FULL PAPER

Stereoselective Total Synthesis of Pectinolides A, C, and H

by **Ramesh Saudagar Ghogare**, **Sachin Bibishan Wadavrao**, and **Akkirala Venkat Narsaiah***)

Organic and Biomolecular Chemistry Division, Indian Institute of Chemical Technology, Hyderabad, Telangana 500007, India (phone: +91-40-27191608; fax: +91-40-27160387; e-mail: vnakkirala@iict.res.in)

A simple and straightforward stereoselective total synthesis of pectinolides A, C, and H is described. The synthesis has been started from commercially available (+)-diethyl L-tartrate and involves *Ohira–Bestmann* reaction, *Corey–Bakshi–Shibata* (*CBS*) reduction, and *Still–Gennari* olefination as key steps.

Keywords: Pectinolides, Unsaturated lactones, Oxidation, CBS Reduction, *Still–Gennari* olefination.

Introduction

Natural products containing an α,β-unsaturated lactone (pyron) ring are exhibiting various pharmacological activities like antifungal, antitumor, antibacterial, cytotoxic, cyclooxygenase, and phospholipase A inhibition. The broad range of biological activities reported for this class of compounds is a result of their inherent tendency to acts as good *Michael* acceptors. The α,β-unsaturated lactones are widely distributed in all parts of plants including Lamiaceae, Lauraceae, Annonaceae, and Piperaceae families. The activity and structural fascination of naturally occurring pyrone molecules has been the subject of intense research [1] (*Fig. 1*).

Pectinolides A – C (**1** – **3**) [2] and H (**4**) [3] were isolated from $CHCl_3$ extracts of the Mexican medicinal plant *Hyptis pectinata*, belonging to the Lamiaceae family, which is used in the treatment of fever, antiseptics for skin and eye infections, gastric disturbances [4], muscular pain, rhinopharyngitis, and lung congestion [5]. Pectinolide A displayed antimicrobial activity against *Staphylococcus aureus* and *Bacillus subtilis* in the concentration range of 6.25 – 12.5 μg/ml. Pectinolides B and C were active with an MIC of 12.5 – 25 μg/ml against *B. subtilis* and a value of 100 μg/ml against *S. aureus*. Pectinolide H also displayed a significant antimicrobial activity against two multidrug resistant strains of *S. Aureus*, XU-212, which is highly resistant to tetracycline, and SA 1199 B, which is resistant to certain fluoroquinolones. Pectinolides A – C exhibited significant cytotoxic activity (ED_{50} < 4 μg/ml) against a variety of tumor cell lines. The fascinating structural features and potential biological activity of pectinolides A, C, and H attracted many synthetic chemists and led to their synthesis *via* various routes [6].

Results and Discussions

As part of our regular research program in the synthesis of biologically active molecules [7], herein, we report the stereoselective total synthesis of pectinolides A, C, and H, based on $LiAlH_4$ reduction in *p*-methoxy benzylideneacetal, *Ohira–Bestmann* homologation reaction, coupling of a terminal alkyne with pentanal, *Corey–Bakshi–Shibata* (*CBS*) reduction, and *cis*-olefination using the *Still–Gennari* reagent followed by cyclization.

On the basis of a strategy represented in the retrosynthetic analysis outlined in *Scheme 1*, the synthesis was started with commercially available (+)-diethyl L-tartrate (**5**). The ester was reacted with *p*-methoxybenzaldehyde dimethyl acetal in the presence of *p*-toluene sulfonic acid (PTSA) in toluene at reflux to give the corresponding *p*-methoxybenzylideneacetal diethyl ester **6** in 70% yield.

Thus, obtained acetal ester was reductively opened with $LiAlH_4$ in the presence of $AlCl_3$ [8] to give (2*S*,3*S*)-3-(4-methoxybenzyloxy)butane-1,2,4-triol **7** in 70% yield. The regioselective protection of the 1,2-diol was carried out using 2,2-dimethoxypropane [$Me_2C(OMe)_2$] in the presence of PTSA in dry acetone at −60 °C to afford compound **8** in 85% yield [9]. The primary alcohol in compound **8** was oxidized to the aldehyde under *Swern* conditions [10], and the latter was subjected to one carbon homologation using the *Ohira–Bestmann* reagent [11] to afford the alkyne **9** in 75% yield.

The alkyne **9** was coupled with *n*-pentanal in the presence of *n*-BuLi in dry THF at −78 °C to give the alkynol **10** as a diastereoisomeric mixture in 80% yield. To obtain the required diastereoisomer, **10** was oxidized under *Swern* condition to afford the corresponding alkynone **11** in 90% yield, which was subjected to stereoselective reduction using (*S*)-2-methyl-CBS-oxazaborolidine and

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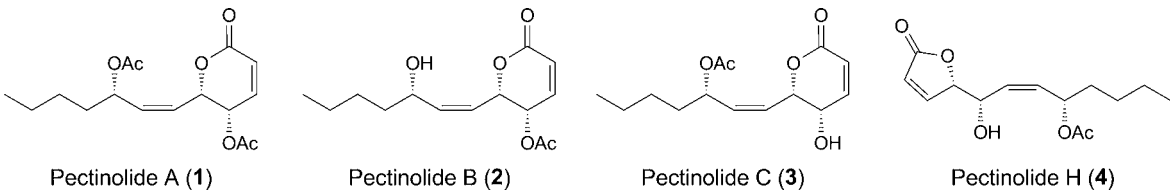
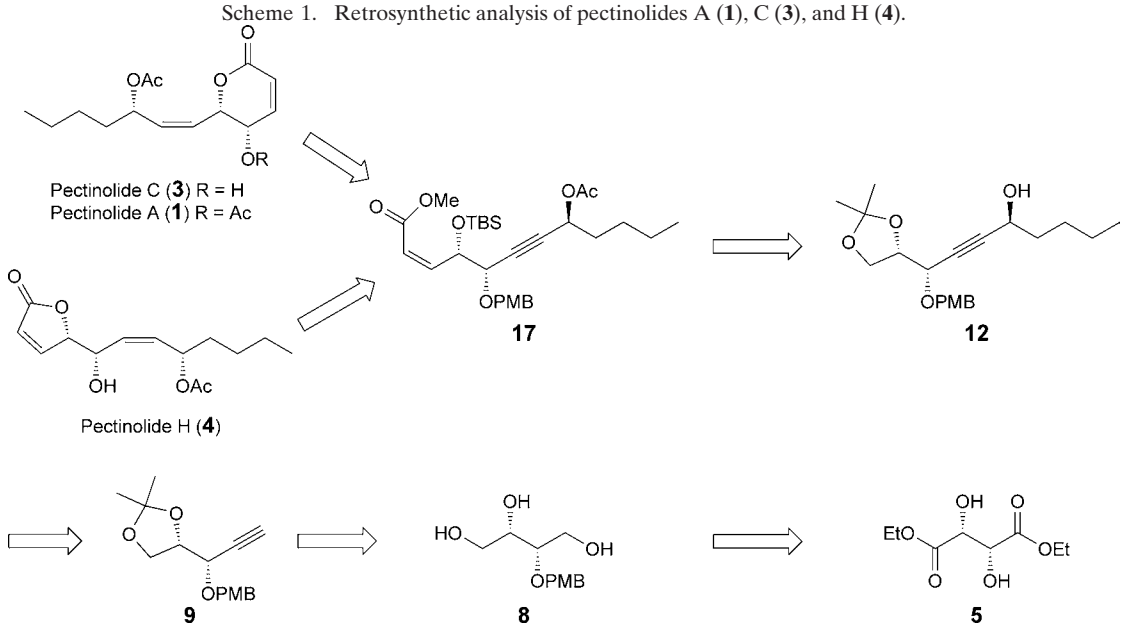


Fig. 1. Structures of pectinolides.

Scheme 1. Retrosynthetic analysis of pectinolides A (**1**), C (**3**), and H (**4**).



BH_3-DMS [12] at −40 °C to give alcohol **12** (major isomer) in 90% yield with 96% *de.*[1]).

Thus, newly created chiral alcohol was acetylated with Ac_2O in the presence of pyridine and a catalytic amount of 4-(dimethylamino)pyridine (DMAP) in CH_2Cl_2 at 0 °C to afford compound **13** in 92% yield. The deprotection of the acetonide group was achieved by using 50% aq. solution of TFA in CH_2Cl_2 to give diol **14** in 90% yield. Thus, afforded diol was converted to bis(silyl) ether **15** in 90% yield using ^{t}BuMe$_2$SiCl, pyridine and a catalytic amount of DMAP in CH_2Cl_2 at 0 °C. In the next step, the primary silyl ether was deprotected selectively in the presence of camphor sulfonic acid (CSA) at 0 °C by using CH_2Cl_2/MeOH (3:1) solvent mixture to afford **16** in 80% yield (*Scheme 2*).

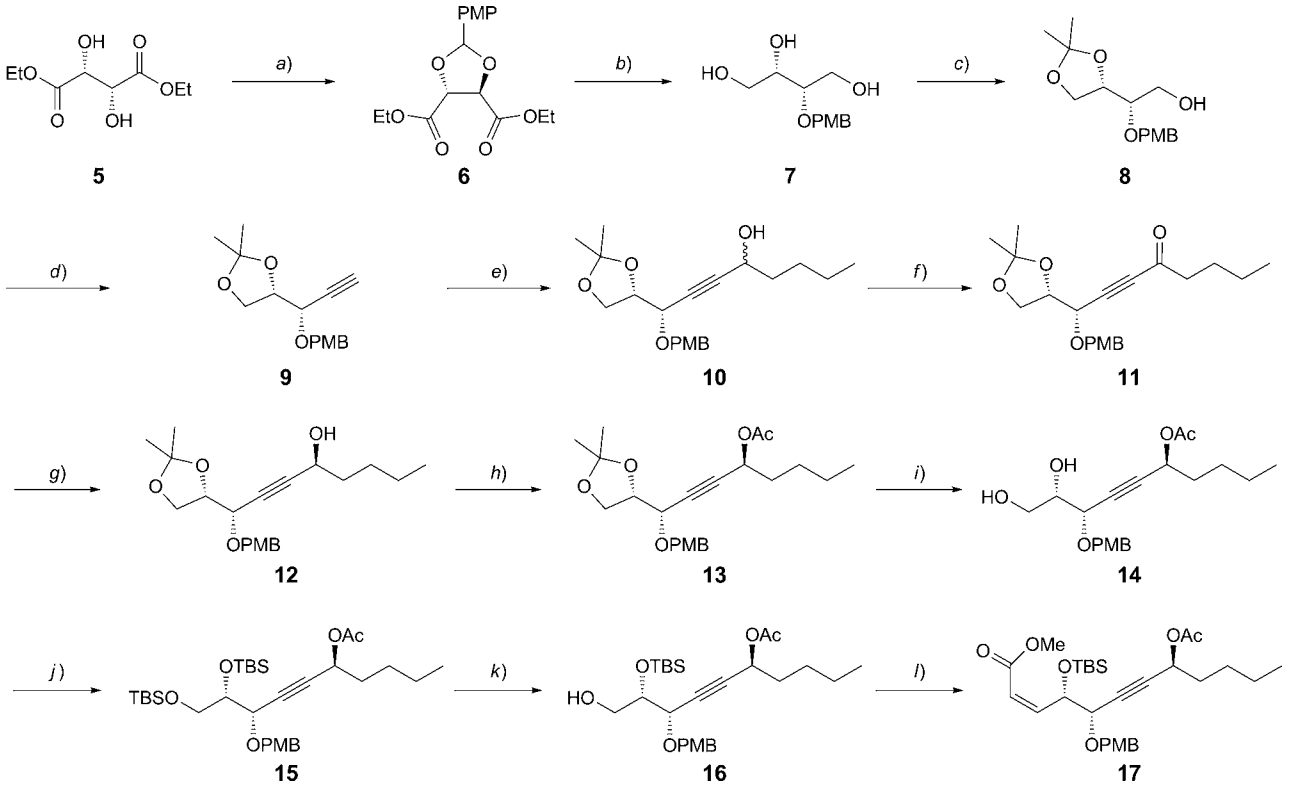
The primary alcohol was oxidized to the aldehyde with *Dess–Martin* periodinane [13] and subjected to *Still–Gennari* olefination to get stereoselectively the *cis*-olefin ester **17** in 88% yield [14]. The six-membered α,*β*-unsaturated *δ*-lactone **18** was achieved from **17** by deprotection of the PMB ether using 4,5-dichloro-3,6-dioxocyclohexa-1,4-diene-1,2-dicarbonitrile (DDQ) in CH_2Cl_2/H_2O (20:1) solvent mixture at room temperature followed by cyclization in a single step in 85% yield.

The lactone **18** was subjected to deprotection of the silyl ether using tetrabutylammonium fluoride (TBAF) in THF to give the secondary alcohol **19** in 90% yield, and the C≡C bond was reduced to the (*Z*)-olefin by using Pd/$CaCO_3$ (*Lindlar catalyst*) [15] in AcOEt to furnished the target molecule pectinolide C (**3**) in 98% yield. The observed optical rotation of the compound was $[\alpha]_D^{25}$ = 77.8 (*c* = 0.5, MeOH) and the literature reports show $[\alpha]_D^{25}$ = 80.9 (*c* = 0.76, MeOH) [3] and $[\alpha]_D^{25}$ = 72.4 (*c* = 0.5, MeOH) [6b]. Another target molecule, pectinolide A (**1**) was obtained from pectinolide C (**3**) by acetylation with Ac_2O in the presence of pyridine and a catalytic amount of DMAP in CH_2Cl_2 at 0 °C (90% yield) as shown in the *Scheme 3*. The observed optical rotation of **1** was $[\alpha]_D^{25}$ = 190.2 (*c* = 0.5, MeOH) {$[\alpha]_D^{25}$ = 191.3 (*c* = 0.5, MeOH) [6b]}.

In a similar manner, the 5-membered α,*β*-unsaturated *γ*-lactone **20** was achieved by deprotecting the silylether from the (*Z*)-olefin ester **17** using TBAF in THF, followed by cyclization in a single step to give the product in 90% yield. For deprotection of the PMB ether, **20** was treated with DDQ in CH_2Cl_2/H_2O (20:1) mixture at room temperature to give the alcohol **21** in 85% yield, which

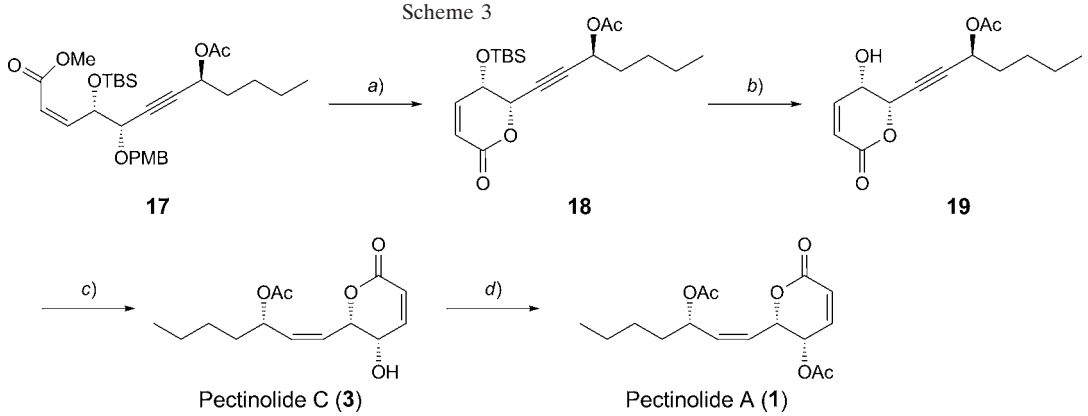
[1]) Diastereomeric excess measured by reverse phase HPLC column XDB-C18 (70:30 CH_3CN/H_2O, flow rate 1 ml/min, 200 nm), t_R: 1.755 and 2.531.

Scheme 2



a) *p*-$MeOC_6H_4CH(OMe)_2$, *p*-TSA, toulene, reflux, 8 h, 70%; *b*) $LiAlH_4$, $AlCl_3$, THF, −30 °C -reflux, 3 h, 70%; *c*) 2,2-DMP [$Me_2C(OMe)_2$], acetone, *p*-TSA, −60 °C,1 h, 85%; *d*) *i*) $(COCl)_2$, DMSO, Et_3N, −78 °C, 3 h, 90%; *ii*) dimethyl-1-diazo-2-oxopropylphosphonate, K_2CO_3, MeOH, 0 °C, 2 h, 72%; *e*) *n*-BuLi, *n*-pentanal, THF, −78 °C, 80%; *f*) $(COCl)_2$, DMSO, Et_3N, −78 °C, 3 h, 90%; *g*) (*S*)-2-methyl-CBS-oxazaborolidine catalyst, THF, −40 °C, BH_3·DMS, 3 h, 90%; *h*) Ac_2O, pyridine, DMAP, CH_2Cl_2, 0 °C, 30 min, 92%.; *i*) 50% TFA, CH_2Cl_2, 0 °C – r.t., 30 min, 90%; *j*) ^{t}BuMe$_2$Si-Cl, pyridine, cat. 4-(dimethylamino)pyridine (DMAP), CH_2Cl_2, 0 °C, 1 h 90%; *k*) CH_2Cl_2/MeOH 3:1, (camphorsulfonic acid) CSA, 0 °C,1 h, 80%; *l*) *i*) *Dess–Martin* periodinane, $NaHCO_3$, CH_2Cl_2, 0 °C, 1 h, 90%; *ii*) $(F_3CCH_2O)_2P(O)CH_2CO_2Me$, NaH, THF, −78 °C, 1 h, 88%.

Scheme 3



a) DDQ, CH_2Cl_2/H_2O 20:1, r.t., 2 h, 85%; *b*) TBAF, THF, 0 °C – r.t., 3 h, 90%; *c*) *Lindlar's* catalyst, quinoline, AcOEt, r.t., 30 min, 98%; *d*) Ac_2O, pyridine, DMAP, CH_2Cl_2, 0 °C, 30 min, 90%.

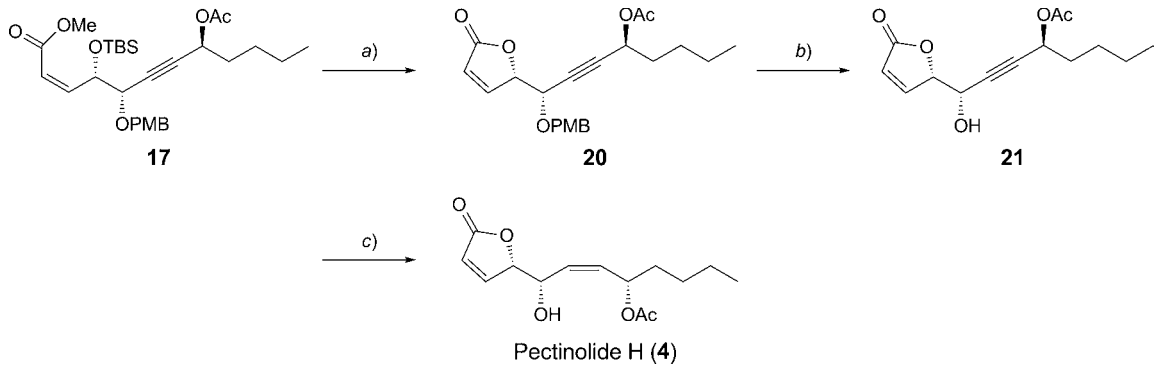
was reduced to (*Z*)-olefin by using $Pd/CaCO_3$ in AcOEt to furnished the target molecule pectinolide H (**4**) in 98% yield (*Scheme 4*).

The observed optical rotation of **4** was $[\alpha]_D^{25} = -42.8$ ($c = 0.2$, $CHCl_3$) {$[\alpha]_D^{25} = -43.7$ ($c = 0.18$, $CHCl_3$) [6d]}. The optical rotation and spectroscopic data of the prepared compounds **1**, **3**, and **4** were in good agreement with those of the reported natural and synthetic products.

Conclusions

In conclusion, we have successfully achieved a new stereoselective total synthesis of naturally occurring pectinolides A, C, and H, by using commercially available (+)-diethyl L-tartrate as starting material. Mixed metal hydride reduction, *Ohira–Bestmann* reagent, selective reduction in ketone with *Corey–Bakshi–Shibata* catalyst,

Scheme 4



a) TBAF, THF, 0 °C – r.t., 3 h, 90%; *b*) DDQ, CH_2Cl_2-H_2O 20:1, r.t., 2 h, 85%; *c*) *Lindlar's* catalyst, quinoline, AcOEt, r.t., 30 min, 98%.

C≡C bond reduction with *Lindlar*'s catalyst, and *Still–Gennari cis*-olefination are the key reactions.

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Experimental Part

General

All reagents were purchased from commercial sources and were used without further purification. All reactions were performed under an inert atmosphere unless noted otherwise. THF was freshly distilled over Na-benzophenone ketyl. Petroleum ether refers to the fraction boiling in the 60 – 80 °C range. TLC: precoated SiO_2 *60* F_{254} plates (*Merck*, Darmstadt, Germany); visualization under UV light, in an I_2 chamber, or by spraying with phosphomolybdic acid. Column chromatography (CC): silica gel (SiO_2; *Acme* grade 60 – 120 mesh). Mp.: *Büchi M-560* melting point apparatus, *Vakola*, Mumbai, India; uncorrected. Optical rotations: *Rudolph Autopol IV* polarimeter (*Rudolph Research Analytical*, Hackettstown, NJ, USA) at 278. IR Spectra: *PerkinElmer FT-IR 240-c* spectrophotometer (*PerkinElmer*, Waltham, MS, USA); $\tilde{\nu}$ in cm^{-1}. ^{1}H- and ^{13}C-NMR spectra: *Bruker-300 MHz* spectrometer (*Burker Corp.* Fällanden, Switzerland); in $CDCl_3$, at 300 and 75 MHz, resp.; δ in ppm rel. to Me_4Si as internal standard, *J* in Hz. MS: *Finnigan MAT 1020* mass spectrometer (*Finnigan*, Ringoes, NJ, USA), operating at 70 eV; in *m*/*z*.

Diethyl (4*R*,5*R*)-2-(4-Methoxyphenyl)-1,3-dioxolane-4,5-dicarboxylate (**6**). To a stirred mixture of *p*-methoxybenzaldehyde dimethyl acetal (6.2 ml, 36.4 mmol) and (+) diethyl L-tartrate (5 g, 24.2 mmol) in toluene (50 ml), PTSA (0.92 g, 4.8 mmol) was added. The resulting mixture was heated to reflux using a *Dean–Stark* trap to azeotropic removal of H_2O for 8 h. Then, the solvent was concentrated and the residue was extracted with AcOEt (2 × 25 ml). The org. layer was washed with sat. $NaHCO_3$ soln. and brine, dried (Na_2SO_4), and concentrated to give **6** (5.5 g, 70%) as a yellow-colored liquid. $[\alpha]_D^{26} = -35.1$ (*c* = 1, $CHCl_3$). IR (neat): 2982, 2924, 2851, 1737, 1614, 1517, 1394, 1215, 1096, 1026, 830, 770. ^{1}H-NMR ($CDCl_3$, 300 MHz): 7.52 (*d*, *J* = 8.7, 2 H); 6.91 (*d*, *J* = 8.7, 2 H); 6.11 (*s*, 1 H); 4.92 (*d*, *J* = 4.1, 1 H); 4.81 (*d*, *J* = 4.1 H, 1); 4.35 – 4.26 (*m*, 4 H); 3.82 (*s*, 3 H); 1.38 – 1.30 (*m*, 6 H). ^{13}C-NMR ($CDCl_3$, 75 MHz): 169.6; 169.1; 160.8; 128.7; 127.5; 113.6; 106.6; 77.4; 77.1; 61.9; 55.2; 14.1; 14.0. ESI-MS: 347 [$(M + Na)^+$], 325 [$(M + H)^+$].

(2*S*,3*S*)-3-[(4-Methoxybenzyl)oxy]butane-1,2,4-triol (**7**). To a stirred soln. of $AlCl_3$ (4.4 g, 33.1 mmol) in dry THF (25 ml), a soln. of $LiAlH_4$ (1.25 g, 33.1 mmol) in dry THF (20 ml) at −30 °C was added. Then, dry CH_2Cl_2 (20 ml) was added and the temperature was allowed to rise to 0 °C. After 10 min, a soln. of **6** (5.4 g, 16.5 mmol) in dry CH_2Cl_2 (15 ml) was added to the above mixture, which was then stirred at room temperature for 1 h and heated at reflux for 2 h. Then, the mixture was cooled to −20 °C and the reaction quenched by adding H_2O (1.5 ml) followed by 10% aq. KOH soln. (2 ml). The mixture was warmed to room temperature, stirred until the gray color disappeared, then filtered through a *Celite* bed, and the precipitate was washed with CH_2Cl_2 (2 × 50 ml). The combined filtrates were concentrated, and the residue was purified by CC (SiO_2; AcOEt/^{i}PrOH, 9:1) to give triol **7** (2.82 g 70%) as a colorless liquid, $[\alpha]_D^{26} = 38$ (*c* = 1.3, $CHCl_3$). IR (neat): 3394, 2927, 1611, 1513, 1464, 1246, 1219, 1031, 821, 772. ^{1}H-NMR ($CDCl_3$, 300 MHz): 7.26 (*d*, *J* = 8.5, 2 H); 6.89 (*d*, *J* = 8.5, 2 H); 4.64 (*d*, *J* = 11.1, 1 H); 4.51 (*d*, *J* = 11.1, 1 H); 3.91 – 3.48 (*m*, 6 H); 3.85 (*s*, 3 H); 2.90 (br. *s*, 1 H); 1.76 (br. *s*, 2 H). ^{13}C-NMR ($CDCl_3$, 75 MHz): 159.3; 129.7; 129.6; 129.5; 113.8; 78.7; 72.1; 71.6; 63.2; 60.4; 55.1. ESI-MS: 265 [$(M + Na)^+$].

(2*S*)-2-[(4*S*)-2,2-Dimethyl-1,3-dioxolan-4-yl]-2-[(4-methoxybenzyl)oxy]ethanol (**8**). To a stirred soln. of **7** (2.6 g,

10.7 mmol) in dry acetone (40 ml) at −60 °C, 2,2-DMP ($Me_2C(OMe)_2$; (1.4 ml, 11.2 mmol) and PTSA (20 mg, 0.1 mmol) were added at the same temperature and the mixture was stirred for 1 h. Then, the reaction was quenched by adding $NaHCO_3$ (50 mg) and the mixture stirred for 30 min, and filtered. The filtrate was concentrated to give a crude product, which was purified by CC (neutral Al_2O_3; AcOEt/hexane 2:8) to give compound **8** as pale yellow liquid, yield; 2.67 g (85%). $[\alpha]_D^{26}$ = −26.2 (*c* = 0.8, $CHCl_3$). IR (neat): 3390, 2925, 1661, 1628, 1550, 1514, 1466, 1219, 772. ^{1}H-NMR ($CDCl_3$, 300 MHz): 7.29 (*d*, *J* = 8.7, 2 H); 6.89 (*d*, *J* = 8.7, 2 H); 4.70 (*d*, *J* = 11.4, 1 H); 4.62 (*d*, *J* = 11.4, 1 H); 4.29 (*dt*, *J* = 6.7, 6.1 H, 1 H); 4.00 (*dd*, *J* = 8.3, 6.5 H, 1 H); 3.81 (*s*, 3 H); 3.80 – 3.77 (*m*, 1 H); 3.75 – 3.64 (*m*, 1 H); 3.61 – 3.51 (*m*, 2 H); 1.43 (*s*, 3 H); 1.37 (*s*, 3 H). ^{13}C-NMR ($CDCl_3$, 75 MHz): 159.3; 130.1; 129.5; 113.8; 109.4; 78.7; 76.5; 72.4; 65.5; 61.6; 55.2; 26.3; 25.2. ESI-MS: 305 [(*M* + Na)$^+$].

(4*S*)-4-{(1*S*)-1-[(4-Methoxybenzyl)oxy]prop-2-yn-1-yl}-2,2-dimethyl-1,3-dioxolane (**9**). To a stirred soln. of dry CH_2Cl_2 (20 ml) and $COCl_2$ (1.2 ml, 13.8 mmol) was added dry DMSO (2 ml, 27.6 mmol) at −78 °C. Then a soln. of alcohol **8** (2.6 g, 9.2 mmol) dissolved in CH_2Cl_2 (10 ml) was added and the mixture was stirred at the same temperature for 2 h. Then Et_3N (6.4 ml, 46 mmol) was added and continued stirring for 30 min. Then, the mixture temperature was allowed to rise to 0 °C and quenched with sat. NH_4Cl soln. The mixture was extracted with CH_2Cl_2 (2 × 10 ml) and the combined organic extracts were washed with brine, dried (Na_2SO_4), and concentrated to give the aldehyde (2.33 g, 90%) which was used for next reaction.

To a stirred soln. of K_2CO_3 (2.3 g, 16.6 mmol) and *dimethyl-1-diazo-2-oxopropyl phosphonate* (1.75 g, 9.1 mmol) in dry MeOH (20 ml) was added drop wise the above aldehyde (2.33 g, 8.3 mmol) which was dissolved in dry MeOH (10 ml) at room temperature. The resulting mixture was stirred for 2 h and confirmed the completion of reaction by TLC. The reaction mixture was filtered through *Celite* pad and the filtrate was concentrated and purified by CC (SiO_2; AcOEt/hexane 1:9) to give the pure alkyne **9** (1.65 g, 72%) as pale yellow oil. $[\alpha]_D^{26}$ = 27.8 (*c* = 1, $CHCl_3$). IR (neat): 3278, 2987, 2922, 2853, 2113, 1612, 1513, 1217, 1068, 1034, 772. ^{1}H-NMR ($CDCl_3$, 300 MHz): 7.30 (*d*, *J* = 8.5, 2 H); 6.88 (*d*, *J* = 8.5, 2 H); 4.78 (*d*, *J* = 11.6, 1 H); 4.72 – 4.45 (*m*, 2 H); 4.35 – 4.20 (*m*, 1 H); 4.16 – 3.88 (*m*, 2 H); 3.81 (*s*, 3 H); 3.44 (*d*, *J* = 9.4, 1 H); 1.40 (*s*, 3 H); 1.35 (*s*, 3 H). ^{13}C-NMR ($CDCl_3$, 75 MHz): 159.3; 129.8; 129.4; 129.4; 113.8; 110.2; 81.6; 80.8; 79.4; 75.5; 70.3; 66.2; 55.2; 26.4; 25.3. ESI-MS: 299 [(*M* + Na)$^+$], 294 [(*M* + H)$^+$].

1-[(4*S*)-2,2-Dimethyl-1,3-dioxolan-4-yl]-1-[(4-methoxybenzyl)oxy]oct-2-yn-4-ol (**10**). To a stirred soln. of **9** (1.6 g, 5.7 mmol) in dry THF (10 ml) was added BuLi (4.3 ml, 6.9 mmol; 1.6M in hexane) at −78 °C. The mixture was stirred for 30 min, and added a soln. of pentanal (0.75 g, 8.5 mmol) dissolved in dry THF (5 ml). The resulting mixture was stirred for 3 h at −78 °C. The reaction mixture was quenched with sat. aq. NH_4Cl soln. (10 ml) and extracted with AcOEt (2 × 25 ml), the combined organic extract washed with brine, dried (Na_2SO_4), and concentrated. The residue was purified by CC (SiO_2; AcOEt/hexane 1:9) to give diastereoisomeric mixture of propargylic alcohol **10** (1.67 g, 80%) as pale yellow oil. ^{1}H-NMR ($CDCl_3$, 300 MHz): 7.25 (*d*, *J* = 8.5, 2 H); 6.85 (*d*, *J* = 8.5, 2 H); 4.73 (*d*, *J* = 11.7, 1 H); 4.57 – 4.34 (*m*, 2 H); 4.28 – 4.10 (*m*, 2 H); 3.96 – 3.88 (*m*, 2 H); 3.81 (*s*, 3 H); 1.83 – 1.61 (*m*, 2 H); 1.55 – 1.20 (*m*, 10 H); 0.93 (*t*, *J* = 7.3, 3 H). ^{13}C-NMR ($CDCl_3$, 75 MHz): 159.3; 129.7; 129.3; 128.6; 113.7; 110.1; 80.8; 80.2; 77.2; 73.2; 69.8; 66.4; 62.3; 55.2; 37.3; 27.2; 26.5; 25.2; 22.3; 13.9. ESI-MS: 385 [(*M* + Na)$^+$].

(1*S*)-1-[(4*S*)-2,2-Dimethyl-1,3-dioxolan-4-yl]-1-[(4-methoxybenzyl)oxy]oct-2-yn-4-one (**11**). To a stirred soln. of dry CH_2Cl_2 (10 ml) and $COCl_2$ (0.35 ml, 6.6 mmol) was added dry DMSO (1.5 ml, 13.2 mmol) at −78 °C. Then a soln. of **10** (1.6 g, 4.4 mmol) dissolved in CH_2Cl_2 (10 ml) was added and the mixture was stirred at the same temperature for 2 h. Then Et_3N (3 ml, 22 mmol) was added and continued stirring for 30 min. The mixture was allowed to rise to 0 °C and quenched with sat. NH_4Cl soln. then, the mixture was extracted with CH_2Cl_2 (2 × 10 ml) and the combined organic extracts were washed with brine, dried (Na_2SO_4), and concentrated. The residue was purified by CC (SiO_2; AcOEt/hexane 5:95) to give the pure ketone **11** (1.43 g, 90%) as colorless liquid. $[\alpha]_D^{26}$ = −13.6 (*c* = 1, $CHCl_3$). IR (neat): 2957, 2931, 2871, 2211, 1677, 1585, 1513, 1461, 1375, 1248, 1219, 1075, 1034, 772. ^{1}H-NMR ($CDCl_3$, 300 MHz): 7.29 (*d*, *J* = 8.2, 2 H); 6.89 (*d*, *J* = 8.2, 2 H); 4.77 (*d*, *J* = 11.7, 1 H); 4.51 (*d*, *J* = 11.7, 1 H); 4.30 – 4.22 (*m*, 1 H); 4.18 – 4.04 (*m*, 2 H); 4.01 – 3.88 (*m*, 1 H); 3.81 (*s*, 3 H); 2.58 (*t*, *J* = 7.4, 2 H); 1.73 – 1.58 (*m*, 3 H); 1.48 – 1.32 (*m*, 7 H); 0.93 (*t*, *J* = 7.3, 3 H). ^{13}C-NMR ($CDCl_3$, 75 MHz): 187.4; 159.5; 129.8; 128.6; 113.8; 110.2; 87.6; 85.6; 85.2; 71.1; 69.2; 66.1; 55.2; 45.2; 26.4; 25.9; 25.1; 22.0; 13.7. ESI-MS: 383 [(*M* + Na)$^+$], 378 [(*M* + NH_4)$^+$].

(1*S*,4*S*)-1-[(4*S*)-2,2-Dimethyl-1,3-dioxolan-4-yl]-1-[(4-ethoxybenzyl)oxy]oct-2-yn-4-ol (**12**). To a stirred soln. of **11** (1.4 g, 5.4 mmol) in dry THF (15 ml) was added (*S*)-(-)-methyl-CBS-oxazaborolidine (1.6 ml, 1 M soln. in toluene, 1.6 mmol) at −40 °C. After 30 min, stirring, BH_3.DMS (0.45 ml, 5.9 mmol) was added drop wise and stirred at the same temperature for 1 h. After completion of the reaction checked by TLC, the mixture was quenched with MeOH (0.1 ml) followed by sat. $NaHCO_3$ soln. Then the reaction mixture was extracted with AcOEt (2 × 15 ml) and the combined organic layers were washed with brine, dried (Na_2SO_4), and concentrated. The crude product was purified by CC (SiO_2; AcOEt/hexane 1:9) to give secondary alcohol **12** (1.26 g, 90%) as

pale yellow liquid with *de* >96%. Diastereomeric excess measured by reverse phase HPLC column *XDB-C18* (7:3 CH_3CN/H_2O, flow rate 1 ml/min, 200 nm), t_R: 1.755 (major) and t_R: 2.531 (minor). $[\alpha]_D^{26} = -3.8$ (c = 1, $CHCl_3$). IR (neat): 3395, 2954, 2929, 2859, 1612, 1513, 1463, 1375, 1247, 1034, 772. ^{1}H-NMR ($CDCl_3$, 300 MHz): 7.29 (*d*, *J* = 8.8, 2 H); 6.88 (*d*, *J* = 8.8, 2 H); 4.75 (*d*, *J* = 11.7, 1 H); 4.58 – 4.34 (*m*, 2 H); 4.31 – 4.13 (*m*, 2 H); 4.12 – 4.01 (*m*, 1 H); 3.98 – 3.88 (*m*, 1 H); 3.81 (*s*, 3 H); 1.83 – 1.62 (*m*, 2 H); 1.55 – 1.21 (*m*, 10 H); 0.93 (*t*, *J* = 7.3, 3 H). ^{13}C-NMR ($CDCl_3$, 75 MHz): 159.3; 129.7; 129.2; 128.5; 113.7; 110.1; 88.7; 80.8; 80.2; 73.2; 69.9; 66.3; 62.3; 55.2; 37.3; 27.2; 26.5; 25.2; 22.3; 13.9. ESI-MS: 385 $[(M + Na)^+]$, 380 $[(M + NH_4)^+]$.

(1*S*,4*S*)-1-[(4*S*)-2,2-Dimethyl-1,3-dioxolan-4-yl]-1-[(4-ethoxybenzyl)oxy]oct-2-yn-4-yl Acetate (**13**). To stirred soln. of **12** (1.2 g, 3.3 mmol) in dry CH_2Cl_2 (15 ml) was added pyridine (0.35 ml, 4.3 mmol) at 0 °C. After 10 min, stirring, Ac_2O (0.4 ml, 4 mmol) followed by cat. DMAP were added. The reaction mixture was then allowed to stir for 30 min, at room temperature. After completion of the reaction as indicated by TLC, cold H_2O was poured into reaction mixture (10 ml) and extracted with CH_2Cl_2 (2 × 10 ml). The combined organic layers were washed with brine, dried (Na_2SO_4), and concentrated. The crude product was purified by CC (SiO_2; AcOEt/hexane 5:95) to give the pure acetate **13** (1.23 g, 92%) as colorless oil. $[\alpha]_D^{26} = -14.6$ (c = 1, $CHCl_3$). IR (neat): 2955, 2931, 2866, 1742, 1612, 1513, 1371, 1222, 1074, 1033, 772. ^{1}H-NMR ($CDCl_3$, 300 MHz): 7.29 (*d*, *J* = 8.4, 2 H); 6.87 (*d*, *J* = 8.4, 2 H); 5.49 – 5.35 (*m*, 1 H); 4.75 (*d*, *J* = 11.5, 1 H); 4.56 – 4.44 (*m*, 2 H); 4.29 – 4.13 (*m*, 1 H); 4.12 – 4.01 (*m*, 1 H); 3.99 – 3.85 (*m*, 1 H); 3.81 (*s*, 3 H); 2.08 (*s*, 3 H); 1.87 – 1.67 (*m*, 2 H); 1.54 – 1.21 (*m*, 10 H); 0.91 (*t*, *J* = 7.3, 3 H). ^{13}C-NMR ($CDCl_3$, 75 MHz): 169.8; 159.3; 129.8; 129.7; 129.2; 113.7; 110.1; 84.0; 82.1; 81.3; 73.2; 69.8; 66.2; 63.8; 55.2; 34.2; 27.1; 26.4; 25.3; 22.1; 20.9; 13.8. ESI-MS: 427 $[(M + Na)^+]$, 422 $[(M + NH_4)^+]$.

(5*S*,8*S*,9*S*)-9,10-Dihydroxy-8-[(4-methoxybenzyl)oxy]dec-6-yn-5-yl Acetate (**14**). To a stirred soln. of **13** (1.2 g, 3 mmol) in CH_2Cl_2 was added 50% aq. soln. of TFA at 0 °C. After 30 min, reaction was quenched by sat. $NaHCO_3$ soln. and extracted with CH_2Cl_2 (2 × 10 ml). The combined organic layer was washed with brine, dried (Na_2SO_4), and concentrated. The crude product was purified by CC (SiO_2; AcOEt/hexane 3:7) to give diol **14** (0.97 g, 90%) as yellowish liquid. $[\alpha]_D^{26} = -27.1$ (c = 1, $CHCl_3$). IR (neat): 3457, 2954, 2923, 2854, 1738, 1612, 1513, 1371, 1228, 1028, 772. ^{1}H-NMR ($CDCl_3$, 300 MHz): 7.28 (*d*, *J* = 8.5, 2 H); 6.88 (*d*, *J* = 8.5, 2 H); 5.47 – 5.30 (*m*, 1 H); 4.76 (*d*, *J* = 11.1, 1 H); 4.44 (*d*, *J* = 11.1, 1 H); 4.29 – 4.14 (*m*, 1 H); 3.93 – 3.63 (*m*, 3 H); 3.80 (*s*, 3 H); 2.91 (br. *s*, 1 H); 2.84 (br. *s*, 1 H); 2.09 (*s*, 3 H); 1.88 – 1.68 (*m*, 2 H); 1.50 – 1.20 (*m*, 4 H); 0.92 (*t*, *J* = 7.5, 3 H). ^{13}C-NMR ($CDCl_3$, 75 MHz): 170.0; 159.4; 129.8; 129.7; 128.9; 113.8; 85.9; 81.2; 73.4; 72.7; 70.9; 64.0; 63.0; 55.2; 34.2; 27.1; 22.1; 20.9; 13.8. ESI-MS: 387 $[(M + Na)^+]$, 382 $[(M + NH_4)^+]$.

(5*S*,8*S*,9*S*)-9,10-bis{[*tert*-Butyl(dimethyl)silyl]oxy}-8-[(4-methoxybenzyl)oxy]dec-6-yn-5-yl Acetate (**15**). To a stirred soln. of **14** (0.9 g, 2.5 mmol) in dry CH_2Cl_2 (10 ml) was added pyridine (0.68 g, 10 mmol) and ^{t}BuMe$_2$SiCl (0.83 g, 5.5 mmol) at 0 °C. Then, the reaction mixture was stirred at room temperture for 1 h. Crushed ice was added and the mixture was extracted with CH_2Cl_2 (2 × 15 ml). The org. extracts were washed with brine, dried (Na_2SO_4), and concentrated. The crude product was purified by CC (SiO_2; AcOEt/hexane 3:7) to give the compound **15** (1.31 g, 90%) as colorless syrup. $[\alpha]_D^{26} = 14.6$ (c = 1, $CHCl_3$). IR (neat): 2953, 2928, 2856, 1744, 1612, 1513, 1465, 1367, 1247, 1228, 1083, 1037, 832, 773. ^{1}H-NMR ($CDCl_3$, 300 MHz): 7.28 (*d*, *J* = 8.4, 2 H); 6.85 (*d*, *J* = 8.4, 2 H); 5.50 – 5.30 (*m*, 1 H); 4.71 (*d*, *J* = 11.3, 1 H); 4.51 – 4.37 (*m*, 2 H); 4.27 – 4.12 (*m*, 1 H); 3.81 (*s*, 3 H); 3.84 – 3.78 (*m*, 1 H); 3.71 – 3.55 (*m*, 1 H); 2.08 (*s*, 3 H); 1.84 – 1.62 (*m*, 2 H); 1.50 – 1.22 (*m*, 4 H); 0.98 – 0.78 (*m*, 21 H); 0.18 – 0.03 (*m*, 12 H). ^{13}C-NMR ($CDCl_3$, 75 MHz): 169.8; 159.1; 129.9; 129.6; 129.1; 113.6; 84.3; 82.5; 75.4; 72.9; 70.4; 64.6; 64.1; 55.2; 34.5; 27.1; 25.9; 25.8; 22.2; 21.0; 18.1; 13.8; −4.4; −4.7; −4.8; −5.4. ESI-MS: 610 $[(M + NH_4)^+]$.

(5*S*,8*S*,9*S*)-9-{[*tert*-Butyl(dimethyl)silyl]oxy}-10-hydroxy-8-[(4-methoxybenzyl)oxy]dec-6-yn-5-yl Acetate (**16**). To a stirred soln. **15** (1.25 g, 2.1 mmol) in CH_2Cl_2/MeOH (20 ml, 3:1) was added CSA (50 mg, 0.2 mmol) at 0 °C and continued stirring for 1 h. After completion of the reaction, the mixture was quenched by adding sat. aq. $NaHCO_3$ and extracted with CH_2Cl_2 (2 × 10 ml). The combined organic extracts were washed with brine, dried (Na_2SO_4), and concentrated. The crude product was purified by CC (SiO_2; AcOEt/hexane 3:7) to give alcohol **16** (0.8 g, 80%), as yellowish liquid; $[\alpha]_D^{26} = -3.7$ (c = 1, $CHCl_3$). IR (neat): 3395, 2954, 2928, 2856, 1742, 1612, 1513, 1465, 1370, 1247, 1222, 1225, 1036, 772. ^{1}H-NMR ($CDCl_3$, 300 MHz): 7.27 (*d*, *J* = 8.5, 2 H); 6.87 (*d*, *J* = 8.5, 2 H); 5.52 – 5.36 (*m*, 1 H); 4.72 (*d*, *J* = 11.2, 1 H); 4.42 (*d*, *J* = 11.2, 1 H); 4.18 – 4.12 (*m*, 1 H); 3.86 – 3.60 (*m*, 3 H); 3.81 (*s*, 3 H); 2.08 (*s*, 3 H); 1.83 – 1.72 (*m*, 2 H); 1.50 – 1.26 (*m*, 4 H); 0.96 – 0.84 (*m*, 12 H); 0.03 (*m*, 6 H). ^{13}C-NMR ($CDCl_3$, 75 MHz): 169.9; 159.2; 129.7; 129.3; 129.2; 113.6; 84.6; 82.5; 73.8; 70.8; 70.3; 64.1; 64.0; 55.2; 34.3; 27.1; 25.7; 22.1; 20.9; 18.0; 13.8; −4.6; −4.9. ESI-MS: 501 $[(M + Na)^+]$, 496 $[(M + NH_4)^+]$.

Methyl (2*Z*,4*S*,5*S*,8*S*)-8-(Acetyloxy)-4-{[*tert*-butyl(dimethyl)silyl]oxy}-5-[(4-methoxybenzyl)oxy]dodec-2-en-6-ynoate (**17**). To a stirred soln. of dry CH_2Cl_2 (5 ml) and alcohol **16** (0.75 g, 1.56 mmol) was added $NaHCO_3$ (0.13 g, 1.56 mmol) at 0 °C. After 5 min, *Dess–Martin* periodinane (0.8 g, 1.9 mmol) was added and continued stirring for 1 h at the same temperature. Then reaction mixture was quenched by adding Na_2SO_3 (0.4 g, 3.1 mmol) and continue

stirred for 30 min. The mixture was extracted with CH_2Cl_2 (2 × 10 ml) and the combined organic extracts were washed with brine, dried (Na_2SO_4), and concentrated. The crude product was purified by CC (SiO_2; AcOEt/hexane 2:8) to give aldehyde (0.67 g, 90%) which was used for next reaction.

To a stirred soln. of dry THF (10 ml) and methyl-2-[*bis*(2,2,2-trifluoroethoxy) phosphoryl] acetate (0.53 g, 1.7 mmol) was added NaH (37 mg, 1.54 mmol) at 0 °C and continued stirring for 30 min. Then the reaction mixture was cooled to −78 °C and added the above aldehyde (0.67 g, 1.4 mmol) dissolved in dry THF (5 ml) and continue stirred for 1 h at −78 °C. The reaction was then quenched with sat. NH_4Cl, solvent was removed under reduced pressure and the residue was extracted with AcOEt (2 × 10 ml). The combined organic extracts were washed with brine, dried (Na_2SO_4), and concentrated. The crude product was purified by CC (SiO_2; AcOEt/hexane 1:9) to give pure (*Z*)-olefin ester **17** (0.65 g, 85%) as colorless liquid; $[\alpha]_D^{26} = -15.5$ (c = 1, $CHCl_3$). IR (neat): 2927, 2855, 1745, 1726, 1662, 1462, 1373, 1232, 1190, 1053, 879. ^{1}H-NMR ($CDCl_3$, 300 MHz): 7.29 (*d*, *J* = 8.7, 2 H); 6.88 (*d*, *J* = 8.5, 2 H); 6.38 (*dd*, *J* = 9.6, 3.7 H, 1 H); 5.96 (*d*, *J* = 11.9, 1 H); 5.50 – 5.38 (*m*, 1 H); 4.74 (*d*, *J* = 11.4, 1 H); 4.48 – 4.38 (*m*, 2 H); 4.18 (*d*, *J* = 6.2, 1 H); 3.81 (*s*, 3 H); 3.63 (*s*, 3 H); 2.08 (*s*, 3 H); 1.80 – 1.70 (*m*, 2 H); 1.48 – 1.28 (*m*, 4 H); 0.98 – 0.86 (*m*, 12 H); 0.05 (*m*, 6 H). ^{13}C-NMR ($CDCl_3$, 75 MHz): 169.9; 166.1; 159.2; 146.1; 129.8; 129.2; 120.1; 113.8; 84.6; 82.5; 73.8; 70.8; 70.4; 64.0; 55.2; 51.5; 34.5; 27.1; 25.7; 22.1; 21.0; 18.0; 13.8; −4.6; −4.9. ESI-MS m/z: 550 [$(M + NH_4)^+$].

(3*S*)-1-[(2*S*,3*S*)-3-{[*tert*-Butyl(dimethyl)silyl]oxy}-3,6-dihydro-6-oxo-2*H*-pyran-2-yl]hept-1-yn-3-yl Acetate (**18**). To a stirred soln. of **17** (300 mg, 0.56 mmol) in CH_2Cl_2/H_2O (5 ml, 20:1) mixture was added DDQ (254 mg, 1.1 mmol) at room temperature and continued stirring for 2 h. After completion of reaction, then, the mixture was quenched by adding sat. aq. $NaHCO_3$ and extracted with CH_2Cl_2 (2 × 5 ml). The combined organic extracts were washed with brine, dried over Na_2SO_4, and concentrated. The crude product was purified by CC (SiO_2; AcOEt/hexane 2:8) to give cyclized lactone **18** (180 mg 85%) as yellow liquid; $[\alpha]_D^{26} = 18.3$ (c = 1, $CHCl_3$). IR (neat): 2924, 2854, 1722, 1638, 1457, 1372, 1271, 1220, 1105, 771. ^{1}H-NMR ($CDCl_3$, 300 MHz): 6.84 (*dd*, *J* = 9.6, 3.5 H, 1 H); 6.12 (*d*, *J* = 9.8, 1 H); 5.38 (*dd*, *J* = 5.3, 2.4 H, 1 H); 4.42 – 4.34 (*m*, 2 H); 2.10 (*s*, 3 H); 1.68 – 1.54 (*m*, 2 H); 1.44 – 1.30 (*m*, 4 H); 0.94 – 0.80 (*m*, 12 H); 0.08 (*m*, 6 H). ^{13}C-NMR ($CDCl_3$, 75 MHz): 170.3; 161.4; 140.1; 125.7; 85.0; 83.0; 75.8; 74.5; 64.4; 34.7; 27.5; 26.1; 22.6; 21.4; 18.4; 14.3; −4.2; −4.5. ESI-MS: 398 [$(M + NH_4)^+$].

(3*S*)-1-[(2*S*,3*S*)-3,6-Dihydro-3-hydroxy-6-oxo-2*H*-pyran-2-yl]hept-1-yn-3-yl Acetate (**19**). To a stirred soln. of **18** (150 mg, 0.4 mmol) in dry THF (5 ml) at 0 °C was added TBAF (0.8 ml, 1M, THF, 0.8 mmol) and continued stirring at room temperature for 3 h. Then, the solvent was removed under reduced pressure and residue was adsorbed on silica gel and purified by CC (SiO_2; AcOEt/hexane 4:6) to give pure alcohol **19** (95 mg, 90%) as colorless liquid; $[\alpha]_D^{26} = 42.8$ (c = 1, $CHCl_3$). IR (neat): 3447, 2927, 2855, 1724, 1639, 1373, 1224, 1106, 712. ^{1}H-NMR ($CDCl_3$, 300 MHz): 6.80 (*dd*, *J* = 9.8, 3.5, 1 H); 6.10 (*d*, *J* = 9.8, 1 H); 5.36 (*dd*, *J* = 5.4, 2.5 H, 1 H); 4.38 – 4.28 (*m*, 2 H); 2.10 (*s*, 3 H); 1.86 – 1.68 (*m*, 2 H); 1.48 – 1.26 (*m*, 4 H); 0.96 (*t*, *J* = 7.5, 3 H). ^{13}C-NMR ($CDCl_3$, 75 MHz): 170.2; 161.1; 142.6; 124.8; 86.1; 83.8; 73.7; 71.1; 64.3; 34.5; 27.4; 22.4; 21.2; 14.1. ESI-MS: 289 [$(M + Na)^+$], 284 [$(M + NH_4)^+$].

(1*Z*,3*S*)-1-[(2*S*,3*S*)-3,6-Dihydro-3-hydroxy-6-oxo-2*H*-pyran-2-yl]hept-1-en-3-yl Acetate (**3**). The stirred mixture of **19** (70 mg, 0.26 mmol) and $Pd/CaCO_3$ (*Lindlar* catalyst) (50 mg) was poisoned by adding one drop of quinoline in AcOEt (3 ml) for 30 min, at room temperature under H_2 atmosphere. After completion of reaction, the mixture was filtered through *Celite* pad and filtrate was concentrated and purified by CC (SiO_2; AcOEt/hexane 4:6) to give (*Z*)-olefin **3** (69 mg, 98%) as colorless oil. $[\alpha]_D^{25} = 77.8$ (c = 0.5, MeOH), lit. $[\alpha]_D^{25} = 80.9$ (c = 0.76, MeOH) [3], $[\alpha]_D^{25} = 72.4$ (c = 0.5, MeOH) [6b]. IR (neat): 3447, 2957, 2927, 2858, 1730, 1661, 1373, 1248, 1167, 1042, 830, 775. ^{1}H-NMR ($CDCl_3$, 300 MHz): 6.88 (*dd*, *J* = 9.8, 5.6, 1 H); 6.18 (*d*, *J* = 9.8, 1 H); 5.80 – 5.68 (*m*, 2 H); 5.52 (*ddd*, *J* = 9.8, 7.6, 5.8 H, 1H); 5.28 (*dd*, *J* = 6.1, 5.2 H, 1 H); 4.13 (*dd*, *J* = 5.6, 2.4 H, 1 H); 2.08 (*s*, 3 H); 1.78 – 1.54 (*m*, 2 H); 1.46 – 1.22 (*m*, 4 H); 0.94 (*t*, *J* = 7.5, 3 H). ^{13}C-NMR ($CDCl_3$, 75 MHz): 170.3; 162.0; 144.6; 133.3; 125.7; 122.5; 77.4; 70.8; 63.1; 34.7; 27.5; 22.6; 21.4; 14.3. ESI-MS m/z: 286 [$(M + NH_4)^+$].

(2*S*,3*S*)-2-[(1*Z*,3*S*)-3-(Acetyloxy)hept-1-en-1-yl]-3,6-dihydro-6-oxo-2*H*-pyran-3-yl Acetate (**1**). To stirred soln. of **3** (40 mg, 0.15 mmol) in dry CH_2Cl_2 (2 ml), pyridine (15 µl, 0.18 mmol) was added at 0 °C. After 10 min, was added Ac_2O (17 µl, 0.16 mmol) followed by cat. DMAP. The reaction mixture was then allowed to stir for 30 min, at room temperature. After completion of the reaction as indicated by TLC, cold H_2O was poured into reaction mixture (2 ml) and extracted with CH_2Cl_2 (2 × 2 ml). The combined organic layers were washed with brine, dried (Na_2SO_4), and concentrated. The crude product was purified by CC (SiO_2; AcOEt/hexane 25:75) mixture to give the pure acetate **1** (41 mg, 90%) as colorless oil. $[\alpha]_D^{25} = 190.2$ (c = 0.5, MeOH), lit. $[\alpha]_D^{25} = 191.3$ (c = 0.5, MeOH) [6b]. IR (neat): 2956, 2931, 2859, 1747, 1463, 1372, 1232, 1078, 1023, 838, 779. ^{1}H-NMR ($CDCl_3$, 300 MHz): 6.92 (*dd*, *J* = 9.8, 5.6 H, 1 H); 6.22 (*d*, *J* = 9.8, 1 H); 5.75 (*dd*, *J* = 11.6, 8.5 H, 1 H); 5.62 (*d*, *J* = 9.8, 1 H); 5.50 (*dd*, *J* = 8.5, 3.0 H, 1 H); 5.33 (*ddd*, *J* = 9.8, 7.5, 6.0 H, 1 H); 5.16 (*dd*, *J* = 6.1, 3.2 H, 1 H); 2.08 (*s*, 3 H); 2.04 (*s*, 3 H); 1.82 – 1.72 (*m*, 2 H); 1.46 – 1.24 (*m*, 4 H); 0.90 (*t*, *J* = 7.5, 3 H). ^{13}C-NMR ($CDCl_3$, 75 MHz): 170.2;

169.8; 162.1; 140.1; 133.6; 126.2; 125.0; 75.0; 69.2; 64.3; 34.2; 27.1; 22.1; 21.0; 20.8; 13.8. ESI-MS: 311 [$(M + H)^+$].

(1*S*,4*S*)-1-[(4-methoxybenzyl)oxy]-1-(5-oxo-2,5-dihydrofuran-2-yl)oct-2-yn-4-yl Acetate (**20**). To a stirred soln. of **17** (250 mg, 0.8 mmol) in dry THF (5 ml) at 0 °C was added TBAF (1.6 ml, 1 M, THF, 0.16 mmol) and continued stirring at room temperature for 3 h. Then the reaction mixture was concentrated and the obtained residue was purified by CC (SiO_2; AcOEt/hexane 2:8) to give lactone **20** (163 mg, 90%) as colorless liquid. $[\alpha]_D^{26} = -27.3$ (*c* = 0.5, $CHCl_3$). IR (neat): 2957, 2934, 2873, 1744, 1660, 1459, 1373, 1233, 1162, 1050, 849. ^{1}H-NMR ($CDCl_3$, 300 MHz): 7.54 – 7.48 (*m*, 1 H); 7.35 (*d*, *J* = 8.6, 2 H); 6.87 (*d*, *J* = 8.6, 2 H); 6.19 (*d*, *J* = 11.9, 1 H); 5.36 – 5.28 (*m*, 2 H); 5.12 (*dd*, *J* = 6.2, 3.7 H, 1 H); 4.88 (*d*, *J* = 11.4, 1 H); 4.57 (d, *J* = 11.4, 1 H); 3.81 (*s*, 3 H); 2.08 (*s*, 3 H); 1.78 – 1.68 (*m*, 2 H); 1.48 – 1.18 (*m*, 4 H); 0.90 (*t*, *J* = 7.6, 3 H). ^{13}C-NMR ($CDCl_3$, 75 MHz): *δ* 172.2; 170.2; 152.7; 129.8; 129.2; 123.1; 113.8; 85.2; 84.5; 84.2; 65.1; 63.7; 55.2; 33.8; 26.8; 21.9; 20.7; 13.6. ESI-MS: 409 [$(M + Na)^+$], 387 [$(M + H)^+$].

(1*S*,4*S*)-1-(2,5-Dihydro-5-oxofuran-2-yl)-1-hydroxyoct-2-yn-4-yl Acetate (**21**). To a stirred soln. of **20** (140 mg, 0.36 mmol) in CH_2Cl_2/H_2O (5 ml, 20:1) was added DDQ (160 mg, 0.72 mmol) at room temperature, and continued stirring for 2 h. After completion of reaction, mixture was quenched by adding sat. aq. $NaHCO_3$ soln. and extracted with CH_2Cl_2 (2 × 5 ml). The combined organic extracts were washed with brine, dried (Na_2SO_4), and concentrated. The crude product was purified by CC (SiO_2; AcOEt/hexane 3:7) to give alcohol **21** (82 mg, 85%) as yellowish liquid. $[\alpha]_D^{26} = -33.9$ (c 0.3, $CHCl_3$). IR (neat): 3409, 2958, 2933, 2869, 1740, 1660, 1373, 1239, 1161, 1054, 830. ^{1}H-NMR ($CDCl_3$, 300 MHz): 7.55 – 7.48 (*m*, 1 H); 6.20 (*d*, *J* = 12.1, 1 H); 5.34 – 5.26 (*m*, 2 H); 5.12 (*dt*, *J* = 7.5, 2.1 H, 1 H); 2.08 (*s*, 3 H), 1.80 – 1.70 (*m*, 2 H); 1.43 – 1.29 (*m*, 4 H); 0.90 (*t*, *J* = 7.5, 3 H). ^{13}C-NMR ($CDCl_3$, 75 MHz): 172.3; 170.3; 152.8; 123.2; 85.3; 84.7; 84.4; 65.3; 63.8; 33.9; 26.9; 22.0; 20.9; 13.7. ESI-MS: 289 [$(M + Na)^+$], 284 [$(M + NH_4)^+$].

(1*S*,2*Z*,4*S*)-1-[(2*S*)-2,5-Dihydro-5-oxofuran-2-yl]-1-hydroxyoct-2-en-4-yl Acetate (**4**). The stirred mixture of **21** (50 mg, 0.18 mmol) and Pd/$CaCO_3$ (*Lindlar*'s catalyst) (50 mg) was poisoned by adding one drop of quinoline in AcOEt (2 ml) for 30 min, at room temperature under H_2 atmosphere. After completion of reaction, mixture was filtered through *Celite* pad and the filtrate was concentrated and purified by CC (SiO_2; AcOEt/hexane mixture 3:7) to give (*Z*)-olefin **4** (49 mg, 98%) as colorless oil. $[\alpha]_D^{25} = -42.8$ (*c* = 0.2, $CHCl_3$). IR (neat): 3446, 2956, 2857, 1750, 1461, 1372, 1248, 1167, 1041, 829, 774. ^{1}H-NMR ($CDCl_3$, 300 MHz): 7.55 (*dd*, *J* = 6.0, 1.5 H, 1 H); 6.21 (*dd*, *J* = 5.3, 2.2 H, 1 H); 5.54 – 5.35 (*m*, 3 H); 5.15 (*dt*, *J* = 5.3, 1.5 H, 1 H); 4.96 (*dd*, *J* = 7.5, 5.3 H, 1 H); 3.74 (*d*, *J* = 3.0, 1 H); 2.08 (*s*, 3 H); 1.73 – 1.50 (*m*, 2 H); 1.36 – 1.24 (*m*, 4 H); 0.88 (*t*, *J* = 7.5, 3 H). ^{13}C-NMR ($CDCl_3$, 75 Mz): 172.5; 170.5; 153.1; 133.4; 128.7; 123.5; 84.6; 70.1; 65.5; 34.1; 27.2; 22.3; 21.1; 13.9. ESI-MS m/z: 291 [$(M + Na)^+$], 286 [$(M + NH_4)^+$].

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