A Concise Approach for the Synthesis of Core Fragment C7–C15 of (+)-Migrastatin Using Desymmetrization Strategy

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Abstract: The core fragment C7–C15 the (+)-migrastatin was constructed in a stereoconvergent manner utilizing desymmetrization approach. The strategy involved the generation of *Z*-configuration of trisubstituted double bond at C11–C12, epimerization at C10, ring opening of the pyran lactol with C2 Wittig ylide, and regioselective Sharpless dihydroxylation.

Key words: (+)-migrastatin, desymmetrization, epimerization, Sharpless asymmetric dihydroxylation

Migrastatin (**1**, Figure 1) is a novel macrolide natural product, isolated from a cultured broth of *Streptomyces* sp. MK929-43F1 by Imoto and co-workers in 2000.[1,2] It was shown by Kosan Bioscience researchers that cultures of *Streptomyces platensis* (strain NRRL 18993) also produce migrastatin.[3] Migrastatin displays a remarkable inhibitory effect on the migration of human tumor cells and also selectively inhibits the anchorage-independent growth of human small cell lung carcinoma Ms-1 cells.[4] More recently, it has been shown to inhibit P-glycoprotein and consequently sensitizes drug-resistant P-glycoprotein-overexpressing cells to anticancer drugs like taxol, vinblastine, and vincristine.[5] The structure of migrastatin was established unambiguously by X-ray analysis of a derivative.[6] This compound consists of a 14-membered lactone linked to an alkylglutarimide side chain and contains five stereogenic centers, two *E*-disubstituted double bonds, and one *Z*-trisubstituted double bond.

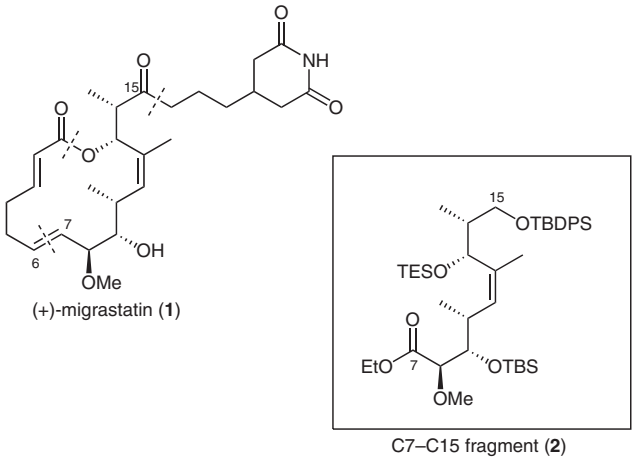

Figure 1

The first total synthesis of migrastatin (**1**) was achieved by Danishefsky and co-workers[7] and recently an alternative route has been described by Reymond and Cossy.[8] A semi-synthetic approach has been described from isomigrastatin by Shen and co- workers.[9]

Our ongoing research on the synthesis of biologically active molecules by desymmetrization strategy, and the notable biological activity of (+)-migrastatin encouraged us to select this molecule as a target for total synthesis. We herein report the synthesis of core fragment C7–C15 fragment of (+)-migrastatin (**1**).

The challenge in the construction of **2** was the proper positioning of the chiral centers (C8, C9, C10, C13, C14), the *Z*-configuration of C11–C12 double bond and to provide functionalities for the proper attachment leading to the C6–C7 double bond in **1**.

We embarked on the synthesis of the (+)-migrastatin (**1**) fragment by a retrosynthetic analysis starting with **2**[31] which can be obtained by subjecting the compound **3** to regioselective sharpless asymmetric dihydroxylation, regioselective monomethylation of diol, and TBDMS protection. The compound **3** is resulted from **4** by epimerization at C10 and ring opening of pyran lactol with ethoxycarbonyl methylene triphenylphosphorane. The compound **4** in turn could be easily prepared from **5** by selective protection of primary alcohol and generation of *Z*-configured double bond. The compound **5** could be easily prepared from **6** through acetal ester, its reduction and debenzylation. Compound **6**[20] is obtained by regioselective methylation of the known precursor **7** (Scheme 1).

Our synthesis started with the precursor **7**, which was prepared earlier in our group and utilized to make several natural products.[10] The lactone **7** was subjected to regioslective methylation using LDA and methyl iodide to afford the methylated lactone **6**[11] in 92% yield. The hydrolysis of the bicyclic lactone **6** with catalytic amount of sulfuric acid in methanol afforded acetal ester **8**[21] along with a minor amount of the α-isomer (at C1 center) in 86% yield.[12] Reduction of **8** with $LiAlH_4$ followed by debenzylation with Li-napthanelide[13] afforded diol **5**[22] in 80% yield. The primary alcohol in compound **5** was selectively protected with TBDPSCl and imidazole in CH_2Cl_2 to the corresponding TBDPS ether, and the secondary alcohol was mesylated with methane sulfonyl chloride and Et_3N in CH_2Cl_2 to give the compound **9**[23] in 90% yield (Scheme 2).

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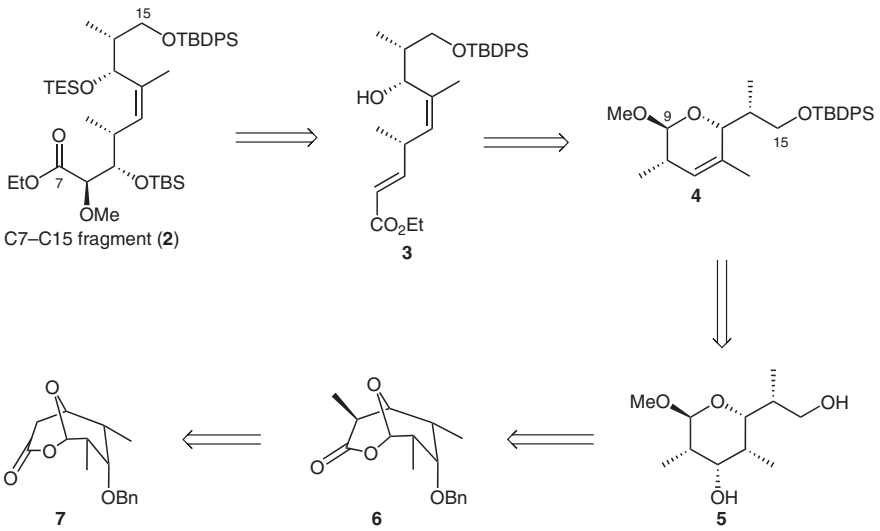
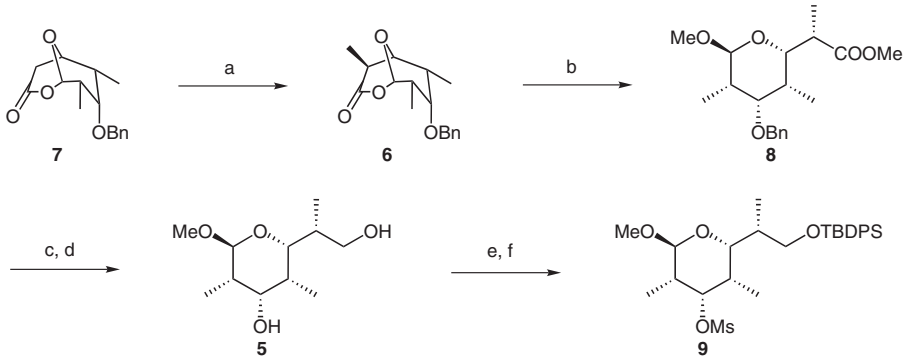
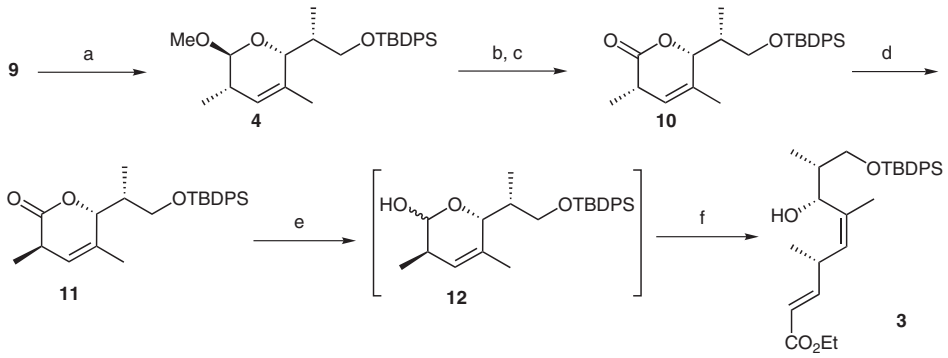


Scheme 1 Retrosynthetic strategy



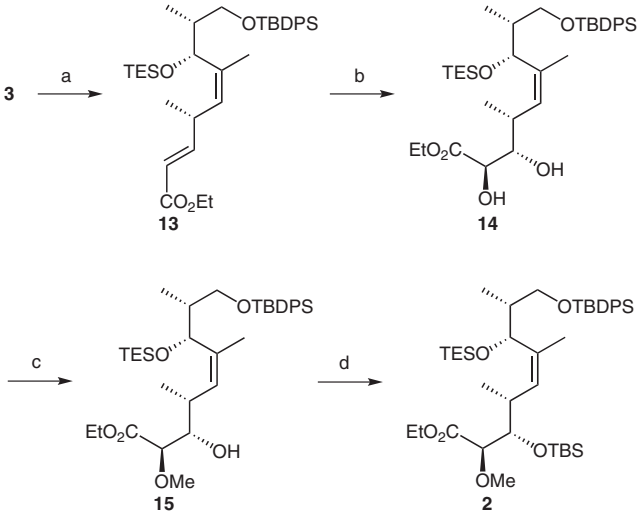
Scheme 2 *Reagents and conditions*: (a) LDA, MeI, THF, –78 °C, 92%; (b) MeOH, cat. H_2SO_4, 86%; (c) $LiAlH_4$, THF, 0 °C to r.t.; (d) Li naphthanelide, –23 °C, 3–4 h, (80%,overall yield for two steps); (e) TBDPSCl, imidazole, CH_2Cl_2, 0 °C, 0.5–1 h, 98%; (f) MsCl, Et_3N, CH_2Cl_2, 0 °C to r.t.,16–20 h, 90%

Compound **9** was treated with DBU (neat) at the 70 °C for 8–12 h to afford **4**[24] in 40% yield.[14] Hydrolysis using AcOH–H_2O–THF (6:3:1) at 50–55 °C afforded the lactol[15] which was further oxidized with bis(acetoxy)iodobenzene (BAIB) and 2,2,6,6-tetramethylpiperidine-*N*-oxide (TEMPO)[16] to afford the lactone **10** in 60% (overall yield for two steps). The lactone **10**[25] was treated with DBU in dry THF at –10 °C to afford the required epimer **11** in 45% yield.[12] The epimerized lactone **11**[26] when reduced with DIBAL-H in anhydrous THF at –78 °C resulted in lactol **12**. Exposure of crude lactol **12** to ethoxycarbonylmethylene triphenylphosphorane in toluene at reflux conditions resulted in ring opening of pyran to aliphatic chain with secondary alcohol and α,β-unsaturated ester **3**[17,27] in 92% overall yield for the two steps (Scheme 3).



Scheme 3 *Reagents and conditions*: (a) DBU (neat), –70 °C, 8–12 h, 40%; (b) AcOH–H_2O–THF (6:3:1), 50–55 °C, 12 h; (c) BAIB, TEMPO, CH_2Cl_2, 0 °C to r.t., 2–3 h, (60%, overall yield for two steps); d) DBU, THF, –10 °C, 0.5 h, 45%; (e) DIBAL-H, THF, –78 °C, 2 h; (f) $Ph_3P{=}CHCO_2Et$, toluene, reflux, 2–4 h, (92%, overall yield for two steps).

Silylation of secondary alcohol in compound **3** using TESCl, imidazole as the corresponding TES ether **13**[28] followed by regioselective Sharpless asymmetric dihydroxylation[18] using AD mix-α, $MeSO_2NH_2$ in *t*-BuOH–H_2O (1:1) gave diol **14**[29] (72% yield).



Scheme 4 *Reagents and conditions*: (a) TESCl, imidazole, CH_2Cl_2, 0 °C to r.t., 24 h, 94%; (b) AD mix-α, *t*-BuOH–H_2O (1:1), $MeSO_2NH_2$, 0 °C, 24–36 h, 72% (based on recovery of starting material); (c) Ag_2O, MeI, MS 4 Å, MeCN, r.t., 1–2 d, 80%; (d) TBSOTf, 2,6-lutidine, CH_2Cl_2, –23 °C to 0 °C, 2–3 h, 88%.

The α-OH in diol **14** was selectively protected as methyl ether by using modified Gurjar's protocol.[19] Treatment of diol with silver oxide, methyl iodide, and MS 4 Å in acetonitrile at room temperature resulted in monoprotected methyl ether **15**[30] selectively in 80% yield, and the free secondary hydroxyl group was protected as *tert*-butyl dimethylsilylether using 2,6-lutidine and *tert*-butyldimethylsilyl trifluoromethane sulfonate in dichloromethane in 90% yield (Scheme 4). Thus the core fragment C7–C15 of (+)-migrastatin has been synthesized.

In conclusion, the synthesis of core fragment C7–C15 of migrastatin has been accomplished wherein the required stereogenic centers and the *Z*-configuration of trisubstituted double bond at C11–C12 have been achieved by using desymmetrization approach. Further efforts for the total synthesis of migrastatin are currenly under way in our laboratory.

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(20) **Analytical Data for Compound 6**
$[\alpha]_D^{25}$ –54.7 (*c* 3.0, $CHCl_3$). IR: ν_{max} = 2928, 1742, 1455, 1073 cm^{-1}. ^1H NMR (200 MHz, $CDCl_3$): δ = 7.35–7.20 (m, 5 H), 5.38 (d, *J* = 2.7 Hz, 1 H), 4.70–4.40 (ABq, 2 H), 3.65 (d, *J* = 4.0 Hz, 1 H), 3.60–3.52 (m, 1 H), 2.75 (q, *J* = 7.0 Hz, 2 H), 2.30–2.10 (m, 1 H), 2.10–1.96 (m, 1 H), 1.42 (d, *J* = 6.5 Hz, 3 H), 1.15 (d, *J* = 6.8 Hz, 3 H), 0.96 (d, *J* = 6.8 Hz, 3 H). MS: *m/z* = 290 [M^+]. Anal. Calcd (%) for $C_{17}H_{22}O_4$: C, 70.32; H, 7.64. Found: C, 70.01; H, 7.32.
(21) **Analytical Data for Compound 8**
$[\alpha]_D^{25}$ +77.6 (*c* 1.5, $CHCl_3$). IR (neat): ν_{max} = 2827, 1739, 1456, 1082 cm^{-1}. ^1H NMR (400 MHz, $CDCl_3$): δ = 7.36–7.22 (m, 5 H), 4.54 (s, 2 H), 4.52 (s, 1 H), 4.00–3.95 (m, 1 H), 3.86 (t, *J* = 3.5 Hz, 1 H), 3.72 (s, 3 H), 3.28 (s, 3 H), 2.75–2.64 (m, 1 H), 2.25–2.10 (m, 2 H), 1.14–1.05 (m, 6 H), 1.02 (d, *J* = 6.6 Hz, 3 H). ^{13}C NMR (100 MHz, $CDCl_3$): δ = 176.0, 138.8, 128.2, 127.2, 127.1, 104.2, 74.9, 71.7, 69.4, 54.7, 51.5, 41.7, 36.4, 32.5, 13.1, 13.0, 7.5. MS: *m/z* = 307 [M^+ + 1 – 30]. Anal. Calcd (%) for $C_{19}H_{28}O_5$: C, 67.83; H, 8.39. Found: C, 67.13; H, 8.26.
(22) **Analytical Data for Compound 5**
$[\alpha]_D^{25}$ +35.4 (*c* 2.0, $CHCl_3$). IR (KBr): ν_{max} = 3489, 2924,

2855, 1724, 1460, 1377, 1130, 1073, 1029 cm^{-1}. ^1H NMR (200 MHz, $CDCl_3$): δ = 4.50 (s, 1 H), 4.05 (t, *J* = 5.3 Hz, 1 H), 3.69–3.55 (m, 3 H), 3.35 (s, 3 H), 3.15–2.98 (br, 1 H), 2.07–1.90 (m, 3 H), 1.67–1.55 (br, 1 H), 1.04 (d, *J* = 6.8 Hz, 3 H), 0.97 (d, *J* = 6.8 Hz, 3 H), 0.81 (d, *J* = 6.8 Hz, 3 H), ^{13}C NMR (50 MHz, $CDCl_3$): δ = 104.2, 75.7, 68.2, 67.6, 54.7, 38.6, 35.9, 35.7, 12.5, 12.5, 7.4. ESI-MS: *m/z* = 241.1 [M + Na]$^+$. HRMS: *m/z* calcd for $C_{11}H_{22}O_4Na$ [M + Na]$^+$: 241.1410; found: 241.1415.

(23) **Analytical Data for Compound 9**
$[\alpha]_D^{25}$ +3.0 (*c* 1, $CHCl_3$). IR (KBr): ν_{max} = 2926, 2856, 1464, 1360, 1177, 1079, 1019, 954 cm^{-1}.^1H NMR (300 MHz, $CDCl_3$): δ = 7.61 (d, *J* = 7.7 Hz, 4 H), 7.43–7.28 (m, 6 H), 5.1 (t, *J* = 5.6 Hz, 1 H), 4.40 (s, 1 H), 3.83–3.60 (m, 3 H), 3.09 (s, 3 H), 2.98 (s, 3 H), 2.24–2.12 (m, 2 H), 1.89–1.73 (m, 1 H), 1.15–1.02 (m, 12 H), 0.97 (d, *J* = 6.8 Hz, 3 H), 0.91 (d, *J* = 7.5 Hz, 3 H). ^{13}C NMR (75 MHz, $CDCl_3$): δ = 136.0, 135.8, 134.1, 133.9, 129.7, 129.7, 127.7, 103.7, 80.4, 69.8, 65.5, 60.5, 54.9, 38.8, 37.9, 36.9, 35.0, 27.2, 19.5, 14.4, 13.4, 13.0, 8.15. ESI-MS: *m/z* = 557.2 [M + Na]$^+$. HRMS: *m/z* calcd for $C_{28}H_{42}O_6NaSi$ [M + Na]$^+$: 557.2366; found: 557.2369.

(24) **Analytical Data for Compound 4**
$[\alpha]_D^{25}$ +100.9 (*c* 0.8, $CHCl_3$). IR (KBr): ν_{max} = 2960, 2926, 2856, 2827, 1465, 1384, 1108, 1086, 1030, 954 cm^{-1}. ^1H NMR (300 MHz, $CDCl_3$): δ = 7.66 (d, *J* = 7.5 Hz, 4 H), 7.43–7.31 (m, 6 H), 5.31 (d, *J* = 5.2 Hz, 1 H), 4.38 (s, 1 H), 3.93 (s, 1 H), 3.66–3.48 (qd, *J* = 4.5, 9.8 Hz, 2 H), 3.37 (s, 3 H), 2.21–1.92 (m, 2 H), 1.46 (s, 3 H), 1.21 (d, *J* = 6.7 Hz, 3 H).1.08 (s, 12 H), 0.85 (d, *J* = 7.5 Hz, 3 H). ^{13}C NMR (75 MHz, $CDCl_3$): δ = 135.5, 129.4, 129.4, 127.5, 123.7, 101.8, 73.1, 64.6, 54.9, 36.9, 34.0, 26.8, 19.1, 18.6, 14.9. ESI-MS: *m/z* = 461.2 [M + Na]$^+$. HRMS: *m/z* calcd for $C_{27}H_{38}O_3NaSi$ [M + Na]$^+$: 461.2494; found: 461.2487.

(25) **Analytical Data for Compound 10**
$[\alpha]_D^{25}$ –14.3 (*c* 0.5, $CHCl_3$). IR (KBr): ν_{max} = 2927, 2856, 1739, 1465, 1427, 1364, 1109 cm^{-1}. ^1H NMR (300 MHz, $CDCl_3$): δ = 7.69–7.58 (m, 4 H), 7.44–7.31 (m, 6 H), 5.33 (d, *J* = 5.2 Hz, 1 H), 4.76 (s, 1 H), 3.66–3.55 (m, 1 H), 3.54–3.41 (m, 1 H), 3.05–2.85 (m, 1 H), 2.21–2.01 (m, 1 H), 1.62 (s, 3 H), 1.17 (d, *J* = 7.3 Hz, 6 H), 1.04 (s, 9 H). ^{13}C NMR (75 MHz, $CDCl_3$): δ = 176.0, 135.5, 134.7, 129.4, 129.4, 127.7, 127.5, 123.1, 94.9, 77.4, 76.5, 73.6, 64.8, 37.0, 34.8, 26.9, 26.5, 19.2, 18.4, 15.1. ESI-MS: *m/z* = 445.2 [M + Na]$^+$. HRMS: *m/z* calcd for $C_{26}H_{34}O_3NaSi$ [M + Na]$^+$: 445.2174; found: 445.2173.

(26) **Analytical Data for Compound 11**
$[\alpha]_D^{25}$ –10.6 (*c* 1.0, $CHCl_3$). IR (KBr): ν_{max} = 3000, 2851, 1750, 1432, 1380, 1210 cm^{-1}. ^1H NMR (300 MHz, $CDCl_3$): δ = 7.69–7.57 (m, 4 H), 7.44–7.31 (m, 6 H), 5.33 (d, *J* = 5.2 Hz, 1 H), 4.60 (s, 1 H), 3.61–3.45 (m, 2 H), 2.86–2.76 (m, 1 H), 2.19–1.91 (m, 1 H), 1.62 (s, 3 H), 1.10–0.90 (m, 15 H). ^{13}C NMR (75 MHz, $CDCl_3$): δ = 176.0, 135.5, 134.7, 129.4, 129.4, 127.7, 127.5, 123.1, 94.9, 77.4, 76.5, 73.6, 64.8, 37.0, 34.8, 26.9, 26.5, 19.2, 18.4, 15.1. ESI-MS: *m/z* = 445.2 [M + Na]$^+$. HRMS: *m/z* calcd for $C_{26}H_{34}O_3NaSi$ [M + Na]$^+$: 445.2174; found: 445.2173.

(27) **Analytical Data for Compound 3**
$[\alpha]_D^{25}$ +44.3 (*c* 0.6, $CHCl_3$). IR (KBr): ν_{max} = 3420, 2960, 2929, 2858, 1716, 1464, 1428, 1385, 1109, 1035, 703 cm^{-1}. ^1H NMR (300 MHz, $CDCl_3$): δ = 7.61 (d, *J* = 6.0 Hz, 4 H), 7.38–7.27 (m, 6 H), 6.87–6.77 (dd, *J* = 6.0, 15.1 Hz, 1 H), 5.72 (d, *J* = 15.1 Hz, 1 H), 5.03 (d, *J* = 9.8 Hz, 1 H), 4.36 (d, *J* = 9.0 Hz, 1 H), 4.14–4.04 (q, *J* = 6.7 Hz, 2 H), 3.80–3.60 (dq, *J* = 3.7, 7.5, 10.5 Hz, 2 H), 3.40–3.28 (m, 2 H), 1.92–1.76 (m, 1 H), 1.65 (s, 3 H), 1.19 (t, *J* = 6.7 Hz, 3 H), 1.02–0.99 (m, 12 H), 0.60 (d, *J* = 6.8 Hz, 3 H). ^{13}C NMR (75 MHz, $CDCl_3$): δ = 167.0, 152.6, 136.6, 135.8, 135.8, 135.7, 135.7, 135.6, 133.0, 133.0, 130.1, 130.0, 128.0, 127.9, 127.9, 127.8, 119.7, 74.0, 68.9, 60.3, 37.9, 34.3, 27.0, 27.0, 26.9, 20.0, 19.3, 17.9, 14.4, 13.3. ESI-MS: *m/z* = 517 [M + Na]$^+$. HRMS: *m/z* calcd for $C_{30}H_{42}O_4NaSi$ [M + Na]$^+$: 517.2750; found: 517.2757.

(28) **Analytical Data for Compound 13**
$[\alpha]_D^{25}$ +19.7 (*c* 0.4, $CHCl_3$). IR (KBr): ν_{max} = 2959, 2877, 1722, 1650, 1463, 1426, 1385, 1262, 1108, 1065, 1014, 703 cm^{-1}. ^1H NMR (300 MHz, $CDCl_3$): δ = 7.63–7.53 (m, 4 H), 7.37–7.22 (m, 6 H), 6.87–6.74 (dd, *J* = 6.6, 15.9 Hz, 1 H), 5.72 (d, *J* = 15.9 Hz, 1 H), 4.96 (d, *J* = 9.2 Hz, 1 H), 4.28 (d, *J* = 9.2 Hz, 1 H), 4.18–4.05 (q, *J* = 6.6 Hz, 2 H), 3.78–3.52 (dq, *J* = 3.6, 5.3, 10.2 Hz, 2 H), 3.40–3.28 (m, 1 H), 1.77–1.61 (m, 1 H), 1.57 (s, 3 H), 1.27–1.15 (m, 6 H), 1.05–0.95 (m, 12 H), 0.75 (t, *J* = 7.9 Hz, 9 H), 0.44–0.30 (q, *J* = 6.6 Hz, 6 H). ^{13}C NMR (75 MHz, $CDCl_3$): δ = 167.0, 152.4, 137.4, 135.9, 135.9, 134.2, 134.1, 129.7, 128.6, 127.7, 119.6, 71.2, 66.0, 60.4, 40.4, 34.7, 27.2, 20.7, 19.5, 14.4, 13.9, 7.06, 5.05. ESI-MS: *m/z* = 631.3 [M + Na]$^+$. HRMS: *m/z* calcd for $C_{36}H_{56}O_4NaSi_2$ [M + Na]$^+$: 631.3614; found: 631.3619.

(29) **Analytical Data for Compound 14**
$[\alpha]_D^{25}$ –6.0 (*c* 0.3, $CHCl_3$). IR (KBr): ν_{max} = 3440, 2959, 2877, 1722, 1650, 1463, 1426, 1385, 1262, 1108, 1065, 1014, 703 cm^{-1}. ^1H NMR (300 MHz, $CDCl_3$): δ = 7.73–7.56 (m, 4 H), 7.48–7.28 (m, 6 H), 5.08 (d, *J* = 10.2 Hz, 1 H), 4.32 (d, *J* = 9.3 Hz, 1 H), 4.23–4.20 (m, 2 H), 3.88–3.75 (m, 1 H), 3.69–3.47 (m, 2 H), 3.01–2.84 (m, 2 H), 1.89–1.71 (m, 2 H), 1.70–1.59 (m, 3 H), 1.43–1.21 (m, 3 H), 1.08 (s, 9 H), 0.99 (d, *J* = 6.6 Hz, 3 H), 0.93–0.74 (m, 12 H), 0.57–0.37 (q, *J* = 6.6 Hz, 6 H). ^{13}C NMR (75 MHz, $CDCl_3$): δ = 173.9, 140.6, 135.9, 134.2, 129.6, 128.9, 127.7, 80.0, 71.7, 71.3, 70.5, 66.3, 62.1, 61.3, 59.0, 40.8, 34.9, 32.1, 31.1, 31.1, 29.9, 29.5, 27.2, 22.9, 29.5, 27.2, 22.9, 19.5, 18.5, 17.8, 17.4, 14.4, 14.3, 7.1, 5.5, 5.1, 0.20. ESI-MS: *m/z* = 665.0 [M + Na]$^+$. HRMS: *m/z* calcd for $C_{36}H_{58}O_6NaSi_2$ [M + Na]$^+$: 665.3669; found: 665.3672.

(30) **Analytical Data for Compound 15**
$[\alpha]_D^{25}$ –3.0 (*c* 0.4, $CHCl_3$). IR (KBr): ν_{max} = 3513, 2960, 2874, 1721, 1650,1462, 1426, 1386, 1260, 1109, 1064, 1014 cm^{-1}. ^1H NMR (300 MHz, $CDCl_3$): δ = 7.70–7.62 (m, 4 H), 7.44–7.32 (m, 6 H), 5.14 (d, *J* = 10.0 Hz, 1 H), 4.39 (d, *J* = 9.2 Hz, 1 H), 4.32–4.22 (m, 2 H), 3.87–3.81 (dd, *J* = 3.3, 9.4 Hz, 1 H), 3.68–3.61 (dd, *J* = 6.4, 9.4 Hz, 3 H), 3.39–3.32 (m, 1 H), 3.35 (s, 3 H), 3.12–2.97 (m, 1 H), 2.86 (d, *J* = 9.2 Hz, 1 H), 1.87–1.73 (m, 1 H), 1.65 (s, 3 H), 1.31 (t, *J* = 7.1 Hz, 3 H), 1.08 (s, 9 H), 1.00 (d, *J* = 6.9 Hz, 3 H), 0.89–0.79 (m, 12 H), 0.59–0.45 (q, *J* = 6.6 Hz, 6 H). ^{13}C NMR (75 MHz, $CDCl_3$): δ = 173.8, 137.3, 135.6, 134.1, 127.4, 134.1, 129.4, 127.4, 85.4, 77.4, 77.1, 77.1, 76.9, 76.5, 71.2, 70.6, 66.0, 61.4, 59.2, 40.5, 33.2, 29.6, 26.9, 19.3, 18.2, 16.7, 14.2, 14.0, 6.9, 4.7. ESI-MS: *m/z* = 679.0 [M + Na]$^+$. HRMS: *m/z* calcd for $C_{37}H_{60}O_6NaSi_2$ [M + Na]$^+$: 679.3826; found: 679.3837.

(31) **Analytical Data for Compound 2**
$[\alpha]_D^{25}$ –3.0 (*c* 0.4, $CHCl_3$). IR (KBr) ν_{max} = 2959, 2877, 1722, 1650, 1463, 1426, 1385, 1262, 1108, 1065, 1014, 703 cm^{-1}. ^1H NMR (300 MHz, $CDCl_3$): δ = 7.70–7.63 (m, 4 H), 7.45–7.31 (m, 6 H), 5.13 (d, *J* = 10.1 Hz, 1 H), 4.33 (d, *J* = 3.2 Hz, 1 H), 4.28–4.15 (m, 3 H), 3.95–3.89 (dd, *J* = 3.3, 9.4 Hz, 1 H), 3.53–3.40 (m, 2 H), 3.31 (s, 3 H), 2.95–2.82 (m, 1 H),1.89–1.78 (m, 1 H), 1.65 (s, 3 H), 1.32–1.24 (m, 3 H), 1.09 (s, 9 H), 0.97–0.78 (m, 24 H), 0.56–0.45 (m, 6 H), 0.12 (s, 3 H), 0.06 (s, 3 H). ^{13}C NMR (75 MHz, $CDCl_3$): δ = 136.9, 135.6, 134.1, 127.4, 127.4, 129.3, 86.6, 73.0, 71.9, 66.4, 60.7, 59.5, 40.9, 33.2, 31.9, 31.4, 29.6, 26.9, 25.8, 22.6, 19.3, 18.3, 17.2, 14.2, 6.9, 4.6, –4.4, –5.0. ESI-MS: *m/z* = 793.6 [M + Na]$^+$. HRMS: *m/z* calcd for $C_{43}H_{74}O_6NaSi_3$ [M + Na]$^+$: 793.6826; found: 793.6837.