Supporting Information

Strikingly Simple Direct α-Allylation of Aldehydes with Allyl Alcohols: Remarkable Advance in the Tsuji-Trost Reaction

Masanari Kimura, Yoshikazu Horino, Ryutaro Mukai, Shuji Tanaka, and Yoshinao Tamaru*

Department of Applied Chemistry, Faculty of Engineering, Nagasaki University, Bunkyo-machi, Nagasaki 852-8521, Japan

General Procedure (run 1, Table 1): To a solution of $Pd(OAc)_2$ (22.6 mg, 0.1 mmol), PPh_3 (53.0 mg, 0.2 mmol) and LiCl (44.0 mg, 1.0 mmol) in dry THF (5 mL) were successively added cyclohexanecarboxaldehyde (124.6 mg, 1.1 mmol), allyl alcohol (59.0 mg, 1.0 mmol), triethylamine (124.9 mg, 1.2 mmol), and triethylborane (2.4 mmol, 1.0 M hexane solution) via syringe at ambient temperature under N_2. The mixture (yellow suspension all through the reaction) was stirred at ambient temperature for 48 h. The mixture was filtered through a Celite® pad and washed with EtOAc. The filtrate was washed with aqueous $NaHCO_3$, and the organic phase was dried ($MgSO_4$) and concentrated in vacuo to give yellow oil, which was purified by means of column chromatography over silica gel (EtOAc-hexane, 1/32 v/v) to give **3a** (111.3 mg, 74%, R_f = 0.71; EtOAc-hexane, 1/4 v/v) and **4a** (8.1 mg, 5%, R_f = 0.51).

GLC Analysis of the reaction using $PdCl_2$ as the catalyst: The scenario outlined in this paragraph is in accord with the results obtained by the GLC analysis of the reaction of **1c** and **2a** (cf., run 3, Table 1) using $PdCl_2$ as the starting Pd(II) species; a mixture of **1c** (1.0 mmol), **2a** (1.2 mmol), $PdCl_2$ (0.2 mmol), PPh_3 (0.4 mmol), Et_3B (2.4 mmol), and n-decane (0.4 mmol, an internal standard) in dry THF (5 ml) was stirred for 2 h at

room temperature and then Et_3N (1.2 mmol) was added. The stirring was continued at room temperature, during which the appearance of the reaction mixture (yellow suspension) did not change. The mixture was monitored by GLC: silicone DC 550 (Shimazu); He 50 ml/min; initial time 5 min, initial temperature 80 °C, rate 10 °C/min, final temperature 240 °C, final time 25 min. The calibrated amounts of PPh_3 (retention time 43 min), **1c** (14 min), and **3e** (18 min) at 1, 2, 3, 4, 5, and 6 h were as follows:

PPh_3 (mmol):	0.19	0.19	0.09	0.07	0.04	0.04
1c (mmol):	0.96	0.96	0.66	0.20	0.02	0.02
3e (mmol):	0.00	0.00	0.21	0.74	0.89	0.89

These data clearly indicate that in the absence of Et_3N (initial 2 hours), no alkylation takes place; however, at the moment of addition of it, alkylation sets in and completes within 3 h. We could not detect $Ph_3P{=}O$ by the GLC analysis of the reaction mixture and also of the authentic sample; however, ^{31}P NMR of the reaction mixture showed a resonance at δ 27.8 ppm ascribable to $Ph_3P{=}O$ (authentic sample at δ 27.7 ppm, relative to an external H_3PO_4 standard, 162 MHz in $CDCl_3$ at 30 °C) along with three additional resonances [δ 16.9 (relative intensity to $Ph_3P{=}O$ = 1.5), 19.3 (0.5), 22.0 (2.7)]. Characterization of phosphorus compounds corresponding to these resonances is under investigation.

1-Allylcyclohexanecarboxaldehyde (3a): IR (neat) 1699 (s), 1452 (s), 1194 (s), 1138 (m), 995 (m), 918 (m) cm^{-1}; ^1H NMR (400 MHz, $CDCl_3$) δ 1.12–1.34 (m, 6 H), 1.40-1.60 (m, 2 H), 1.75-1.88 (m, 2 H), 2.11 (d, J = 7.3 Hz, 2 H), 4.96 (dm, J = 10.6 Hz, 1 H), 4.97 (dm, J = 18.0 Hz, 1 H), 5.59 (ddt, J = 18.0, 10.6, 7.3 Hz, 1 H), 9.38 (s, 1 H); HRMS, calcd for: $C_{10}H_{16}O$: 152.1201, found *m/z* (relative intensity) 152.1180 (M^+, 1), 125 (1), 123 (100). Anal. calcd for $C_{10}H_{16}O$: C, 78.90; H, 10.59; found: C, 79.10; H, 10.59.

1-*trans*-Cinnamylcyclohexanecarboxaldehyde (3b): IR (neat) 1699 (s), 1598 (w), 1249 (m), 1204 (m), 1026 (m), 966 (m), 916 (m), 750 (m) cm^{-1}; ^1H NMR (400 MHz,

$CDCl_3$) δ 1.21–1.40 (m, 6 H), 1.51–1.64 (m, 2 H), 1.88–1.94 (m, 2 H), 2.34 (dd, J = 7.7, 1.5 Hz, 2 H), 6.06 (dt, J = 15.4, 7.7 Hz, 1 H), 6.38 (d, J = 15.4 Hz, 1 H), 7.18–7.33 (m, 5 H), 9.61 (s, 1 H); HRMS, calcd for: $C_{16}H_{20}O$: 228.1514, found *m/z* (relative intensity): 228.1528 (M^+, 3), 199 (16), 117 (100). Anal. calcd for $C_{16}H_{20}O$: C, 84.16; H, 8.83; found: C, 83.68; H, 9.04.

***trans*-2,2-Dimethyl-5-phenyl-4-pentenal (3c)**: IR (neat) 1724 (s), 968 (m), 740 (m) cm^{-1}; ^1H NMR (400 MHz, $CDCl_3$) δ 1.11 (s, 6 H), 2.37 (br d, J = 7.7 Hz, 2 H), 6.11 (dt, J = 7.7, 15.4 Hz, 1 H), 6.42 (d, J = 15.4 Hz, 1 H), 7.19-7.34 (m, 5 H), 9.52 (s, 1 H); ^{13}C NMR ($CDCl_3$, 100 MHz): δ 21.4, 40.6, 46.2, 124.8, 126.2, 128.6, 127.3, 133.6, 137.2, 205.7; HRMS, calcd for: $C_{13}H_{16}O$: 188.1201, found *m/z* (relative intensity): 188.1183 (M^+, 100), 159 (11), 117 (26).

2-Methyl-2-phenyl-4-pentenal (3d): IR (neat) 1724 (s), 954 (m), 918 (m), 761 (s) cm^{-1}; ^1H NMR ($CDCl_3$, 400 MHz): δ 1.44 (s, 3 H), 2.63 (ddt, J = 7.1, 13.9, 1.1 Hz, 1 H), 2.70 (ddt, J = 7.1, 13.9, 1.1 Hz, 1 H), 5.03 (dm, J = 10.3 Hz, 1 H), 5.06 (dm, J = 17.2 Hz, 1 H), 5.55 (ddt, J = 10.3, 17.2, 7.1 Hz, 1 H), 7.23-7.40 (m, 5 H), 9.51 (s, 1 H); HRMS, calcd for $C_{12}H_{14}O$: 174.1045, found *m/z* (relative intensity): 174.1037 (M^+, 15), 145 (100), 133 (11).

***trans*-2-Methyl-2,5-diphenyl-4-pentenal (3e):** IR (neat) 1722 (s), 1598 (m), 1028 (m), 968 (s), 734(s), 700 (s) cm^{-1}; ^1H NMR ($CDCl_3$, 400 MHz): δ 1.48 (s, 3 H), 2.76 (ddd, J = 1.1, 7.5, 13.2 Hz, 1 H), 2.82 (ddd, J = 1.1, 7.5, 13.2 Hz, 1 H), 5.93 (dt, J = 15.5, 7.5 Hz, 1 H), 6.39 (dt, J = 15.5, 1.1 Hz, 1 H), 7.15-7.41 (m, 10 H), 9.55 (s, 1 H); ^{13}C NMR ($CDCl_3$, 400 MHz): δ 19.0, 40.0, 54.1, 124.9, 126.1, 127.1, 127.2, 127.4, 128.4, 128.9, 133.6, 137.2, 139.5, 201.9; HRMS, calcd for $C_{18}H_{18}O$: 250.1358, found *m/z* (relative intensity): 250.1340 (M^+, 18), 221 (1), 133 (5), 117 (100).

2-Methyl-2,4-diphenyl-4-pentenal (3f): IR (neat) 1724 (s), 904 (m), 779 (m), 761 (m), 700 (s) cm^{-1}; ^1H NMR ($CDCl_3$, 400 MHz): δ 1.35 (s, 3 H), 3.09 (dm, J = 13.9 Hz, 1 H), 3.25 (dm, J = 13.9 Hz, 1 H), 4.88 (s, 1 H), 5.17 (s, 1 H), 7.14-7.42 (m, 10 H), 9.42

(s, 1 H); ^{13}C NMR ($CDCl_3$, 100 MHz): δ 18.9, 41.7, 54.3, 117.6, 126.5, 127.1, 127.3, 128.1, 128.5, 139.5, 142.3, 145.0, 201.3; HRMS, calcd for $C_{18}H_{18}O$: 250.1358, found *m/z* (relative intensity): 250.1378 (M^+, 19), 221 (100), 133 (43), 117 (23).

2-(2-cyclohexenyl)-2-phenylpropanal (3g, mixture of two diastereomers ca. 1:2): IR (neat) 1722 (s), 1687 (w), 1598 (w), 1028 (w), 941 (w), 759 (m), 723 (m), 700 (s) cm^{-1}; ^{1}H NMR ($CDCl_3$, 400MHz): major isomer δ 1.40 (s, 3 H), 1.30-1.82 (m, 4 H), 1.91-1.97 (m, 2 H), 3.09-3.13 (m, 1 H), 5.18 (dm, J = 9.9 Hz, 1 H), 5.70 (m, 1 H), 7.19-7.39 (m, 5 H), 9.59 (s, 1 H); minor isomer δ 1.39 (s, 3 H), 5.53 (dm, 1 H), 5.79 (m, 1 H), 9.60 (s, 1 H); ^{13}C NMR ($CDCl_3$, 100 MHz): major isomer δ 14.4, 22.4, 24.9, 25.1, 41.0, 56.7, 127.2, 127.7, 128.7, 129.9, 139.2, 202.3; minor isomer 15.0, 22.5, 24.0, 25.2, 40.5, 56.9, 126.7, 127.3, 128.8, 129.7, 139.2, 202.9; HRMS, calcd for $C_{15}H_{18}O$: 214.1358, found *m/z* (relative intensity): 214.1358 (M^+, 100), 185 (29).

***trans*-2-Methyl-2-phenyl-4-hexenal (3h):** IR (neat) 1724 (s), 968 (m), 759 (m), 700 (s) cm^{-1}; ^{1}H NMR ($CDCl_3$, 400 MHz): δ 1.41 (s, 3 H), 1.60 (dd, J = 1.4, 6.6 Hz, 3 H), 2.60 (dd, J = 1.5, 7.3 Hz, 2 H), 5.18 (dtq, J = 15.0, 7.3, 1.4 Hz, 1 H), 5.48 (dtq, J = 15.0, 1.5, 6.6 Hz, 1 H), 7.23-7.41 (m, 5 H), 9.51 (s, 1 H); ^{13}C NMR ($CDCl_3$, 100 MHz): δ 17.9, 19.1, 39.4, 53.9, 125.4, 127.2, 128.9, 129.3, 140.0, 202.4; HRMS, calcd for $C_{13}H_{16}O$: 188.1201, found *m/z* (relative intensity): 188.1217 (M^+, 36), 159 (45), 104 (8), 77 (100).

2,3-Dimethyl-2-phenyl-4-pentenal (3h', mixture of two diastereomers 1:1.3): IR (neat) 1724 (s), 970 (s), 918 (m), 759 (s), 700 (s) cm^{-1}: ^{1}H NMR ($CDCl_3$, 400 MHz): major isomer δ 1.05 (d, J = 6.6 Hz, 3 H), 1.40 (s, 3 H), 3.10 (m, 1 H), 4.92 (dm, J = 10.3 Hz, 1 H), 4.93 (dm, J = 17.4 Hz, 1 H), 5.48 (ddd, J = 7.7, 10.3, 17.4 Hz, 1 H) , 7.20-7.42 (m, 5 H), 9.62 (s, 1 H); minor isomer δ 0.81 (d, J = 6.9 Hz, 3 H), 1.40 (s, 3 H), 3.10 (m, 1 H), 5.09 (dm, J = 10.3 Hz, 1 H), 5.12 (dm, J = 17.3 Hz, 1 H), 5.73 (ddd, J = 7.7, 10.3, 17.3 Hz, 1 H), 7.20-7.42 (m, 5 H), 9.60 (s, 1 H); ^{13}C NMR ($CDCl_3$, 400 MHz): major isomer δ 14.4, 15.0, 42.1, 56.7, 115.7, 127.2, 127.6, 128.8, 138.7, 139.2, 202.4; minor isomer δ 14.4, 14.8, 42.2, 56.7, 116.3, 127.2, 127.6, 128.8, 138.8, 139.5, 202.4.

2-Methyl-2-phenyl-4,6-heptadienal (3i): IR (neat) 1735 (s), 1685 (m), 974 (m), 763 (m), 700 (s) cm^{-1}; ^1H NMR ($CDCl_3$, 400 MHz): δ 1.42 (s, 3 H), 2.65 (dd, J = 7.7, 14.3 Hz, 1 H), 2.70 (dd, J = 7.7, 14.3 Hz, 1 H), 4.95 (dd, J = 1.1, 9.9 Hz, 1 H), 5.07 (dd, J = 1.5, 16.5 Hz, 1 H), 5.41 (dt, J = 7.7, 15.3 Hz, 1 H), 6.06 (dd, J = 10.4 15.3 Hz, 1 H), 6.20 (ddd, J = 9.9, 10.4, 16.5 Hz, 1 H), 7.20-7.38 (m, 5 H), 9.49 (s, 1 H); ^{13}C NMR ($CDCl_3$, 100 MHz): δ 19.0, 39.5, 53.9, 115.9, 127.1, 127.4, 128.9, 129.0, 134.6, 136.7, 139.4, 201.8; HRMS, calcd for $C_{14}H_{16}O$: 200.1202, found *m/z* (relative intensity): 200.1209 (M^+, 6), 171 (6), 156 (7), 133 (14), 77 (100).

1-Cyclohexyl-3-buten-1-ol (4a): IR (neat) 3379 (s), 1639 (m), 986 (m), 910 (m) cm^{-1}; ^1H NMR (400 MHz, $CDCl_3$) δ 0.95-1.42 (m, 6 H), 1.56-1.91 (m, 5 H), 2.13 (ddm, J = 8.1, 13.9 Hz, 1 H), 2.33 (dm, J = 13.9 Hz, 1H), 3.39 (m, 1 H), 5.13 (dm, J = 10.3 Hz, 1 H), 5.14 (dm, J = 17.2 Hz, 1 H), 5.84 (ddm, J = 10.3, 17.2 Hz, 1 H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 26.2, 26.3, 26.6, 28.2, 29.2, 38.9, 43.2, 74.8, 117.9, 135.6; HRMS, calcd for: $C_{10}H_{18}O$: 154.1358, found *m/z* (relative intensity) 154.1266 (M^+, 27), 136 (47), 71 (100). Anal. calcd for $C_{10}H_{18}O$: C, 77.87; H, 11.76; found: C, 77.48; H, 11.42.

1-Cyclohexyl-2-phenyl-3-buten-1-ol (4b): IR (neat) 3415 (s), 966 (m), 750 (m) cm^{-1}; ^1H NMR (400 MHz, $CDCl_3$) δ 1.02-1.30 (m, 6 H), 1.54-1.75 (m, 4 H), 1.84 (m, 1 H), 3.45 (dd, J = 9.2, 7.3 Hz, 1 H), 3.56 (m, 1 H), 5.17 (dd, J = 17.2, 1.7 Hz, 1 H), 5.20 (dd, J = 10.3, 1.7 Hz, 1 H), 6.14 (ddd, J = 17.2, 10.3, 9.2 Hz, 1 H), 7.18-7.25 (m, 3 H), 7.27-7.34 (m, 2 H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 26.0, 26.4, 26.5, 26.7, 30.2, 39.7, 53.7, 78.2, 117.6, 126.5, 128.0, 128.7, 138.5, 142.2; HRMS, calcd for: $C_{16}H_{22}O$: 230.1671, found *m/z* (relative intensity) 230.1690 (M^+, 6), 213 (9), 147 (39), 83 (100). Anal. calcd for $C_{16}H_{22}O$: C, 83.43; H, 9.63; found: C, 83.10; H, 9.73.

2-Methyl-4-phenyl-5-hexen-3-ol (4c): IR (neat) 3460 (s), 1636 (m), 993 (s) cm^{-1}; ^1H NMR (400 MHz, $CDCl_3$) δ 0.89 (d, J = 6.8 Hz, 3 H), 0.94 (d, J = 6.8 Hz, 3 H), 1.55 (d hept, J = 4.4, 6.8 Hz, 1 H), 1.75 (br s, 1 H), 3.38 (dd, J = 8.1, 9.2 Hz, 1 H), 3.59 (m, 1 H), 5.17 (dm, J = 10.3 Hz, 1 H), 5.18 (dm, J = 16.9 Hz, 1 H), 6.13 (ddd, J = 9.2, 10.3,

16.9 Hz, 1 H), 7.26-7.32 (m, 5 H); ^{13}C NMR ($CDCl_3$, 100 MHz): δ 15.8, 20.2, 29.8, 54.7, 78.5, 117.5, 126.6, 128.0, 128.7, 138.8, 142.1; HRMS, calcd for $C_{13}H_{18}O - H_2O$: 172.1252, found *m/z* (relative intensity): 172.1251 ($M^+ - H_2O$, 4), 117 (100).

(*E*)-2-Benzyl-5-phenyl-2-pentenal (6): IR (neat) 3026 (m), 1683 (s), 891 (m) cm^{-1}; ^{1}H NMR ($CDCl_3$, 400MHz): δ 2.69-2.78 (m, 4 H), 3.58 (s, 2 H), 6.61 (t, J = 7.0 Hz, 1 H), 7.09-7.20 (m, 5 H), 7.21-7.31 (m, 5 H), 9.44 (s, 1 H); HRMS, calcd for $C_{18}H_{18}O$: 250.1358, found *m/z* (relative intensity): 250.1353 (M^+, 42), 159 (24), 145 (25), 115 (7), 91 (100).

***trans*-2-Allyl-2-benyl-5-phenyl-3-pentenal (7a):** IR (neat) 3062 (m), 3028 (m), 1724 (s), 1637 (w), 975 (m), 918 (m), 734 (m), 700 (s) cm^{-1}; ^{1}H NMR ($CDCl_3$, 400 MHz): δ 2.37 (dm, J = 7.3 Hz, 2 H), 2.95 (d, J = 13.9 Hz, 1 H), 2.97 (d, J = 13.9 Hz, 1 H), 3.40 (br d, J = 7.0 Hz, 2 H), 5.09 (dm, J = 17.6 Hz, 1 H), 5.13 (dm, J = 10.2 Hz, 1 H), 5.43 (dt, J = 16.1, 1.5 Hz, 1 H), 5.63 (dt, J = 16.1, 6.9, 1 H), 5.77 (ddt, J = 10.3, 17.6, 7.3 Hz, 1 H), 7.06-7.30 (m, 10 H), 9.52 (s, 1 H); HRMS, calcd for $C_{21}H_{22}O$: 290.1671, found *m/z* (relative intensity): 290.1667 (M^+, 0.4), 261 (3), 170 (2), 117 (9), 91 (100).

***trans*-2-Benzyl-(2-*trans*-cinnamyl)-5-phenyl-3-pentenal (7b):** IR (neat) 3026 (s), 1722 (s) 1600 (m), 968 (s), 732 (s), 700 (s) cm^{-1}; ^{1}H NMR ($CDCl_3$, 400 MHz): δ 2.48 (ddd, J = 1.5, 7.3, 14.7 Hz, 1 H), 2.54 (ddd, J = 1.5, 7.3, 14.7 Hz, 1 H), 2.96 (d, J = 13.9 Hz, 1 H), 3.03 (d, J = 13.9 Hz, 1 H), 3.41 (br d, J = 6.6 Hz, 2 H), 5.49 (dt, J = 16.1, 1.5 Hz, 1 H), 5.67 (dt, J = 16.1, 6.6 Hz, 1 H), 6.12 (dt, J = 15.7, 7.3 Hz, 1 H), 6.40 (dt, J = 15.7, 1.4 Hz, 1 H), 7.10-7.40 (m, 15 H), 9.58 (s, 1 H); ^{13}C NMR ($CDCl_3$, 100 MHz): δ 36.6, 39.5, 40.2, 56.3, 124.8, 126.1, 126.6, 127.3, 128.1, 128.5, 130.5, 133.0, 133.8, 136.5, 137.2, 139.6, 202.4; HRMS, calcd for $C_{27}H_{26}O$: 366.1984, found *m/z* (relative intensity): 366.1984 (M^+, 2), 337.1895 (2), 263 (4), 117 (100).

2-Allyl-2-cyclohexenecarboxaldehyde (7c): IR (neat) 3076 (w), 3018 (w), 1724 (s), 1639 (w), 997 (w), 918 (m) cm^{-1}; ^{1}H NMR ($CDCl_3$, 400 MHz): δ 1.43-1.74 (m, 3 H),

1.91-2.08 (m, 3 H), 2.31 (dm, J = 7.7 Hz, 2 H), 5.06 (dm, J = 10.6 Hz, 1 H), 5.07 (dm, J = 17.9 Hz, 1 H), 5.51 (dm, J = 10.3 Hz, 1 H), 5.69 (ddm, J = 10.6, 17.9 Hz, 1 H), 6.01 (dt, J = 10.3, 3.9 Hz, 1 H), 9.47 (s, 1 H); ^{13}C NMR ($CDCl_3$, 100 MHz): δ 18.9, 24.8, 27.6, 40.6, 50.8, 118.5, 126.2, 126.5, 132.1, 132.9, 202.9; HRMS, calcd for: $C_{10}O_{14}O$: 150.1045, found *m/z* (relative intensity) 150.1085 (M^+, 6), 121 (100).

2-*trans*-Cinnamyl-2-cyclohexenecarboxaldehyde (7d): IR (neat) 3058 (m), 3024 (s), 1722 (s), 1681 (w), 966 (s), 748 (s), 692 (s); ^{1}H NMR ($CDCl_3$, 400 MHz): δ 1.51-1.72 (m, 2 H), 1.92-2.03 (m, 4 H), 2.45 (dd, J = 1.1, 7.3 Hz, 2 H), 5.55 (dm, J = 10.3 Hz, 1 H), 6.03 (dt, J = 10.3, 4.03 Hz, 1 H), 6.09 (dt, J = 15.8, 7.7 Hz, 1 H), 6.41 (d, J = 15.8 Hz, 1 H), 7.18-7.40 (m, 5 H), 9.51 (s, 1 H); ^{13}C NMR ($CDCl_3$, 100 MHz): δ 18.9, 24.8, 27.8, 39.8, 51.4, 124.7, 127.3, 128.5, 132.3, 133.6, 137.2, 202.8; HRMS, calcd for: $C_{16}O_{18}O$: 226.1358, found *m/z* (relative intensity) 226.1334 (M^+, 7), 197 (3), 117 (100). Anal. calcd for $C_{16}H_{18}O$: C, 84.91; H, 8.02; found: C, 84.80; H, 8.02.

***trans*-2-Benzyl-2-(*trans*-3-phenyl-1-propenyl)-4-hexenal (7e):** IR (neat) 3028 (m), 1724 (s), 1602 (w), 970 (m), 732 (m), 700 (s) cm^{-1}; ^{1}H NMR ($CDCl_3$, 400 MHz): δ 1.66 (dm, J = 6.23 Hz, 3 H), 2.30 (d, J = 7.0 Hz, 2 H), 2.93 (s, 2 H), 3.39 (d, J = 6.6 Hz, 2 H), 5.34-5.44 (m, 1 H), 5.41 (d, J = 16.3 Hz, 1 H), 5.45-5.56 (m, 1 H), 5.60 (dt, J = 16.3, 7.0 Hz, 1 H), 7.02-7.36 (m, 10 H), 9.50 (s, 1 H); ^{13}C NMR ($CDCl_3$, 100 MHz): δ 18.1, 36.3, 39.5, 39.8, 56.0, 125.4, 126.2, 126.5, 128.0, 128.4, 128.6, 129.5, 130.1, 130.7, 132.6, 136.8, 139.8, 202.8; HRMS, Calcd for $C_{22}H_{24}O$ – CHO: 275.1800, found *m/z* (relative intensity): 275.1811 (M^+ - CHO, 5), 117 (22), 91 (100).