Supporting Information
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Supporting information

Me$_3$Ga-Mediated Addition of Acetylenes to $\alpha$-ketoesters: A Promising Method for the Synthesis of $\alpha$-hydroxyesters

Experimental Procedures

All reagents and all solvents were obtained from commercial suppliers and used without further purification except as indicated below. The $\alpha$-ketoesters were prepared according to the literatures. All reactions were carried out under an nitrogen atmosphere using standard Schlenk techniques. Solvents were dried and distilled prior to use according to the standard method. Unless otherwise indicated, all materials were obtained from commercial sources and Liquid $\alpha$-ketoester were freshly distilled before they were used. For thin-layer chromatography (TLC), compounds were visualized by irradiation with UV light on GF 254 silica gel plates. $^1$H NMR and $^13$C NMR spectra were recorded in CDCl$_3$ at Bruker ARX-300 MHz spectrometer with chemical shifts referenced to SiMe$_4$ as internal standard. HRESIMS were recorded on an Agilent 6210 TOF LC/MS equipped with electrospray ionization (ESI) probe operating in positive or negative ion mode.

General procedure for Me$_3$Ga-Mediated Addition of Acetylenes to $\alpha$-ketoesters

In a 20 mL Schlenk reaction tube, commercially available 1M solution of Me$_3$Ga (0.15 mL, 0.15 mmol, 1M in toluene) was mixed with 4-Methoxyphenylacetylene (20mg, 0.15 mmol) in anhydrous hexane (1 mL) at room temperature under an nitrogen atmosphere for an hour. Then the mixture was cooled to 0°C and methyl benzoylformate (0.1mmol) was added, and stirred at room temperature for indicated time in Table 2, then saturated NH$_4$Cl (1 mL) was added to quench the reaction. The aqueous layer was separated and further extracted with AcOEt; the organic layers were combined and dried. Evaporation of the solvent gave the crude product, which was further purified by preparative TLC (PE/EA = 10:1) to give corresponding $\alpha$-hydroxyesters.
The spectroscopic data of compounds 3a-3q

Methyl 2-hydroxy-4-(4-methoxyphenyl)-2-phenylbut-3-ynoate (3a)
Pale yellow oil. $^1$H NMR (300 MHz, CDCl₃): $\delta$ = 3.81 (s, 3H), 3.82 (s, 3H), 6.84-6.72 (m, 2H), 7.37-7.48 (m, 5H), 7.73-7.76 (m, 2H). $^{13}$C NMR (75 MHz, CDCl₃): $\delta$ = 54.2, 55.2, 73.2, 85.5, 86.3, 113.8, 113.9, 126.2, 128.3, 128.7, 133.4, 139.4, 160.0, 172.5. HRMS: calculated for C₁₈H₁₆O₄Na: 319.0946 [M+Na]$^+$; found: 319.0949.

Ethyl 2-hydroxy-4-(4-methoxyphenyl)-2-phenylbut-3-ynoate (3b)
Pale yellow oil. $^1$H NMR (300 MHz, CDCl₃): $\delta$ = 1.25 (t, $J$=7.2 Hz, 3H), 3.81 (s, 3H), 4.31 (br, 1H), 4.22-4.30 (m, 2H), 6.84-6.87 (m, 2H), 7.36-7.47 (m, 5H), 7.73-7.76 (m, 2H). $^{13}$C NMR (75 MHz, CDCl₃): $\delta$ = 13.8, 55.2, 63.4, 73.2, 85.7, 86.1, 113.8, 113.9, 126.2, 128.2, 128.5, 133.4, 139.5, 160.0, 171.9. HRMS: calculated for C₁₉H₁₈O₄Na: 333.1103 [M+Na]$^+$; found: 333.1106.

Isopropyl 2-hydroxy-4-(4-methoxyphenyl)-2-phenylbut-3-ynoate (3c)
Pale yellow oil. $^1$H NMR (300 MHz, CDCl₃): $\delta$ = 1.11 (d, $J$=6.6 Hz, 3H), 1.30 (d, $J$=6.3 Hz, 2H), 3.81 (s, 3H), 4.32 (br, 1H), 5.06-5.10 (m, 1H), 6.84-6.87 (m, 2H), 7.32-7.46 (m, 5H), 7.71-7.75 (m, 2H). $^{13}$C NMR (75 MHz, CDCl₃): $\delta$ = 21.1, 21.3, 55.2, 71.5, 73.2, 85.9, 113.9, 114.1, 126.2, 127.1, 128.1, 128.4, 133.3, 139.6, 159.9, 171.4. HRMS: calculated for C₂₀H₂₀O₄Na: 347.1259 [M+Na]$^+$; found: 347.1263.

Benzyl 2-hydroxy-4-(4-methoxyphenyl)-2-phenylbut-3-ynoate (3d)
Pale yellow oil. $^1$H NMR (300 MHz, CDCl₃): $\delta$ = 3.80 (s, 3H), 4.27 (br, 1H), 5.14 (d, $J$=12.6 Hz, 1H), 5.31 (d, $J$=12.6 Hz, 1H), 6.82-6.85 (m, 2H), 7.17-7.28 (m, 5H), 7.34-7.41 (m, 5H), 7.72-7.75 (m, 2H). $^{13}$C NMR (75MHz, CDCl₃): $\delta$ = 55.2, 68.4, 73.4, 85.6, 86.5, 113.9, 126.3, 127.4, 128.1, 128.2, 128.3, 128.4, 128.6, 133.4, 134.9, 139.2, 160.0, 171.7. HRMS: calculated for C₂₄H₂₆O₄Na: 395.1259 [M+Na]$^+$; found: 395.1260.
Methyl 2-(4-fluorophenyl)-2-hydroxy-4-(4-methoxyphenyl)-2-phenylbut-3-yonoate (3e)
Pale yellow oil. $^1$H NMR (300 MHz, CDCl$_3$): $\delta = 3.82$ (s, 3H), 4.28 (br, 1H), 6.85 (d, $J$=8.4 Hz, 2H), 7.07 (t, $J$=8.4 Hz, 2H), 7.45 (d, $J$=8.4 Hz, 2H), 7.72 (dd, $J$=5.4, 3.3 Hz, 2H). $^{13}$C NMR (75 MHz, CDCl$_3$): $\delta = 54.3, 55.2, 72.7, 85.4, 86.4, 113.6, 113.9, 115.0, 115.3, 128.2, 128.3, 128.7, 133.4, 135.1, 135.2, 160.1, 161.2, 164.5, 172.3.

HRMS: calculated for C$_{18}$H$_{15}$FO$_4$Na: 337.0852 [M+Na]$^+$; found: 337.0853.

Methyl 2-hydroxy-4-(4-methoxyphenyl)-2-(thiophen-2-yl)but-3-yonoate(3f)
yellow oil. $^1$H NMR (300 MHz, CDCl$_3$): $\delta = 3.83$ (s, 3H), 3.89 (s, 3H), 6.86 (d, $J$=8.7 Hz, 2H), 7.00-7.03 (m, 1H), 7.32-7.34 (m, 2H), 7.45-7.48 (m, 2H); $^{13}$C NMR (75 MHz, CDCl$_3$): $\delta = 54.5, 55.2, 70.5, 85.2, 85.7, 113.5, 113.9, 126.2, 126.3, 126.8, 127.4, 133.5, 143.8, 160.1, 171.5. HRMS: calculated for C$_{16}$H$_{14}$O$_4$SNa: 325.0510 [M+Na]$^+$; found: 325.0513.

Methyl 2-hydroxy-4-(4-methoxyphenyl)-2-p-tolybut-3-yonoate(3g)
Pale yellow oil. $^1$H NMR (300 MHz, CDCl$_3$): $\delta = 2.36$ (s, 3H), 3.81 (s, 3H), 3.82 (s, 3H), 6.84-6.87 (m, 2H), 7.19-7.26 (m, 2H), 7.44-7.48 (m, 2H), 7.61-7.63 (m, 2H). $^{13}$C NMR (75 MHz, CDCl$_3$): $\delta = 21.1, 54.1, 55.2, 73.1, 85.7, 86.2, 113.9, 125.7, 126.1, 129.0, 133.4, 136.6, 138.5, 160.0, 172.6. HRMS: calculated for C$_{19}$H$_{18}$O$_4$Na: 333.1103 [M+Na]$^+$; found: 333.1105.

Ethyl 2-(4-chlorophenyl)-2-hydroxy-4-(4-methoxyphenyl)but-3-yonoate(3h)
Pale yellow oil. $^1$H NMR (300 MHz, CDCl$_3$): $\delta = 1.24$ (t, $J$=7.2 Hz, 3H), 3.82 (s, 3H), 4.19-4.29 (m, 2H), 4.34 (br, 1H), 6.85-6.88 (m, 2H), 7.26-7.37 (m, 2H), 7.43-7.46 (m, 2H), 7.67-7.70 (m, 2H). $^{13}$C NMR (75 MHz, CDCl$_3$): $\delta = 13.8, 55.3, 63.6, 72.7, 85.4, 86.3, 113.7, 113.9, 127.8, 128.4, 129.0, 133.4, 134.5, 138.1, 160.1, 171.6. HRMS: calculated for C$_{19}$H$_{17}$ClO$_4$Na: 367.0713 [M+Na]$^+$; found: 367.0718.
Ethyl 2-hydroxy-4-(4-methylphenyl)-2-p-tolybut-3-ynoate(3i)
Pale yellow oil. $^1$H NMR (300 MHz, CDCl$_3$): $\delta$ = 1.24 (t, $J$=7.2 Hz, 3H), 2.36 (s, 3H), 3.82 (s, 3H), 4.22-4.32 (m, 2H), 4.26 (br, 1H), 6.84-6.87 (m, 2H), 7.18 -7.21 (m, 2H), 7.44 -7.47 (m, 2H), 7.60-7.63 (m, 2H). $^{13}$C NMR (75MHz, CDCl$_3$): $\delta$ = 13.8, 21.1, 55.2, 63.4, 73.1, 85.8, 85.9, 113.8, 114.0, 126.1, 128.9, 133.4, 136.7, 138.4, 159.9, 171.1. HRMS: calculated for C$_{20}$H$_{20}$O$_4$Na: 347.1259 [M+Na]$^+$; found: 347.1262.

Ethyl 2-(4-fluorophenyl)-2-hydroxy-4-(4-methoxyphenyl)but-3-ynoate(3j)
Pale yellow oil. $^1$H NMR (300 MHz, CDCl$_3$): $\delta$ = 1.24 (t, $J$=7.2 Hz, 3H), 2.36 (s, 3H), 3.82 (s, 3H), 4.22-4.32 (m, 2H), 4.31 (br, 1H), 6.85-6.88 (m, 2H), 7.04 -7.10 (m, 2H), 7.43 -7.46 (m, 2H), 7.70-7.75 (m, 2H). $^{13}$C NMR (75 MHz, CDCl$_3$): $\delta$ = 13.8, 55.2, 63.5, 72.7, 85.6, 86.2, 113.7, 113.9, 114.9, 115.2, 128.1, 128.3, 133.4, 135.3, 160.0, 161.2, 164.4, 171.8. HRMS: calculated for C$_{19}$H$_{17}$O$_4$Na: 351.1009 [M+Na]$^+$; found: 351.1013.

Ethyl 2-(3,4-dimethylphenyl)-2-hydroxy-4-(4-methoxyphenyl)but-3-ynoate(3k)
Pale yellow oil. $^1$H NMR (300 MHz, CDCl$_3$): $\delta$ = 1.26 (t, $J$=7.2 Hz, 3H), 2.26 (s, 3H), 2.29 (s, 3H), 3.82 (s, 3H), 4.12-4.37 (m, 2H), 4.22 (br, 1H), 6.84-6.87 (m, 2H), 7.14 (d, $J$=8.1 Hz, 1H), 7.43 -7.46 (m, 2H), 7.70-7.75 (m, 2H). $^{13}$C NMR (75 MHz, CDCl$_3$): $\delta$ = 13.8, 19.5, 19.9, 55.2, 63.3, 73.1, 85.9, 113.7, 113.8, 114.1, 115.2, 123.7, 127.1, 129.5, 133.4, 136.5, 137.0, 159.9, 172.1. HRMS: calculated for C$_{21}$H$_{22}$O$_4$Na: 361.1416 [M+Na]$^+$; found: 361.1416.

Ethyl 2-hydroxy-2,4-bis(4-methoxyphenyl)but-3-ynoate(3l)
Pale yellow oil. $^1$H NMR (300 MHz, CDCl$_3$): $\delta$ = 1.24 (t, $J$=6.9Hz, 3H), 3.82 (s, 6H), 4.22-4.32 (m, 2H), 4.25 (br, 1H), 6.84-6.92 (m, 4H), 7.45 (d, $J$=8.7 Hz, 2H), 7.65 (d, $J$=8.7 Hz, 2H). $^{13}$C NMR (75MHz, CDCl$_3$): $\delta$ = 13.8, 55.2, 63.3, 72.8, 85.9, 86.0, 113.4, 113.6, 114.0, 127.5, 131.7, 133.4, 159.7, 160.0, 172.1. HRMS: calculated for C$_{20}$H$_{20}$O$_4$Na: 363.1208 [M+Na]$^+$; found: 363.1212.
Ethyl 2-(4-bromophenyl)-2-hydroxy-4-(4-methoxyphenyl)but-3-ynoate (3m)
Pale yellow oil. $^1$H NMR (300 MHz, CDCl$_3$): $\delta = 1.24 (t, J=7.2$ Hz, 3H), 3.82 (s, 3H), 4.19-4.29 (m, 2H), 4.34 (br, 1H), 6.85-6.88 (m, 2H), 7.26-7.37 (m, 2H), 7.43-7.46 (m, 2H), 7.67-7.70 (m, 2H). $^{13}$C NMR (75 MHz, CDCl$_3$): $\delta =$ 13.8, 55.3, 63.6, 72.7, 85.3, 86.3, 113.6, 113.9, 122.8, 129.1, 131.3, 133.4, 138.6, 160.1, 171.5. HRMS: calculated for C$_{12}$H$_7$BrO$_4$Na: 413.0188 [M+Na]$^+$; found: 413.0187.

![Ethyl 2-(4-bromophenyl)-2-hydroxy-4-(4-methoxyphenyl)but-3-ynoate](image)

Methyl 2-hydroxyl-2,4-diphenyl-3-yn-butyrate (3n)
Pale yellow oil. $^1$H NMR (CDCl$_3$, 300 MHz): $\delta = 3.82$ (s, 3H), 4.29 (s, 1H), 7.33-7.41 (m, 6H), 7.52-7.55 (m, 2H), 7.74-7.77 (m, 2H).

Methyl 4-(4-fluorophenyl)-2-hydroxy-2-phenylbut-3-ynoate (3o)
Pale yellow oil. $^1$H NMR (CDCl$_3$, 300 MHz): $\delta = 3.82$ (s, 3H), 4.28 (br, 1H), 7.00-7.06 (m, 2H), 7.44-7.36 (m, 3H), 7.49-7.53 (m, 2H), 7.72-7.75 (m, 2H). $^{13}$C NMR (75MHz, CDCl$_3$): $\delta =$ 54.3, 72.8, 85.2, 86.6, 115.2, 115.9, 126.1, 128.4, 128.8, 133.8, 133.9, 139.2, 161.2, 164.5, 172.4. HRMS: calculated for C$_{17}$H$_{15}$FO$_3$Na: 284.0849, [M+Na]$^+$; found: 284.0849.

Ethyl 2-hydroxy-4-(4-methoxyphenyl)-2-methylbut-3-ynoate (3q)
Pale yellow oil. $^1$H NMR (300 MHz, CDCl$_3$): $\delta = 1.35$ (t, $J=7.2$ Hz, 3H), 1.77 (s, 3H), 3.56 (br, 1H), 3.81 (s, 3H), 4.33 (q, $J=7.2$ Hz, 2H), 6.81-6.84 (m, 2H), 7.36-7.39 (m, 2H). $^{13}$C NMR (300 MHz, CDCl$_3$): $\delta =$ 14.0, 27.1, 55.2, 62.8, 68.2, 83.8, 87.0, 113.8, 114.0, 133.2, 159.8, 172.8. HRMS: calculated for C$_{16}$H$_{16}$O$_4$Na: 271.0946 [M+Na]$^+$; found: 271.0947.

References:
Compilation of NMR spectra of new compounds: