hz, 1H, $OCHHPh$), 4.52–4.47 (m, 4H, H-1_B, $OCHHPh$, OSO_2CH_2Ph), 4.35–4.25 (m, 2H, H-3_A, $OCHHCH{=}CH_2$), 4.05 (dd, J_{gem}=12.4 Hz, J_{vic}=5.6 Hz, 1H, $OCHHCH{=}CH_2$), 3.95 (t, $J_{2,1}$=$J_{2,3}$=2.2 Hz, 1H, H-2_A), 3.82 (dq, $J_{5,4}$=9.0 Hz, $J_{5,6}$=6.3 Hz, 1H, H-5_A), 3.70 (s, 3H, $C_6H_4OCH_3$), 3.60 (t, $J_{4,5}$=$J_{4,3}$=9.0 Hz, 1H, H-4_A), 3.39 (dd, $J_{3,4}$=9.0 Hz, $J_{3,2}$=2.9 Hz, 1H, H-3_B), 3.35 (t, $J_{4,5}$=$J_{4,3}$=9.0 Hz, 1H, H-4_B), 3.28 (dq, $J_{5,4}$=9.0 Hz, $J_{5,6}$=6.0 Hz, 1H, H-5_B), 1.27 (d, $J_{6,5}$=6.0 Hz, 3H, H-6_B), 1.19 (d, $J_{6,5}$=6.3 Hz, 3H, H-6_A); ^{13}C NMR ($CDCl_3$, 100 MHz) δ 154.4, 152.8 ($2C_{ipso}$-MP), 137.8, 137.5, 137.3 ($3C_{ipso}$-Bn), 133.6 ($OCH_2CH{=}CH_2$), 130.4 (C_{ipso}-SO_2Bn), 128.1–127.1 (C-Ar), 117.5, 115.5, 114.3 (C-Ar MP, $OCH_2CH{=}CH_2$), 97.1, 96.6 (C_{1A}, C_{1B}), 79.8, 78.9, 77.2, 76.6, 76.0, 75.3, 75.1, 73.3, 72.3, 71.4, 70.5, 67.8 (C_{2A}, C_{2B}, C_{3A}, C_{3B}, C_{4A}, C_{4B}, C_{5A}, C_{5B}, $3OCH_2Ph$, $OCH_2CH{=}CH_2$), 57.2, 55.3 (OCH_3, SO_2CH_2Ph), 17.8, 17.4 (C_{6A}, C_{6B}). MALDI-MS for $C_{50}H_{56}O_{12}S$ (*m*/*z*): M_r (calcd) 880.35, M_r (found) 903.54 $(M+Na)^+$. Anal. Calcd: C 68.16, H 6.41. Found: C 67.98, H 6.36.

*4.1.12. 4-Methoxyphenyl 3-O-allyl-4-O-benzyl-β-D-rhamnopyranosyl-(1→3)-2,4-di-O-benzyl-α-D-rhamnopyranoside (**27**)*

Disaccharide **25β** (776 mg, 0.882 mmol) was dissolved in dry DMF (15 mL) under Ar atmosphere and then $NaNH_2$ (690 mg, 17.6 mmol) was added. The mixture was stirred at rt for 48 h, after that we added MeOH (60 mL) and then, dropwise, AcOH to neutralize the solution, that was then concentrated. The residue was dissolved in CH_2Cl_2 (300 mL) and washed with 1 M $NaHCO_3$ (300 mL) and brine (300 mL). The organic layer was collected, dried over anhydrous Na_2SO_4, filtered and concentrated to give a residue that, after column chromatography (10–50% ethyl acetate in petroleum ether), afforded **27** (333 mg, 52%) as a yellowish oil. $[\alpha]_D^{21}$ +24.0 (*c* 1.0, CH_2Cl_2). ^{1}H NMR ($CDCl_3$, 300 MHz) δ 7.44–7.26 (m, 15H, H-Ar), 6.98 (d, J_{ortho}=9.0 Hz, 2H, $C_6H_2H_2OCH_3$), 6.80 (d, J_{ortho}=9.0 Hz, 2H, $C_6H_2H_2OCH_3$), 6.16–6.00 (m, 1H, $OCH_2CH{=}CH_2$), 5.46 (d, $J_{1,2}$=2.4 Hz, 1H, H-1_A), 5.39 (d, J_{vic}=17.3 Hz, 1H, trans $OCH_2CH{=}CHH$), 5.27 (d, J_{vic}=11.2 Hz, 1H, cis $OCH_2CH{=}CHH$), 5.00 (d, J_{gem}=12.0 Hz, 1H, $OCHHPh$), 4.97 (d, J_{gem}=11.7 Hz, 1H, $OCHHPh$), 4.87 (d, J_{gem}=12.6 Hz, 1H, $OCHHPh$), 4.73–4.64 (m, 3H, $OCHHPh$), 4.46–4.43 (m, 2H, H-3_A, H-1_B), 4.28 (dd, J_{gem}=12.0 Hz, J_{vic}=6.0 Hz, 1H, $OCHHCH{=}CH_2$), 4.15 (dd, J_{gem}=12.0 Hz, J_{vic}=6.0 Hz, 1H, $OCHHCH{=}CH_2$), 3.98–3.95 (m, 2H, H-2_A, H-2_B), 3.88 (dq, $J_{5,4}$=9.0 Hz, $J_{5,6}$=6.0 Hz, 1H, H-5_A), 3.79 (s, 3H, OCH_3), 3.68 (t, $J_{4,5}$=$J_{4,3}$=9.0 Hz, 1H, H-4_A), 3.53 (t, $J_{4,5}$=$J_{4,3}$=9.0 Hz, 1H, H-4_B), 3.38 (dd, $J_{3,4}$=9.0 Hz, $J_{3,2}$=2.7 Hz, 1H, H-3_B), 3.34 (dq, $J_{5,4}$=9.0 Hz, $J_{5,6}$=6.0 Hz, 1H, H-5_B), 1.36–1.33 (m, 6H, H-6_B, H-6_A); ^{13}C NMR ($CDCl_3$, 50 MHz) δ 154.4, 149.7 ($2C_{ipso}$-MP), 137.8, 137.7, 137.3 ($3C_{ipso}$-Bn), 134.3 ($OCH_2CH{=}CH_2$), 127.9–127.1 (C-Ar), 117.2, 116.3, 114.0 (C-Ar MP, $OCH_2CH{=}CH_2$), 96.9, 96.3 (C_{1A}, C_{1B}), 80.8, 79.3, 79.0, 75.6, 74.9, 74.3, 74.1, 72.1, 71.1, 70.0, 68.2, 67.8 (C_{2A}, C_{2B}, C_{3A}, C_{3B}, C_{4A}, C_{4B}, C_{5A}, C_{5B}, $3OCH_2Ph$, $OCH_2CH{=}CH_2$), 55.1 (OCH_3), 17.6, 17.4 (C_{6A}, C_{6B}). ESI-MS for $C_{43}H_{50}O_{10}$ (*m*/*z*): M_r (calcd) 726.34, M_r (found) 749.57 $(M+Na)^+$. Anal. Calcd: C 71.05, H 6.93. Found: C 71.10, H 6.95.

*4.1.13. 4-Methoxyphenyl 2,4-di-O-benzyl-3-deoxy-3-(2,2,2-trichloroethoxycarbonylamino)-α-D-fucopyranosyl-(1→2)-3-O-allyl-4-O-benzyl-β-D-rhamnopyranosyl-(1→3)-2,4-di-O-benzyl-α-D-rhamnopyranoside (**4**)*

Acceptor **27** (179 mg, 0.246 mmol) was mixed with donor **6** (281 mg, 0.499 mmol). The mixture was coevaporated three times with toluene (5 mL), then mixed with freshly activated AW-300 4 Å molecular sieves, cooled to −40 °C and suspended in 1:1 v/v Et_2O/CH_2Cl_2 (4.0 mL) under Ar atmosphere. The mixture was treated with NIS (141 mg, 0.627 mmol) and AgOTf (54 mg, 0.209 mmol). The temperature was allowed to rise gradually to −20 °C. After 90 min stirring at −20 °C, the mixture was diluted with CH_2Cl_2 (100 mL) and washed with 10% $Na_2S_2O_3$ (100 mL) and then with 1 M $NaHCO_3$ (100 mL). The organic layer was collected, dried over anhydrous Na_2SO_4, filtered and concentrated to give an oily residue. After column chromatography (10–30% ethyl acetate in petroleum ether), **4** (196 mg, 65%) was obtained as a yellowish oil. $[\alpha]_D^{21}$ +130 (*c* 0.5, CH_2Cl_2). ^{1}H NMR ($CDCl_3$, 500 MHz) δ 7.54–7.33 (m, 25H, H-Ar), 7.02 (d, J_{ortho}=9.0 Hz, 2H, $C_6H_2H_2OCH_3$), 6.88 (d, J_{ortho}=9.0 Hz, 2H, $C_6H_2H_2OCH_3$), 6.06–5.98 (m, 1H, $OCH_2CH{=}CH_2$), 5.78 (d, $J_{1,2}$=2.8 Hz, 1H, H-1_C), 5.43 (d, $J_{1,2}$=3.2 Hz, 1H, H-1_A), 5.39 (d, J_{vic}=17.5 Hz, 1H, trans $OCH_2CH{=}CHH$),

5.29 (d, J_{vic}=10.0 Hz, 1H, cis $OCH_2CH{=}CHH$), 5.15 (d, J_{gem}=12.4 Hz, 1H, $OCHHPh$), 5.12 (d, J_{gem}=12.5 Hz, 1H, $OCHHPh$), 5.05 (d, $J_{H,NH}$=4.5 Hz, 1H, NH), 4.87 (d, J_{gem}=12.5 Hz, 1H, $OCHHPh$), 4.79–4.53 (m, 11H, H-1_B, H-5_C, OCH_2CCl_3, $7OCHHPh$), 4.36–4.18 (m, 6H, H-2_B, H-3_A, H-3_C, H-4_C, $OCH_2CH{=}CH_2$), 3.99 (br s, 1H, H-2_A), 3.95 (dq, $J_{5,4}$=9.9 Hz, $J_{5,6}$=6.0 Hz, 1H, H-5_A), 3.87–3.83 (m, 4H, H-2_C, OCH_3), 3.68 (t, $J_{4,5}{=}J_{4,3}$=9.9 Hz, 1H, H-4_A), 3.59 (t, $J_{4,5}{=}J_{4,3}$=9.0 Hz, 1H, H-4_B), 3.39 (dd, $J_{3,4}$=9.0 Hz, $J_{3,2}$=2.4 Hz, 1H, H-3_B), 3.33 (dq, $J_{5,4}$=9.0 Hz, $J_{5,6}$=6.0 Hz, 1H, H-5_B), 1.41 (d, $J_{6,5}$=6.0 Hz, 3H, H-6_C), 1.33 (d, $J_{6,5}$=6.0 Hz, 3H, H-6_B), 1.27 (d, $J_{6,5}$=6.0 Hz, 3H, H-6_A); ^{13}C NMR ($CDCl_3$, 50 MHz) δ 154.9, 153.9, 150.6 (CO, $2C_{ipso}$-MP), 138.8, 138.6, 138.5, 138.0, 137.9 ($5C_{ipso}$-Bn), 134.6 ($OCH_2CH{=}CH_2$), 129.0–125.3 (C-Ar), 118.2, 117.2, 114.5 ($OCH_2CH{=}CH_2$, C-Ar MP), 98.4, 98.1, 95.7, 95.1 (C_{1A}, C_{1B}, C_{1C}, CCl_3), 83.6, 80.8, 80.4, 79.0, 77.1, 76.2, 75.4, 75.1, 74.2, 73.5, 73.2, 72.6, 72.1, 71.6, 71.0, 70.0, 68.0, 66.0 (C_{2A}, C_{2B}, C_{2C}, C_{3A}, C_{3B}, C_{4A}, C_{4B}, C_{4C}, C_{5A}, C_{5B}, C_{5C}, $5OCH_2Ph$, $OCH_2CH{=}CH_2$, OCH_2CCl_3), 55.6, 52.0 (C_{3C}, OCH_3), 18.7, 17.8, 16.8 (C_{6A}, C_{6B}, C_{6C}). MALDI-MS for $C_{66}H_{74}Cl_3NO_{15}$ (*m/z*): M_r (calcd) 1225.41, M_r (found) 1248.64 $(M+Na)^+$. Anal. Calcd: C 64.57, H 6.08, N 1.14. Found: C 64.45, H 6.03, N 1.12.

*4.1.14. 4-Methoxyphenyl 2,4-di-O-benzyl-3-deoxy-3-(2,2,2-trichloroethoxycarbonylamino)-α-D-fucopyranosyl-(1→2)-4-O-benzyl-β-D-rhamnopyranosyl-(1→3)-2,4-di-O-benzyl-α-D-rhamnopyranoside (**28**)*

A solution of **4** (39 mg, 31.7 μmol) in 2:1 v/v MeOH/CH_2Cl_2 (2.1 mL) was treated with $PdCl_2$ (1.7 mg, 9.5 μmol). The mixture was vigorously stirred at rt overnight and then filtered over a Celite pad, diluted with CH_2Cl_2 (30 mL) and washed with water (30 mL). The organic layer was collected, dried over anhydrous Na_2SO_4, filtered and concentrated. The residue was subjected to column chromatography (10% ethyl acetate in toluene) to give **28** (32 mg, 86%) as a colourless oil. $[\alpha]_D^{21}$ +54.4 (*c* 1.5, CH_2Cl_2). ^{1}H NMR ($CDCl_3$, 400 MHz) δ 7.39–7.12 (m, 25H, H-Ar), 6.95 (d, J_{ortho}=9.0 Hz, 2H, $C_6H_2H_2OCH_3$), 6.81 (d, J_{ortho}=9.0 Hz, 2H, $C_6H_2H_2OCH_3$), 5.37 (d, $J_{1,2}$=2.7 Hz, 1H, H-1_A), 5.23 (d, $J_{1,2}$=3.2 Hz, 1H, H-1_C), 4.92 (d, J_{gem}=10.4 Hz, 1H, $OCHHPh$), 4.84–4.24 (m, 14H, $9OCHHPh$, H-1_B, H-3_C, CH_2CCl_3, NH), 3.92–3.86 (m, 3H, H-2_A, H-3_A, H-5_C), 3.77 (s, 3H, OCH_3), 3.73 (dd, $J_{2,3}$=10.9 Hz, $J_{2,1}$=3.2 Hz, 1H, H-2_C), 3.65–3.55 (m, 2H, H-4_C, H-5_A), 3.47 (t, $J_{4,5}{=}J_{4,3}$=8.8 Hz, 1H, H-4_A), 3.34 (br s, 1H, H-2_B), 3.27–3.20 (m, 3H, H-3_B, H-4_B, H-5_B), 1.34 (d, $J_{6,5}$=6.2 Hz, 3H, H-6_C), 1.28–1.25 (m, 6H, H-6_A, H-6_B); ^{13}C NMR ($CDCl_3$, 100 MHz) δ 155.0, 153.9, 150.5 (CO, $2C_{ipso}$-MP), 138.7, 138.6, 138.0, 137.7, 136.7 ($5C_{ipso}$-Bn), 129.1–125.3 (C-Ar), 117.9, 114.6 (C-Ar MP), 99.8, 98.8, 97.8, 95.6 (C_{1A}, C_{1B}, C_{1C}, CCl_3), 82.1, 80.8, 80.6, 80.4, 76.6, 76.5, 76.0, 75.7, 75.6, 75.2, 74.4, 74.3, 73.4, 72.8, 71.6, 68.0, 66.8 (C_{2A}, C_{2B}, C_{2C}, C_{3A}, C_{3B}, C_{4A}, C_{4B}, C_{4C}, C_{5A}, C_{5B}, C_{5C}, $5OCH_2Ph$, OCH_2CCl_3), 55.6, 52.2 (C_{3C}, OCH_3), 18.4, 18.0, 16.7 (C_{6A}, C_{6B}, C_{6C}). MALDI-MS for $C_{63}H_{70}Cl_3NO_{15}$ (*m/z*): M_r (calcd) 1185.38, M_r (found) 1208.43 $(M+Na)^+$. Anal. Calcd: C 63.72, H 5.94, N 1.18. Found: C 63.63, H 6.02, N 1.16.

*4.1.15. 2,4-Di-O-benzyl-3-deoxy-3-(2,2,2-trichloroethoxycarbonylamino)-α-D-fucopyranosyl-(1→2)-3-O-allyl-4-O-benzyl-β-D-rhamnopyranosyl-(1→3)-2,4-di-O-benzyl-α-D-rhamnopyranose (**29**)*

A solution of **4** (130 mg, 0.106 mmol) in 2:2:1 v/v/v toluene/CH_3CN/water (15 mL) was treated with CAN (290 mg, 0.530 mmol) and stirred at rt overnight. The solution was then diluted with ethyl acetate (100 mL) and washed with 1 M $NaHCO_3$ (100 mL) and then with water (100 mL). The organic layer was collected, dried over anhydrous Na_2SO_4, filtered and concentrated to give a residue that, after column chromatography (10–50% ethyl acetate in petroleum ether), afforded **29** (81 mg, 68%; α/β=4.5:1) as a yellowish oil. α-anomer: ^{1}H NMR ($CDCl_3$, 400 MHz) δ 7.42–7.18 (m, 25H, H-Ar), 6.02–5.90 (m, 1H, $OCH_2CH{=}CH_2$), 5.73 (d, $J_{1,2}$=2.8 Hz, 1H, H-1_C), 5.34 (d, J_{vic}=17.2 Hz, 1H, trans $OCH_2CH{=}CHH$), 5.24 (d, J_{vic}=10.3 Hz, 1H, cis $OCH_2CH{=}CHH$), 5.18 (d, $J_{1,2}$=2.3 Hz, 1H, H-1_A), 5.12 (d, J_{gem}=10.5 Hz, 1H, $OCHHPh$), 5.07 (d, J_{gem}=12.0 Hz, 1H, $OCHHPh$), 5.01 (d, $J_{H,NH}$=6.3 Hz, 1H, NH), 4.78–4.13 (m, 18H, H-1_B, H-2_B, H-3_A, H-3_C, H-4_C, H-5_C, $8OCHHPh$, CH_2CCl_3, $OCH_2CH{=}CH_2$), 3.97 (dq, $J_{5,4}$=7.9 Hz, $J_{5,6}$=6.2 Hz, 1H, H-5_A), 3.81–3.74 (m, 2H, H-2_A, H-2_C), 3.59 (t, $J_{4,5}{=}J_{4,3}$=7.9 Hz, 1H, H-4_A), 3.53 (t, $J_{4,5}{=}J_{4,3}$=9.4 Hz, 1H, H-4_B), 3.31 (dd, $J_{3,4}$=9.4 Hz, $J_{3,2}$=1.8 Hz, 1H, H-3_B), 3.23 (dq, $J_{5,4}$=9.4 Hz, $J_{5,6}$=6.2 Hz, 1H, H-5_B), 1.39 (d, $J_{6,5}$=6.1 Hz, 3H, H-6_C), 1.29–1.25 (m, 6H, H-6_A, H-6_B); ^{13}C NMR ($CDCl_3$, 100 MHz) δ 153.9 (CO), 138.8, 138.5, 138.4, 138.0, 137.9 ($5C_{ipso}$), 134.5 ($OCH_2CH{=}CH_2$), 128.7–126.8 (C-Ar), 117.2 ($OCH_2CH{=}CH_2$), 97.9, 95.6, 95.0, 92.6 (C_{1A}, C_{1B}, C_{1C}, CCl_3), 83.5, 80.3, 78.9, 77.6, 76.3, 76.1, 75.3, 75.0, 74.1, 73.5, 73.3, 72.3, 71.9, 71.6, 71.1, 69.9, 67.5, 65.9 (C_{2A}, C_{2B}, C_{2C}, C_{3A}, C_{3B}, C_{4A}, C_{4B}, C_{4C}, C_{5A}, C_{5B}, C_{5C}, $5OCH_2Ph$, OCH_2CCl_3, $OCH_2CH{=}CH_2$), 51.9 (C_{3C}), 18.5, 17.7, 16.7 (C_{6A}, C_{6B}, C_{6C}). MALDI-MS for $C_{59}H_{68}Cl_3NO_{14}$ (*m/z*): M_r (calcd) 1119.37, M_r (found) 1142.73 $(M+Na)^+$. Anal. Calcd: C 63.18, H 6.11, N 1.25. Found: C 63.04, H 6.18, N 1.24.

*4.1.16. 4-Methoxyphenyl 3-acetamido-3-deoxy-α-D-fucopyranosyl-(1→2)-β-D-rhamnopyranosyl-(1→3)-α-D-rhamnopyranoside (**2**)*

A solution of **28** (9.0 mg, 7.6 μmol) in 2:1 v/v AcOH/Ac_2O (900 μL) was treated with Zn/Cu couple (23 mg) and vigorously stirred for 3 days. The mixture was filtered over a Celite pad, then diluted with ethyl acetate (15 mL) and washed with 1 M $NaHCO_3$ (15 mL) and water (15 mL). The organic layer was collected, dried over anhydrous Na_2SO_4, filtered and concentrated to give a residue that was dissolved in 9:1 v/v MeOH/HCOOH (1.0 mL). The solution was treated with a catalytic amount of 10% Pd/C under argon atmosphere. After 2 h in an ultrasound bath, the mixture was filtered over a Celite pad and concentrated. The residue was subjected to a Sephadex G-10 column chromatography with water as eluant. After lyophilization, compound **2** (2.5 mg, 55%) was recovered as

a white waxy solid. $[\alpha]_D^{21}$ −224 (*c* 0.2, water). ^{1}H NMR (D_2O, 400 MHz) (see also Table 1) δ 7.20 (d, J_{ortho}=9.0 Hz, 2H, $C_6H_2H_2OCH_3$), 7.08 (d, J_{ortho}=9.0 Hz, 2H, $C_6H_2H_2OCH_3$), 3.89 (s, 3H, OCH_3), 1.98 (s, 3H, Ac); ^{13}C NMR (D_2O, 100 MHz) (see also Table 1) δ 176.0 (CO), 150.0, 147.5 ($2C_{ipso}$-MP), 120.3, 116.4 (C-Ar MP), 56.8 (OCH_3), 24.1 ($COCH_3$). MALDI-MS for $C_{27}H_{41}NO_{14}$ (*m*/*z*): M_r (calcd) 603.25, M_r (found) 626.26 $(M+Na)^+$. Anal. Calcd: C 53.72, H 6.85, N 2.32. Found: C 53.50, H 6.99, N 2.29.

Acknowledgements

NMR and MS facilities of CIMCF (Centro Interdipartimentale di Metodologie Chimiche Fisiche) are acknowledged.

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