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A New and Convenient Method for the Synthesis of Dehydroamino Acids Starting from Ethyl *N*-Boc- and *N*-*Z*-α-Tosylglycinates and Various Nitro Compounds

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Ethyl *N*-Boc- and *N*-*Z*-α-tosylglycinates, which were readily available from *t*-butyl or benzyl carbamate, ethyl glyoxylate, and sodium *p*-toluenesulfinate in formic acid, were reacted with a variety of nitro compounds in the presence of a base to afford the corresponding α,β-didehydroamino acid derivatives in good yields. Eventually, it was found that the (*Z*)-isomer was predominantly formed in the present method.

Increasing interest in α,β-didehydroamino acids has developed in recent years based on both their importance as commodity chemicals and their presence in biologically active natural products. Many reports related to the preparation of α,β-didehydroamino acids have so far been published, for example: 1) the reaction of β-hydroxy-α-amino acids with tosyl chloride under basic conditions followed by β-elimination to afford the corresponding dehydroalanine or 2-amino-2-butenoic acid,[1] 2) the oxidation of 3-(benzylthio)amino acids to the sulfoxide followed by thermolysis to form dehydroamino acid derivatives,[2] 3) the condensation of a variety of α-keto esters with benzyl carbamate in the presence of acid catalyst to give the corresponding α,β-didehydroamino acid derivatives,[3] 4) the permethylation of α-*N*-(benzyloxycarbonyl)amino-β-(dimethylamino)propionate followed by Hofmann elimination to afford dehydroalanine derivatives,[4] 5) the acylation of α-imino esters, which are derived from of α-azido esters and lithium ethoxide, under basic conditions,[5] 6) the *N*-chlorination of amino acid ester derivatives with *t*-butyl hypochlorite followed by dehydrochlorination with DBU,[6] 7) the reaction of *N*-acyl-2-[bis(alkyloxy)phosphoryl]glycine ester with a variety of ketones and aldehydes under basic conditions to afford the corresponding α,β-didehydroamino acid derivatives.[7] Recently, intensive studies toward the asymmetric hydrogenation of dehydroamino acid derivatives have also been developed, since they would provide a quite efficient route to optically active usual and unusual amino acid derivatives.[8a,b] Moreover, α,β-didehydroamino acids are also found in many natural products including AM-toxin,[9] tentoxin,[10] phomopsin which is a fungal metabolite that binds to microtubules,[11] Ser-, and Thr-phosphatase inhibitors motuporin,[12] microcystin,[13] nodularin,[14] and the antitumor agents azinomycins.[15] In this paper, we report on a new and convenient method for the synthesis of α,β-didehydroamino acid derivatives starting from ethyl *N*-*t*-butoxycarbonyl(Boc)- and *N*-benzyloxycarbonyl(*Z*)-α-tosylglycinates (**1a** and **1b**) and a variety of nitro compounds.

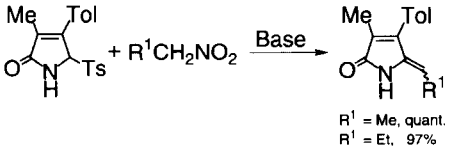
Previously, we had reported that 3-methyl-4(*p*-tolyl)-5-tosyl-1,5-dihydro-2*H*-pyrrol-2-one reacted with nitro compounds under basic conditions to afford the corresponding 5-*exo*-methylene compounds, as shown below (Scheme 1).[16]

Compounds **1a** and **1b** were readily prepared from *t*-butyl or benzyl carbamate, ethyl glyoxylate, and sodium *p*-toluenesulfinate tetrahydrate in 50% aqueous- and 99%-formic acid, respectively (Scheme 2).

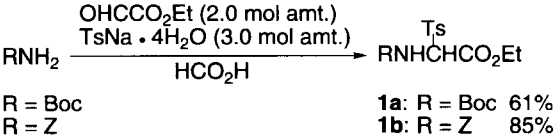
Coupling reactions of compounds **1a** and **1b** with various kinds of nitro compounds under basic conditions were examined. The results are summarized in Table 1.

First, compound **1a** was treated with 2 molar amounts of nitromethane in the presence of 3.6 molar amounts of 1,8-diazabicyclo[5.4.0]undec-7-ene (DBU) in THF at -40 °C to room temperature to afford the desired ethyl *N*-Boc-α,β-didehydroalaninate (**2a**) in 63% yield (Entry 1). Nitroethane was also reacted with **1a** under the same reaction conditions to furnish the expected ethyl 2-(*t*-butoxycarbonylamino)-2-butenoate (**3a**) as a mixture of (*Z*)- and (*E*)-isomers in 78% yield, in which (*Z*)-isomer was predominantly formed. Each stereochemistry was assigned by an NOE measurement.

Because the reaction of **1a** with nitroalkanes succeeded in the formation of a variety of *N*-Boc-dehydroamino acid derivatives (dehydrovaline **4a**, dehydronorvaline **5a**, dehy-



Scheme 1.



Scheme 2.

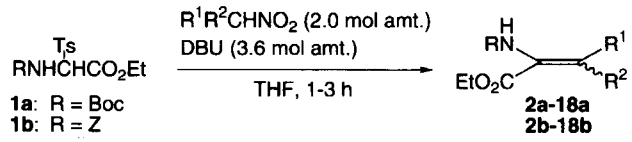


Table 1. Preparation of Various Dehydroamino Acid Derivatives

Entry	Substrate	R^1	R^2	Temp	Product	Yield/ %	Z/E[a]
1	**1a**	H	H	−40 °C	**2a**	63	—
2	**1a**	Me	H	−40 °C → r.t.	**3a**	78	97 / 3
3	**1a**	Me	Me	−40 °C → r.t.	**4a**	68	—
4	**1a**	Et	H	0 °C → r.t.	**5a**	74	95 / 5
5	**1a**	Et	Me	−40 °C → r.t.	**6a**	63	67 / 33
6	**1a**	^{i}Pr	H	−40 °C → r.t.	**7a**	73	94 / 6
7[b]	**1a**	^{i}Pr	Me	−40 °C → r.t.	**8a**	68	93 / 7
8	**1a**	$ZNH(CH_2)_2$	H	−40 °C → r.t.	**9a**	79	100 / 0
9	**1a**	$BocNH(CH_2)_2$	H	−40 °C → r.t.	**10a**	73	97 / 3
10	**1a**	$ZNH(CH_2)_3$	H	−40 °C → r.t.	**11a**	70	100 / 0
11	**1a**	$BocNH(CH_2)_3$	H	−40 °C → r.t.	**12a**	82	100 / 0
12	**1a**	EtO_2C	H	−40 °C → r.t.	**13a**	54	64 / 36
13[c]	**1a**	BnO	H	−40 °C → r.t.	**14a**	65	100 / 0
14	**1a**	$MeSCH_2$	H	−40 °C → r.t.	**15a**	70	86 / 14
15	**1a**	C_6H_5	H	r.t.	**16a**	73	97 / 3
16	**1a**	*p*-$MeOC_6H_4$	H	r.t.	**17a**	65	100 / 0
17	**1a**	3,4-$(MeO)_2C_6H_3$	H	r.t.	**18a**	62	100 / 0
18	**1b**	H	H	−40 °C	**2b**	63	—
19	**1b**	Me	H	−40 °C → r.t.	**3b**	78	97 / 3
20	**1b**	Me	Me	−40 °C → r.t.	**4b**	68	—
21	**1b**	Et	H	0 °C → r.t.	**5b**	70	94 / 6
22	**1b**	Et	Me	−40 °C → r.t.	**6b**	61	67 / 33
23	**1b**	^{i}Pr	H	−40 °C → r.t.	**7b**	66	94 / 6
24[b]	**1b**	^{i}Pr	Me	−40 °C → r.t.	**8b**	66	79 / 21
25	**1b**	$ZNH(CH_2)_2$	H	−40 °C → r.t.	**9b**	67	100 / 0
26	**1b**	$BocNH(CH_2)_2$	H	−40 °C → r.t.	**10b**	74	98 / 2
27	**1b**	$ZNH(CH_2)_3$	H	−40 °C → r.t.	**11b**	84	100 / 0
28	**1b**	$BocNH(CH_2)_3$	H	−40 °C → r.t.	**12b**	76	100 / 0
29	**1b**	EtO_2C	H	−40 °C → r.t.	**13b**	54	64 / 36
30[c]	**1b**	BnO	H	−40 °C → r.t.	**14b**	63	100 / 0
31	**1b**	$MeSCH_2$	H	−40 °C → r.t.	**15b**	83	90 / 10
32	**1b**	C_6H_5	H	r.t.	**16b**	68	93 / 7
33	**1b**	*p*-$MeOC_6H_4$	H	r.t.	**17b**	70	100 / 0
34	**1b**	3,4-$(MeO)_2C_6H_3$	H	r.t.	**18b**	70	95 / 5

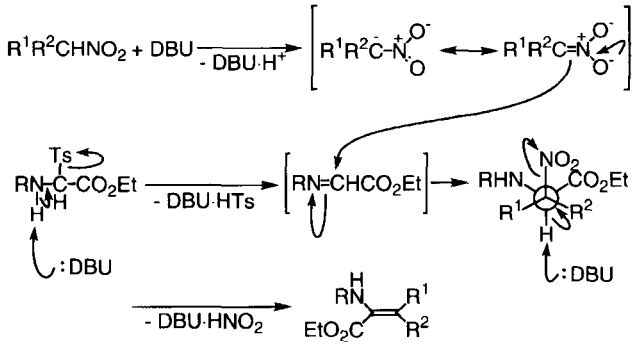
a) A mixture of (*Z*), (*E*)-isomers thus obtained is separable by preparative silica-gel TLC except for Entries 5, 7, 22, and 24. b) In cases of Entries 7 and 24, after treatment of the corresponding nitro compound with 2.4 molar amounts of NaH at r.t. for 10 min, 1.2 molar amounts of DBU were added at r.t., and then the mixture was cooled at −40 °C. c) In cases of Entries 13 and 30, after treatment of the corresponding nitro compound with 2.4 molar amounts of KO^{t}Bu at r.t. for 10 min, 1.2 molar amounts of DBU were added at −40 °C.

droleucine **7a**, and β-methyldehydroleucine **8a**) in satisfactory yields, the preparation of dehydroornithine and dehydrolysine derivatives (**9a—12a**) by utilizing γ- or δ-*N*-protected aminonitroalkanes was attempted (Entries 8—11). Eventually, the reaction proceeded very smoothly under the same reaction conditions to furnish the corresponding products **9a—12a** in good yields. In the cases of dehydrolysine derivatives, the products were obtained as a single isomer with (*Z*)-configuration (Entries 10 and 11). Ethyl *N*-Boc-α,β-didehydroaspartate (**13a**) could also be produced in moderate yield (Entry 12). Although the preparation of dehydroserine derivative **14a** was carried out under similar reaction conditions, compound **14a** was obtained in very poor yield. The improvement in the yield was examined by using bases, such as sodium hydride, lithium diisopropylamide, and potassium *t*-butoxide. Consequently, a treatment of benzyloxynitromethane with 2.4 molar amounts of KO^{t}Bu at room temperature for 10 min followed by the addition of 1.2 molar amounts of DBU at −40 °C was conducted to afford the expected product **14a** in 65% yield (Entry 13). Furthermore, a treatment of **1a** with 2-(methylthio)nitroethane, which was prepared from 2-acetoxynitroethane and 15%-aqueous sodium methanethiolate, afforded the desired dehydromethionine derivative in 70% yield (Entry 14). The formation of ethyl *N*-Boc-α,β-didehydrophenylalaninate (**16a**) with (*Z*)-configuration predominantly was achieved by the

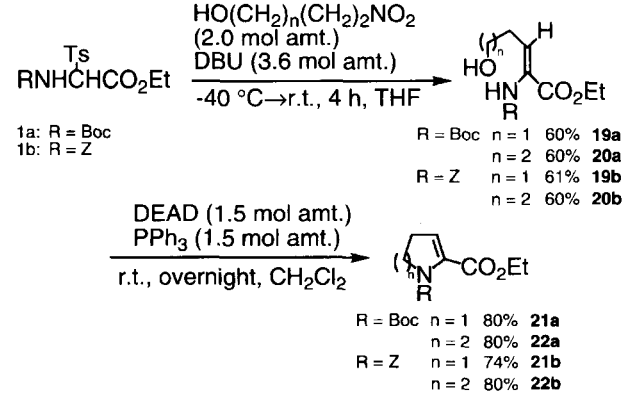
reaction of **1a** with α-nitrotoluene. Similarly, the dehydrotyrosine derivative **17a** was prepared as a single isomer in reasonable yield (Entry 16). In the same way, a variety of dehydroamino acid derivatives **2b**—**18b** were successfully synthesized from the reaction of **1b** and various nitro compounds in good yields, respectively (Entries 18—34).

A possible reaction mechanism is as follows: Initially, deprotonation at the α-position of the nitro group was followed by the addition of the resulting anion to the schiff base generated from **1a** or **1b** and DBU, and subsequent elimination of the nitrite anion took place, resulting in the formation of the dehydroamino acid derivatives, as shown in Scheme 3.

In the light of the results mentioned above, we tried to synthesize cyclic dehydroamino acids, like dehydroproline and dehydropiperidine-2-carboxylic acid derivatives, according to Scheme 4. First, **1a** was reacted with 2 molar amounts of 3-nitro-1-propanol or 4-nitro-1-butanol in the presence of DBU at -40 °C to room temperature for 4 h in THF to afford the corresponding δ- and ε-hydroxydehydroamino acid derivatives **19a** (n = 1) and **20a** (n = 2) with only (*Z*)-configuration in moderate yields, respectively. Cyclization of the resulting compounds, **19a** and **20a**, to the cyclic compounds, **21a** and **22a**, could be performed in high yields by using 1.5 molar amounts of diethyl azodicarboxylate (DEAD) and 1.5 molar amounts of triphenylphosphine (PPh_3) in CH_2Cl_2 at room temperature, respectively. In the same way, compounds **19b** and **20b** derived from **1b** and the correponding hydroxynitroalkanes were also converted to the desired cyclic dehydroamino acid derivatives, **21b** and **22b**, in high yields, respectively (Scheme 4).



Scheme 3.



Scheme 4.

As mentioned above, the present method proved to be very useful and convenient for preparing various kinds of α,β-didehydroamino acid derivatives, since the nitro compounds are also easily available as the starting material as well as the reagents (**1a** and **1b**).

Experimental

All of the melting points were determined with a micro melting apparatus (Yanagimoto Seisakusho) and were uncorrected. The ^{1}H NMR, IR, and MS spectra were recorded on JEOL JNM-LA 400FT (400 MHz) and LA 300FT (300 MHz) NMR spectrometers, a JASCO FT/IR-230 infrared spectrometer, and a JEOL SX-102A mass spectrometer, respectively. The chemical shifts of NMR are reported in the δ-scale relative to TMS as an internal standard. All of the solvents were distilled and stored over a drying agent. Thin-layer chromatography (TLC) and flash-columm chromatography were performed by using Merck's silica-gel 60 PF_{254} (Art. 7749) and Cica-merck's silica-gel 60 (No. 9385-5B), respectively.

A General Procedure for Synthesis of Nitro Compounds: To a solution of sodium nitrite (1.38 g, 20 mmol) and phloroglucinol dihydrate (1.78 g, 11 mmol) in dimethyl sulfoxide (DMSO, 20 ml) was added a solution of 3-bromo-1-propanol (1.39 g, 10 mmol) in DMSO (5 ml) at room temperature under a N_2 atmosphere. The solution was stirred overnight at the temperature, and was then extracted with diethyl ether after dilution with a large amount of brine. The organic layer was dried over anhydrous $MgSO_4$. After evaporation of the solvent, the product was separated by flash-column chromatography (SiO_2, hexane : ethyl acetate = 1 : 1, v/v) to afford 3-nitro-1-propanol (0.586 g, 66%) as a pale yellow oil.

The physical and spectral data of nitro compounds thus prepared are given in the following.

4-(*N*-*Z*-Amino)-1-nitrobutane: An oil; IR (neat) 3421, 2939, 1699, 1542, 1522, 1375, 1244, 1135 cm^{-1}; ^{1}H NMR (400 MHz; $CDCl_3$) δ = 1.61 (tt, J = 6.6, 7.7 Hz, 2H), 2.05 (tt, J = 6.8, 7.7 Hz, 2H), 3.26 (dt, J = 6.6, 6.6 Hz, 2H), 4.41 (t, J = 6.8 Hz, 2H), 4.75—4.85 (br, 1H), 5.10 (s, 2H), 7.33—7.40 (m, 5H); FAB-MS m/z 252 (M^+; 0.60%).

3-(*N*-*Z*-Amino)-1-nitropropane: An oil; IR (neat) 3335, 2948, 1699, 1555, 1524, 1455, 1378, 1256, 1143, 1025, 740, 698 cm^{-1}; ^{1}H NMR (400 MHz; $CDCl_3$) δ = 2.23 (tt, J = 6.6, 6.8 Hz, 2H), 3.32 (dt, J = 6.3, 6.6 Hz, 2H), 4.45 (t, J = 6.8 Hz, 2H), 4.80—5.00 (br, 1H), 5.10 (s, 2H), 7.30—7.40 (m, 5H); FAB-MS m/z 238 (M^+; 0.90%).

Benzyloxynitromethane: An oil; IR (neat) 2943, 1566, 1455, 1375, 1077, 745, 697 cm^{-1}; ^{1}H NMR (400 MHz; $CDCl_3$) δ = 4.85 (s, 2H), 5.25 (s, 2H), 7.35—7.45 (m, 5H); EI-MS m/z 167 (M^+; 1.61%).

4-(*N*-Boc-amino)-1-nitrobutane: An oil; IR (neat) 3350, 2977, 2934, 1701, 1552, 1523, 1458, 1366, 1252, 1171 cm^{-1}; ^{1}H NMR (400 MHz; $CDCl_3$) δ = 1.44 (s, 9H), 1.59 (tt, J = 6.6, 7.7 Hz, 2H), 2.05 (tt, J = 6.8, 7.7 Hz, 2H), 3.18 (dt, J = 6.6, 6.6 Hz, 2H), 4.42 (t, J = 6.8 Hz, 2H), 4.50—4.60 (br, 1H); FAB-MS m/z 218 (M^+; 0.68%).

3-(*N*-Boc-amino)-1-nitropropane: An oil; IR (neat) 3348, 2979, 2935, 1697, 1556, 1521, 1454, 1367, 1273, 1253, 1170 cm^{-1}; ^{1}H NMR (400 MHz; $CDCl_3$) δ = 1.41 (s, 9H), 2.21 (tt, J = 6.6, 6.8 Hz, 2H), 3.25 (dt, J = 6.3, 6.6 Hz, 2H), 4.45 (t, J = 6.8 Hz, 2H), 4.65—4.75 (br, 1H); FAB-MS m/z 204 (M^+; 1.10%).

***p*-Methoxy-α-nitrotoluene:** An oil; IR (neat) 2936, 2839, 1551, 1513, 1371, 1178, 820 cm^{-1}; ^{1}H NMR (300 MHz; $CDCl_3$) δ = 3.83 (s, 3H), 5.37 (s, 2H), 6.93 (d, J = 8.8 Hz, 2H), 7.37 (d,

J = 8.8 Hz, 2H); EI-MS m/z 167 (M^+; 1.99%).

3-Methyl-2-nitrobutane: An oil; bp 49.0—50.0 °C/20 Torr (1 Torr = 133.322 Pa); IR (neat) 2973, 1548, 1451, 1395, 1364, 1021, 868 cm^{-1}; ^1H NMR (300 MHz; $CDCl_3$) δ = 0.98 (d, J = 6.8 Hz, 3H+3H), 1.49 (d, J = 6.8 Hz, 3H), 2.21 (dqq, J = 6.8, 6.8, 6.8 Hz, 1H), 4.34 (dq, J = 6.8, 6.8 Hz, 1H); EI-MS m/z 117 (M^+; 0.50%).

2-Methyl-1-nitropropane: An oil; bp 70.0—70.5 °C/20 Torr [Lit, bp 158—159 °C/755 Torr];[17] IR (neat) 2970, 2938, 2879, 1552, 1469, 1384, 1346, 1231, 733 cm^{-1}; ^1H NMR (400 MHz; $CDCl_3$) δ = 1.04 (d, J = 6.6 Hz, 3H+3H), 2.48 (tqq, J = 6.6, 6.6, 7.3 Hz, 1H), 4.22 (d, J = 7.3 Hz, 2H).

2-(Methylthio)nitroethane: An oil; IR (neat) 2920, 1556, 1433, 1376, 1045, 734 cm^{-1}; ^1H NMR (300 MHz; $CDCl_3$) δ = 2.17 (s, 3H), 3.09 (t, J = 7.1 Hz, 2H), 4.58 (t, J = 7.1 Hz, 2H); EI-MS m/z 121 (M^+; 33.45%).

2-Nitrobutane: An oil; bp 36.0—37.0 °C/20 Torr [Lit, bp 138—139 °C/747 Torr];[18] IR (neat) 2966, 2945, 2867, 1556, 1460, 1377 cm^{-1}; ^1H NMR (400 MHz; $CDCl_3$) δ = 0.97 (t, J = 7.3 Hz, 3H), 1.52 (d, J = 6.6 Hz, 3H), 1.70—1.90 (m, 1H), 1.95—2.10 (m, 1H), 4.43—4.57 (m, 1H).

4-Nitro-1-butanol: An oil; IR (neat) 3293, 2946, 1550, 1386, 1150, 1005, 829 cm^{-1}; ^1H NMR (300 MHz; $CDCl_3$) δ = 1.40—1.50 (br, 1H), 1.60—1.70 (m, 2H), 2.10—2.18 (m, 2H), 3.68—3.76 (m, 2H), 4.45 (t, J = 7.1 Hz, 2H); FAB-MS m/z 119 (M^+; 3.49%).

3-Nitro-1-propanol: An oil; IR (neat) 3412, 2943, 2892, 1556, 1357, 1190, 1055, 950 cm^{-1}; ^1H NMR (300 MHz; $CDCl_3$) δ = 1.55—1.70 (br, 1H), 2.26 (tt, J = 5.7, 6.8 Hz, 2H), 3.78 (dt, J = 4.3, 5.7 Hz, 2H), 4.56 (t, J = 6.8 Hz, 2H); EI-MS m/z 105 (M^+; 1.08%).

α-Nitrotoluene:[19] An oil; IR (neat) 3035, 2915, 1554, 1375, 1204, 848, 720 cm^{-1}; ^1H NMR (300 MHz; $CDCl_3$) δ = 5.44 (s, 2H), 7.40—7.46 (m, 5H).

Ethyl *N*-Boc-α-tosylglycinate (1a): To a mixture of *t*-butyl carbamate (3.515 g, 30 mmol), ethyl glyoxylate (6.125 g, 60 mmol), and sodium *p*-toluenesulfinate tetrahydrate (22.522 g, 90 mmol) was added 50% aqueous formic acid (30 ml) at room temperature under air atmosphere. The solution was stirred for 1.5 d at room temperature. The mixture was then poured into ice water. A crystalline product was collected, washed with water, and dried in a vacuum desiccator (6.520 g, 61%). Mp 122.0—122.5 °C (ethyl acetate–hexane); IR (KBr) 3393, 2987, 2940, 1743, 1705, 1596, 1464, 1368, 1321, 1307, 1259, 1221, 1169, 1150, 1084, 1021, 853, 812, 771, 708, 688, 666 cm^{-1}; ^1H NMR (400 MHz; $CDCl_3$) δ = 1.32 (s, 9H), 1.34 (t, J = 7.1 Hz, 3H), 2.44 (s, 3H), 4.33 (q, J = 7.1 Hz, 2H), 5.55 (d, J = 10.0 Hz, 1H), 5.77 (d, J = 10.0 Hz, 1H), 7.35 (d, J = 8.2 Hz, 2H), 7.81 (d, J = 8.2 Hz, 2H). Found: C, 53.73; H, 6.55; N, 3.70%. Calcd for $C_{16}H_{23}NO_6S$: C, 53.77; H, 6.49; N, 3.92%.

Ethyl *N*-Z-α-Tosylglycinate (1b): To a mixture of benzyl carbamate (3.023 g, 20 mmol), ethyl glyoxylate (4.083 g, 40 mmol), and sodium *p*-toluenesulfinate tetrahydrate (15.000 g, 60 mmol) was added 99% formic acid (20 ml) at room temperature under air atmosphere. The solution was stirred for 2 d at room temperature. The solution was then poured into ice water. A crystalline product was collected, washed with water, and dried in a vacuum desiccator (6.654 g, 85%). Mp 94.5—95.5 °C (ethyl acetate–hexane); IR (KBr) 3337, 2979, 1753, 1723, 1698, 1538, 1455, 1354, 1320, 1214, 1165, 1084, 1029, 868, 817, 789, 721, 695 cm^{-1}; ^1H NMR (400 MHz; $CDCl_3$) δ = 1.32 (t, J = 7.1 Hz, 3H), 2.44 (s, 3H), 4.30 (q, J = 7.1 Hz, 2H), 5.03 (s, 2H), 5.61 (d, J = 10.1 Hz, 1H), 6.01 (d, J = 10.1 Hz, 1H), 7.26—7.37 (m, 5H+2H), 7.78 (d, J = 8.3 Hz, 2H). Found: C, 58.29; H, 5.46; N, 3.72%. Calcd for $C_{19}H_{21}NO_6S$: C, 58.30; H, 5.41; N, 3.58%.

A General Procedure for Synthesis of Dehydroamino Acid Derivatives: To a solution of nitroethane (75 mg, 1.0 mmol) in tetrahydrofuran (THF, 10 ml) was added a solution of DBU (274 mg, 1.8 mmol) in THF (5 ml) at room temperature under a N_2 atmosphere. The solution was stirred for 10 min at the temperature, and then cooled at −40 °C. To the solution was added a solution of **1b** (197 mg, 0.5 mmol) in THF (3 ml) by using a mechanically driven syringe for a period of 1 h. After addition, the mixture was gradually warmed to room temperature and stirred for 60 min. Then, the solvent was removed in vacuo to afford a residue, which was partitioned between ethyl acetate and water. The aqueous layer was extracted with ethyl acetate, and the combined extracts were washed with brine, dried over anhydrous $MgSO_4$, and concentrated under reduced pressure. The residue was subjected to preparative TLC (SiO_2, benzene : ethyl acetate = 15 : 1, v/v) to afford ethyl 2-(*N*-*Z*-amino)-2-butenoate (**3b**):[20] Separable (*Z*)- and (*E*)-isomers.

The physical and spectral data of compounds **2a**—**22a** and **2b**—**22b** are shown in the following.

Ethyl α-*N*-Boc-α,β-didehydroalaninate (2a): An oil; IR (neat) 3421, 2980, 2933, 1735, 1712, 1638, 1513, 1394, 1370, 1321, 1239, 1157, 1066, 952, 892, 856, 804, 712 cm^{-1}; ^1H NMR (300 MHz; $CDCl_3$) δ = 1.34 (t, J = 7.1 Hz, 3H), 1.49 (s, 9H), 4.28 (q, J = 7.1 Hz, 2H), 5.73 (s, 1H), 6.14 (s, 1H), 7.00—7.10 (br, 1H); EI-MS m/z 215 (M^+; 0.60%).

Ethyl 2-(*N*-Boc-amino)-2-butenoate (3a) (*Z*/*E* = 97/3): (*Z*)-form; An oil; IR (neat) 3315, 2982, 1716, 1660, 1504, 1395, 1274, 1098, 1050, 854, 804, 755, 698 cm^{-1}; ^1H NMR (400 MHz; $CDCl_3$) δ = 1.28 (t, J = 7.1 Hz, 3H), 1.44 (s, 9H), 1.77 (d, J = 7.3 Hz, 3H), 4.19 (q, J = 7.1 Hz, 2H), 5.75—6.10 (br, 1H), 6.63 (q, J = 7.3 Hz, 1H); EI-MS m/z 229 (M^+; 1.30%). When γ-methyl protons were irradiated, 2.0% and 7.9% of NOE were observed for the NH proton and the olefinic proton, respectively.

(*E*)-form; An oil; IR (neat) 3365, 2980, 1716, 1653, 1507, 1373, 1248, 1161, 1039, 1050, 902, 858, 780 cm^{-1}; ^1H NMR (400 MHz; $CDCl_3$) δ = 1.35 (t, J = 7.1 Hz, 3H), 1.47 (s, 9H), 2.06 (d, J = 7.3 Hz, 3H), 4.29 (q, J = 7.1 Hz, 2H), 6.50—6.60 (m, 1H), 6.75—6.85 (m, 1H); EI-MS m/z 229 (M^+; 3.03%).

Ethyl α-*N*-Boc-α,β-didehydrovalinate (4a): Mp 63.0—64.0 °C (ethyl acetate–hexane); IR (KBr) 3346, 2981, 2932, 1718, 1692, 1503, 1443, 1372, 1312, 1274, 1254, 1226, 1163, 1095, 1055, 1027, 894, 832, 660 cm^{-1}; ^1H NMR (300 MHz; $CDCl_3$) δ = 1.30 (t, J = 7.1 Hz, 3H), 1.46 (s, 9H), 1.88 (s, 3H), 2.12 (s, 3H), 4.21 (q, J = 7.1 Hz, 2H), 5.70—5.80 (br, 1H). Found: C, 59.11; H, 8.65; N, 5.55%. Calcd for $C_{12}H_{21}NO_4$: C, 59.24; H, 8.70; N, 5.76%.

Ethyl 2-(*N*-Boc-amino)-2-pentenoate (5a) (*Z*/*E* = 95/5): (*Z*)-form; An oil; IR (neat) 3338, 2978, 2936, 2877, 1707, 1657, 1493, 1392, 1368, 1308, 1277, 1247, 1162, 1109, 1050, 854, 777 cm^{-1}; ^1H NMR (300 MHz; $CDCl_3$) δ = 1.07 (t, J = 7.5 Hz, 3H), 1.31 (t, J = 7.1 Hz, 3H), 1.47 (s, 9H), 2.22 (dq, J = 7.2, 7.5 Hz, 2H), 4.22 (q, J = 7.1 Hz, 2H), 5.85—6.00 (br, 1H), 6.53 (t, J = 7.2 Hz, 1H); EI-MS m/z 243 (M^+; 4.01%). When γ-methylene protons were irradiated, 2.3% and 6.9% of NOE were observed for the NH proton and the olefinic proton, respectively.

(*E*)-form; An oil; IR (neat) 3338, 2978, 2936, 2877, 1707, 1657, 1493, 1392, 1368, 1308, 1277, 1247, 1162, 1109, 1050, 854, 777 cm^{-1}; ^1H NMR (300 MHz; $CDCl_3$) δ = 1.08 (t, J = 7.5 Hz, 3H), 1.37 (t, J = 7.1 Hz, 3H), 1.47 (s, 9H), 2.55 (dq, J = 7.2, 7.5 Hz, 2H), 4.28 (q, J = 7.1 Hz, 2H), 6.50—6.60 (m, 1H), 6.60—6.75 (m, 1H); EI-MS m/z 243 (M^+; 12.83%).

Ethyl α-*N*-Boc-α,β-didehydroisoleucinate (6a) (*Z*/*E* = 67/33):

Mp 60.0—61.0 °C (heptane, a mixture of (*Z*), (*E*)-isomers); IR(KBr) 3347, 2973, 2920, 1708, 1652, 1499, 1371, 1322, 1271, 1247, 1256, 1227, 1162, 1096, 1058, 1029, 886, 825 cm^{-1}. Found: C, 60.57; H, 9.18; N, 5.27%. Calcd for $C_{13}H_{24}NO_4$: C, 60.68; H, 9.01; N, 5.44%.

(*Z*)-form; ^{1}H NMR (400 MHz; $CDCl_3$) δ = 1.04 (t, *J* = 7.6 Hz, 3H), 1.30 (t, *J* = 7.1 Hz, 3H), 1.46 (s, 9H), 2.08 (s, 3H), 2.23 (q, *J* = 7.6 Hz, 2H), 4.21 (q, *J* = 7.1 Hz, 2H), 5.60—5.80 (br, 1H). When γ-methylene protons were irradiated, 4.3% and 3.8% of NOE were observed for the NH proton and the β-methyl protons, respectively.

(*E*)-form; ^{1}H NMR (400 MHz; $CDCl_3$) δ = 1.10 (t, *J* = 7.6 Hz, 3H), 1.30 (t, *J* = 7.1 Hz, 3H), 1.46 (s, 9H), 1.84 (s, 3H), 2.47 (q, *J* = 7.6 Hz, 2H), 4.21 (q, *J* = 7.1 Hz, 2H), 5.70—5.85 (br, 1H).

Ethyl α-*N*-Boc-α,β-didehydroleucinate (7a) (*Z*/*E* = 93/7): (*Z*)-form; mp 37.0—38.0 °C (acetone–water); IR (KBr) 3338, 2975, 2871, 1708, 1655, 1491, 1366, 1310, 1256, 1159, 1117, 1048, 961, 844, 777 cm^{-1}; ^{1}H NMR (400 MHz; $CDCl_3$) δ = 1.05 (d, *J* = 6.8 Hz, 3H+3H), 1.31 (t, *J* = 7.1 Hz, 3H), 1.46 (s, 9H), 2.70 (dqq, *J* = 6.8, 6.8, 10.3 Hz, 1H), 4.22 (q, *J* = 7.1 Hz, 2H), 5.70—5.80 (br, 1H), 6.38 (d, *J* = 10.3 Hz, 1H). Found: C, 60.67; H, 9.10; N, 5.24%. Calcd for $C_{13}H_{23}NO_4$: C, 60.68; H, 9.01; N, 5.44%. When γ-methine proton was irradiated, 2.8% and 5.2% of NOE were observed for the NH proton and the olefinic proton, respectively.

(*E*)-form; An oil; IR (neat) 3418, 2960, 2929, 2871, 1730, 1653, 1508, 1457, 1372, 1328, 1247, 1160, 1045, 1028, 904, 858, 772, 669 cm^{-1}; ^{1}H NMR (400 MHz; $CDCl_3$) δ = 1.06 (d, *J* = 6.8 Hz, 3H+3H), 1.34 (t, *J* = 7.1 Hz, 3H), 1.47 (s, 9H), 3.30 (dqq, *J* = 6.8, 6.8, 10.3 Hz, 1H), 4.28 (q, *J* = 7.1 Hz, 2H), 6.40—6.60 (m, 1H+1H); EI-MS *m*/*z* 257 (M^+; 16.79%).

Ethyl α-*N*-Boc-β-methyl-α,β-didehydroleucinate (8a) (*Z*/*E* = 93/7): Mp 91.0—93.0 °C (heptane, a mixture of (*Z*), (*E*)-isomers); IR (KBr) 3348, 2977, 2933, 1715, 1705, 1635, 1488, 1391, 1366, 1304, 1230, 1170, 1076, 1049, 897, 854, 817, 781, 736 cm^{-1}. Found: C, 61.67; H, 9.33; N, 4.98%. Calcd for $C_{14}H_{25}NO_4$: C, 61.74; H, 9.62; N, 5.14%.

(*Z*)-form; ^{1}H NMR (400 MHz; $CDCl_3$) δ = 1.01 (d, *J* = 6.8 Hz, 3H+3H), 1.29 (t, *J* = 7.1 Hz, 3H), 1.45 (s, 9H), 1.94 (s, 3H), 3.00—3.10 (m, 2H), 4.20 (q, *J* = 7.1 Hz, 2H), 5.60—5.80 (br, 1H). When γ-methine proton was irradiated, 7.2% and 2.9% of NOE were observed for the NH proton and the β-methyl protons, respectively.

(*E*)-form; ^{1}H NMR (400 MHz; $CDCl_3$) δ = 1.03 (d, *J* = 6.8 Hz, 3H+3H), 1.29 (t, *J* = 7.1 Hz, 3H), 1.45 (s, 9H), 1.71 (s, 3H), 3.40—3.50 (m, 1H), 4.20 (q, *J* = 7.1 Hz, 2H), 5.70—5.80 (br, 1H).

Ethyl α-*N*-Boc-δ-*N*′-*Z*-α,β-didehydroornithinate (9a) (*Z*/*E* = 100/0): (*Z*)-form; An oil; IR (neat) 3338, 2979, 2936, 1718, 1703, 1660, 1508, 1368, 1249, 1164, 1048, 777, 738, 698 cm^{-1}; ^{1}H NMR (400 MHz; $CDCl_3$) δ = 1.30 (t, *J* = 7.1 Hz, 3H), 1.46 (s, 9H), 2.45 (dt, *J* = 6.8, 7.6 Hz, 2H), 3.37 (dt, *J* = 6.6, 6.8 Hz, 2H), 4.22 (q, *J* = 7.1 Hz, 2H), 5.10 (s, 2H), 5.30—5.40 (br, 1H), 6.10—6.20 (br, 1H), 6.51 (t, *J* = 7.6 Hz, 1H), 7.30—7.40 (m, 5H); EI-MS *m*/*z* 392 (M^+; 1.44%). When γ-methylene protons were irradiated, 3.1% and 11.8% of NOE were observed for the NH proton and the olefinic proton, respectively.

Ethyl α-*N*-Boc-δ-*N*′-Boc-α,β-didehydroornithinate (10a) (*Z*/*E* = 96/4): (*Z*)-form; An oil; IR (neat) 3350, 2979, 2933, 1707, 1698, 1660, 1508, 1457, 1392, 1367, 1250, 1168, 1096, 1048, 861, 780, 734 cm^{-1}; ^{1}H NMR (400 MHz; $CDCl_3$) δ = 1.31 (t, *J* = 7.1 Hz, 3H), 1.43 (s, 9H), 1.47 (s, 9H), 2.42 (dt, *J* = 6.8, 7.6 Hz, 2H), 3.28 (dt, *J* = 5.8, 6.8 Hz, 2H), 4.23 (q, *J* = 7.1 Hz, 2H), 4.90—5.00 (br, 1H), 6.08—6.18 (br, 1H), 6.51 (t, *J* = 7.6 Hz, 1H); EI-MS *m*/*z* 358 (M^+; 1.71%). When γ-methylene protons were irradiated, 3.1% and 9.0% of NOE were observed for the NH proton and the olefinic proton, respectively.

(*E*)-form; An oil; IR (neat) 3355, 2979, 2933, 1731, 1714, 1681, 1504, 1455, 1392, 1367, 1251, 1172, 1096, 1049, 920, 861, 780 cm^{-1}; ^{1}H NMR (400 MHz; $CDCl_3$) δ = 1.35 (t, *J* = 7.1 Hz, 3H), 1.44 (s, 9H), 1.47 (s, 9H), 2.72 (dt, *J* = 6.8, 7.6 Hz, 2H), 3.25 (m, 2H), 4.29 (q, *J* = 7.1 Hz, 2H), 4.70—4.80 (br, 1H), 6.60—6.70 (m, 1H+1H); EI-MS *m*/*z* 358 (M^+; 1.08%).

Ethyl α-*N*-Boc-ε-*N*′-*Z*-α,β-didehydrolysinate (11a) (*Z*/*E* = 100/0): (*Z*)-form; mp 69.0—70.0 °C (ethyl acetate–hexane); IR (KBr) 3340, 2979, 2936, 1714, 1705, 1658, 1499, 1455, 1368, 1251, 1165, 1096, 1046, 856, 778, 738, 698 cm^{-1}; ^{1}H NMR (400 MHz; $CDCl_3$) δ = 1.28 (t, *J* = 7.1 Hz, 3H), 1.43 (s, 9H), 1.71 (quintet, *J* = 6.8 Hz, 2H), 2.27 (dt, *J* = 6.8, 7.6 Hz, 2H), 3.22 (dt, *J* = 6.3, 6.8 Hz, 2H), 4.22 (q, *J* = 7.1 Hz, 2H), 5.09 (s, 2H), 5.20—5.25 (br, 1H), 6.10—6.18 (br, 1H), 6.53 (t, *J* = 7.6 Hz, 1H), 7.30—7.37 (m, 5H). Found: C, 61.89; H, 7.43; N, 6.85%. Calcd for $C_{21}H_{30}N_2O_6$: C, 62.05; H, 7.44; N, 6.89%. When γ-methylene protons were irradiated, 3.7% and 11.3% of NOE were observed for the NH proton and the olefinic proton, respectively.

Ethyl α-*N*-Boc-ε-*N*′-Boc-α,β-didehydrolysinate (12a) (*Z*/*E* = 100/0): (*Z*)-form; An oil; IR (neat) 3357, 2979, 2934, 1715, 1700, 1660, 1508, 1456, 1392, 1367, 1250, 1170, 1046, 867, 782 cm^{-1}; ^{1}H NMR (400 MHz; $CDCl_3$) δ = 1.31 (t, *J* = 7.1 Hz, 3H), 1.44 (s, 9H), 1.47 (s, 9H), 1.67 (quintet, *J* = 6.8 Hz, 2H), 2.24 (dt, *J* = 6.8, 7.6 Hz, 2H), 3.14 (dt, *J* = 5.8, 6.8 Hz, 2H), 4.22 (q, *J* = 7.1 Hz, 2H), 4.82—4.90 (br, 1H), 6.25—6.30 (br, 1H), 6.50 (t, *J* = 7.6 Hz, 1H); EI-MS *m*/*z* 372 (M^+; 0.31%). When γ-methylene protons were irradiated, 4.9% and 10.1% of NOE were observed for the NH proton and the olefinic proton, respectively.

Diethyl α-*N*-Boc-α,β-didehydroaspartate (13a) (*Z*/*E* = 64/36): (*Z*)-form; An oil; IR (neat) 3313, 2981, 2936, 1741, 1686, 1632, 1480, 1395, 1369, 1282, 1214, 1147, 1066, 1030, 853, 809, 771, 751 cm^{-1}; ^{1}H NMR (400 MHz; $CDCl_3$) δ = 1.29 (t, *J* = 7.1 Hz, 3H), 1.33 (t, *J* = 7.1 Hz, 3H), 1.47 (s, 9H), 4.20 (q, *J* = 7.1 Hz, 2H), 4.31 (q, *J* = 7.1 Hz, 2H), 5.38 (s, 1H), 9.44—9.50 (br, 1H); EI-MS *m*/*z* 287 (M^+; 58.69%).

(*E*)-form; An oil; IR (neat) 3303, 2980, 2930, 2854, 1739, 1715, 1626, 1538, 1456, 1395, 1370, 1340, 1304, 1240, 1143, 1027, 854, 819, 771, 746, 669 cm^{-1}; ^{1}H NMR (400 MHz; $CDCl_3$) δ = 1.27 (t, *J* = 7.1 Hz, 3H), 1.34 (t, *J* = 7.1 Hz, 3H), 1.48 (s, 9H), 4.19 (q, *J* = 7.1 Hz, 2H), 4.33 (q, *J* = 7.1 Hz, 2H), 6.51 (s, 1H), 6.64—6.68 (br, 1H); EI-MS *m*/*z* 287(M^+; 7.61%). When olefinic proton was irradiated, 3.5% of NOE was observed for the NH proton.

Ethyl α-*N*-Boc-β-*O*-benzyl-α,β-didehydroserinate (14a) (*Z*/*E* = 100/0): To a suspension of ^{t}BuOK (47 mg, 0.42 mmol) in THF (1 ml) was added a solution of benzyloxynitromethane (58 mg, 0.35 mmol) in THF (1 ml) at room temperature under N_2. After the mixture was stirred for 10 min, it was cooled down at −40 °C and a solution of DBU in THF (1 ml) was added to it. To the solution was added a solution of **1a** (62 mg, 0.17 mmol) in THF (3 ml) by using a mechanically driven syringe in a period of 1 h. After addition, the mixture was gradually warmed to room temperature and stirred for 60 min. Then, the solvent was removed in vacuo to afford a residue, which was partitioned between ethyl acetate and water. The aqueous layer was extracted with ethyl acetate, and the combined extracts were washed with brine, dried over anhydrous $MgSO_4$, and concentrated under reduced pressure. The residue was subjected to preparative TLC (SiO_2, benzene : ethyl acetate = 10 : 1, v/v) to afford ethyl α-*N*-Boc-β-*O*-benzyl-α,β-didehydroserinate (**14a**): (*Z*)-(35 mg, 65%) isomer.

(*Z*)-form; mp 74.0—75.0 °C (ethyl acetate–hexane); IR (KBr)

3334, 2979, 2933, 1710, 1655, 1497, 1369, 1286, 1243, 1166, 1056, 739, 698 cm^{-1}; ^1H NMR (400 MHz; $CDCl_3$) δ = 1.27 (t, J = 7.1 Hz, 3H), 1.46 (s, 9H), 4.19 (q, J = 7.1 Hz, 2H), 5.06 (s, 2H), 5.54—5.60 (br, 1H), 7.30 (s, 1H), 7.32—7.40 (m, 5H). Found: C, 63.23; H, 7.29; N, 4.21%. Calcd for $C_{17}H_{23}NO_5$: C, 63.53; H, 7.21; N, 4.36%. When NH proton was irradiated, 1.9% and 7.8% of NOE were observed for the benzyl protons of the β-*O*-benzyl group and ^{t}Bu protons of the Boc group, respectively.

Ethyl α-*N*-Boc-α,β-didehydromethioninate (15a) (*Z*/*E* = 86/14): (*Z*)-form; mp 37.0—38.0 °C (ethyl acetate–hexane); IR (KBr) 3341, 2980, 2935, 1733, 1693, 1494, 1369, 1297, 1063, 869, 783 cm^{-1}; ^1H NMR (400 MHz; $CDCl_3$) δ = 1.32 (t, J = 7.1 Hz, 3H), 1.47 (s, 9H), 2.07 (s, 3H), 3.26 (d, J = 7.6 Hz, 2H), 4.25 (q, J = 7.1 Hz, 2H), 6.15—6.25 (br, 1H), 6.55 (t, J = 7.6 Hz, 1H). Found: C, 52.17; H, 7.71; N, 4.96%. Calcd for $C_{12}H_{21}NO_4S$: C, 52.34; H, 7.69; N, 5.09%. When γ-methylene protons were irradiated, 2.6% and 15.7% of NOE were observed for the NH proton and the olefinic proton, respectively.

(*E*)-form; An oil; IR (neat) 3281, 2981, 2918, 1716, 1657, 1507, 1457, 1372, 1244, 1160, 1046, 733 cm^{-1}; ^1H NMR (400 MHz; $CDCl_3$) δ = 1.36 (t, J = 7.1 Hz, 3H), 1.47 (s, 9H), 2.09 (s, 3H), 3.65 (d, J = 7.6 Hz, 2H), 4.30 (q, J = 7.1 Hz, 2H), 6.60—6.70 (br, 1H), 6.78 (t, J = 7.6 Hz, 1H); EI-MS m/z 275 (M^+; 2.70%).

Ethyl α-*N*-Boc-α,β-didehydrophenylalaninate (16a)[20,21] (*Z*/*E* = 91/9): (*Z*)-form; mp 70.0—70.5 °C (hexane); IR (KBr) 3323, 2979, 2933, 1718, 1643, 1482, 1367, 1258, 1163, 1079, 1048, 1028, 767, 693 cm^{-1}; ^1H NMR (300 MHz; $CDCl_3$) δ = 1.36 (t, J = 7.1 Hz, 3H), 1.40 (s, 9H), 4.31 (q, J = 7.1 Hz, 2H), 6.10—6.30 (br, 1H), 7.24 (s, 1H), 7.24—7.55 (m, 5H). Found: C, 65.87; H, 7.27; N, 4.79%. Calcd for $C_{16}H_{21}NO_4$: C, 65.96; H, 7.21; N, 4.81%.

(*E*)-form; An oil; IR (neat) 3324, 2979, 2933, 1715, 1644, 1486, 1392, 1368, 1260, 1205, 1164, 1078, 1048, 1029, 928, 857, 838, 767, 693 cm^{-1}; ^1H NMR (300 MHz; $CDCl_3$) δ = 1.00 (t, J = 7.1 Hz, 3H), 1.50 (s, 9H), 4.08 (q, J = 7.1 Hz, 2H), 6.70—6.80 (br, 1H), 7.30—7.40 (m, 5H+1H); EI-MS m/z 291 (M^+; 18.50%).

Ethyl α-*N*-Boc-*p*-*O*-methyl-α,β-didehydrotyrosinate (17a) (*Z*/*E* = 100/0): (*Z*)-form; An oil; IR (neat) 3326, 2979, 2935, 1729, 1714, 1642, 1605, 1514, 1368, 1286, 1254, 1175, 1030, 831, 777, 733 cm^{-1}; ^1H NMR (400 MHz; $CDCl_3$) δ = 1.35 (t, J = 7.1 Hz, 3H), 1.42 (s, 9H), 3.83 (s, 3H), 4.28 (q, J = 7.1 Hz, 2H), 6.00—6.20 (br, 1H), 6.88 (d, J = 8.8 Hz, 2H), 7.26 (s, 1H), 7.52 (d, J = 8.8 Hz, 2H); EI-MS m/z 321 (M^+; 16.69%). When both ortho protons of the aromatic ring were irradiated, 4.9% and 15.1% of NOE were observed for the NH proton and the olefinic proton, respectively.

Ethyl α-*N*-Boc-3,4-di-*O*-methyl-α,β-didehydrodopa (18a) (*Z*/*E* = 100/0): (*Z*)-form; mp 125.0—126.0 °C (ethyl acetate–hexane); IR (KBr) 3320, 2975, 2938, 1707, 1638, 1601, 1521, 1493, 1367, 1335, 1290, 1254, 1169, 1132, 1061, 1024, 791, 767, 698 cm^{-1}; ^1H NMR (400 MHz; $CDCl_3$) δ = 1.36 (t, J = 7.1 Hz, 3H), 1.56 (s, 9H), 3.88 (s, 3H), 3.91 (s, 3H), 4.30 (q, J = 7.1 Hz, 2H), 6.00—6.20 (br, 1H), 6.86 (d, J = 8.3 Hz, 1H), 7.15 (d, J = 8.3 Hz, 1H), 7.20 (s, 1H), 7.26 (s, 1H). Found: C, 61.28; H, 7.20; N, 3.90%. Calcd for $C_{18}H_{25}NO_6$: C, 61.52; H, 7.17; N, 3.99%. When the proton at the 6-position of the aromatic ring was irradiated, 2.4% and 14.2% of NOE were observed for the NH proton and the olefinic proton, respectively.

Ethyl α-*N*-*Z*-α,β-Didehydroalaninate (2b):[20] An oil; IR (neat) 3412, 3033, 1740, 1637, 1519, 1395, 1376, 1191, 1066, 1027, 894, 803, 744, 698 cm^{-1}; ^1H NMR (400 MHz; $CDCl_3$) δ = 1.33 (t, J = 7.1 Hz, 3H), 4.28 (q, J = 7.1 Hz, 2H), 5.17 (s, 2H), 5.79 (s, 1H), 6.23 (s, 1H), 7.20—7.30 (br, 1H), 7.33—7.40 (m, 5H); EI-MS m/z 249 (M^+; 1.26%).

Ethyl 2-(*N*-*Z*-Amino)-2-butenoate (3b)[20] (*Z*/*E* = 97/3): (*Z*)-form; An oil; IR (neat) 3340, 2980, 2934, 1709, 1661, 1493, 1367, 1275, 1167, 1096, 1048, 908, 848, 776 cm^{-1}; ^1H NMR (400 MHz; $CDCl_3$) δ = 1.28 (t, J = 7.1 Hz, 3H), 1.81 (d, J = 7.3 Hz, 3H), 4.20 (q, J = 7.1 Hz, 2H), 5.15 (s, 2H), 6.20—6.30 (br, 1H), 6.74 (q, J = 7.3 Hz, 1H), 7.30—7.40 (m, 5H); EI-MS m/z 263 (M^+; 0.65%). When γ-methyl protons were irradiated, 1.6% and 13.2% of NOE were observed for the NH proton and the olefinic proton, respectively.

(*E*)-form; An oil; IR (neat) 3360, 2929, 1731, 1635, 1519, 1455, 1396, 1338, 1263, 1219, 1120, 1051, 855, 742, 698 cm^{-1}; ^1H NMR (400 MHz; $CDCl_3$) δ = 1.33 (t, J = 7.1 Hz, 3H), 2.08 (d, J = 7.3 Hz, 3H), 4.28 (q, J = 7.1 Hz, 2H), 5.13 (s, 2H), 6.80—7.00 (m, 1H+1H), 7.33—7.38 (m, 5H); EI-MS m/z 263 (M^+; 12.91%).

Ethyl α-*N*-*Z*-α,β-Didehydrovalinate (4b): An oil; IR (neat) 3320, 2981, 2970, 1712, 1643, 1502, 1454, 1372, 1308, 1248, 1092, 1048, 774, 740, 698 cm^{-1}; ^1H NMR (400 MHz; $CDCl_3$) δ = 1.26 (t, J = 7.1 Hz, 3H), 1.88 (s, 3H), 2.16 (s, 3H), 4.20 (q, J = 7.1 Hz, 2H), 5.14 (s, 2H), 5.90—6.10 (br, 1H), 7.30—7.40 (m, 5H); EI-MS m/z 277 (M^+; 1.29%).

Ethyl 2-(*N*-*Z*-Amino)-2-pentenoate (5b)[20] (*Z*/*E* = 94/6): (*Z*)-form; An oil; IR (neat) 3325, 2973, 2937, 1717, 1657, 1500, 1395, 1371, 1307, 1247, 1175, 1112, 1052, 863, 772 cm^{-1}; ^1H NMR (300 MHz; $CDCl_3$) δ = 1.07 (t, J = 7.5 Hz, 3H), 1.29 (t, J = 7.1 Hz, 3H), 2.22 (dq, J = 7.2, 7.5 Hz, 2H), 4.21 (q, J = 7.1 Hz, 2H), 5.14 (s, 2H), 6.10—6.30 (br, 1H), 6.60 (t, J = 7.2 Hz, 1H), 7.25—7.40 (m, 5H); EI-MS m/z 277 (M^+; 2.65%). When γ-methylene protons were irradiated, 1.7% and 7.9% of NOE were observed for the NH proton and the olefinic proton, respectively.

(*E*)-form; An oil; IR (neat) 3361, 2970, 2934, 1717, 1663, 1507, 1457, 1375, 1265, 1216, 1028, 971, 867, 742, 698 cm^{-1}; ^1H NMR (300 MHz; $CDCl_3$) δ = 1.08 (t, J = 7.5 Hz, 3H), 1.33 (t, J = 7.1 Hz, 3H), 2.57 (dq, J = 7.2, 7.5 Hz, 2H), 4.27 (q, J = 7.1 Hz, 2H), 5.13 (s, 2H), 6.72—6.88 (br, 1H), 6.82 (t, J = 7.2 Hz, 1H), 7.30—7.45 (m, 5H); EI-MS m/z 277 (M^+; 1.99%).

Ethyl α-*N*-*Z*-α,β-Didehydroisoleucinate (6b) (*Z*/*E* = 67/33): Mp 38.0—39.0 °C (heptane, a mixture of (*Z*), (*E*)-isomers); IR (KBr) 3325, 2977, 2935, 1718, 1655, 1499, 1368, 1306, 1243, 1213, 1181, 1102, 1051, 910, 740, 698 cm^{-1}. Found: C, 65.67; H, 7.34; N, 4.84%. Calcd for $C_{16}H_{21}NO_4$: C, 65.95; H, 7.27; N, 4.81%.

(*Z*)-form; ^1H NMR (400 MHz; $CDCl_3$) δ = 1.10 (t, J = 7.6 Hz, 3H), 1.25 (t, J = 7.1 Hz, 3H), 2.12 (s, 3H), 2.23 (q, J = 7.6 Hz, 2H), 4.20 (q, J = 7.1 Hz, 2H), 5.14 (s, 2H), 5.80—5.90 (br, 1H), 7.30—7.38 (m, 5H). When γ-methylene protons were irradiated, 3.2% and 4.9% of NOE were observed for the NH proton and the β-methyl protons, respectively.

(*E*)-form; ^1H NMR (400 MHz; $CDCl_3$) δ = 1.10 (t, J = 7.6 Hz, 3H), 1.25 (t, J = 7.1 Hz, 3H), 1.85 (s, 3H), 2.51 (q, J = 7.6 Hz, 2H), 4.20 (q, J = 7.1 Hz, 2H), 5.14 (s, 2H), 5.90—6.00 (br, 1H), 7.30—7.38 (m, 5H).

Ethyl α-*N*-*Z*-α,β-Didehydroleucinate (7b)[20] (*Z*/*E* = 94/6): (*Z*)-form; An oil; IR (neat) 3316, 2962, 2871, 1718, 1657, 1500, 1395, 1370, 1311, 1263, 1228, 1181, 1160, 1118, 1048, 775, 737, 698 cm^{-1}; ^1H NMR (400 MHz; $CDCl_3$) δ = 1.05 (d, J = 6.6 Hz, 3H+3H), 1.28 (t, J = 7.1 Hz, 3H), 2.71 (dqq, J = 6.6, 6.6, 10.3 Hz, 1H), 4.20 (q, J = 7.1 Hz, 2H), 5.15 (s, 2H), 5.90—6.05 (br, 1H), 6.46 (d, J = 10.3 Hz, 1H), 7.33—7.38 (m, 5H); EI-MS m/z 291 (M^+; 5.54%). When γ-methine proton was irradiated, 1.7% and 5.0% of NOE were observed for the NH proton and the olefinic proton, respectively.

(*E*)-form; An oil; IR (neat) 3416, 2963, 2932, 2874, 1731, 1646, 1520, 1471, 1375, 1327, 1245, 1194, 1104, 1026, 1000, 886, 788, 737, 698 cm^{-1}; ^1H NMR (400 MHz; $CDCl_3$) δ = 1.06 (d, J = 6.8 Hz, 3H+3H), 1.33 (t, J = 7.1 Hz, 3H), 3.33 (dqq, J = 6.8, 6.8, 10.3 Hz, 1H), 4.27 (q, J = 7.1 Hz, 2H), 5.14 (s, 2H), 6.60 (d, J = 10.3 Hz, 1H), 6.70—6.85 (br, 1H), 7.32—7.38 (m, 5H); EI-MS m/z 291 (M^+; 10.29%).

Ethyl α-*N*-Z-β-Methyl-α,β-didehydroleucinate (8b) (Z/E = 79/21): An oily mixture of (*Z*), (*E*)-isomers; IR (neat) 3313, 2965, 1730, 1710, 1499, 1455, 1367, 1307, 1249, 1184, 1077, 1050, 777, 739, 698 cm^{-1}; EI-MS m/z 305 (M^+; 8.55%).

(*Z*)-form; ^1H NMR (400 MHz; $CDCl_3$) δ = 1.00 (d, J = 6.6 Hz, 3H+3H), 1.28 (t, J = 7.1 Hz, 3H), 1.99 (s, 3H), 3.00—3.15 (m, 1H), 4.20 (q, J = 7.1 Hz, 2H), 5.13 (s, 2H), 5.90—6.00 (br, 1H), 7.30—7.40 (m, 5H). When γ-methine proton was irradiated, 6.7% and 2.0% of NOE were observed for the NH proton and the β-methyl protons, respectively.

(*E*)-form; ^1H NMR (400 MHz; $CDCl_3$) δ = 1.03 (d, J = 6.6 Hz, 3H+3H), 1.29 (t, J = 7.1 Hz, 3H), 1.72 (s, 3H), 3.45—3.55 (m, 1H), 4.23 (q, J = 7.1 Hz, 2H), 5.13 (s, 2H), 6.05—6.10 (br, 1H), 7.30—7.40 (m, 5H).

Ethyl α-*N*-Z-δ-*N*′-Z-α,β-Didehydroornithinate (9b) (Z/E = 100/0): (*Z*)-form; An oil; IR (neat) 3329, 2956, 1710, 1701, 1665, 1523, 1455, 1251, 1144, 1095, 1052, 775, 740, 697 cm^{-1}; ^1H NMR (300 MHz; $CDCl_3$) δ = 1.26 (t, J = 7.1 Hz, 3H), 2.43 (dt, J = 6.8, 7.6 Hz, 2H), 3.33 (dt, J = 6.6, 6.8 Hz, 2H), 4.19 (q, J = 7.1 Hz, 2H), 5.08 (s, 2H), 5.12 (s, 2H), 5.30—5.42 (br, 1H), 6.50—6.55 (br, 1H), 6.56 (t, J = 7.6 Hz, 1H), 7.28—7.40 (m, 5H+5H); EI-MS m/z 392 (M^+; 1.44%). When γ-methylene protons were irradiated, 3.1 % and 10.6% of NOE were observed for the NH proton and the olefinic proton, respectively.

Ethyl α-*N*-Z-δ-*N*′-Boc-α,β-didehydroornithinate (10b) (Z/E = 98/2): (*Z*)-form; mp 77.0—78.0 °C (ethyl acetate–hexane); IR (KBr) 3339, 2978, 1725, 1698, 1665, 1515, 1366, 1250, 1171, 1093, 1062, 747, 697 cm^{-1}; ^1H NMR (300 MHz; $CDCl_3$) δ = 1.29 (t, J = 7.1 Hz, 3H), 1.44 (s, 9H), 2.42 (dt, J = 6.8, 7.5 Hz, 2H), 3.28 (dt, J = 5.9, 6.8 Hz, 2H), 4.22 (q, J = 7.1 Hz, 2H), 4.84—4.94 (br, 1H), 5.15 (s, 2H), 6.32—6.42 (br, 1H), 6.58 (t, J = 7.5 Hz, 1H), 7.32—7.38 (m, 5H). Found: C, 61.21; H, 7.19; N, 7.14%. Calcd for $C_{28}H_{30}N_2O_6$: C, 61.10; H, 7.21; N, 6.99%. When γ-methylene protons were irradiated, 2.4% and 12.1% of NOE were observed for the NH proton and the olefinic proton, respectively.

(*E*)-form; An oil; IR (neat) 3338, 2979, 2918, 1725, 1698, 1538, 1514, 1453, 1410, 1365, 1280, 1227, 1207, 1171, 1134, 1093, 1063, 1029, 903, 883, 777, 747, 697 cm^{-1}; ^1H NMR (300 MHz; $CDCl_3$) δ = 1.33 (t, J = 7.1 Hz, 3H), 1.44 (s, 9H), 2.75 (dt, J = 6.8, 7.5 Hz, 2H), 3.25 (m, 2H), 4.28 (q, J = 7.1 Hz, 2H), 4.70—4.80 (br, 1H), 5.13 (s, 2H), 6.70—6.80 (m, 1H), 6.85—6.95 (m, 1H), 7.30—7.40 (m, 5H); EI-MS m/z 392 (M^+; 0.90%).

Ethyl α-*N*-Z-ε-*N*′-Z-α,β-Didehydrolysinate (11b) (Z/E = 100/0): (*Z*)-form; mp 59.5—60.5 °C (ethyl acetate–hexane); IR (neat) 3337, 2940, 1718, 1710, 1657, 1522, 1455, 1372, 1252, 1095, 1045, 776, 737, 698 cm^{-1}; ^1H NMR (400 MHz; $CDCl_3$) δ = 1.28 (t, J = 7.1 Hz, 3H), 1.70 (quintet, J = 6.8 Hz, 2H), 2.26 (dt, J = 6.8, 7.6 Hz, 2H), 3.20 (dt, J = 6.3, 6.8 Hz, 2H), 4.20 (q, J = 7.1 Hz, 2H), 5.08 (s, 2H), 5.00—5.20 (br, 1H), 6.40—6.44 (br, 1H), 6.59 (t, J = 7.6 Hz, 1H), 7.29—7.38 (m, 5H+5H). Found: C, 65.18; H, 6.43; N, 6.52%. Calcd for $C_{24}H_{28}N_2O_6$: C, 65.44; H, 6.41; N, 6.36%. When γ-methylene protons were irradiated, 2.7% and 11.7% of NOE were observed for the NH proton and the olefinic proton, respectively.

Ethyl α-*N*-Z-ε-*N*′-Boc-α,β-didehydrolysinate (12b) (Z/E = 100/0): (*Z*)-form; An oil; IR (neat) 3339, 2978, 1725, 1698, 1665, 1515, 1366, 1250, 1171, 1093, 1062, 747, 697 cm^{-1}; ^1H NMR (400 MHz; $CDCl_3$) δ = 1.28 (t, J = 7.1 Hz, 3H), 1.43 (s, 9H), 1.66 (quintet, J = 6.8 Hz, 2H), 2.25 (dt, J = 6.8, 7.6 Hz, 2H), 3.12 (dt, J = 6.8, 6.8 Hz, 2H), 4.21 (q, J = 7.1 Hz, 2H), 4.69—4.75 (br, 1H), 5.15 (s, 2H), 6.55—6.60 (br, 1H), 6.60 (t, J = 7.6 Hz, 1H), 7.32—7.38 (m, 5H); EI-MS m/z 406 (M^+; 0.54%). When γ-methylene protons were irradiated, 2.8% and 10.4% of NOE were observed for the NH proton and the olefinic proton, respectively.

Diethyl α-*N*-Z-α,β-Didehydroaspartate (13b) (Z/E = 64/36): (*Z*)-form; An oil; IR (neat) 3308, 2983, 1745, 1685, 1636, 1488, 1369, 1281, 1199, 1065, 1032, 790, 753, 698 cm^{-1}; ^1H NMR (400 MHz; $CDCl_3$) δ = 1.29 (t, J = 7.1 Hz, 3H), 1.31 (t, J = 7.1 Hz, 3H), 4.19 (q, J = 7.1 Hz, 2H), 4.30 (q, J = 7.1 Hz, 2H), 5.17 (s, 2H), 5.43 (s, 1H), 7.30—7.40 (m, 5H), 9.60—9.70 (br, 1H); EI-MS m/z 321 (M^+; 4.53%).

(*E*)-form; An oil; IR (neat) 3303, 2982, 2933, 1744, 1714, 1539, 1456, 1400, 1281, 1215, 1151, 1037, 858, 752, 698, 669 cm^{-1}; ^1H NMR (400 MHz; $CDCl_3$) δ = 1.28 (t, J = 7.1 Hz, 3H), 1.32 (t, J = 7.1 Hz, 3H), 4.19 (q, J = 7.1 Hz, 2H), 4.31 (q, J = 7.1 Hz, 2H), 5.16 (s, 2H), 6.62 (s, 1H), 6.80—7.00 (br, 1H), 7.30—7.40 (m, 5H); EI-MS m/z 321 (M^+; 7.82%). When the olefinic proton was irradiated, 3.3% of NOE was observed for the NH proton.

Ethyl α-*N*-Z-β-*O*-Benzyl-α,β-didehydroserinate (14b) (Z/E = 100/0): Compound **14b** was prepared from **1b** and benzyloxynitromethane in the same way as described for compound **14a**. (*Z*)-form; An oil; IR (neat) 3314, 2927, 1716, 1654, 1507, 1455, 1373, 1217, 1128, 1060, 738, 697 cm^{-1}; ^1H NMR (300 MHz; $CDCl_3$) δ = 1.24 (t, J = 7.1 Hz, 3H), 4.17 (q, J = 7.1 Hz, 2H), 5.06 (s, 2H), 5.15 (s, 2H), 5.75—5.83 (br, 1H), 7.30—7.40 (m, 5H+5H+1H); EI-MS m/z 355 (M^+; 2.32%). When the NH proton was irradiated, 1.4% and 1.4% of NOE were observed for the benzyl protons of the β-*O*-benzyl group and the benzyl protons of the *Z* group, respectively.

Ethyl α-*N*-Z-α,β-Didehydromethioninate (15b) (Z/E = 90/10): (*Z*)-form; mp 45.0—46.0 °C (ethyl acetate–hexane); IR (KBr) 3315, 2979, 2927, 1716, 1701, 1653, 1507, 1276, 1044, 773, 698 cm^{-1}; ^1H NMR (400 MHz; $CDCl_3$) δ = 1.29 (t, J = 7.1 Hz, 3H), 2.05 (s, 3H), 3.26 (d, J = 7.6 Hz, 2H), 4.22 (q, J = 7.1 Hz, 2H), 5.14 (s, 2H), 6.40—6.50 (br, 1H), 6.62 (t, J = 7.6 Hz, 1H), 7.30—7.38 (m, 5H). Found: C, 57.95; H, 6.21; N, 4.53%. Calcd for $C_{15}H_{19}NO_4S$: C, 58.23; H, 6.19; N, 4.53%. When γ-methylene protons were irradiated, 2.5% and 7.8% of NOE were observed for the NH proton and the olefinic proton, respectively.

(*E*)-form; An oil; IR (neat) 3317, 2982, 2930, 1727, 1655, 1519, 1455, 1398, 1375, 1227, 1027, 862, 746, 699 cm^{-1}; ^1H NMR (400 MHz; $CDCl_3$) δ = 1.34 (t, J = 7.1 Hz, 3H), 2.09 (s, 3H), 3.67 (d, J = 7.6 Hz, 2H), 4.29 (q, J = 7.1 Hz, 2H), 5.15 (s, 2H), 6.86—6.98 (br, 1H), 6.62 (t, J = 7.6 Hz, 1H), 7.33—7.42 (m, 5H); EI-MS m/z 309 (M^+; 8.54%).

Ethyl α-*N*-Z-α,β-Didehydrophenylalaninate (16b)[7,20,21] (Z/E = 93/7): (*Z*)-form; mp 65.0—65.5 °C (ethyl acetate–hexane); [Lit, mp 60.0—62.0 °C (ethyl acetate–hexane)];[20] IR (KBr) 3309, 2981, 1717, 1644, 1498, 1454, 1394, 1370, 1263, 1137, 1080, 1027, 776, 659 cm^{-1}; ^1H NMR (400 MHz; $CDCl_3$) δ = 1.32 (t, J = 7.1 Hz, 3H), 4.28 (q, J = 7.1 Hz, 2H), 5.11 (s, 2H), 6.30—6.40 (br, 1H), 7.30—7.55 (m, 5H+5H+1H). Found: C, 69.97; H, 5.86; N, 4.25%. Calcd for $C_{19}H_{19}NO_4$: C, 70.14; H, 5.89; N, 4.31%.

(*E*)-form; An oil; IR (neat) 3307, 2925, 2854, 1715, 1646, 1498, 1456, 1265, 1217, 1048 cm^{-1}; ^1H NMR (400 MHz; $CDCl_3$) δ = 0.99 (t, J = 7.1 Hz, 3H), 4.07 (q, J = 7.1 Hz, 2H), 5.18 (s, 2H), 6.95—7.05 (br, 1H), 7.26—7.40 (m, 5H+5H+1H); EI-MS m/z 325

(M^+; 27.40%).

Ethyl α-*N*-Z-*p*-*O*-Methyl-α,β-didehydrotyrosinate (17b) (Z/E = 100/0): (*Z*)-form; An oil; IR (neat) 3290, 2980, 1735, 1718, 1637, 1604, 1509, 1369, 1253, 1175, 1036, 1027, 830, 773, 698 cm^{-1}; ^1H NMR (400 MHz; $CDCl_3$) δ = 1.31 (t, J = 7.1 Hz, 3H), 3.83 (s, 3H), 4.26 (q, J = 7.1 Hz, 2H), 5.13 (s, 2H), 6.20—6.40 (br, 1H), 6.84 (d, J = 8.8 Hz, 2H), 7.25—7.40 (m, 5H), 7.35 (s, 1H), 7.49 (d, J = 8.8 Hz, 2H); EI-MS *m/z* 355 (M^+; 1.99%). When both ortho protons of aromatic ring were irradiated, 4.3% and 18.3% of NOE were observed for the NH proton and the olefinic proton, respectively.

Ethyl α-*N*-Z-3,4-Di-*O*-methyl-α,β-didehydrodopa (18b) (Z/E = 95/5): (*Z*)-form; mp 123.0—124.0 °C (ethyl acetate–hexane); IR (KBr) 3210, 2987, 2970, 1715, 1692, 1637, 1514, 1413, 1399, 1274, 1230, 1133, 1019, 854, 754, 704 cm^{-1}; ^1H NMR (400 MHz; $CDCl_3$) δ = 1.32 (t, J = 7.1 Hz, 3H), 3.72 (s, 3H), 3.90 (s, 3H), 4.27 (q, J = 7.1 Hz, 2H), 5.13 (s, 2H), 6.20—6.35 (br, 1H), 6.81 (d, J = 8.8 Hz, 1H), 7.12 (s, 1H), 7.12 (d, J = 8.8 Hz, 1H), 7.25—7.35 (m, 5H+1H). Found: C, 65.40; H, 6.07; N, 3.56%. Calcd for $C_{21}H_{23}NO_6$: C, 65.44; H,6.02; N, 3.63%. When the proton at the 2-position of the aromatic ring was irradiated, 4.4% and 14.4% of NOE were observed for the NH proton and the olefinic proton, respectively.

(*E*)-form; An oil; IR (neat) 3412, 3304, 1714, 1670, 1518, 1420, 1363, 1222, 1136, 1092, 1025, 903, 780 cm^{-1}; ^1H NMR (400 MHz; $CDCl_3$) δ = 1.09 (t, J = 7.1 Hz, 3H), 3.85 (s, 3H), 3.89 (s, 3H), 4.13 (q, J = 7.1 Hz, 2H), 5.18 (s, 2H), 6.80—7.00 (m, 1H+1H+1H+1H), 7.30—7.43 (m, 5H+1H); EI-MS *m/z* 385 (M^+; 90.17%).

Ethyl 2-(*N*-Boc-amino)-5-hydroxy-2-pentenoate (19a) (Z/E = 100/0): (*Z*)-form; An oil; IR (neat) 3331, 2979, 2935, 1702, 1657, 1497, 1392, 1368, 1282, 1248, 1166, 1093, 1051, 855, 777 cm^{-1}; ^1H NMR (400 MHz; $CDCl_3$) δ = 1.32 (t, J = 7.1 Hz, 3H), 1.47 (s, 9H), 1.50—1.60 (br, 1H), 2.50 (dt, J = 5.9, 7.8 Hz, 2H), 3.82 (dt, J = 5.9, 7.8 Hz, 2H), 4.24 (q, J = 7.1 Hz, 2H), 6.26—6.32 (br, 1H), 6.62 (t, J = 7.8 Hz, 1H); EI-MS *m/z* 259 (M^+; 0.54%). When γ-methylene protons were irradiated, 3.2% and 16.0% of NOE were observed for the NH proton and the olefinic proton, respectively.

Ethyl 2-(*N*-Boc-amino)-6-hydroxy-2-hexenoate (20a) (Z/E = 100/0): (*Z*)-form; An oil; IR (neat) 3334, 2979, 2936, 1704, 1659, 1504, 1455, 1392, 1368, 1252, 1165, 1093, 1050, 940, 903, 856, 778 cm^{-1}; ^1H NMR (400 MHz; $CDCl_3$) δ = 1.31 (t, J = 7.1 Hz, 3H), 1.46 (s, 9H), 1.60—1.80 (br, 1H), 1.75 (tt, J = 5.9, 6.4 Hz, 2H), 2.34 (dt, J = 6.4, 7.9 Hz, 2H), 3.64 (dt, J = 5.9, 7.7 Hz, 2H), 4.23 (q, J = 7.1 Hz, 2H), 6.26—6.40 (br, 1H), 6.54 (t, J = 7.9 Hz, 1H); EI-MS *m/z* 273 (M^+; 1.26%). When γ-methylene protons were irradiated, 2.6% and 9.3% of NOE were observed for the NH proton and the olefinic proton, respectively.

Ethyl 2-(*N*-Z-Amino)-5-hydroxy-2-pentenoate (19b) (Z/E = 100/0): (*Z*)-form; An oil; IR (neat) 3418, 2957, 2902, 1714, 1660, 1505, 1455, 1395, 1372, 1233, 1150, 1094, 1049, 901, 773, 699 cm^{-1}; ^1H NMR (300 MHz; $CDCl_3$) δ = 1.30 (t, J = 7.1 Hz, 3H), 1.50—1.60 (br, 1H), 2.51 (dt, J = 5.9, 7.9 Hz, 2H), 3.82 (dt, J = 5.9, 7.9 Hz, 2H), 4.23 (q, J = 7.1 Hz, 2H), 5.15 (s, 2H), 6.40—6.55 (br, 1H), 6.68 (t, J = 7.9 Hz, 1H), 7.30—7.40 (m, 5H); EI-MS *m/z* 293 (M^+; 0.18%). When γ-methylene protons were irradiated, 4.4% and 7.7% of NOE were observed for the NH proton and the olefinic proton, respectively.

Ethyl 2-(*N*-Z-Amino)-6-hydroxy-2-hexenoate (20b) (Z/E = 100/0): (*Z*)-form; An oil; IR (neat) 3315, 2939, 1711, 1658, 1503, 1455, 1394, 1372, 1265, 1147, 1094, 1050, 774, 753, 698 cm^{-1}; ^1H NMR (400 MHz; $CDCl_3$) δ = 1.29 (t, J = 7.1 Hz, 3H), 1.50—1.70 (br, 1H), 1.76 (tt, J = 5.9, 6.4 Hz, 2H), 2.34 (dt, J = 6.4, 7.9 Hz, 2H), 3.64 (dt, J = 5.9, 7.7 Hz, 2H), 4.21 (q, J = 7.1 Hz, 2H), 5.15 (s, 2H), 6.40—6.50 (br, 1H), 6.61 (t, J = 7.9 Hz, 1H), 7.33—7.40 (m, 5H); EI-MS *m/z* 307 (M^+; 6.01%). When γ-methylene protons were irradiated, 2.7% and 9.6% of NOE were observed for the NH proton and the olefinic proton, respectively.

Ethyl α-*N*-Boc-α,β-didehydroprolinate (21a): To a solution of ethyl 2-(*N*-Boc-amino)-5-hydroxy-2-pentenoate (**19a**) (61 mg, 0.23 mmol), and PPh_3 (92 mg, 0.35 mmol) in CH_2Cl_2 (5 ml) was added a solution of diethyl azodicarboxylate (61 mg, 0.35 mmol) in CH_2Cl_2 (3 ml) at 0 °C under a N_2 atmosphere. After addition, the mixture was gradually warmed to room temperature and stirred overnight. The solvent was then removed in vacuo to afford a residue, which was partitioned between ethyl acetate and water. The aqueous layer was extracted with ethyl acetate, and the combined extracts were washed with brine, dried over anhydrous $MgSO_4$, and concentrated under reduced pressure. The residue was subjected to preparative TLC (SiO_2, benzene : ethyl acetate = 5 : 1, v/v) to afford ethyl α-*N*-Boc-α,β-didehydroprolinate (**21a**) in 80% yield as a pale yellow oil. IR (neat) 2979, 2935, 1736, 1706, 1626,1478, 1458, 1367, 1313, 1249, 1166, 1033, 996, 927, 862, 763 cm^{-1}; ^1H NMR (300 MHz; $CDCl_3$) δ = 1.33 (t, J = 7.2 Hz, 3H), 1.45 (s, 9H), 2.63 (ddd, J = 2.9, 8.9, 8.9 Hz, 2H), 3.93 (dd, J = 8.9, 8.9 Hz, 2H), 4.26 (q, J = 7.2 Hz, 2H), 5.78 (dd, J = 2.9, 2.9 Hz, 1H); EI-MS(EI$^+$) *m/z* 241 (M^+; 2.79%).

In the same way, compounds **22a**, **21b**, and **22b** were prepared from the corresponding hydroxy derivatives (**20a**, **19b**, and **20b**).

Ethyl α-*N*-Boc-α,β-didehydropiperidine-2-carboxylate (22a): An oil; IR (neat) 2979, 2935, 1736, 1707, 1645,1455, 1367, 1338, 1271, 1229, 1158, 1067, 1050, 960, 884, 853, 757 cm^{-1}; ^1H NMR (300 MHz; $CDCl_3$) δ = 1.31 (t, J = 7.2 Hz, 3H), 1.44 (s, 9H), 1.75—1.85 (m, 2H), 2.23 (ddd, J = 3.9, 6.6, 6.6 Hz, 2H), 3.56—3.62 (m, 2H), 4.22 (q, J = 7.2 Hz, 2H), 5.99 (dd, J = 3.9, 3.9 Hz, 1H); EI-MS *m/z* 255 (M^+; 27.52%).

Ethyl α-*N*-Z-α,β-Didehydroprolinate (21b): An oil; IR (neat) 2981, 2902, 1730, 1711, 1634, 1445, 1409, 1338, 1314, 1244, 1180, 1123, 1035, 1002, 925, 748, 698 cm^{-1}; ^1H NMR (300 MHz; $CDCl_3$) δ = 1.21 (t, J = 7.2 Hz, 3H), 2.66 (ddd, J = 2.9, 8.9, 8.9 Hz, 2H), 4.00 (dd, J = 8.9, 8.9 Hz, 2H), 4.12 (q, J = 7.2 Hz, 2H), 5.15 (s, 2H), 5.83 (dd, J = 2.9, 2.9 Hz, 1H), 7.33—7.37 (m, 5H); EI-MS *m/z* 275 (M^+; 44.21%).

Ethyl α-*N*-Z-α,β-Didehydropiperidine-2-carboxylate (22b): An oil; IR (neat) 2940, 2905, 1732, 1714, 1646, 1455, 1396, 1336, 1254, 1228, 1190, 1118, 1068, 1049, 756, 698 cm^{-1}; ^1H NMR (300 MHz; $CDCl_3$) δ = 1.15 (t, J = 7.2 Hz, 3H), 1.78—1.88 (m, 2H), 2.24 (ddd, J = 3.9, 6.6, 6.6 Hz, 2H), 3.63—3.70 (m, 2H), 4.03 (q, J = 7.2 Hz, 2H), 5.14 (s, 2H), 6.06 (dd, J = 3.9, 3.9 Hz, 1H), 7.32—7.36 (m, 5H); EI-MS *m/z* 289 (M^+; 37.83%).

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