Synthesis of Phenol Abietane Diterpenes Based on the Oxidative Radical Cyclization Utilizing the $Mn(OAc)_3/Ac_2O$ System

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Abstract: A new route to phenol abietane diterpenes from *trans*-communic acid is reported. The key step is the transformation of a β-ketoester into the corresponding *O*-acetylsalicilate, via a manganese(III)-based oxidative free-radical cyclization carried out in Ac_2O. Utilizing this, the first synthesis of (–)-sugikurojin A has been achieved. The immunosuppressor 19-hydroxyferruginol has also been synthesized.

Key words: enantiospecific synthesis, abietane diterpenoids, phenols

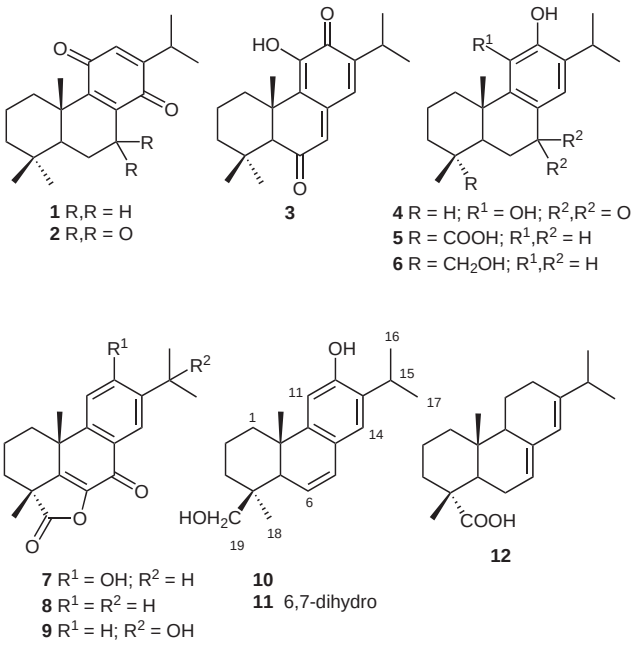

Figure 1 Some representative oxygenated abietane diterpenes.

Abietane diterpenes comprise an important group of secondary metabolites, which are widespread in the vegetable kingdom. In recent years interest in this type of terpenoids has increased, as a result of the isolation of compounds, mainly phenols and related derivatives, showing remarkable biological activities.[1] As representative examples we might cite (–)-12-deoxyroyleanone (**1**), an antileishmanial agent,[2,3] and cryptoquinone (**2**), which shows cytotoxic activity against mouse lymphoid neoplasm (P388) cells.[4] Other relevant oxidized abietane diterpenes are taxodione (**3**)[5,6] and salvinolone (**4**),[7] which are active against methicillin-resistant *Staphylococcus aureus* (MRSA) and vancomycin-resistant *Enterococcus* (VRE). Recently, the isolation of 6,7-dehydro-19-hydroxyferruginol (sugikurojin A, **10**), a new diterpene from *Cryptomeria japonica*, has been reported;[8] very recent studies have revealed that 19-hydroxyferruginol (**11**)[9] is a target for tolerance after transplantation and in autoimmune diseases (Figure 1).[10]

Despite the interest in this type of compound, few syntheses have been described, most of them being total syntheses involving polyene cascade cyclizations,[11] Diels–Alder cycloadditions,[12] electrophilic cyclizations,[13] Robinson annulation[14] and domino acylation–cycloalkylation.[15] Enantioselective syntheses of these compounds have also been reported, in most cases starting from podocarpic[9,16] and abietic acid.[3a,b,6,17] During the last few years, our group has reported new procedures to introduce oxygenated functions on the C ring of abietic acid (**12**); utilizing these, compounds **1** and **5**–**9** were synthesized from this diterpene.[3a,18]

Following our research into the synthesis of phenol abietane diterpenes, we are now interested in developing a new route to C-18 functionalized abietane, such as the recently isolated sugikurojin A (**10**) and the bioactive 6,7-dihydro-derivative **11**, starting from *trans*-communic acid (**17**), a labdane diterpene very abundant in some species of *Juniperus*[19] and *Cupressus*.[20] Scheme 1 shows the planned synthetic strategy. The key step is the elaboration of the aromatic C ring, which will be accomplished via an oxidative free-radical cyclization of a suitable unsaturated β-ketoester; thus, compound **15**, obtained from aldehyde **16**, will be transformed into aromatic ester **14**. The isopropyl group of the abietane skeleton will be introduced through the methoxycarbonyl group, providing the 15-hydroxy derivative **13**. After removing the 15-hydroxy group, via cationic reduction or dehydration–hydrogenation processes, deprotecting the phenol and reducing the ester group, the bioactive 19-hydroxyferruginol (**11**) will

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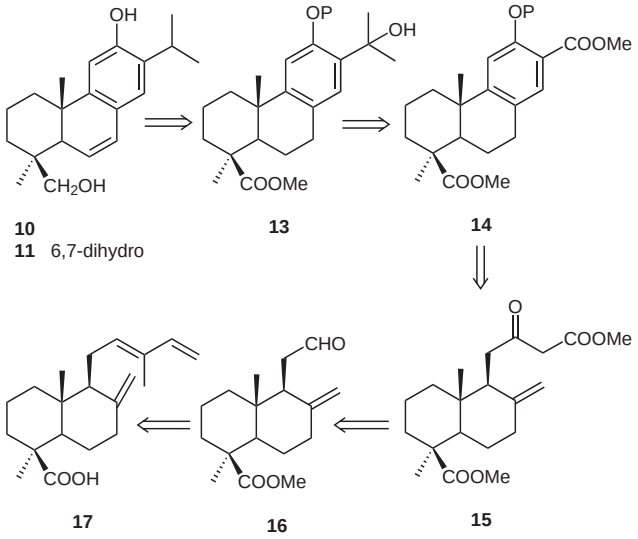
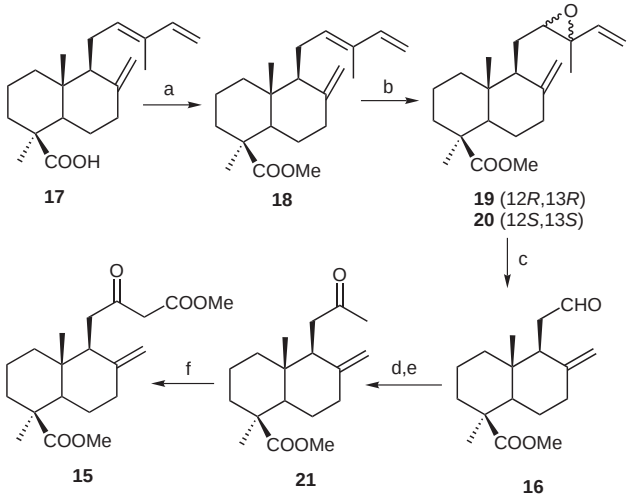


Scheme 1 Retrosynthetic analysis of compounds **10** and **11**.

be obtained. The Δ^6 double bond of sugikurojin A (**10**) will be created after elimination of a suitable 7-hydroxy derivative obtained after benzylic oxidation.

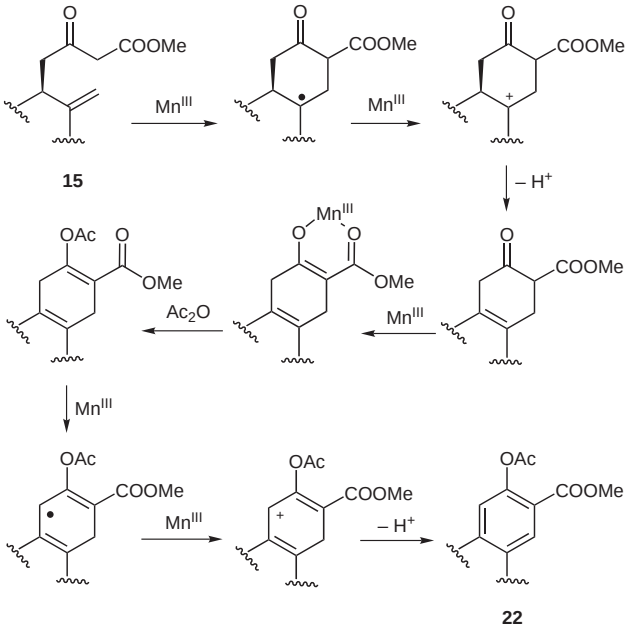
The synthesis of ketoester **15** is depicted in Scheme 2. Epoxidation of methyl ester **18** gave a mixture of diastereomeric 12,13-epoxiderivatives **19** and **20**,[21] which was converted into aldehyde **16** by treatment with HIO_4 in THF at room temperature.[22] Treatment of compound **16** with MeMgBr (1 equiv) and further oxidation with Jones reagent gave methylketone **21**, which was converted into β-ketoester **15** after treatment with Me_2CO_3 and NaH in benzene.

Next, the construction of the aromatic C ring was undertaken. Snider et al. have reported the transformation of unsaturated β-ketoesters, such as compound **15**, into the



Scheme 2 *Reagents and conditions*: (a) CH_2N_2, Et_2O, r.t., 10 min (97%); (b) MCPBA, $NaHCO_3$, CH_2Cl_2, 0 °C to r.t., 12 h (87%); (c) HIO_4, THF, –10 °C, 1 h (83%); (d) MeMgBr, Et_2O, 0 °C (96%); (e) Jones reagent, acetone, 0 °C, 15 min (92%); (f) Me_2CO_3, NaH, benzene, 3 h (89%).

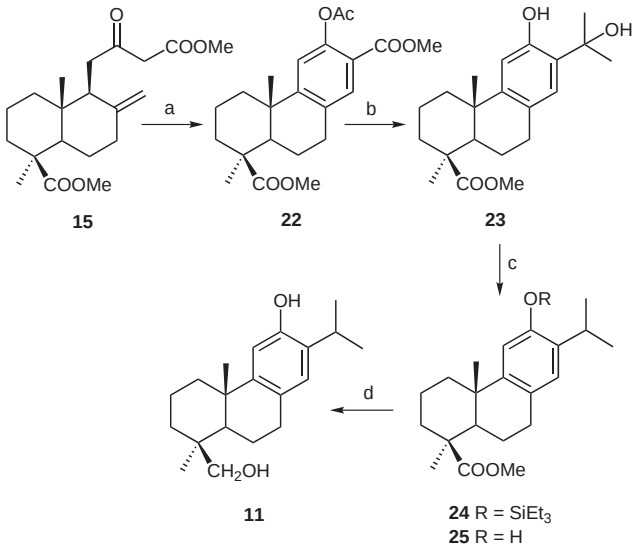
corresponding alkyl salycilates, via manganese(III)-based oxidative free-radical cyclizations; the use of $Mn(OAc)_3$ and LiCl in acetic acid has been described to minimize the overoxidation of cyclization products, improving the yield of end compounds.[23] However, a complex mixture of compounds was obtained when ketoester **15** was oxidized under these conditions. These results, which can be attributed to the overoxidation of resulting phenol, incited us to essay a reaction medium, such as Ac_2O, which could simultaneously act as the solvent and as the reagent to protect the phenolic hydroxyl group. We have found that the treatment of compound **15** with 4 equivalents of $Mn(OAc)_3 \cdot 2H_2O$ and 3 equivalents of LiCl in Ac_2O at 120 °C for 12 hours affords the methyl *O*-acetyl salycilate **22** in 74% yield.[24] A possible mechanism for this transformation is postulated in Scheme 3. Compound **22** could be formed after acetylation of an intermediate manganese(III) enolate.



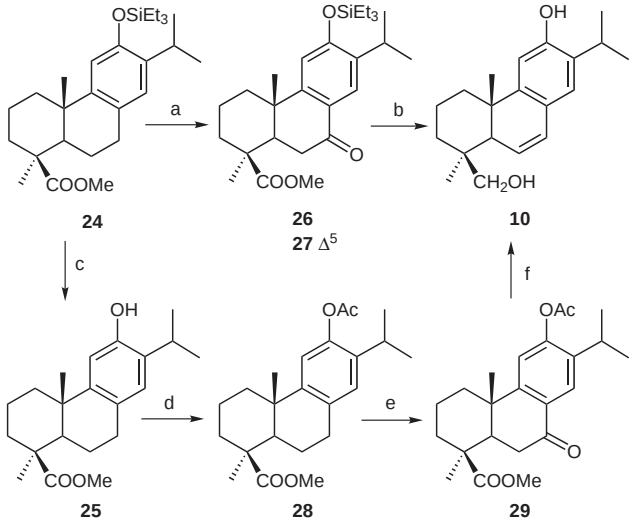
Scheme 3 A tentative mechanism for the formation of compound **22**

Scheme 4 shows the transformation of bicyclic ketoester **15**[25] into the bioactive 19-hydroxyferruginol (**11**), via the *O*-acetyl salycilate **22**. Treatment of this compound with MeMgBr in excess afforded the abietane phenol **23**. When this compound was treated with Et_3SiH and CF_3COOH the 15-hydroxy group was removed, producing the silyl ether **24**. It should be noted that small quantities of phenol **25** were also obtained when the reaction conditions were not completely anhydrous. Refluxing of compound **24** with $LiAlH_4$ in THF caused reduction of the ester group and simultaneous deprotection of the silyl ether, affording 19-hydroxyferruginol (**11**).

The synthesis of sugikurojin A (**10**) starting from silyl ether **24** is shown in Scheme 5. Heating of this compound with Na_2CrO_4 and NaOAc in Ac_2O–AcOH led to the



Scheme 4 *Reagents and conditions*: (a) $Mn(OAc)_3$ (4 equiv), LiCl (3 equiv), Ac_2O, 120 °C, 12 h (74%); (b) MeMgBr (excess), Et_2O, 0 °C, 15 min (92%); (c) Et_3SiH, CF_3COOH, CH_2Cl_2, –40 °C, 30 min (87%); (d) $LiAlH_4$, THF, r.t. to reflux, 12 h (95%).



Scheme 5 *Reagents and conditions*: (a) Na_2CrO_4, NaOAc, Ac_2O, AcOH, 70 °C, 3 h (83%); (b) $LiAlH_4$, THF, r.t. to reflux, 12 h (98%); (c) TBAF, THF, r.t., 20 min (94%); (d) Ac_2O, pyridine, r.t., 24 h (93%); (e) Jones reagent, acetone, r.t., 2 d (76%); (f) $LiAlH_4$, THF, r.t., 10 h (88%).

corresponding 7-oxoderivative **26**; the α,β-unsaturated ketone **27** was also obtained when the oxidation time was prolonged. Refluxing of compound **26** with $LiAlH_4$ in THF gave directly sugikurojin A (**10**).

An alternative route to hydroxy phenol **10** from silyl derivative **24**, which prevents the overoxidation to α,β-unsaturated ketones, such as **27**, involves the removal of silyl group and the further acetylation to obtain the acetoxyester **28**, which was then transformed into sugikurojin A (**10**) under the same reaction conditions utilized for compound **26**. It must be emphasized that benzylic alcohols derived from ketones **26** and **29** never were isolated under the reduction conditions, and consequently the Δ^7 double bond of compound **10** should be probably formed by elimination of the aluminum oxide complex, favored by its secondary and benzylic character. Spectroscopic properties of compound **10** were identical to those reported in the literature for the natural product,[8] but the optical rotation of our synthetic compound was $[\alpha]_D^{25}$ –29.2 {*c* 0.92, $CHCl_3$; lit.[8] $[\alpha]_D^{25}$ +32.8 (*c* 0.39, $CHCl_3$)}.

In summary, a new route to phenolic abietane diterpenes from *trans*-communic acid (**17**), via a manganese(III)-based oxidative free-radical cyclization in Ac_2O of a suitable unsaturated β-ketoester, is described. This new procedure, by which A-ring-functionalized diterpenes can be prepared, has been utilized to carry out the first synthesis of (–)-sugikurojin A (**10**). The bioactive 19-hydroxyferruginol (**11**) was also prepared.

Acknowledgment

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References and Notes

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(21) The epoxidation of ester **18** to give compounds **19** and **20** was previously described by Barrero et al., who reported a 40% yield for this transformation. See: Barrero, A. F.; Quintana, R.; Altarejos, J. *Tetrahedron* **1991**, *47*, 4441.
(22) Aldehyde **16** was obtained by the same procedure from the mixture of 12*R*,13*S*- and 12*S*,13*R*-epoxy derivatives, resulting from the epoxidation of methyl *cis*-communate. See: Barrero, A. F.; Sánchez, J. F.; Elmerabet, J.; Jimenez-Gonzalez, D.; Macías, F. A.; Simonet, A. M. *Tetrahedron* **1999**, *55*, 7289.
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(24) **Typical Procedure for Radical Cyclization**
Strictly deoxygenated Ac_2O (20 mL) was added to a mixture of manganese(III) acetate dihydrate (3.21 g, 12 mmol) and LiCl (365 mg, 8.6 mmol) under argon atmosphere, and the resulting suspension was stirred at r.t. for 15 min. Then, a solution of β-ketoester (**15**, 1 g, 2.86 mmol) in deoxygenated Ac_2O (20 mL) was added, and the mixture was stirred at reflux for 9 h, at which time TLC showed no starting material. The reaction mixture was cooled to 0 °C, and then quenched with H_2O (10 mL). After stirring for 10 min, *t*-BuOMe (120 mL) was added and the reaction mixture was stirred for an additional 10 min. The mixture was washed with H_2O (10 × 30 mL) and brine (3 × 20 mL). The dried organic layer was evaporated and the residue was directly purified by flash chromatography (hexane–*t*-BuOMe, 7:3) to yield **22** (0.82 g, 74%) as a yellow syrup.
(25) Spectroscopic properties of natural terpenoids (**10** and **11**) were identical to those reported in the literature. All new compounds were fully characterized spectroscopically and had satisfactory high-resolution mass spectroscopy data.

Selected Data

Compound **15**: $[a]_D^{25}$ +13.6 (*c* 0.9, $CHCl_3$). ^{1}H NMR (500 MHz, $CDCl_3$): δ = 0.52 (3 H, s), 1.05 (1 H, ddd, *J* = 13.4, 13.4, 4.1 Hz), 1.14 (1 H, ddd, *J* = 13.2, 13.2, 4.1 Hz), 1.19 (3 H, s), 1.41 (1 H, dd, *J* = 12.5, 2.7 Hz), 1.51 (1 H, dt, *J* = 14.1, 3.1 Hz), 1.59 (1 H, m), 1.77 (1 H, ddd, *J* = 17.6, 13.4, 4.2 Hz), 1.81 (1 H, dt, *J* = 13.8, 3,6 Hz), 1.95–2.10 (2 H, m), 2.17 (1 H, br d, *J* = 12.6 Hz), 2.36–2.44 (2 H, m), 2.61 (1 H, dd, *J* = 17.5, 3.3 Hz), 2.71 (1 H, dd, *J* = 17.5, 10.2 Hz), 3.43 (1 H, d, *J* = 15.4 Hz), 3.47 (1 H, d, *J* = 15.4 Hz), 3.61 (3 H, s), 3.72 (3 H, s), 4.34 (1 H, br s), 4.77 (1 H, br s). ^{13}C NMR (125 MHz, $CDCl_3$): δ = 38.3 (C-1), 20.1 (C-2), 39.5 (C-3), 44.5 (C-4), 50.7 (C-5), 26.0 (C-6), 38.1 (C-7), 148.5 (C-8), 56.2 (C-9), 39.7 (C-10), 39.8 (C-11), 202.3 (C-12), 49.3 (C-13), 106.8 (C-14), 29.0 (C-15), 177.8 (C-16, $COOCH_3$), 13.1 (C-17), 167.9 ($COOCH_3$), 51.4 ($COOCH_3$), 52.5 ($COOCH_3$).

Compound **22**: $[a]_D^{25}$ +64.5 (*c* 1.1, $CHCl_3$). ^{1}H NMR (400 MHz, $CDCl_3$): δ = 1.01 (3 H, s), 1.07 (1 H, ddd, *J* = 13.6, 13.6, 4.1 Hz), 1.27 (3 H, s), 1.41 (1 H, ddd, *J* = 13.3, 13.3, 4.1 Hz), 1.51 (1 H, dd, *J* = 12.2, 1.4 Hz), 1.63 (1 H, m), 1.90–2.07 (2 H, m), 2.18 (1 H, m), 2.28 (1 H, br d, *J* = 13.7 Hz), 2.31 (3 H, s), 2.77 (1 H, ddd, *J* = 16.9, 12.7, 6.4 Hz), 2.94 (1 H, dd, *J* = 16.9, 4.5 Hz), 3.65 (3 H, s), 3.82 (3 H, s), 6.94 (1 H, s), 7.69 (1 H, s). ^{13}C NMR (100 MHz, $CDCl_3$): δ = 37.7 (C-1), 20.0 (C-2), 39.1 (C-3), 44.2 (C-4), 51.5 (C-5), 20.9 (C-6), 31.5 (C-7), 133.6 (C-8), 148.8 (C-9), 39.2 (C-10), 120.8 (C-11), 154.9 (C-12), 120.2 (C-13), 132.7 (C-14), 170.1 ($COOCH_3$), 28.6 (C-16), 177.8 ($COOCH_3$), 23.0 (C-20), 52.2 ($COOCH_3$), 52.3 ($COOCH_3$), 21.2 ($OCOCH_3$), 165.2 ($OCOCH_3$).

Compound **23**: $[a]_D^{25}$ +48.4 (*c* 0.6, $CHCl_3$). ^{1}H NMR (400 MHz, $CDCl_3$): δ = 1.00 (3 H, s), 1.06 (1 H, ddd, *J* = 13.7, 13.7, 4.4 Hz), 1.26 (3 H, s), 1.37 (1 H, ddd, *J* = 13.2, 13.2, 3.8 Hz), 1.50 (1 H, d, *J* = 12.1 Hz), 1.63 (3 H, s), 1.66 (3 H, s), 1.86–2.04 (3 H, m), 2.09 (1 H, s), 2.12–2.23 (2 H, m), 2.27 (1 H, d, *J* = 13.4 Hz), 2.68 (1 H, ddd, *J* = 16.3, 12.7, 6.0 Hz), 2.79 (1 H, dd, *J* = 16.3, 4.9 Hz), 3.64 (3 H, s), 6.73 (1 H, s), 6.77 (1 H, s). ^{13}C NMR (100 MHz, $CDCl_3$): δ = 37.9 (C-1), 20.2 (C-2), 39.5 (C-3), 44.2 (C-4), 51.5 (C-5), 21.4 (C-6), 31.6 (C-7), 126.4 (C-8), 149.2 (C-9), 38.5 (C-10), 114.4 (C-11), 153.7 (C-12), 129.0 (C-13), 125.9 (C-14), 75.9 (C-15), 30.5 (C-16), 30.6 (C-17), 28.3 (C-18), 178.2 (C-19), 23.0 (C-20), 53.1 ($COOCH_3$).

Compound **24**: $[a]_D^{25}$ +30.8 (*c* 0.8, $CHCl_3$). ^{1}H NMR (500 MHz, $CDCl_3$): δ = 0.77 (6 H, q, *J* = 7.9 Hz), 1.01 (9 H, t, *J* = 7.9 Hz), 1.02 (3 H, s), 1.08 (1 H, ddd, *J* = 14.0, 14.0, 4.1 Hz), 1.18 (3 H, d, *J* = 6.9 Hz), 1.19 (3 H, d, *J* = 6.9 Hz), 1.27 (3 H, s), 1.41 (1 H, ddd, *J* = 13.4, 13.4, 3.9 Hz), 1.54 (1 H, d, *J* = 12.0 Hz), 1.64 (1 H, br d, *J* = 14.0 Hz), 1.90–2.01 (2 H, m), 2.13 (1 H, br d, *J* = 14.1 Hz), 2.17 (1 H, dd, *J* = 13.6, 5.7 Hz), 2.28 (1 H, br d, *J* = 13.4 Hz), 2.73 (1 H, ddd, *J* = 16.3, 12.6, 5.9 Hz), 2.83 (1 H, dd, *J* = 16.3, 5.0 Hz), 3.21 (1 H, sept, *J* = 6.9 Hz), 3.66 (3 H, s), 6.65 (1 H, s), 6.82 (1 H, s). ^{13}C NMR (125 MHz, $CDCl_3$): δ = 37.9 (C-1), 20.3 (C-2), 39.7 (C-3), 44.2 (C-4), 51.4 (C-5), 21.5 (C-6), 31.6 (C-7), 127.6 (C-8), 146.1 (C-9), 38.3 (C-10), 115.1 (C-11), 151.2 (C-12), 136.2 (C-13), 126.6 (C-14), 26.9 (C-15), 23.0 (C-16), 23.1 (C-17), 28.7 (C-18), 178.1 (C-19), 23.2 (C-20), 53.0 ($COOCH_3$), 5.7 ($SiCH_2CH_3$), 7.0 ($SiCH_2CH_3$).

Compound **25**: $[a]_D^{25}$ +72.6 (*c* 0.6, $CHCl_3$). ^{1}H NMR (400 MHz, $CDCl_3$): δ = 1.01 (3 H, s), 1.07 (1 H, ddd, *J* = 13.6, 13.6, 4.1 Hz), 1.22 (3 H, d, *J* = 6.9 Hz), 1.23 (3 H, d, *J* = 6.9 Hz), 1.26 (3 H, s), 1.39 (1 H, ddd, *J* = 13.3, 13.3, 4.1 Hz), 1.52 (1 H, d, *J* = 12.1 Hz), 1.61 (1 H, m), 1.80–2.05 (2 H, m), 2.16 (2 H, m), 2.27 (1 H, br d, *J* = 13.3 Hz), 2.71 (1 H, ddd, *J* = 16.4, 12.7, 5.9 Hz), 2.83 (1 H, dd, *J* = 16.4, 5.3 Hz), 3.11

(1 H, sept, *J* = 6.9 Hz), 3.65 (3 H, s), 4.54 (1 H, br s), 6.63 (1 H, s), 6.83 (1 H, s). ^{13}C NMR (100 MHz, $CDCl_3$): δ = 37.9 (C-1), 20.2 (C-2), 39.6 (C-3), 44.2 (C-4), 51.4 (C-5), 21.4 (C-6), 31.6 (C-7), 127.7 (C-8), 146.7 (C-9), 38.4 (C-10), 112.2 (C-11), 151.1 (C-12), 132.0 (C-13), 126.9 (C-14), 27.0 (C-15), 22.7 (C-16), 22.9 (C-17), 28.9 (C-18), 178.2 (C-19), 23.1 (C-20), 53.0 ($COOCH_3$).

Compound **26**: ^{1}H NMR (400 MHz, $CDCl_3$): δ = 0.80 (6 H, q, *J* = 7.9 Hz), 1.01 (9 H, t, *J* = 7.9 Hz), 1.08 (3 H, s), 1.13 (1 H, ddd, *J* = 13.6, 13.6, 4.1 Hz), 1.19 (3 H, d, *J* = 6.9 Hz), 1.21 (3 H, d, *J* = 6.9 Hz), 1.25 (3 H, s), 1.51 (1 H, ddd, *J* = 13.3, 13.3, 4.1 Hz), 1.60 (1 H, m), 1.70 (1 H, br d, *J* = 14.2 Hz), 2.03 (2 H, m), 2.20 (1 H, br d, *J* = 12.8 Hz), 2.31 (1 H, br d, *J* = 13.6 Hz), 2.92 (1 H, dd, *J* = 17.5, 2.1 Hz), 3.13 (1 H, dd, *J* = 17.5, 14.6 Hz), 3.21 (1 H, sept, *J* = 6.9 Hz), 3.69 (3 H, s), 6.72 (1 H, s), 7.91 (1 H, s). ^{13}C NMR (125 MHz, $CDCl_3$): δ = 37.7 (C-1), 19.9 (C-2), 38.7 (C-3), 44.1 (C-4), 50.5 (C-5), 37.7 (C-6), 197.3 (C-7), 137.7 (C-8), 154.2 (C-9), 38.5 (C-10), 113.8 (C-11), 158.8 (C-12), 128.2 (C-13), 126.1 (C-14), 27.2 (C-15), 22.6 (C-16), 22.7 (C-17), 28.2 (C-18), 177.3 (C-19), 21.5 (C-20), 53.0 ($COOCH_3$), 5.6 ($SiCH_2CH_3$), 6.8 ($SiCH_2CH_3$).

Compound **28**: $[a]_D^{25}$ +36.0 (*c* 0.4, $CHCl_3$). ^{1}H NMR (400 MHz, $CDCl_3$): δ = 1.02 (3 H, s), 1.07 (1 H, ddd, *J* = 13.6, 13.6, 4.2 Hz), 1.18 (3 H, d, *J* = 6.9 Hz), 1.19 (3 H, d, *J* = 6.8 Hz), 1.27 (3 H, s), 1.39 (1 H, ddd, *J* = 13.4, 13.4, 3.8 Hz), 1.53 (1 H, d, *J* = 12.1 Hz), 1.60 (1 H, br d, *J* = 14.2 Hz), 1.90–2.05 (2 H, m), 2.13–2.21 (2 H, m), 2.28 (1 H, m), 2.29 (3 H, s), 2.77 (1 H, ddd, *J* = 16.7, 12.7, 6.2 Hz), 2.88 (1 H, dd, *J* = 16.7, 5.9 Hz), 2.91 (1 H, sept, *J* = 6.8 Hz), 3.65 (3 H, s), 6.65 (1 H, s), 6.84 (1 H, s). ^{13}C NMR (100 MHz, $CDCl_3$): δ = 37.8 (C-1), 20.1 (C-2), 39.5 (C-3), 44.2 (C-4), 51.4 (C-5), 21.2 (C-6), 31.8 (C-7), 133.4 (C-8), 146.5 (C-9), 38.5 (C-10), 119.3 (C-11), 146.9 (C-12), 137.2 (C-13), 127.2 (C-14), 27.4 (C-15), 23.1 (C-16), 23.2 (C-17), 28.7 (C-18), 178.0 (C-19), 23.2 (C-20), 52.7 ($COOCH_3$), 21.1 ($OCOCH_3$), 170.1 ($OCOCH_3$).

Compound **29**: $[a]_D^{25}$ +53.3 (*c* 0.9, $CHCl_3$). ^{1}H NMR (400 MHz, $CDCl_3$): δ = 1.11 (3 H, s), 1.20 (3 H, d, *J* = 6.8 Hz), 1.22 (3 H, d, *J* = 6.8 Hz), 1.25 (3 H, s), 1.53 (1 H, ddd, *J* = 13.1, 13.1, 4.1 Hz), 1.68 (1 H, m), 1.98 (1 H, dt, *J* = 10.6, 3.6 Hz), 2.06 (1 H, dd, *J* = 14.5, 3.3 Hz), 2.26 (1 H, br d, *J* = 14.6 Hz), 2.33 (3 H, s), 2.98 (1 H, m), 2.97 (1 H, ddd, *J* = 17.9, 6.7, 3.3 Hz), 3.00 (1 H, sept, *J* = 6.8 Hz), 3.21 (1 H, dd, *J* = 17.9, 14.5 Hz), 3.69 (3 H, s), 7.02 (1 H, s), 8.01 (1 H, s). ^{13}C NMR (100 MHz, $CDCl_3$): δ = 37.7 (C-1), 19.7 (C-2), 38.6 (C-3), 44.1 (C-4), 50.3 (C-5), 37.6 (C-6), 198.2 (C-7), 139.0 (C-8), 153.0 (C-9), 38.7 (C-10), 119.1 (C-11), 153.6 (C-12), 128.9 (C-13), 126.5 (C-14), 27.3 (C-15), 22.9 (C-16), 23.0 (C-17), 27.5 (C-18), 177.2 (C-19), 21.6 (C-20), 51.8 ($COOCH_3$), 177.2 ($COOCH_3$), 21.2 ($OCOCH_3$), 169.3 ($OCOCH_3$).