Bioorganic & Medicinal Chemistry Letters 19 (2009) 3093–3095

Contents lists available at ScienceDirect

Bioorganic & Medicinal Chemistry Letters

journal homepage: www.elsevier.com/locate/bmcl

(*S*)-Camphorsulfonic acid catalyzed highly stereoselective synthesis of pseudoglycosides

Bala Kishan Gorityala, Shuting Cai, Jimei Ma, Xue-Wei Liu *

Division of Chemistry and Biological Chemistry, School of Physical and Mathematical Sciences, Nanyang Technological University, Singapore 637371, Singapore

ARTICLE INFO

Article history:
Received 8 January 2009
Revised 31 March 2009
Accepted 2 April 2009
Available online 8 April 2009

Keywords:
Glycosylation
Ferrier rearrangement
α-Selectivity
2,3-Unsaturated glycosides

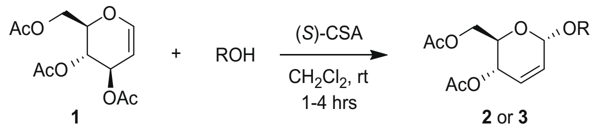
ABSTRACT

A mild and efficient synthesis of pseudoglycosides has been developed using metal free (*S*)-camphorsulfonic acid. (*S*)-CSA acts as an excellent catalyst for conversion of 2,4,6-tri-*O*-acetyl-D-glucal to 2,3-unsaturated O-glycosides. A wide range of biologically active natural products, alcohols and thiols could be coupled with glucal to give the desired pseudoglycosides in good to excellent yields with exclusive α-stereoselectivity.

Nowadays the diversity oriented synthesis (DOS) for synthesizing small molecule libraries with definite stereoselectivity has increased.[1] A variety of biologically active natural products are oxygen rich and synthesized from combinatorial libraries.[2] Attracted by these facts we began to develop oxygen rich small molecule libraries and natural products connected to sugar skeletons with the aid of Ferrier rearrangement. The primordial work of Ferrier and Prasad resulted in Ferrier rearrangement,[3] an acid catalyzed reaction between glucal and an alcohol,[4] is an old and reliable procedure for the formation of 2,3-unsaturated O-glycosides. This rearrangement is believed to proceed through a cyclic allylic oxocarbonium intermediate that is formed *via* displacement of the C-3 substituent in a glucal, followed by the preferential attack of a nucleophile from the quasi-equatorial orientation.[5] 2,3-Unsaturated O-glycosides are known to play a vital role in the synthesis of antibiotics,[6] oligosaccharides,[7] uronic acids,[8] complex carbohydrates[9] and various natural products[10] and they are important building blocks in many bioactive molecules.[11]

Moreover, the unsaturated part in sugar moiety allows many modifications such as hydroxylation, epoxidation, hydrogenation and aminohydroxylation which contribute their complexities and diversities. Over the decades Ferrier rearrangement has seen extensive development as this rearrangement could be undergone by various Lewis acids and oxidants.[12] However the metal catalysts and metal triflates used in this transformation are highly expensive and most of the other catalysts suffer from drawbacks such as air sensitivity, strong oxidizing conditions, low anomeric selectivity and usage of excess catalyst. And moreover, the strong acidic conditions could result in undesired side products, hence a mild, inexpensive and metal free catalyst which would deliver the desired pseudoglycosides with high anomeric selectivity and yield is highly desirable.

The usage of organic acids in glycosylation is strictly limited and, therefore, we set out to explore the catalytic potential of organic acids in the Ferrier rearrangement. The treatment of glucal with propargyl alcohol in the presence of acetic acid (pK_a 4.76) to obtain desired 2,3-unsaturated glycoside was unsuccessful. Then we tested the activity of racemic camphorsulfonic acid (pK_a 1.17) under the same conditions, which gave the desired pseudoglycoside with good anomeric selectivity (78% yield, α/β 5:1) in 1 h. Attracted by this result, optically pure camphorsulfonic acids (both *R* and *S*) were used to test the effect of chirality on anomeric selectivity. To our interest, both (*R*) and (*S*)-CSA furnished the desired 2,3-unsaturated glycosides in good to excellent yields (80 and 92%, respectively) with predominant α-selectivity (α/β 10:1) in 1 h. The reactions involving (*R*)-CSA delivered higher yields if the reaction time is prolonged to 2 h, hence we used (*S*)-CSA rather than (*R*)-CSA. To the best of our knowledge, (*S*)-camphorsulfonic acid has not been used in this area. Camphorsulfonic acid has got importance in organic synthesis as this catalyst is used in the



1

2 or **3**

Scheme 1. A synthetic model for the Ferrier rearrangement.

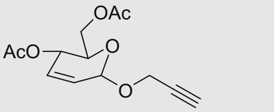
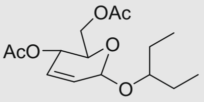
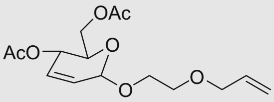
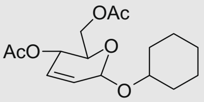
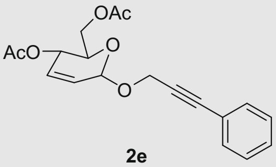
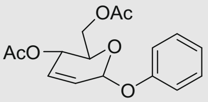
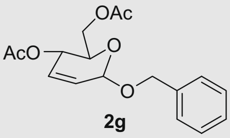
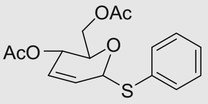
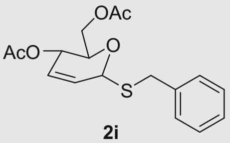
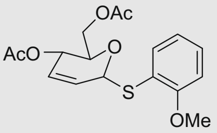
---

* Corresponding author. Tel.: +65 6316 8901; fax: +65 67911961.
E-mail address: xuewei@ntu.edu.sg (X.-W. Liu).

0960-894X/$ - see front matter © 2009 Elsevier Ltd. All rights reserved.
doi:10.1016/j.bmcl.2009.04.003

synthesis of ligands,[13] chromans,[14] as an auxillary,[15] in some polymerization reactions[16] and it is extensively used in the optical resolution of amines.[17]

Table 1
Ferrier reaction of 2,3-tri-*O*-glucal with alcohols and thiols in the presence of (*S*)-camphorsulfonic acid

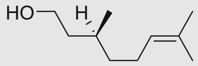
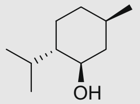
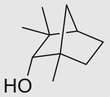
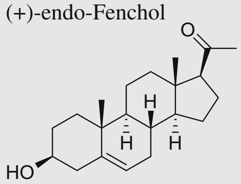
Entry	Product	Time (h)	Yield (%)	α/β[a]
1	 **2a**	1	92	10:1[12k]
2	 **2b**	1	90	α[12n]
3	 **2c**	1.5	83	α[22]
4	 **2d**	1	85	α[12o]
5	 **2e**	1	82	α[12n]
6	 **2f**	1.5	82	α[12k]
7	 **2g**	1.5	85	α
8	 **2h**	2	68	α
9	 **2i**	2	75	α
10	 **2j**	2	78	20:1[23]

[a] The α/β ratio was determined from the anomeric proton ration in the ^{1}H NMR spectra.

In the present study, we describe the successful implementation of (*S*)-camphorsulfonic acid as a catalyst in the Ferrier rearrangement for the synthesis of 2,3-unsaturated O-glycosides (Scheme 1). In view of atom economy low amount of catalyst was used. Typically, (*S*)-CSA was added to the mixture of glucal and alcohol in dichloromethane at room temperature. When the reaction was complete, simple aqueous work up and subsequent purification of the crude product by column chromatography gave the desired glycosides. The structure and stereochemistry of the glycosylated products were elucidated from ^{1}H, ^{13}C and 2D NMR spectroscopic data. To further establish the scope of the reaction, a variety of *O* and *S* pseudoglycosides were synthesized in good to excellent yields (68–92%) and most of the glycosylation products were obtained in exclusively pure diastereomers as resulted in Table 1. Based on the anomeric ratios obtained from ^{1}H NMR spectra, it is evident that catalytic reactions using all nucleophiles (Table 1, entries 2–9) except propargyl alcohol and *O*-methoxy benzenethiol (Table 1, entries 1 and 10) gave exclusive α-selectivity. The predominant formation of the α-anomer may arise from a thermodynamic anomeric effect.

Encouraged by these results, we next explored the scope of this route for the synthesis of pseudoglycals connected to various biologically important natural products such as citronellol,[18] L-menthol,[19] borneol,[19] endo-fenchol and preglenolone[20] glycosides, these all have served as challenging targets to study and transform because of their diversity of the biological activities and their structural complexity. Some of them were generally synthesized by enzymatic[21] as well as Koenigs–Knorr–Zemplen[19] methods, which are expensive, lengthy and tedious. We used our catalytic system to synthesize sugar-containing natural products with exclusive α-anomeric selectivity in 120–180 min of reaction time (Table 2). Pregnenolone glycoside, which was first isolated from *Nerium Odorum*,[20] operates as a powerful neurosteroid in the brain, modulating the transmission of messages from neuron to neuron

Table 2
Ferrier reaction of 2,3-tri-*O*-acetyl-D-glucal with various natural products alcohols in the presence of (*S*)-CSA

Entry	Natural product alcohols	Product	Time (h)	Yield (%)	α/β
1	 S-(-)-β-Citronellol	3a	3	80	α[24]
2	 L-Menthol	3b	2.5	88	α[25]
3	 (+)-Borneol	3c	3	85	α[26]
4	 (+)-endo-Fenchol	3d	3	84	α[27]
5	 Pregnenolone	3e	4	78	α[28]

and strongly influencing learning and memory. The synthesis of pregnenolone 2,3-unsaturated glycoside achieved by employing (*S*)-CSA with α-selectivity (78% yield). The biological evaluation of the compounds **3a–e** is under way.

In summary, we have demonstrated a new protocol for forming glycosidic linkage in high distereoselective fashion. Many complex natural products, alcohols and thiols could be incorporated with glucal donor in a single process. The main advantage of this method concern about high anomeric selectivity, low cost reagents and friendly environmental conditions.

Acknowledgements

We gratefully thank Nanyang Technological University and the Ministry of Education, Singapore for the financial support.

References and notes

1. (a) Stockwell, B. *Nat. Rev. Genet.* **2000**, *1*, 116; (b) Schreiber, S. L. *Bioorg. Med. Chem.* **1998**, *6*, 1127.
2. Feher, M.; Schmidt, J. M. J. *Chem. Inf. Comput. Sci.* **2003**, *43*, 218.
3. Ferrier, R. J.; Prasad, N. *J. Chem. Soc. C.* **1969**, 570.
4. Ferrier, R. J. *J. Chem. Soc., Perkin Trans. 1* **1979**, 1455.
5. (a) Ferrier, R. J.; Sankey, G. H. *J. Chem. Soc. C* **1966**, 2345; (b) Wieczorek, B.; Thiem, J. *J. Carbohydr. Chem.* **1998**, *17*, 785; (c) Levy, D. E.; Tang, C. *The Chemistry of C-Glycosides*; Pergamon Press: Tarrytown, NY, 1995; (d) Postema, M. H. D. *C-Glycosides Synthesis*; CRC Press: Boca Raton, FL, 1995; (e) Csuk, R.; Shaade, M.; Krieger, C. *Tetrahedron* **1996**, *52*, 6397.
6. Williams, N. R.; Wander, J. D. *The Carbohydrates in Chemistry and Biochemistry*; Academic Press: New York, 1980. 761 pp.
7. Bussolo, V. D.; Kim, Y. J.; Gin, D. Y. *J. Am. Chem. Soc.* **1998**, *120*, 13515.
8. (a) Schmidt, R. R.; Angerbauer, R. *Carbohydr. Res.* **1981**, *89*, 159; (b) Angerbauer, R.; Schmidt, R. R. *Carbohydr. Res.* **1981**, *89*, 193.
9. Schmidt, R. R.; Angerbauer, R. *Angew. Chem., Int. Ed.* **1977**, *16*, 783.
10. Tolstikov, A. G.; Tolstikov, G. A. *Russ. Chem. Rev.* **1993**, *62*, 579.
11. (a) Fraser-Reid, B. *Acc. Chem. Res.* **1985**, *18*, 347; (b) Ferrier, R. J. *Adv. Carbohydr. Chem. Biochem.* **1969**, *24*, 199; (c) Toshima, K.; Tatsuda, K. *Chem. Rev.* **1993**, *93*, 1503; (d) Nicolaou, K. C.; Mitchell, H. J. *Angew. Chem., Int. Ed.* **2001**, *40*, 1576; (e) Feher, M.; Schmidt, J. M. *J. Chem. Inf. Comput. Sci.* **2003**, *43*, 218; (f) Dorgan, B. J.; Jackson, R. F. W. *Synlett* **1996**, 859; (g) Schmidt, R. R.; Angerbauer, R. *Carbohydr. Res.* **1981**, *89*, 193; (h) Schmidt, R. R.; Angerbauer, R. *Carbohydr. Res.* **1979**, *72*, 272; (i) Danishefsky, S. J.; Bilodeau, M. T. *Angew. Chem., Int. Ed.* **1996**, *35*, 1380; (j) Liu, Z. J. *Tetrahedron: Asymmetry* **1999**, *10*, 2119.
12. (a) Descotes, G.; Martin, J. C. *Carbohydr. Res.* **1977**, *56*, 168; (b) Klaffke, W.; Pudlo, P.; Springer, D.; Thiem, J. L. *Ann. Chem.* **1991**, *6*, 509; (c) Bhate, P.; Harton, D.; Priebe, W. *Carbohydr. Res.* **1985**, *144*, 331; (d) Babu, B. S.; Balsubramanian, K. K. *Tetrahedron Lett.* **2000**, *41*, 1271; (e) Das, S. K.; Reddy, K. A.; Roy, J. *Synlett* **2003**, 1607; (f) Takhi, M.; Rahman, A.; Schmidt, R. R. *Tetrahedron Lett.* **2001**, *42*, 4053; (g) Masson, C.; Soto, J.; Besodes, M. *Synlett* **2000**, 1281; (h) Yadav, J. S.; Reddy, B. V. S.; Chandraiah, L.; Reddy, K. S. *Carbohydr. Res.* **2001**, *332*, 221; (i) Swamy, N. R.; Venkateswarlu, A. *Synthesis* **2002**, 598; (j) Bettadaiah, B. K.; Srinivas, P. *Tetrahedron Lett.* **2003**, *44*, 7257; (k) Yadav, J. S.; Reddy, B. V.; Reddy, J. S. *J. Chem. Soc. Perkin Trans. 1* **2002**, 2390; (l) Yadav, J. S.; Reddy, B. V.; Murthy, C. V.; Kumar, G. M. *Synlett* **2000**, 1450; (m) Smitha, G.; Reddy, S. C. *Synthesis* **2004**, 834; (n) Gorityala, B. K.; Cai, S.; Lorpitthaya, R.; Ma, J.; Pasunooti, K. K.; Liu, X. W. *Tetrahedron Lett.* **2009**, *50*, 676; (o) Zhang, G.; Liu, Q.; Shi, L.; Wang, J. *Tetrahedron* **2008**, *64*, 339; (p) Yadav, J. S.; Reddy, B. V. S.; Geetha, V. *Synth. Commun.* **2003**, *33*, 717; (q) Rafiee, E.; Tangestaninejad, S.; Habibi, M. H.; Mirkhani, V. *Bioorg. Med. Chem. Lett.* **2004**, *14*, 3611.
13. Gayet, A.; Bolea, C.; Andersson, P. G. *Org. Biomol. Chem.* **2004**, *2*, 1887.
14. Makoto, M.; Yamamoto, H. *Bull. Chem. Soc. Jpn.* **1995**, *68*, 2657.
15. Barrett, A. G. M.; Braddock, D. C.; Christian, P. W. N.; Pilipauskas, D.; White, A. J. P.; Williams, D. J. *J. Org. Chem.* **1998**, *63*, 5818.
16. Sejin, O.; Gijung, K.; Narae, K.; Shim, S. E.; Soonja, C. *Macromol. Res.* **2005**, *13*, 187.
17. Richard, M. K.; Jose, W. N. K.; Pouwer, T. R.; Vries, Q. B. *Synthesis* **2003**, *10*, 1626.
18. Mastalic, J.; Jerkovic, I.; Vinkovic, M.; Dzolic, Z.; Vikic-Topic, D. *Crotica. Chem. Acta* **2004**, *77*, 491.
19. Noguchi, K.; Nakagawa, H.; Yoshiyama, M.; Shimura, S.; Kirimura, K.; Usami, S. *J. Ferment. Bioeng.* **1998**, *85*, 436.
20. Yamauchi, T.; Hara, M.; Mihashi, K. *Phytochemistry* **1972**, *1*, 3345.
21. Hotha, S.; Tripathi, V. *Tetrahedron Lett.* **2005**, *61*, 4555.
22. To a mixture of 2,4,6-tri-*O*-acetyl-D-glycal (100 mg, 0.37 mmol) and 2-allyloxy ethanol (1 equiv) in dichloromethane (5 ml) was added 0.5 equiv of (*S*)-camphorsulfonic acid at room temperature. The mixture was stirred for the appropriate amount of time (Table 1, entry 3), and the extent of reaction was monitored by TLC analysis. When the reaction was complete, aqueous work up and subsequent purification of the crude compound by silica gel column chromatography by hexane, ethyl acetate solvent system, gave the desired 2,3-unsaturated glycoside..
   2-(Allyloxy)ethanyl 4,6-di-O-acetyl-2,3-dideoxy-α-D-erythro-hex-2-enopyranoside **(2c):** $[\alpha]_D^{24}$ +272.2 (*c* 0.4, $CHCl_3$); ^{1}H NMR (500 MHz, $CDCl_3$) δ 5.90 (ABX system, J_{AX} = 17.2 Hz, J_{BX} = 9.6 Hz, J_{AB} = 5.4 Hz, 1H), 5.85 (br s, 2H), 5.30 (d, *J* = 9.7 Hz, 1H) 5.26 (dd, *J* = 17.2, 1.6 Hz, 1H), 5.16 (d, *J* = 9.5 Hz, 1H), 5.06 (s, 1H), 4.23 (dd, *J* = 12.1, 5.2 Hz, 1H), 4.15 (dd, *J* = 12.1, 2.3 Hz, 1H), 4.12–4.10 (m, 1H), 4.0 (d, *J* = 5.0 Hz, 2H), 3.89 (dt, *J* = 11.0, 4.5 Hz, 1H), 3.72–3.68(m, 1H), 3.61 (t, *J* = 4.8 Hz, 2H), 2.07 (s, 3H), 2.05 (s, 3H); ^{13}C NMR (125 MHz, CDCl3) δ 170.7, 170.2, 134.6, 129.1, 127.7, 117.1, 94.6, 72.1, 69.2, 67.8, 66.8, 65.2, 62.9, 20.9, 20.7; IR (NaCl neat) *v* 1743, 1317, 1234, 1047 cm^{-1}; HRMS (ESI) *m/z* [M+Na]$^+$ calcd for $C_{15}H_{22}O_7Na$ 337.1263, found 337.1252.
23. *2-Methoxybenzenethainyl 4,6-di-O-acetyl-2,3-dideoxy-α-D-erythro-hex-2-enopyr-?tjl?>anoside* **(2j)**: $[\alpha]_D^{24}$ +262.6 (*c* 0.5, $CHCl_3$); ^{1}H NMR (500 MHz, $CDCl_3$) δ 7.42 (dd, *J* = 7.5, 1.6 Hz,1H), 7.24 (m, 1H), 6.8 (m, 1H), 6.40 (d, *J* = 5.8 Hz, 1H), 5.13 (dd, *J* = 10.1, 4.5 Hz, 1H), 4.94 (t, *J* = 5.8 Hz, 1H), 4.54 (m, 2H), 4.38 (dd, *J* = 12.2, 4.4 Hz, 1H), 4.32 (dd, *J* = 12.2, 2.1 Hz, 1H),3.88 (s, 1H), 2.06 (s, 6H), 1.47 (s, 3H); ^{13}C NMR (125 MHz, $CDCl_3$) δ 170.7, 169.8, 158.7, 144.7, 133.6, 129.1, 122.9, 120.8, 111.0, 98.7, 70.8, 69.8, 62.3, 55.8, 40.4, 20.7, 19.8; IR (NaCl neat) *v* 1743, 1370, 1232, 1037 cm^{-1}; HRMS (ESI) *m/z* [M+Na]$^+$ calcd for $C_{17}H_{20}O_6SNa$ 375.0878, found 375.0871.
24. *(S)-(−)-β-Citronellol 4,6-di-O-acetyl-2,3-dideoxy-α-D-erythro-hex-2-enopyranoside* **(3a)**: $[\alpha]_D^{24}$ +41.5 (c 0.5, $CHCl_3$); ^{1}H NMR (500 MHz, $CDCl_3$) 5.86 (d, *J* = 10.4 Hz, 1H), 5.82 (d, *J* = 10.4 Hz, 1H), 5.29 (dd, *J* = 9.6, 1.1 Hz, 1H), 5.08 (t, *J* = 7.0 Hz, 1H), 5.01 (s, 1H), 4.23 (dd, *J* = 12.1, 5.4 Hz, 1H), 4.16 (dd, *J* = 12.1, 2.2 Hz, 1H), 4.10–4.07 (m, 1H), 3.82 (dd, *J* = 7.4, 2.2 Hz, 1H), 3.55–3.50 (m, 1H), 2.08 (s, 3H), 2.07 (s, 3H), 1.99–1.93 (m, 2H), 1.67–1.65 (m, 4H), 1.59–1.55 (m, 4H), 1.41–1.30 (m, 2H), 1.17–1.12 (m, 1H), 0.88 (d, *J* = 6.6 Hz, 3H); ^{13}C NMR (125 MHz, $CDCl_3$) d 170.8, 170.3, 131.2, 128.9, 127.9, 124.7, 94.3, 67.0, 66.9, 65.3, 63.1, 37.2, 36.5, 29.4, 25.7, 25.4, 20.9, 20.8, 19.3, 17.6; IR (NaCl neat) *v* 1743, 1371, 1232, 1035 cm^{-1}; HRMS (ESI) *m/z* [M+Na]$^+$ calcd for $C_{20}H_{32}O_6Na$ 391.2097, found 391.2089.
25. *L-Menthyl 4,6-di-O-acetyl-2,3-dideoxy-α-D-erythro-hex-2-enopyranoside* **(3b)**: $[\alpha]_D^{24}$ +142.5(*c* 0.5, $CHCl_3$); ^{1}H NMR (500 MHz, $CDCl_3$) δ 5.85 (s, 2H), 5.26 (d, *J* = 10 Hz, 1H), 5.08 (s,1H), 4.18 (dd, *J* = 12.3, 6.7 Hz, 1H), 4.17–414 (m, 2H), 3.39 (dt, *J* = 10.6, 4.4 Hz, 1H), 2.17 (d, *J* = 4.0 Hz, 1H), 2.09 (s, 3H), 2.08 (s, 3H), 1.67–1.59 (m, 2H), 1.44–1.37 (m, 1H), 1.25–1.20 (m,1H), 1.03 (dd, *J* = 23.2, 12.2 Hz, 1H), 0.95 (dd, *J* = 12.1, 3.0 Hz, 1H), 0.92–0.87 (m, 7H), 0.85–0.79 (m, 1H), 0.75 (d, *J* = 7.0 Hz, 3H); ^{13}C NMR (125 MHz, $CDCl_3$) δ 170.8, 170.3, 128.5, 128.0, 96.1, 81.0, 66.6, 65.3, 63.3, 48.8, 43.3, 34.2, 31.7, 25.6, 23.1, 22.3, 21.1, 20.9, 20.8, 16.2; IR (NaCl neat) *v* 1743, 1369, 1234, 1035 cm^{-1}; HRMS (ESI) *m/z* [M+Na]$^+$ calcd for $C_{20}H_{32}O_6Na$ 391.2097, found 391.2089.
26. *(+)-Borneol 4,6-di-O-acetyl-2,3-dideoxy-α-D-erythro-hex-2-enopyranoside* (**3c**): $[\alpha]_D^{24}$ +72.6 (*c* 0.8, $CHCl_3$); ^{1}H NMR (500 MHz, $CDCl_3$) d 5.84–5.79 (m, 2H), 5.27 (d, *J* = 9.8 Hz, 1H), 4.99 (s, 1H), 4.21 (dd, *J* = 12.2, 5.6 Hz, 1H), 4.12 (dd, *J* = 12.2, 2.2 Hz, 1H), 4.10–4.09 (m, 1H), 3.82 (dt, *J* = 6.6, 2.1 Hz, 1H), 2.24–2.22 (m, 1H), 2.07 (s, 3H), 2.06 (s, 3H), 1.96–1.90 (m, 1H), 1.70–1.64 (m, 2H), 1.59 (t, *J* = 4.5 Hz, 1H), 1.23–1.17 (m, 2H), 0.94–0.82 (s, 3H), 0.81(s, 3H), 0.80 (s, 3H); ^{13}C NMR (125 MHz, $CDCl_3$) δ 170.7, 170.2, 128.4, 128.2, 96.1, 85.8, 66.8, 66.7, 64.1, 48.8, 47.7, 46.6, 38.9, 28.2, 28.2, 26.6, 20.9, 20.7, 19.7, 13.6; IR (NaCl neat) *v* 1747, 1369, 1230, 1041 cm^{-1}; HRMS (ESI) *m/z* [M+Na]$^+$ calcd for $C_{20}H_{30}O_6Na$ 389.1940, found 389.1938.
27. *(+)-Endo-fenchyl 4,6-di-O-acetyl-2,3-dideoxy-α-D-erythro-hex-2-enopyranoside* **(3d):** $[\alpha]_D^{24}$ +48.7 (*c* 0.5, $CHCl_3$); ^{1}H NMR (500 MHz, $CDCl_3$) δ 5.83 (s, 2H), 5.25 (d, *J* = 10 Hz, 1H), 4.95(s, 1H), 4.20 (dd, *J* = 12.2, 5.2 Hz, 1H), 4.13–4.09 (m, 2H), 3.42 (d, *J* = 1.5 Hz, 1H), 2.06 (s, 3H), 2.05 (2, 3H), 1.65–1.61 (m, 3H), 1.45 (dd, *J* = 10.1, 1.5 Hz, 1H), 1.38–1.36 (m, 1H), 1.08 (s, 3H), 1.07–1.06 (m, 1H), 1.01 (s, 3H), 0.96–0.94 (m, 1H), 0.85 (s, 3H); ^{13}C NMR (125 MHz, $CDCl_3$) δ 170.8, 170.2, 128.5,127.9, 94.1, 90.1, 66.8, 65.2, 63.1, 48.8, 48.7, 41.3, 39.4, 31.8, 25.9, 21.1, 20.9, 20.8, 19.7; IR (NaCl neat) *v* 1732, 1456, 1259, 1064 cm^{-1}; HRMS (ESI) *m/z* [M+Na]$^+$ Calcd for $C_{20}H_{30}O_6Na$ 389.1940, found 389.1935.
28. *Pregnenolonyl 4,6-di-O-acetyl-2,3-dideoxy-α-D-erythro-hex-2-enopyranoside* **(3e):** $[\alpha]_D^{24}$ **+**162.4 (*c* 0.5, $CHCl_3$); ^{1}H NMR (500 MHz, $CDCl_3$) δ 5.85 (d, *J* = 10.4 Hz, 1H), 5.78 (d, *J* = 10.4 Hz, 1H), 5.32 (s, 1H), 5.26 (d, *J* = 10.0 Hz, 1H), 5.14 (s, 1H), 4.20 (dd, *J* = 12.2, 5.9 Hz,1H), 4.17–413 (m, 2H), 3.57–3.51 (m, 1H), 2.50 (t, *J* = 8.0 Hz, 1H), 2.38–2.34 (m, 1H), 2.32 (d, *J* = 11.0 Hz, 1H), 2.19–2.14 (m, 1H), 2.09 (s, 3H), 2.06 (s, 3H), 2.05 (s, 3H), 2.02 (d, *J* = 9.5 Hz,1H), 1.99–1.95 (m, 1H), 1.88–1.83 (m, 2H), 1.60–1.42 (m, 8H), 1.24–1.18 (m, 1H), 1.17–1.12 (m, 1H), 1.06–1.03 (m, 1H), 0.98–0.95 (m, 4H), 0.60 (s, 3H); ^{13}C NMR (125 MHz, $CDCl_3$) δ 209.5, 170.8, 170.3, 140.7, 128.9, 128.3, 121.5, 92.8, 78.0, 66.8, 65.3, 63.6, 63.1, 56.8, 49.9, 43.9, 40.3, 38.8, 37.1, 36.6, 31.8, 31.7, 31.5, 28.1, 24.4, 22.8, 21.0, 20.9, 20.8, 19.3, 13.2; IR (NaCl neat) *v* 1745, 1699, 1371, 1228, 1035 cm^{-1}; HRMS (ESI) *m/z* [M+Na]$^+$ calcd for $C_{31}H_{44}O_7Na$ 551.2985, found: 551.2994.