Pergamon

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Tetrahedron: *Asymmetry* 14 (2003) 1819–1827

TETRAHEDRON: *ASYMMETRY*

Anionic versus photochemical diastereoselective deconjugation of diacetone D-glucose α,β-unsaturated esters

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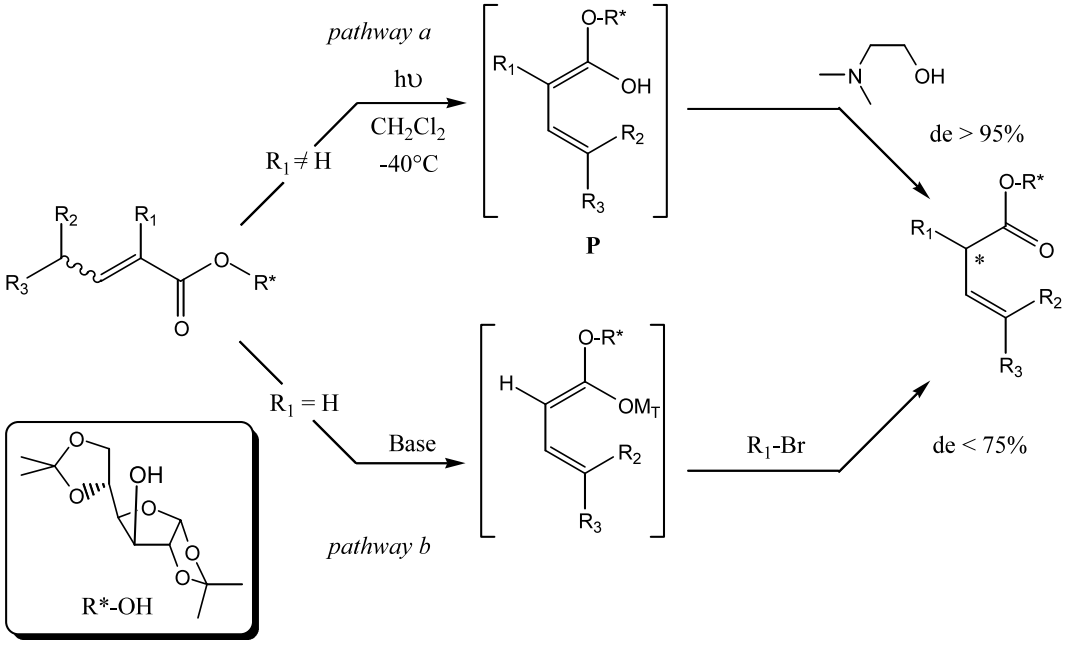
Received 11 March 2003; accepted 2 May 2003

Abstract—Deconjugation of diacetone D-glucose α,β-unsaturated esters has been conducted by deprotonation using NaHMDS with HMPA as co-solvent followed by stereoselective protonation at low temperature. High selectivities (>95%) were obtained with α-methyl linear compounds. © 2003 Elsevier Science Ltd. All rights reserved.

1. Introduction

Some years ago, we reported an efficient diastereoselective photodeconjugation procedure (de >95%) of α,β-unsaturated esters using diacetone D-glucose as a chiral auxiliary[1] (Scheme 1, pathway a). Under UV irradiation, conjugated esters underwent a 1,5-sigmatropic hydrogen shift leading to a prochiral photodienol **P**, which was in situ protonated by an achiral aminoalcohol, such as *N*,*N*-dimethylaminoethanol. This reaction has been successfully applied to the synthesis of natural products, for example (*R*)-lavandulol[2a] and more recently, for related terpenes by Bach et al.[2b] We also found that pantolactone, available in both enantiomeric



Scheme 1.

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doi:10.1016/S0957-4166(03)00365-3

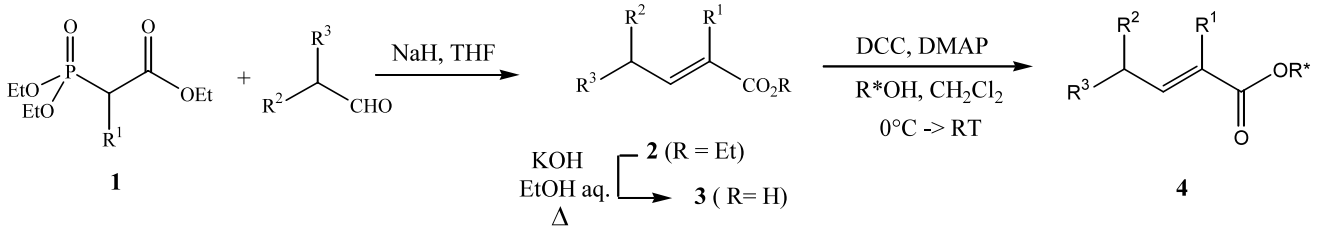
forms, could be an alternative candidate to achieve high selectivities during the protonation step,[2c] while Hénin and Muzart have reported the reaction performed with chiral ammonium carboxylates.[3]

We devised also an alternative, anionic, procedure in which the isomerisation of the C=C bond was combined with an α-alkylation process (Scheme 1, pathway b). Starting from diacetone D-glucose α-unsubstituted conjugated esters ($R_1 = H$), we were able to obtain β,γ-unsaturated isomers in good yields but with lower diastereoselectivities (de <75%) compared to the photochemical reaction.[4] It should be noted that curiously, the sense of the induction was the same for both methods using the same chiral alkoxy group.

2. Results and discussion

As part of a program devoted to the synthesis of amphidinolide R, a complex natural product,[5] we needed to prepare (*R*)-2-methyl-3-hepten-1-ol on a large scale and enantiomerically pure. Photodeconjugation of ester **4a** appeared therefore as a convenient way to this end. The starting material and other related substrates **4b–g** were prepared according to a three-step sequence depicted in Scheme 2 and Table 1.

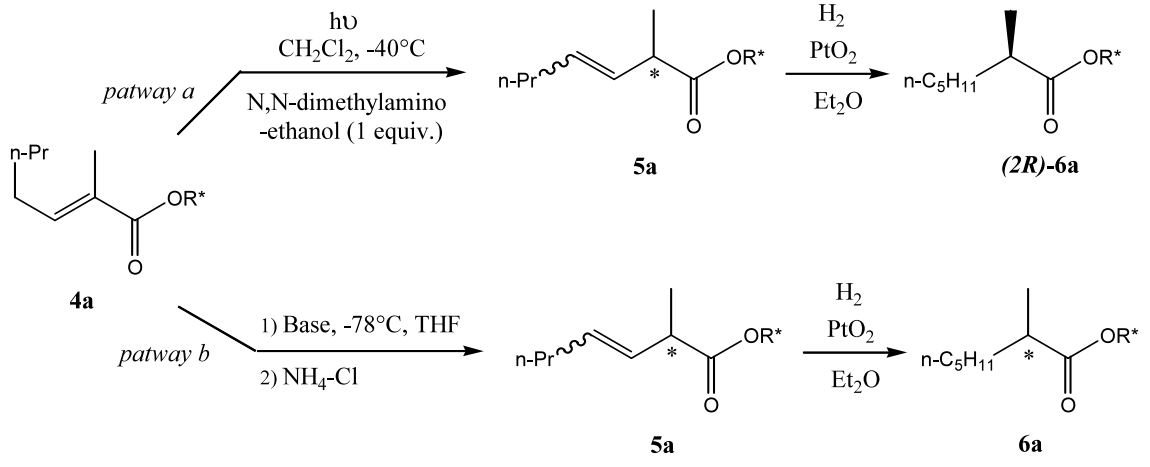
Under irradiation at –40°C, ester **4a** was smoothly converted into β,γ-unsaturated isomer **5a** (Scheme 3, pathway a). The diastereoselectivity measured on **6a**, obtained after reduction of the C=C bond was >95% as previously observed with similar substrates. Reduction with $LiAlH_4$ afforded the corresponding alcohol for which the absolute configuration is known. By comparison of the sign of rotation, the (*R*) configuration was unambiguously attributed to the new stereogenic centre and this configuration was similar to those already obtained for related substrates.[1] However, due to the high dilution conditions (10^{-2} M), the photochemical procedure was difficult to scale up, and therefore we decided to study the deconjugation by action of a base on **4a** (Scheme 3, pathway b). It should be noted that isomerisation of α,β-unsaturated carboxylic deriva-



Scheme 2.

Table 1. Preparation of unsaturated esters **4a–e**

Ester **2**	R^1	R^2	R^3	*E*/*Z*	Yield	Acid **3**	Ester **4**
2a	Me	H	*n*-Propyl	90/10	73%	**3a** 85%	**4a** 85%
2b	Me	H	*n*-Hexyl	85/15	95%	**3b** 72%	**4b** 73%
2c	*i*-Pr	H	*n*-Propyl	87/13	60%	**3c** 95%	**4c** 73%
2d	F	H	*i*-Pr	98/2	87%	**3d** 71%	**4d** 72%
2e	*n*-Bu	H	Me	60/40	81%	**3e** 91%	**4e** 84%



Scheme 3.

tives has been scarcely described under anionic conditions[6] and to our knowledge, no powerful method using readily available chiral entities has been reported.

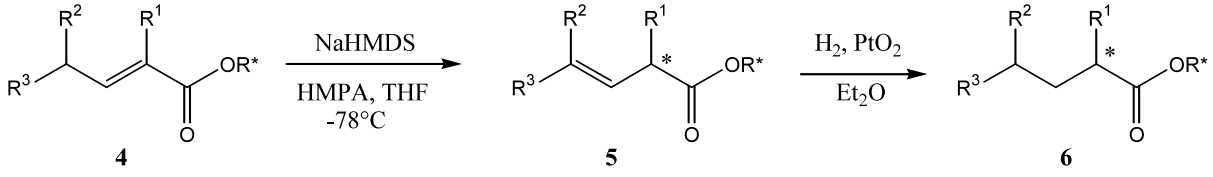
First attempts performed at low temperature on **4a** using LDA were disappointing. Fortunately, the replacement of the lithium base by NaHMDS was highly beneficial and β,γ-unsaturated ester **5a** was isolated in good yield as a mixture of *E*/*Z* isomers. However, the selectivity determined from the reduced compound **6a** was moderate. This low value could be relayed apparently to a low control of the *E*/*Z* selectivity of the enolate. In order to modify this ratio, we decided to add as a co-solvent HMPA, which is well known to favour the *Z*-enolate.[7] The diastereoselectivity obtained in this case for **6a** was >95%, which shows unambiguously the importance of the configuration of the pre-formed enolate. Other additives like DMPU were not so efficient and only partial deconjugation was observed. By using the most efficient conditions, the reaction was next generalised to other α-substituted α,β-unsaturated esters **4b–g** bearing the same diacetone D-glucose moiety (Scheme 4 and Table 2).

While a similar selectivity was observed with parent ester **4b** (de >95%), results with other substrates were disappointing. The presence of a bulkier group (R = *i*-Pr for **4c** or *n*-butyl for **4e**) on carbon 2 affected considerably the level of induction and only poor de values were measured for saturated esters **6c** and **6e**. Ester **4f**, which is usually a substrate of choice to deliver under UV activation the β,γ-unsaturated isomer was totally recovered unchanged under the anionic conditions. This lack of reactivity could be due either to an unfavourable formation of the dienolate because of steric hindrance, either to its rapid protonation at the γ-position to avoid 1,3-allylic interactions. To determine the exact reason of this surprising unreactivity of **4f**, ester **5f** already prepared by the photochemical process in high de (95%)[1] was submitted to the same anionic conditions (NaHMDS) at low temperature. In this case, the compound was recovered intact with still the same diastereoselectivity and no traces of ester **4f** were detected in the crude mixture. Consequently, we have attributed the lack of reactivity to steric difficulties in abstracting the γ-proton.

Under basic conditions, α-fluoroester **4d** led to considerable degradation and diacetone D-glucose was the sole compound isolated. This could be explained by the formation of a ketene as already pointed out by Kunz et al. during alkylation of related saturated diacetone D-glucose esters.[8,9] For tiglate ester **4g**, the formation of isomer **5g** was partially observed by ^{1}H NMR on the crude mixture; unfortunately, attempts to purify this compound from the basic reaction mixture was unsuccessful and the starting material **4g** was mainly recovered.

The absolute configuration of the new stereogenic centres for **5a** and **5b** were determined by comparison with data already obtained from the photochemical process. The major diastereomer isolated was the same in both cases. This indicates that asymmetric protonation occurs on the same face probably due to very similar transition states.

One of the major drawbacks of the photochemical process is the impossibility to carry out the reaction with esters connected to small or medium rings; therefore the isomerisation procedure under basic conditions appears very attractive because of the relative importance of such compounds in total synthesis. Recently, Trost et al. reported an effective isomerisation of cycloalkene carboxylates bearing various chiral auxiliaries and selectivities up to 66% were recorded with a

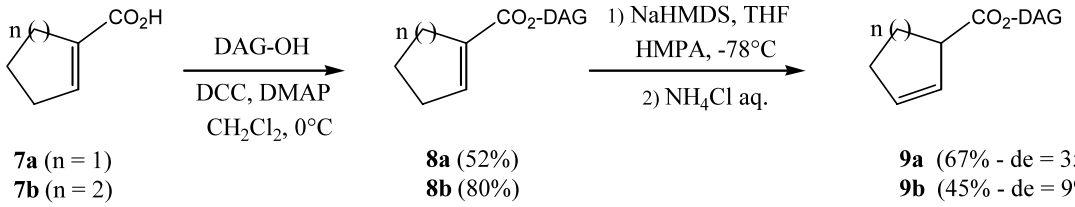


Scheme 4.

Table 2. Asymmetric deconjugation of diacetone D-glucose esters **4a–g**

4	R^1	R^2	R^3	Conversion	**5** Yield	*E*/*Z*	**6** (de)[a]	**6** Yield
a	Me	H	*n*-Propyl	>99%	77%	60/40	>95%	93%
b	Me	H	*n*-Hexyl	>99%	80%	65/35	>95%	73%
c	*i*-Pr	H	*n*-Propyl	>99%	83%	60/40	20%	95%
d	F	H	*i*-Pr	>99%	[b]	–	–	–
e	*n*-Bu	H	Me	52%	48%	60/40	25%	85%
f[c]	Me	Me	Me	0%	0%	–	–	–
g[c]	Me	H	H	>99%	0%[d]	–	–	–

[a] De measured using ^{1}H or ^{13}C NMR spectra.
[b] Diacetone D-glucose was the sole product isolated.
[c] Previously synthesised (Ref. 1).
[d] Reconjugation apparently occurred during the purification on silica.



Scheme 5.

menthyl derivative.[10] Similarly, diacetone D-glucose esters **8a** and **8b** were prepared from 2-cyclopentenoic and 2-cyclohexenoic acid and submitted to the same anionic conditions, as reported for compounds **4a–g**. Isomerisation occurred and furnished esters **9a** or **9b** in acceptable yields but with low diastereoselectivities of 35 and only 9%, respectively (Scheme 5).

3. Conclusion

The efficiency of both photochemical and anionic reactions can finally be compared. While the photochemical process was observed with a large number of substrates, the anionic version described therein is much easier to carry out onto a large scale but is efficient in only a few cases. The selectivities and the configuration of the new stereogenic centre are similar, which indicates that the dienol and dienolate intermediates are selectively protonated on the same diastereotopic face. According to previous diastereoselective protonations of enolates,[11] it could be assumed that the selectivities observed resulted from a kinetic *C*-protonation by ammonium chloride. While diacetone glucose is a readily available reagent, this non-photochemical approach could be attractive for direct applications in total synthesis.

4. Experimental

The ^{1}H, ^{13}C and ^{19}F NMR spectra were recorded in $CDCl_3$ using a Bruker AM 300 or a DRX 500 instrument. FT-IR were recorded on a Perkin–Elmer Spectrum One instrument. Optical rotations were measured on a Perkin–Elmer 343 spectrometer. Mass spectra were obtained on a Finigan-MAT 95XL instrument. Flash-chromatographies were performed on silica gel 60 (40–63 mesh).

4.1. Triethyl 2-phosphonohexanoate, 1e

Ethyl 2-bromohexanoate (12.21 g, 54.72 mmol) and triethylphosphite (18.8 ml (109.44 mmol) were heated under reflux overnight. After removal of ethyl bromide by distillation under atmospheric pressure, compound **1e** (12.17 g, 43.46 mmol) was obtained pure by distillation under vacuum. Yield 80%. $Bp_{0.05}$ = 76–78°C. ^{1}H NMR ($CDCl_3$): δ 4.00–4.30 (m, 6H), 2.18 (dddd,, J= 0.7, 3.9, 10.8 and 22.5 Hz, 1H), 1.70–2.05 (m, 3H), 1.20–1.45 (m, 12H), 0.89 (t, J=6.8 Hz, 3H). ^{13}C NMR ($CDCl_3$): δ 13.7, 14.1, 16.3, 22.1, 26.6, 30.4 (d, J=15.2 Hz), 45.8 (d, J=131.3 Hz), 61.9 (d, J=89.4 Hz), 169.2. MS: m/z 281 ($M^{+\bullet}$+1, 100), 230 (51), 152 (28), 151 (29), 111 (35).

4.2. General procedure for the synthesis of unsaturated ethyl esters 2

To a suspension of sodium hydride (22 mmol) in anhydrous THF (60 ml) was added dropwise a solution of phosphonoacetate **1** (22 mmol) in THF (20 ml). After 90 min at rt, a solution of aldehyde (20 mmol) in the same solvent was slowly added. The resulting mixture was stirred overnight, hydrolysed carefully with wet ether; the organic layer was washed with brine, dried on $MgSO_4$ and concentrated under vacuo. The crude mixture was purified by flash-chromatography on silica (eluent: AcOEt/hexanes: 3/97).

4.2.1. Ethyl 2-methyl-2-heptenoate, 2a.[12] Yield 73% (*E*/*Z*=90/10). ^{1}H NMR ($CDCl_3$): *E*-isomer: δ 6.75 (tq, J=7.3 and 1.1 Hz, 1H), 4.14 (q, J=7.3 Hz, 2H), 2.17 (dt, J=7.0 and 7.0 Hz, 2H), 1.82 (s, 3H), 1.5–1.2 (m, 2H), 0.93 (t, J=7.3 Hz, 3H). *Z*-isomer: δ 5.91 (tq, J=7.7 and 1.1 Hz, 1H), 4.18 (q, J=7.35 Hz, 2H), 2.43 (m, 2H), 1.82 (s, 3H), 1.5–1.2 (m, 2H), 0.93 (t, J=7.30 Hz, 3H).

4.2.2. Ethyl 2-methyl-2-decenoate, 2b.[13] Yield 95% (*E*/*Z*=85/15). ^{1}H NMR ($CDCl_3$): *E*-isomer: δ 6.76 (tq, J=7.35 and 1.4 Hz, 1H), 4.19 (q, J=7.35 Hz, 2H), 2.16 (dt, J=7.35 and 7.35 Hz, 2H), 1.82 (s, 3H), 1.5–1.2 (m, 13H), 0.88 (t, J=7.35 Hz, 3H). *Z*-isomer: δ 5.92 (tq, J=7.35 and 1.6 Hz, 1H), 4.19 (q, J=7.35 Hz, 2H), 2.38 (dt, J=7.35 and 7.35 Hz, 2H), 1.89 (s, 3H), 1.5–1.2 (m, 13H), 0.88 (t, J=7.35 Hz, 3H). ^{13}C NMR ($CDCl_3$): *E*-isomer: δ 168.3, 142.4, 127.6, 60.3, 31.7, 29.3, 29.1, 28.6, 22.6, 20.6, 14.2, 14.0, 12.2. *Z*-isomer: δ 168.3, 142.9, 127.4, 59.9, 31.7, 29.6, 29.1, 28.5, 22.6, 20.6, 14.2, 14.0, 12.2. IR: ν=2960, 2920, 2860, 1720, 1650, 1470, 1270 cm^{-1}. MS: m/z 213 ($M^{+\bullet}$+1), 113, 100, 74. Anal. calcd for $C_{13}H_{24}O_2$: C, 73.54; H, 11.39. Found: C, 73.85; H, 11.68.

4.2.3. Ethyl 2-isopropyl-2-heptenoate, 2c. Yield 60% (*E*/*Z*=13/87). ^{1}H NMR ($CDCl_3$): *E*-isomer: δ 6.56 (t, J=7.35 Hz, 1H), 4.19 (q, J=7.4 Hz, 2H), 2.90 (hept, J=6.6 Hz, 1H), 2.19 (dt, J=7.4 and 7.35 Hz, 2H), 1.20–1.50 (m, 7H), 1.17 (d, J=6.6 Hz, 6H), 0.90 (t, J=6.6 Hz, 3H). *Z*-isomer: δ 5.68 (t, J=6.6 Hz, 1H), 4.22 (q, J=7.35 Hz, 2H), 2.68 (hept, J=6.6 Hz, 1H), 2.28 (dt, J=7.4 and 7.35 Hz, 2H), 1.20–1.50 (m, 7H), 1.05 (d, J=6.6 Hz, 6H), 0.90 (t, J=6.6 Hz, 3H). ^{13}C NMR ($CDCl_3$): *E*-isomer: δ 167.7, 140.8, 137.8, 59.9,

31.2, 29.7, 27.7, 27.3, 20.9, 14.2, 13.8. *Z*-isomer: δ 168.1, 139.0, 135.1, 59.9, 31.9, 31.4, 29.3, 22.7, 22.2, 14.2, 13.8. IR: 2960, 2930, 2870, 1715, 1640, 1465, 1380, 1255 cm^{-1}. MS: m/z 198 ($M^{+\bullet}$), 183, 169, 155, 153, 109.

4.2.4. (*E*)-Ethyl 2-fluoro-5-methyl-2-hexenoate, 2d.[14] Yield 87%. ^1H NMR ($CDCl_3$): δ 5.92 (dt, $J=22.1$ Hz, $J=8.2$ Hz, 1H), 4.29 (q, $J=7.1$ Hz, 2H), 2.42 (ddd, $J=8.4$ Hz, $J=6.9$ Hz, $J=1.8$ Hz, 2H), 1.72 (m, 1H), 1.33 (t, $J=7.1$ Hz, 3H), 0.90 (d, $J=6.9$ Hz, 6H). ^{13}C NMR ($CDCl_3$): δ 161.0 (d, $J=35.7$ Hz), 144.2 (d, $J=250.3$ Hz), 122.3 (d, $J=17.8$ Hz), 61.1, 34.6, 28.6, 22.1, 14.0. ^{19}F NMR ($CDCl_3$): −122.0 (d, $J=22.3$ Hz). IR: 2960, 2870, 1730, 1666, 1465, 1380, 1215 cm^{-1}.

4.2.5. Ethyl 2-butyl-2-pentenoate, 2e. Yield 81% (*E*/*Z*= 60/40). ^1H NMR ($CDCl_3$): *E*-isomer: δ 6.70 (t, $J=7.4$ Hz, 1H), 4.17 (q, $J=7.2$ Hz, 2H), 2.27 (t, $J=7.4$ Hz, 2H), 2.17 (quint, $J=7.5$ Hz, 2H), 1.20–1.48 (m, 4H), 1.28 (t, $J=7.1$ Hz, 3H), 1.04 (t, $J=7.4$ Hz, 3H), 0.89 (t, $J=7.1$ Hz, 3H). *Z*-isomer: δ 5.81 (t, $J=7.3$ Hz, 1H), 4.20 (q, $J=7.2$ Hz, 2H), 2.39 (quint, $J=7.5$ Hz, 2H), 2.23 (t, $J=6.6$ Hz, 2H), 1.20–1.48 (m, 4H), 1.29 (t, $J=7.1$ Hz, 3H), 1.01 (t, $J=7.5$ Hz, 3H), 0.89 (t, $J=7.0$ Hz, 3H). ^{13}C NMR ($CDCl_3$): *E*-isomer: δ 168.1, 143.6, 132.1, 60.2, 31.6, 26.38, 22.6, 21.8, 14.2, 13.9, 13.4. *Z*-isomer: δ 168.1, 142.4, 131.9, 59.9, 34.2, 31.3, 22.9, 22.2, 14.2, 13.9, 13.6. MS: m/z 184 ($M^{+\bullet}$, 22), 167, 149, 127, 113, 69. Anal. calcd for $C_{11}H_{20}O_2$: C, 71.69; H, 10.94. Found: C, 71.76; H, 11.24.

4.3. Cleavage of ethyl esters 2

Ethyl ester **2** (15 mmol) diluted in ethanol (5 ml) was added to a solution of potassium hydroxide (1.23 g, 22.05 mmol) in ethanol (95 ml) and water (5 ml). The mixture was heated for 3 h under reflux, cooled to rt, half-concentrated under vacuum and acidified with a 2N H_2SO_4 solution. After extraction with petroleum ether, the organic phase was dried over $MgSO_4$, filtered and concentrated. The resulting oil was purified by flash-chromatography or used directly without further purification.

4.3.1. 2-Methyl-2-heptenoic acid, 3a.[15] Yield 85% (*E*/*Z*=97/3). ^1H NMR ($CDCl_3$): *E*-isomer: δ 10.5–12.5 (s, 1H), 6.92 (tq, $J=7.35$ and 1.5 Hz, 1H), 2.20 (dt, $J=7.36$ and 6.61 Hz, 2H), 1.83 (d, $J=1.5$ Hz, 3H), 1.20–1.50 (m, 4H), 0.91 (t, $J=7.4$ Hz, 3H). *Z*-isomer: δ 10.5–12.5 (s, 1H), 6.09 (qt, $J=7.35$ and 1.4 Hz, 1H), 2.51 (m, 2H), 1.91 (s, 3H), 1.21–1.50 (m, 4H), 0.91 (t, $J=7.4$ Hz, 3H).

4.3.2. 2-Methyl-2-decenoic acid, 3b.[16] Yield 72% (*E*/*Z*= 93/7). ^1H NMR ($CDCl_3$): *E*-isomer: δ 10.5–11.5 (sl, 1H), 6.92 (tq, $J=7.4$ and 1.5 Hz, 1H), 2.20 (dt, $J=7.4$ and 5.15 Hz, 2H), 1.83 (s, 3H), 1.20–1.50 (m, 10H), 0.88 (t, $J=6.6$ Hz, 3H). *Z*-isomer: δ 10.5–11.5 (sl, 1H), 6.09 (tq, $J=7.35$ and 1.47 Hz, 1H), 2.51 (m, 2H), 1.83 (s, 3H), 1.20–1.50 (m, 10H), 0.88 (t, $J=6.6$ Hz, 3H). ^{13}C NMR ($CDCl_3$): *E*-isomer: δ 173.6, 145.7, 127.0, 31.8, 29.3, 29.1, 28.9, 28.5, 22.6, 14.1, 11.9. *Z*-isomer: δ 173.6, 146.9, 126.1, 31.8, 29.8, 29.1, 28.9, 28.5, 20.4, 14.1, 11.9. IR: 3060, 2960, 2920, 2860, 2660, 2550, 1690, 1640, 1430, 1380, 1290 cm^{-1}. MS: m/z 185 (M+1), 100.

4.3.3. 2-Isopropyl-2-heptenoic acid, 3c. Yield 95% (*E*/*Z*=18/82). ^1H NMR ($CDCl_3$): *E*-isomer: δ 11.5–12.5 (m, 1H), 6.78 (t, $J=7.35$ Hz, 1H), 2.29 (hept, $J=7.35$ Hz, 1H), 1.20–1.55 (m, 6H), 1.04 (d, $J=7.35$ Hz, 6H), 0.89 (t, $J=7.4$ Hz, 3H). *Z*-isomer: δ 11.5–12.5 (m, 1H), 5.91 (t, $J=7.35$ Hz, 1H), 2.42 (hept, $J=7.35$ Hz, 1H), 1.20–1.50 (m, 6H), 1.04 (d, $J=7.35$ Hz, 6H), 0.89 (t, $J=7.4$ Hz, 3H).

4.3.4. (*E*)-2-Fluoro-5-methyl-2-hexenoic acid, 3d. Yield 71%. ^1H NMR ($CDCl_3$): 6.11 (dt, $J=21.3$ Hz, $J=8.0$ Hz, 1H), 2.45 (ddd, $J=8.8$ Hz, $J=6.6$ Hz, $J=2.2$ Hz, 2H), 1.74 (m, 1H), 0.92 (d, $J=6.6$ Hz, 6H). ^{13}C NMR ($CDCl_3$): δ 166.0 (d, $J=37.1$ Hz), 146.6 (d, $J=247.6$ Hz), 125.4 (d, $J=17.6$ Hz), 61.1, 34.4, 28.7, 22.1. ^{19}F NMR ($CDCl_3$): −122.1 (d, $J=21.9$ Hz). IR: 3090, 2960, 2870, 2660, 2550, 1705, 1665, 1440, 1240, 1115 cm^{-1}.

4.3.5. (*E*)-2-Butyl-2-pentenoic acid, 3e. Yield 91% (*E*/*Z*=60/40). ^1H NMR ($CDCl_3$): *E*-isomer: δ 11.50–11.85 (m, 1H), 6.89 (t, $J=7.4$ Hz, 1H), 2.51 (dq, $J=7.50$ and 7.66 Hz, 1H), 2.10–2.35 (m, 3H), 1.15–1.55 (m, 4H), 1.06 (t, $J=7.5$ Hz, 3H), 0.91 (t, $J=7.2$ Hz, 3H). *Z*-isomer: δ 11.50–11.90 (m, 1H), 6.00 (t, $J=7.4$ Hz, 1H), 2.16–2.51 (m, 4H), 1.15–1.55 (m, 4H), 1.10 (t, $J=7.5$ Hz, 3H), 0.89 (t, $J=7.2$ Hz, 3H). ^{13}C NMR ($CDCl_3$): *E*-isomer: δ 173.9, 146.8, 131.4, 34.0, 31.5, 26.1, 22.6, 22.1, 13.9. *Z*-isomer: δ 173.9, 146.9, 130.7, 34.0, 31.4, 26.1, 23.2, 22.3, 13.2. Anal. calcd for $C_9H_{16}O_2$: C, 69.19; H, 10.32. Found: C, 69.43; H, 10.56.

4.4. Conversion of acids 3 and 7 into diacetone D-glucose esters 4 and 8

Typical procedure: To a solution of acid **3** (or **7**) (10 mmol) in methylene chloride (10 ml) were successively added DMAP (0.366 g, 3 mmol) and diacetone D-glucose (2.60 g, 10 mmol). The reaction was next cooled to 0°C and a solution of dicyclohexylcarbodiimide (2.06 g, 10 mmol) in the same solvent (3 ml) was dropwise added. After stirring for 10 min at 0°C, the ice–water bath was removed and the mixture was stirred overnight at rt. Urea was filtered off and the solvent removed by concentration under vacuo. Ester **4** (or **8**) was obtained pure by flash-chromatography (eluent: AcOEt/hexanes: 10/90).

4.4.1. (*E*)-(1,2;5,6-Di-*O*-isopropylidene-D-glucofuranose-3-*O*-yl) 2-methyl-2-heptenoate, 4a. Yield 85% (*E*/*Z*=90/10). ^1H NMR ($CDCl_3$): δ 6.77 (tq, $J=7.36$ and 1.47 Hz, 1H), 5.87 (d, $J=3.67$ Hz, 1H), 5.26 (d, $J=1.47$ Hz, 1H), 4.51 (d, $J=3.67$ Hz, 1H), 4.26 (d, $J=2.2$ Hz, 1H), 4.2–4.3 (m, 1H), 4.2–3.9 (m, 2H), 2.16 (q, $J=7.35$ Hz, 2H), 1.82 (d, $J=1.47$ Hz, 3H), 1.51 (s, 3H), 1.39 (s, 3H), 1.28 (s, 6H), 1.45–1.2 (m, 4H), 0.89 (t, $J=7.35$ Hz, 3H). ^{13}C NMR ($CDCl_3$): δ 167.0, 142.6, 127.4, 112.5, 109.5, 105.4, 83.7, 80.3, 76.2, 73.0, 67.5, 28.8, 27.1, 27.1, 26.9, 26.5, 22.8, 14.2, 12.6. IR: 2990, 2960, 2930, 2870, 1720, 1650, 1460, 1370 cm^{-1}. MS: m/z 385 ($M^{+\bullet}$+1), 327. UV (CH_2Cl_2): $\varepsilon_{238}=2570$. $[\alpha]_D^{21}=-28$ (*c* 1.0,

CH_2Cl_2). HRMS calcd for $C_{20}H_{33}O_7$: 385.2227. Found: 385.2226.

4.4.2. (*E*)-(1,2;5,6-Di-*O*-isopropylidene-D-glucofuranose-3-*O*-yl) 2-methyl-2-decenoate, 4b. Yield 73%. ^{1}H NMR ($CDCl_3$): δ 6.78 (tq, $J=7.4$ and 1.4 Hz, 1H), 5.88 (d, $J=3.7$ Hz, 1H), 5.28 (d, $J=2.2$ Hz, 1H), 4.53 (d, $J=3.7$ Hz, 1H), 4.2–4.3 (m, 2H), 4.0–4.2 (m, 2H), 2.07 (dt, $J=7.4$ and 7.3 Hz, 2H), 2.04 (s, 3H), 1.83 (s, 3H), 1.82 (s, 3H), 1.52 (s, 3H), 1.30 (s, 3H), 1.36–1.22 (m, 10H), 0.88 (t, $J=6.6$ Hz, 3H). ^{13}C NMR ($CDCl_3$): δ 166.7, 144.1, 127.1, 112.2, 109.2, 105.9, 83.4, 80.0, 76.3, 72.7, 67.2, 31.7, 29.3, 29.0, 28.8, 28.5, 26.7, 26.7, 26.2, 25.2, 22.6, 14.0, 12.3. IR: 2990, 2930, 2850, 1720, 1650, 1460, 1370 cm^{-1}. MS: m/z 443 ($M^{+\bullet}$+1), 100. $[\alpha]_D^{21}=-33$ (c 1.0, CH_2Cl_2). Anal. calcd for $C_{23}H_{38}O_7$: C, 64.76; H, 8.98. Found: C 64.69; H, 9.43.

4.4.3. (1,2;5,6-Di-*O*-isopropylidene-D-glucofuranose-3-*O*-yl) 2-isopropyl-2-heptenoate, 4c. Yield 73% ($E/Z=90/10$). ^{1}H NMR ($CDCl_3$): *E*-isomer: δ 6.58 (t, $J=7.4$ Hz, 1H), 5.86 (d, $J=3.7$ Hz, 1H), 5.30 (d, $J=1.4$ Hz, 1H), 4.52 (d, $J=3.7$ Hz, 1H), 3.90–4.20 (m, 4H), 2.68 (hept, $J=7.4$ Hz, 1H), 1.90–2.10 (m, 4H), 1.53 (s, 3H), 1.40 (s, 3H), 1.29 (s, 6H), 1.20–1.45 (m, 2H), 0.89–0.95 (m, 9H). ^{13}C NMR ($CDCl_3$): *E*-isomer: δ 167.1, 142.1, 126.3, 112.1, 109.2, 105.1, 83.4, 80.1, 75.8, 73.0, 67.5, 57.2, 28.8, 27.2, 27.1, 26.9, 26.5, 22.8, 13.8, 13.4. IR: 2960, 2930, 2870, 1740, 1630, 1450, 1370, 1220 cm^{-1}. MS: m/z 413 ($M^{+\bullet}$+H$^+$), 397, 355, 153. $[\alpha]_D^{21}=-21$ (c 1.0, CH_2Cl_2). HRMS calcd for $C_{22}H_{37}O_7$: 413.2539. Found: 413.2534.

4.4.4. (1,2;5,6-Di-*O*-isopropylidene-D-glucofuranose-3-*O*-yl) 2-fluoro-5-methyl-2-hexenoate, 4d.[2d] Yield 72%. ^{1}H NMR ($CDCl_3$): δ 5.97 (dt, $J=21.3$ Hz, $J=8.1$ Hz, 1H), 5.91 (d, $J=3.7$ Hz, 1H), 5.36 (s, 1H), 4.55 (d, $J=3.7$ Hz, 1H), 4.26–4.21 (m, 2H), 4.13–4.00 (m, 2H), 2.43 (ddd, $J=8.1$, 6.6 Hz and 1.5 Hz, 1H), 1.71 (m, 1H), 1.53 (s, 3H), 1.41 (s, 3H), 1.31 (s, 6H), 0.94 (d, $J=6.6$ Hz, 6H). ^{13}C NMR ($CDCl_3$): δ 159.6 (d, $J=37.1$ Hz), 146.4 (d, $J=224.2$ Hz), 124.0 (d, $J=17.1$ Hz), 112.4, 109.3, 105.0, 83.2, 79.8, 72.5, 67.2, 34.1, 28.6, 26.8, 26.2, 25.1, 22.1. ^{19}F NMR ($CDCl_3$): −122.6 (d, $J=21.1$ Hz). IR: 3090, 2960, 2870, 2660, 2550, 1705, 1665, 1440, 1240, 1115 cm^{-1}. MS: m/z 389 ($M^{+\bullet}$+1), 331, 291, 245, 119, 103, 101, 85. $[\alpha]_D^{21}=-33$ (c 1.0, CH_2Cl_2). Anal. calcd for $C_{19}H_{29}O_7F$: C, 58.75; H, 7.52. Found: C, 58.87; H, 7.97.

4.4.5. (*E*)-(1,2;5,6-Di-*O*-isopropylidene-D-glucofuranose-3-*O*-yl) 2-butyl-2-pentenoate, 4e. Yield 84%. ^{1}H NMR ($CDCl_3$): δ 6.71 (t, $J=7.5$ Hz, 1H), 5.86 (d, $J=3.7$ Hz, 1H), 5.27 (d, $J=2.0$ Hz, 1H), 4.50 (d, $J=3.7$ Hz, 1H), 4.10–4.25 (m, 2H), 3.95–4.06 (m, 2H), 2.27 (t, $J=7.1$ Hz, 2H), 2.18 (quint, $J=7.5$ Hz, 2H), 1.51 (s, 3H), 1.39 (s, 3H), 1.29 (s, 6H), 1.25–1.45 (m, 4H), 1.03 (t, $J=7.5$ Hz, 3H), 0.89 (t, $J=3.9$ Hz, 3H). ^{13}C NMR ($CDCl_3$): δ 166.6, 145.2, 131.5, 112.1, 109.2, 105.0, 83.3, 80.1, 76.1, 72.5, 67.2, 31.4, 26.7, 26.5, 26.4, 25.1, 22.6, 21.8, 13.9, 13.2. IR: 2960, 2920, 2860, 1720, 1650, 1470, 1270 cm^{-1}. MS: m/z 398 (M), 384, 383, 341, 238, 139, 113, 101, 69.. $[\alpha]_D^{21}=-32$ (c 0.1, CH_2Cl_2). Anal. calcd for $C_{21}H_{34}O_7$: C, 63.29; H 8.60. Found: C, 63.12; H, 7.97.

4.4.6. (1,2;5,6-Di-*O*-isopropylidene-D-glucofuranose-3-*O*-yl) cyclopent-1-ene carboxylate, 8a. Yield 52%. ^{1}H NMR ($CDCl_3$): δ 6.82 (tt, $J=2.5$ and 1.9 Hz, 1H), 5.88 (d, $J=3.6$ Hz, 1H), 5.28 (d, $J=2.3$ Hz, 1H), 4.53 (d, $J=3.8$ Hz, 1H), 4.20–4.31 (m, 2H), 4.00–4.20 (m, 2H), 2.46–2.62 (m, 4H), 1.96 (tt $J=7.9$ and 7.5 Hz, 2H), 1.52 (s, 3H), 1.41 (s, 3H), 1.31 (s, 3H), 1.30 (s, 3H). ^{13}C NMR ($CDCl_3$): δ 163.6, 145.0, 135.9, 112.1, 109.1, 105.0, 83.3, 79.8, 75.8, 72.6, 66.9, 33.3, 31.2, 29.3, 26.6, 26.1, 25.1, 22.9. IR: 2990, 2940, 2900, 1720, 1630, 1460, 1370, 1080 cm^{-1}. MS: m/z 355 (M+1), 313, 297, 225. $[\alpha]_D^{21}=-36$ (c 0.1, CH_2Cl_2). HRMS calcd for $C_{18}H_{26}O_7$+H: 355.1756. Found: 355.1753.

4.4.7. (1,2;5,6-Di-*O*-isopropylidene-D-glucofuranose-3-*O*-yl) cyclohex-1-ene carboxylate, 8b. Yield 80%. ^{1}H NMR ($CDCl_3$): δ 7.01 (tt, $J=1.9$ and 1.7 Hz, 1H), 5.88 (d, $J=3.6$ Hz, 1H), 5.27 (d, $J=1.5$ Hz, 1H), 4.52 (d, $J=3.8$ Hz, 1H), 4.29–4.31 (m, 2H), 4.00–4.12 (m, 2H), 2.15–2.30 (m, 4H), 1.55–1.71 (m, 4H), 1.52 (s, 3H), 1.41 (s, 3H), 1.31 (s, 3H), 1.30 (s, 3H). ^{13}C NMR ($CDCl_3$): δ 166.2, 141.1, 130.3, 112.4, 109.4, 105.4, 83.7, 80.2, 76.3, 72.9, 67.4, 27.0, 26.9, 26.5, 26.1, 25.5, 24.4, 22.2, 21.6. IR: 2990, 2940, 2900, 1720, 1650, 1460, 1380, 1230, 1080 cm^{-1}. MS: m/z 369 (M+1), 311. $[\alpha]_D^{21}=-36$ (c 0.1, CH_2Cl_2). HRMS calcd for $C_{19}H_{28}O_7$+H: 369.1913. Found: 369.1911.

4.5. General procedure for anionic deconjugations

To a solution of conjugated ester **4**/**8** (2 mmol) and HMPA (3 equiv.) in THF (10 ml) was added at −78°C a 1 M THF solution of NaHMDS (3 mmol). After stirring for 90 min, saturated aqueous NH_4Cl solution (3 ml) was added at once. The organic layer was washed with water (5 ml) and with brine (5 ml). After drying on $MgSO_4$, filtration and concentration under vacuo, the pale yellow viscous oil was purified by flash-chromatography on silica (eluent: AcOEt/hexanes: 5/95).

4.5.1. (2*R*)-(1,2;5,6-Di-*O*-isopropylidene-D-glucofuranose-3-*O*-yl) 2-methyl-3-heptenoate, 5a. Yield 77% ($E/Z=60/40$). ^{1}H NMR ($CDCl_3$): E+Z isomers: δ 5.87 (d, $J=3.7$ Hz, 0.4H) and 5.85 (d, $J=3.6$ Hz, 0.6H), 5.65–5.40 (m, 2H), 5.26 (s, 1H), 4.45 (d, $J=3.7$ Hz, 0.6H), 4.43 (d, $J=3.6$ Hz, 0.4H), 4.20 (sl, 2H), 4.15–3.95 (m, 2H), 3.13 (dq, $J=2.2$ and 7.3 Hz, 1H), 1.99 (ddt, $J=7.3$, 7.3 and 2.9 Hz, 2H), 1.52 (s, 3H), 1.40 (s, 3H), 1.30 (s, 6H), 1.40–1.25 (m, 2H), 1.26 (d, $J=6.9$ Hz, 3H), 0.88 (t, $J=7.3$ Hz, 3H). ^{13}C NMR ($CDCl_3$): *E*-isomer: δ 172.9, 132.2, 131.7, 128.2, 127.9, 111.9, 111.8, 108.8, 104.8, 83.1, 79.8, 75.6, 75.5, 72.0, 72.0, 67.1, 67.0, 42.6, 37.9, 34.1, 29.1, 26.4, 25.9, 24.9, 22.2, 21.9, 17.5, 16.8, 13.4, 13.2. IR: 2990, 2940, 2870, 1750, 1720, 1460, 1370, 1070 cm^{-1}. UV (CH_2Cl_2): $\varepsilon_{231}=1530$. MS: m/z 385.3 (M+H$^+$), 327.3 (M–OC(CH$_3$)$_2^+$). HRMS calcd for $C_{20}H_{33}O_7$: 385.2227. Found: 385.2226.

4.5.2. (2*R*)-(1,2;5,6-Di-*O*-isopropyliden-D-glucofuranose-3-*O*-yl) 2-methyl-3-decenoate, 5b. Yield 80% ($E/Z=65/35$). ^{1}H NMR ($CDCl_3$): E+Z isomers: δ 5.86 (d, $J=3.7$ Hz, 1H), 5.65–5.40 (m, 2H), 5.26 (sl, 1H), 4.45 (d,

$J=3.7$ Hz, 0.6H, *E*-isomer) and 4.43 (d, $J=3.7$ Hz, 0.4H, *Z*-isomer), 3.95–4.25 (m, 4H), 3.49 (quint, $J=7.4$ Hz, 0.4 H), 3.12 (quint, $J=7.3$ Hz, 0.6 H), 1.95–2.15 (m, 2H), 1.52 (s, 3H), 1.40 (s, 3H), 1.30 (s, 6H), 1.20–1.40 (m, 11H), 0.88 (t, $J=6.5$ Hz, 3H). ^{13}C NMR ($CDCl_3$): *E*-isomer: δ 173.4, 132.9, 128.0, 112.3, 109.2, 105.1, 83.4, 80.1, 75.8, 72.3, 67.4, 42.9, 32.4, 31.7, 29.3, 29.0, 28.8, 28.5, 26.7, 26.2, 25.2, 22.6, 17.2. IR: 2990, 2960, 2930, 2860, 1750, 1460, 1380, 1080 cm^{-1}. MS: *m*/*z* 427 (M+1), 369. HRMS calcd for $C_{23}H_{39}O_7$: M+1= 427.2695. Found: M+H$^+$=427.2696.

4.5.3. (2*R*)-(1,2;5,6-Di-*O*-isopropylidene-D-glucofuranose-3-*O*-yl) 2-isopropyl-3-heptenoate, 5c. Yield 83% (*E*/*Z*=60/40). ^{1}H NMR ($CDCl_3$): *E*+*Z* isomers: δ 5.87 (d, $J=3.7$ Hz, 0.4H) and 5.86 (d, $J=3.7$ Hz, 0.6H), 5.28–5.80 (m, 3H), 4.52 (d, $J=3.7$ Hz, 0.4H) and 4.42 (d, $J=3.7$ Hz, 0.6H), 4.15–4.30 (m, 2H), 3.95–4.15 (m, 2H), 2.60–2.85 (m, 1.2H) and 2.40 (m, 0.8H), 1.90–2.10 (m, 2H), 1.52 (s, 3H), 1.40 (s, 3H), 1.30 (s, 3H), 1.29 (s, 3H), 1.20–1.40 (m, 2H), 0.85–1.05 (m, 9H). IR: 2960, 2930, 2870, 1740, 1460, 1370, 1215, 1080 cm^{-1}. MS: *m*/*z* 413 (M+1), 397, 355.

4.5.4. (2*R*)-(1,2;5,6-Di-*O*-isopropylidene-D-glucofuranose-3-*O*-yl) 2-butyl-3-pentenoate, 5e. Yield 48% (*E*/*Z*=60/40). ^{1}H NMR ($CDCl_3$): *E*+*Z* isomers: 5.86 (d, $J=3.6$ Hz, 1H), 5.20–5.70 (m, 2H), 5.26 (d, $J=1.7$ Hz, 1H), 4.42 (d, $J=5.3$ Hz, 1H), 4.17 (sl, 2H), 3.90–4.15 (m, 2H), 3.33 (q, $J=7.3$ Hz, 0.4 H) and 2.95 (q, $J=7.3$ Hz, 0.6H), 1.67 (sl, 3H), 1.51 (s, 3H), 1.39 s, 3H), 1.30 (s, 6H), 1.10–1.40 (m, 6H), 0.87 (t, $J=6.8$ Hz, 3H). ^{13}C NMR ($CDCl_3$): *E*-isomer: δ 173.0, 128.3, 127.8, 112.3, 109.2, 105.1, 83.4, 80.1, 75.8, 72.3, 67.4, 49.3, 32.0, 29.2, 26.7, 26.2, 25.1, 22.4, 17.9, 13.9. *Z*-isomer: δ 172.9, 128.3, 127.1, 112.3, 109.2, 105.1, 83.4, 80.1, 75.8, 72.3, 67.4, 49.3, 32.2, 29.2, 26.7, 26.2, 25.1, 22.4, 17.9, 13.9. IR: 2960, 2930, 2860, 1740, 1455, 1380, 1215, 1155, 1080 cm^{-1}.

4.5.5. (1,2;5,6-Di-*O*-isopropylidene-D-glucofuranose-3-*O*-yl) cyclopent-2-ene carboxylate, 9a. Yield 67% (de= 35%). Major diastereoisomer: ^{1}H NMR (300 MHz, $CDCl_3$): δ 5.90–5.95 (m, 1H), 5.88 (d, $J=3.8$ Hz, 1H), 5.67–5.74 (m, 1H), 5.27 (s, 1H), 4.48 (d, $J=3.8$ Hz, 1H), 3.75–4.25 (m, 4H), 2.46–2.62 (m, 4H), 3.54–3.64 (m, 1H), 2.33–2.57 (m, 2H), 2.10–2.20 (m, 2H), 1.51 (s, 3H), 1.40 (s, 3H), 1.31 (s, 3H), 1.30 (s, 3H). ^{13}C NMR ($CDCl_3$): δ 173.6, 134.6, 128.2, 112.3, 109.3, 105.1, 83.4, 80.1, 76.1, 72.5, 67.4, 50.7, 32.1, 26.7, 26.3, 26.1, 25.1, 23.8. Minor diastereoisomer: ^{1}H NMR (300 MHz, $CDCl_3$): δ 5.90–5.95 (m, 1H), 5.88 (d, $J=3.8$ Hz, 1H), 5.67–5.74 (m, 1H), 5.27 (s, 1H), 4.46 (d, $J=3.8$ Hz, 1H), 3.75–4.25 (m, 4H), 2.46–2.62 (m, 4H), 3.54–3.64 (m, 1H), 2.33–2.57 (m, 2H), 2.10–2.20 (m, 2H), 1.51 (s, 3H), 1.40 (s, 3H), 1.31 (s, 3H), 1.30 (s, 3H). ^{13}C NMR ($CDCl_3$): δ 171.5, 134.8, 126.4, 112.3, 109.3, 105.1, 83.3, 80.0, 76.0, 72.5, 67.3, 50.5, 33.8, 26.6, 26.4, 26.1, 25.1, 23.8. IR (neat): 2980, 2930, 2900, 1730, 1460, 1370, 1070, 850 cm^{-1}. MS.: *m*/*z* 353 (M+1), 295, 261, 154, 81, 69. HRMS calcd for $C_{18}H_{26}O_7$–H: 353.1600. Found: 353.1627.

4.5.6. (1,2;5,6-Di-*O*-isopropylidene-D-glucofuranose-3-*O*-yl) cyclohex-2-ene carboxylate, 9b. Yield 45% (de=9%). Major diastereoisomer: ^{1}H NMR (300 MHz, $CDCl_3$): δ 6.17–6.25 (m, 1H), 5.92 (d, $J=3.6$ Hz, 1H), 5.58 (d, $J=10.0$ Hz, 1H), 5.18 (d, $J=3.6$ Hz, 1H), 4.57 (d, $J=3.6$ Hz, 1H), 4.45–4.54 (m, 1H), 4.04–4.34 (m, 4H), 1.81–2.33 (m, 4H), 1.72–1.83 (m, 2H), 1.53 (s, 3H), 1.40 (s, 3H), 1.35 (s, 3H), 1.31 (s, 3H). Minor diastereoisomer: ^{1}H NMR (300 MHz, $CDCl_3$): δ 6.17–6.25 (m, 1H), 6.01 (d, $J=10.0$ Hz, 1H), 5.92 (d, $J=3.6$ Hz, 1H), 5.22 (d, $J=3.4$ Hz, 1H), 4.54 (d, $J=3.6$ Hz, 1H), 4.35–4.44 (m, 1H), 4.04–4.34 (m, 4H), 1.80–2.33 (m, 4H), 1.71–1.83 (m, 2H), 4.53 (s, 3H), 1.40 (s, 3H), 1.35 (s, 3H), 1.31 (s, 3H). IR: 2990, 2940, 2900, 1750, 1460, 1380, 1250, 1220, 1080, 1020 cm^{-1}. MS.: *m*/*z* 367 (M+1), 343, 325, 309, 97. HRMS calcd for $C_{19}H_{28}O_7$+H: 367.1756. Found: 367.1755.

4.6. Hydrogenation procedure for esters

A solution of β,γ-unsaturated ester 5 (10 mmol) in diethylether (10 ml) containing catalytic amounts of PtO_2 was hydrogenated for 12 h under a hydrogen atmosphere. After filtration over a pad of silica, the solvent was removed by concentration. The colourless and viscous liquid was purified by flash-chromatography or used without further purification.

4.6.1. (2*R*)-(1,2;5,6-Di-*O*-isopropylidene-D-glucofuranose-3-*O*-yl) 2-methyl heptanoate, 6a. Yield 93% (de >95%). ^{1}H NMR ($CDCl_3$): major diastereoisomer (2*R*): δ 5.89 (d, $J=3.6$ Hz, 1H), 5.29 (d, $J=2.5$ Hz, 1H), 4.46 (dd, $J=3.6$ and 1.6 Hz, 1H), 4.28–4.20 (m, 2H), 4.12 (ddd, $J=12.0$, 8.7 and 3.0 Hz, 1H), 4.02 (dd, $J=8.7$ and 4.7 Hz, 1H), 2.48 (tq, $J=6.9$ and 7.0 Hz, 1H), 1.80–1.60 (m, 2H), 1.54 (s, 3H), 1.42 (s, 3H), 1.33 (s, 3H), 1.32 (s, 3H), 1.40–1.20 (m, 6H), 1.18 (d, $J=7.0$ Hz, 3H), 0.90 (t, $J=7.1$ Hz, 3H). ^{1}H NMR ($CDCl_3$): minor diastereoisomer (2*S*): δ 5.94 (d, $J=3.6$ Hz, 1H), 5.24 (d, $J=2.5$ Hz, 1H), 4.44 (dd, $J=3.7$ Hz, 1H), 4.40–3.90 (m, 4H), 2.49 (tq, $J=7.0$ and 7.0 Hz, 1H), 1.80–1.60 (m, 2H), 1.50 (s, 3H), 1.44 (s, 3H), 1.36 (s, 3H), 1.32 (s, 3H), 1.40–1.20 (m, 6H), 1.18 (d, $J=6.95$ Hz, 3H), 0.90 (t, $J=7.1$ Hz, 3H). ^{13}C NMR ($CDCl_3$): major diastereoisomer: δ 175.5, 112.5, 109.6, 105.5, 83.7, 80.4, 75.9, 72.7, 72.0, 67.8, 37.9, 33.9, 32.0, 27.0, 26.0, 26.5, 25.5, 22.8, 17.3, 14.3. IR: 2990, 2960, 2930, 2860, 1750, 1460, 1370, 1080 cm^{-1}. MS: *m*/*z* 387 (M+ H$^+$), 329. $[\alpha]_D^{21}=-13$ (*c* 1.0, CH_2Cl_2). HRMS calcd for $C_{20}H_{35}O_7=387.2382$. Found: (M+H$^+$)=387.2380.

4.6.2. (2*R*)-(1,2;5,6-Di-*O*-isopropylidene-D-glucofuranose-3-*O*-yl) 2-methyl decanoate, 6b. Yield 73% (de >95%). ^{1}H NMR (300 MHz, $CDCl_3$): δ 5.86 (d, $J=3.6$ Hz, 1H), 5.27 (d, $J=2.0$ Hz, 1H), 4.43 (d, $J=3.7$ Hz, 1H), 3.95–4.25 (m, 4H), 2.46 (dq, $J=7.0$ and 6.9 Hz, 1H), 1.58–1.72 (m, 1H), 1.51 (s, 3H), 1.40 (s, 3H), 1.30 (s, 3H), 1.29 (s, 3H), 1.20–1.35 (m, 13H), 1.15 (d, $J=6.9$ Hz, 3H), 0.87 (t, $J=6.4$ Hz, 3H). ^{13}C NMR ($CDCl_3$): δ 175.3, 112.3, 109.3, 105.1, 83.5, 80.2, 75.7, 72.4, 67.5, 39.6, 33.7, 31.8, 29.5, 29.4, 29.2, 27.0, 26.9, 26.8, 26.2, 25.2, 22.6, 16.8, 14.0. IR: 2990, 2930, 2860, 1750, 1710, 1460, 1370, 1080 cm^{-1}. MS: *m*/*z* 429 (M+

H^+), 371 (M–$OC(CH_3)_2^+$). $[\alpha]_D^{21} = -11$ (*c* 1.0, CH_2Cl_2). HRMS calcd for $C_{23}H_{41}O_7$: (M+1H) = 429.2852. Found: (M+1H) = 429.2857.

4.6.3. (1,2;5,6-Di-*O*-isopropylidene-D-glucofuranose-3-*O*-yl) 2-isopropyl heptanoate, 6c. Yield 95% (de = 20%) ^1H NMR ($CDCl_3$): major diastereoisomer (2*R*): δ 5.84 (d, $J = 3.7$ Hz, 1H), 5.29 (dd, $J = 2.5$ and 2.2 Hz, 1H), 4.44 (dd, $J = 3.6$ and 1.6 Hz, 1H), 4.30–3.90 (m, 4H), 2.20–2.10 (m, 1H), 1.80–1.60 (m, 2H), 1.52 (s, 3H), 1.40 (s, 3H), 1.29 (s, 3H), 1.28 (s, 3H), 1.4–1.2 (m, 7H), 1.00–0.80 (m, 9H). ^{13}C NMR ($CDCl_3$): major diastereoisomer: δ 174.5, 112.4, 109.4, 105.1, 83.5, 80.3, 75.7, 72.3, 72.2, 67.7, 53.0, 31.8, 30.8, 39.8, 27.3, 26.8, 26.2, 22.5, 20.6, 20.2, 14.1. IR: 2960, 2930, 2870, 1740, 1460, 1370, 1080 cm^{-1}. MS: *m*/*z* 415 ($M^{+\bullet}$+1), 399, 357. $[\alpha]_D^{21} = -25$ (*c* 1.0, CH_2Cl_2). HRMS calcd for M+1H = 415.2695. Found: $M+H^+ = 415.2697$.

4.6.4. (1,2;5,6-Di-*O*-isopropylidene-D-glucofuranose-3-*O*-yl) 2-propyl hexanoate, 6e. Yield 85% (de = 25%) ^1H NMR ($CDCl_3$): δ 5.85 (d, $J = 3.7$ Hz, 1H), 5.29 (d, $J = 2.4$ Hz, 1H), 4.41 (d, $J = 3.7$ Hz, 1H), 4.10–4.25 (m, 2H), 3.95–4.12 (m, 2H), 2.37 (hept, $J = 5.2$ Hz, 1H), 1.41–1.75 (m, 4H), 1.51 (s, 3H), 1.39 (s, 3H), 1.31 (s, 3H), 1.29 (s, 3H), 1.20–1.35 (m, 9H), 0.89 (t, $J = 7.1$ Hz, 3H). ^{13}C NMR ($CDCl_3$): Major diasteroisomer: δ 175.0, 112.3, 109.3, 105.1, 83.5, 80.2, 75.6, 72.2, 67.6, 45.6, 34.6, 32.1, 29.6, 26.8, 26.7, 26.2, 25.1, 22.6, 20.4, 13.9, 13.8. Minor diastereoisomer: δ 174.9, 112.3, 109.3, 105.1, 83.5, 80.0, 75.6, 72.1, 67.4, 45.6, 34.6, 32.1, 29.4, 26.8, 26.7, 26.2, 25.1, 22.6, 20.5, 13.9, 13.8. IR: 2990, 2960, 2880, 1730, 1460, 1380, 1370, 1260, 1220, 1080 cm^{-1}. MS: *m*/*z* 401 ($M^{+\bullet}$+1), 3999, 381, 343. HRMS calcd for $C_{21}H_{36}O_7$ M+1H = 401.2539. Found: 401.2548.

4.7. Reduction by $LiAlH_4$ of esters 6a and 6b

To a suspension of $LiAlH_4$ (15 mmol) in ether (20 ml), was dropwise added at 0°C an ethereal solution of ester **6** (10 mmol). After 30 min at 0°C, hydrolysis was performed with aqueous ether. After acidification with a 1N HCl solution, the aqueous layer was extracted with ether (3×10 ml). The combined organic layers were washed with brine and dried over $MgSO_4$. After filtration and concentration under vacuo, the pale yellow oil was purified by flash-chromatography on silica (eluent: AcOEt/hexanes: 20/80).

4.7.1. (2*R*)-2-Methylheptan-1-ol.[17] Yield 75%. ^1H NMR ($CDCl_3$): δ 3.51 (dd, $J = 10.3$ and 5.88 Hz, 1H), 3.42 (dd, $J = 10.3$ and 6.6 Hz 1H), 1.70–1.50 (m, 1H), 1.50–1.20 (m, 10H), 1.20–1.00 (m, 1H), 0.92 (d, $J = 6.6$ Hz, 3H), 0.89 (t, $J = 7.3$ Hz, 3H). ^{13}C NMR ($CDCl_3$): δ 68.3, 35.7, 33.1, 32.1, 26.6, 22.6, 16.5, 14.0. IR: 3340, 2960, 2930, 2870, 2860, 1470, 1050 cm^{-1}.

4.7.2. (2*R*)-2-Methyldecan-1-ol.[18] Yield 80%. ^1H NMR ($CDCl_3$): δ 3.50 (dd, $J = 10.3$ and 5.8 Hz, 1H), 3.41 (dd, $J = 10.3$ and 6.6 Hz, 1H), 1.70–1.50 (m, 1H), 1.50–1.00 (m, 14H), 0.91 (d, $J = 6.6$ Hz, 3H), 0.88 (t, $J = 7.3$ Hz, 3H). IR: 3360, 2960, 2920, 2850, 1630, 1470, 1380, 1040 cm^{-1}. $[\alpha]_D^{21} = +3.4$ (*c* 1.0, CH_2Cl_2). Lit. (2*S*) $[\alpha]_D^{21} = -7.8$ (*c* 4.0, $CHCl_3$).

Acknowledgements

F.B. thanks MENSER for financial support. O.P. acknowledges CNRS and Région Rhône-Alpes for substantial funding, 'AIP Jeune Equipe' and 'Programme Emergence', respectively.

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