Synthesis and Properties of a Novel 1-Pyrroline Fatty Ester Derivative from Methyl Isoricinoleate

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Reaction of methyl isoricinoleate [(*Z*)-methyl 9-hydroxyoctadec-12-enoate] with toluene-*p*-sulphonyl chloride gave a mixture of (*Z*)-methyl 9-chlorooctadec-12-enoate **2** and (*Z*)-methyl 9-tosyloxyoctadec-12-enoate **3**, and with methane sulphonyl chloride the corresponding mesyloxy derivative **4**. Treatment of compounds **2**–**4** with NaN_3 in *N*,*N*-dimethylformamide at 50 °C gave (*Z*)-methyl 9-azidooctadec-9-enoate **5**, while at 80 °C methyl 8-(5-hexyl-2-pyrrolin-1-yl)octanoate **6** was obtained. The 1-pyrroline ring was characterized by IR, ^1H and ^{13}C NMR spectroscopy, while the ring cleavage products (methyl 9-acetamido-12-oxooctadecanoate **7** and methyl 9-benzamido-12-oxooctadecanoate **8**) were characterized by GC–MS. Reduction of the C=N bond in compound **6** with $NaBH_4$ gave a mixture of *E*- and *Z*-isomers of the corresponding disubstituted pyrrolidine fatty esters **9a** and **9b**.

We have recently reported the preparation of a number of long chain fatty esters containing one or more azido groups in the alkyl chain of the molecule.[1] Subsequent chemical transformation of the azide function has led to the preparation of long chain fatty acids containing L-amino acid residues (peptido lipids) and other amido derivatives.[2] In extending our study of the azido fatty esters, we report in this paper the preparation of a novel long chain 1-pyrroline ester derivative from methyl isoricinoleate [(*Z*)-methyl 9-hydroxyoctadec-12-enoate, **1**] and describe some of the physical and chemical properties of this novel fatty acid derivative. Long chain fatty acids containing a 1-pyrroline system have not been found in Nature. Several long chain fatty esters containing an *N*-heterocyclic system, *viz.* pyrrole, 2-oxaline or oxazolidin-2-one have been prepared from oxygenated fatty esters.[3–5]

2,5-Dialkyl pyrrolines and pyrrolidines have been identified in the venom of the fire ant (*Solenopsis punctaticeps*),[6,7] and shown to possess necrotizing and hemolysing properties.[8,9] A number of synthetic procedures have been reported for the preparation of dialkyl pyrrolines with emphasis on the subsequent production of 2,5-disubstituted pyrrolidines for entomological studies.[10–14] An efficient method for the preparation of 1-pyrrolines by treatment of α-ketoimidoyl chlorides with amine bases has been recently described by Tian and Livinghouse.[15] Organic azides are good starting blocks for organic molecules to be converted to an array of derivatives including *N*-heterocycles.[16,17] We therefore reasoned that by converting methyl isoricinoleate to the corresponding azidoethylenic fatty ester derivative, an intramolecular cyclization would lead to a 1-pyrroline derivative. The synthetic route to the 1-pyrroline fatty acid derivative from methyl isoricinoleate is given in Scheme 1.

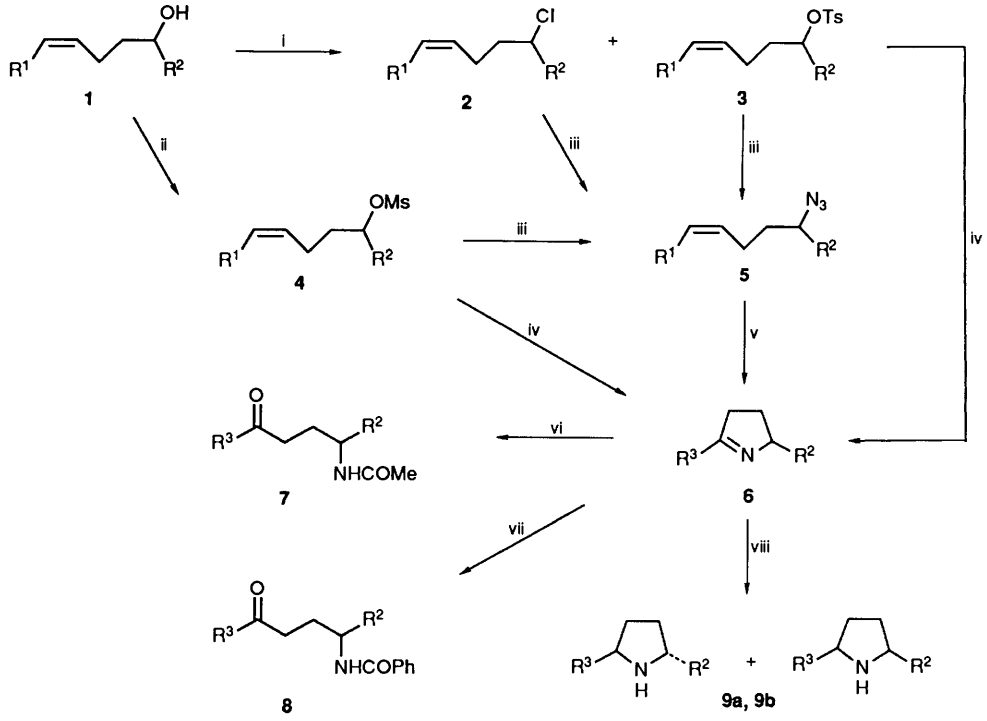
Results and Discussion

Isoricinoleic acid was isolated from *Wrightia tinctoria* seed oil by the partition method described by Gunstone[18] and converted to the methyl ester derivative **1**.[19] In the conversion of the hydroxy function of compound **1** to a better leaving group for reaction with sodium azide, tosylation of the hydroxy group was found to be a sluggish process when compared to that of methyl ricinoleate [(*Z*)-methyl 12-hydroxyoctadec-9-enoate]. When compound **1** was stirred with toluene-*p*-sulphonyl chloride in pyridine for 4 days at ambient temperature, a mixture of (*Z*)-methyl 9-chlorooctadec-12-enoate (**2**, 60%) and (*Z*)-methyl 9-tosyloxyoctadec-12-enoate (**3**, 35%) was obtained. To achieve >90% yield of product **3**, the reaction was stirred for a period of 10 days. Formation of chloro derivatives involving unsaturated hydroxy fatty esters with toluene-*p*-sulphonyl chloride was reported previously by Ucciani *et al.*[20] However, conversion of compound **1** to the mesyloxy derivative **4** was achieved in almost quantitative yield.

When compounds **2**, **3** or **4** were treated with sodium azide at 50 °C in DMF, the corresponding azido derivative **5** was obtained. When the same reaction was carried out at 80 °C, the product was exclusively the 1-pyrroline derivative **6**. Compound **6** was also obtained in high yield by heating compound **5** in DMF or cyclohexane at 80 °C. Compound **6** could be purified by silica gel chromatography and remained stable during GLC analysis.

The IR spectral analysis of compound **6** gave strong absorption bands at ν_{max} 1640 (cyclic imine C=N, str.) and 1740 cm^{-1} (ester C=O, str.). In the ^1H NMR spectral analysis, the protons of the 1-pyrroline ring appeared at δ_H 3.9 (1 H, m, 9-H), 2.03 (2 H, m, 10-H) and 2.45 (2 H, t, *J* 7 Hz, 11-H). The shift of the 13-H and 2-H methylene protons overlapped at δ_H 2.3 (t, *J* 7 Hz). In the ^{13}C NMR analysis of compound **6**, the chemical shift of the imino (C=N) carbon atom of the 1-pyrroline system appeared at δ_C 177.07 (s, C-12) and the ring methine carbon atom at δ_C 72.50 (d, C-9). The C=N bond of the pyrroline system caused deshielding of the adjacent methylene carbon atoms with signals appearing at δ_C 34.07 (C-13) and 36.95 (C-11). The shift of the remaining methylene carbon atom of the five-membered heterocyclic system appeared at δ_C 28.64 (C-10). The shielding γ-effect of the nitrogen atom of the pyrroline ring caused the C-7 and C-14 methylene carbon atoms to appear at 26.62 ppm. The assignment of the various signals was aided by recording the two-dimensional ^1H–^{13}C COSY experiment (Fig. 1). The mass spectral analysis of compound **6** confirmed the presence of the pyrroline nucleus from the base peak at *m/z* 82 (Ion **A**, 100%) and the location of the pyrroline ring system between C-9 and C-12 from the peaks at *m/z* 152 (**B**, 29), 166 (**C**, 69) and 239 (**D**, 46) and 252 (**E**, 64). The intense peak at *m/z* 252 also suggests that the imine bond (C=N) of the pyrroline nucleus was linked to C-12.[6,7]

In order to confirm conclusively the position of the imine bond in the pyrroline nucleus, compound **6** was treated with acetic anhydride. The resulting acetamidooxo derivative **7** was formed by the expected 1,2-cleavage of the pyrroline ring.



$R^1 = Me(CH_2)_4$, $R^2 = (CH_2)_7COOMe$, $R^3 = Me(CH_2)_5$

Scheme 1 *Reagents and conditions:* i, *p*-TsCl, py; ii, $MeSO_2Cl$, Et_3N, CH_2Cl_2; iii, NaN_3, DMF, 50 °C; iv, NaN_3, DMF, 80 °C; v, DMF or C_6H_{12}; vi, Ac_2O; vii, PhCOCl, aq. NaOH; viii, $NaBH_4$, MeOH

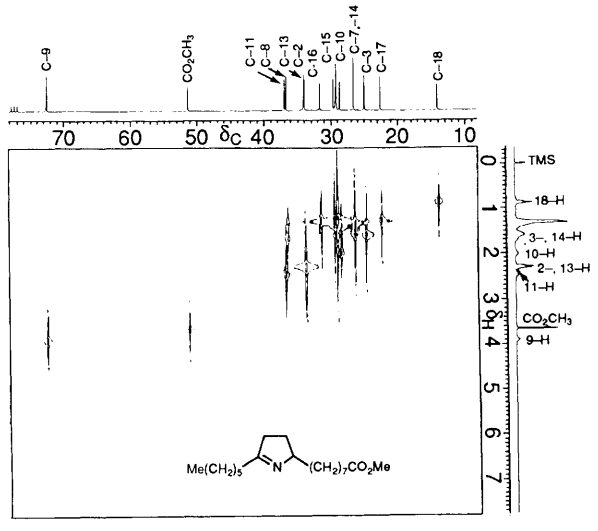
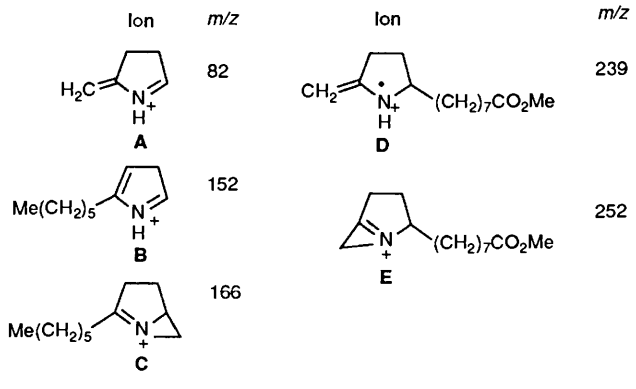
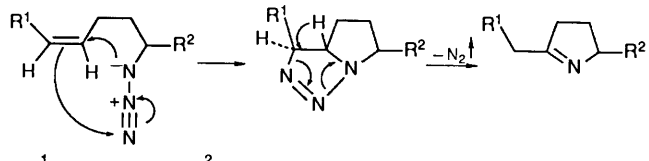


Fig. 1 Heteronuclear-shift-correlated (^1H–^{13}C) spectrum of compound **6**



Reaction of the compound **6** with benzoyl chloride (Schotten–Baumann reaction) gave the corresponding benzamidooxo derivative **8**.[21] The position of the oxo group at C-12 in both derivatives **7** and **8** was confirmed from the peak at *m/z* 113 [$CH_3(CH_2)_5C{\equiv}O^+$]. However, there was no peak of *m/z* 114 present in the mass spectrum of compound **7** or **8**, which ruled out the possibility of an amido group being attached to C-12 in these derivatives.[2] Hence, the C=N bond of the pyrroline ring was attached to the C-12 of the alkyl chain of the fatty ester.

These observations agreed with the mechanism proposed for the intramolecular cycloaddition reaction involving olefinic azides first studied by Logothetis[22] and more recently by Warren and Knaus,[23] and by Hassner *et al.*[24] It is proposed that cyclization of azido derivative **5** to a 2,5-disubstituted pyrroline **6** proceeds *via* a bicyclo intermediate, which upon thermolysis favoured hydrogen migration and the loss of nitrogen to yield the 1-pyrroline derivative. A plausible mechanism for the conversion of compound **5** to **6** is given in Scheme 2.

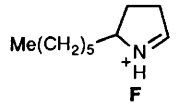
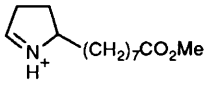


$R^1 = CH_3(CH_2)_4$, $R^2 = (CH_2)_7COOCH_3$

Scheme 2

Compound **6** was readily reduced by $NaBH_4$ to give a mixture of *E*- and *Z*-isomers of the corresponding pyrrolidine derivatives, *i.e.* **9a** and **9b**. This mixture of geometric isomers could not be separated by TLC or GLC (SE-30). However, the presence of *E*- and *Z*-isomers in the reaction product was evident from the ^1H NMR spectrum, where the signals for the ring methine protons (9-H and 12-H) of the *E*- and *Z*-isomers appeared at δ_H 3.12 (m) and 2.93 (m) respectively. The chemical shifts of the protons of the ring methylene groups (10-H and 11-H) for the *E*- and *Z*-form gave signals at δ_H 1.82 (m) and 1.92 (m) respectively. These results agreed with the shift values reported for the *E*- and *Z*-isomers of dialkyl pyrrolidines.[12] The

^{13}C NMR spectral analysis further supported the presence of the mixture of geometric isomers from the chemical shifts of the ring carbon atoms (C-9 and C-12) of the pyrrolidine nucleus, which appeared respectively at δ_C 59.48 and 58.21; and at δ_C 31.42 and 32.42 for the methylene carbon atoms at C-10 and C-11 of the *Z*- and *E*-isomers. The IR spectrum of **9a**, **9b** did not produce a discernible absorption band at *ca.* ν_{max} 3300 cm^{-1} for the anticipated N–H stretching vibration. The mass spectrum of compound **6** showed a base peak at *m/z* 154 (Ion **F**, 100%) and at *m/z* 226 (**G**, 87) which confirmed the position of the pyrrolidine ring system in the alkyl chain of the fatty ester derivative.

Ion	*m/z*
 **F**	154
 **G**	226

Experimental

Isoricinoleic acid was isolated from the seed oil of *Wrightia tinctoria* according to the partition method described by Gunstone.[18] Methyl isoricinoleate **1** was prepared by treatment of the acid with MeOH in the presence of BF_3–MeOH.[19] TLC analysis was performed on microscope glass plates coated with silica gel (*ca.* 0.1 mm thickness) using mixtures of Et_2O in light petroleum as the developer. GLC analysis was conducted on a Hewlett Packard HP5970 gas chromatograph fitted with a 10 m microbore glass column (0.53 mm diam., 2.65 μm film thickness SE-30 stationary phase) using nitrogen (20 cm^3 min^{-1}) as the carrier gas at a column temperature of 190 °C with a flame ionization detector. External standards of methyl myristrate, palmitate and stearate were used as reference compounds and the equivalent chain length (ecl) value calculated accordingly for each component.[25] Light petroleum refers to the fraction boiling in the range 40–60 °C. Elemental analyses were carried out by Butterworth Laboratories Ltd., Teddington, Middlesex, UK. IR spectra were obtained on a Perkin-Elmer model 577 spectrophotometer and NMR spectra on either a JEOL FX-90Q (90 MHz) or JEOL GSX-270 (270 MHz) instrument. Coupling constants *J* are expressed in Hz. GC–MS analysis was carried out on a Hewlett Packard HP5970 gas chromatograph fitted with a 12 m capillary glass column (0.2 mm internal diameter, 0.33 μm film thickness of crosslinked methyl silicone gum) using helium (*ca.* 2 cm^3 min^{-1}) as the carrier gas under temperature-programmed conditions (initial temperature, 170 °C; final temperature, 240 °C; rate 5 °C min^{-1}). The outlet of the column was connected to a Hewlett Packard Mass Selective Detector™. M.p.s were measured on a Reichert thermovar hot-stage microscope and are uncorrected.

Reaction of (Z)-*Methyl* 9-*Hydroxyoctadec*-12-*enoate* **1** *with Toluene*-p-*sulphonyl Chloride*.—A mixture of compound **1** (2.1 g, 6.7 mmol), toluene-*p*-sulphonyl chloride (5 g, 26 mmol) and pyridine (40 cm^3) was stirred at ambient temperature for 4 days. Cold dil. HCl (2 mol dm^{-3}, 100 cm^3) was added and the reaction mixture extracted with CH_2Cl_2 (2 × 70 cm^3). The organic extract was successively washed with dil. HCl (2 mol dm^{-3}, 20 cm^3), water (2 × 50 cm^3) and dried (Na_2SO_4). Silica gel column chromatography (CH_2Cl_2) gave *compound* **2** as an oil (1.33 g, 60%) (Found: C, 69.3; H, 10.8; Cl, 10.3. $C_{19}H_{35}ClO_2$ requires C, 69.0; H, 10.7; Cl, 10.7%); R_F 0.7 (10% Et_2O in light petroleum); ecl 19.7 (SE-30); δ_H(90 MHz; $CDCl_3$) 0.9 (3 H, t, *J* 7.5, CH_3), 1.2–1.5 (14 H, m), 1.5–1.8 (6 H, m), 1.9–2.2 (4 H, m), 2.3 (2 H, t, *J* 7.5, CH_2COOCH_3), 3.6 (3 H, s, $COOCH_3$), 3.9 (1 H, quin, *J* 8.6, >CHCl) and 5.2–5.4 (2 H, m, *CH*=*CH*); δ_C(90 MHz; $CDCl_3$) 14.1 (q, C-18), 22.6 (t, C-17), 24.4 (t), 25.0 (t, C-3), 26.5 (t), 27.3 (t), 29.1 (t), 29.2 (t, 2C), 29.5 (t), 31.6 (t, C-16), 34.1 (t, C-2), 38.6 (t, C-8 and C-10), 51.3 (q, $COOCH_3$), 63.3 (d, C-9), 128.1 (d, C-12), 131.3 (d, C-13) and 173.9 (s, C-1); ν_{max}/cm^{-1} 2960, 2860, 1740, 1440, 1190, 1160 and 720; and *compound* **3** as an oil (1.1 g, 35%) (Found: C, 67.1; H, 9.3; S, 6.8. $C_{26}H_{42}O_5S$ requires C, 66.9; H, 9.1; S, 6.9%); R_F 0.7 (40% Et_2O in light petroleum); δ_H(90 MHz; $CDCl_3$) 0.9 (3 H, t, *J* 7), 1.2–1.4 (16 H, m), 1.6–2.0 (8 H, m), 2.3 (2 H, t, *J* 7), 2.4 (3 H, s, CH_3 of OTs), 3.6 (3 H, s), 4.6 (1 H, quin, *J* 8.5, >*CH*–OTs), 5.0–5.5 (2 H, m), 7.3 (2 H, d, *J* 8, aromatic H) and 7.8 (2 H, d, *J* 8.3, aromatic H); δ_C(90 MHz; $CDCl_3$) 14.0 (q), 21.6 (q, CH_3 of OTs), 22.6 (t), 22.7 (t), 24.6 (t), 24.86 (t), 27.2 (t), 29.0 (t, 2C), 29.2 (t), 29.3 (t, 2C), 31.5 (t), 34.0 (t), 34.3 (t), 51.4 (q), 84.0 (d, C-9), 127.7 (d 2C, arom.), 127.9 (d, C-12), 129.7 (d, 2C aromatic), 131.1 (d, C-13), 134.9 (s, aromatic C), 144.4 (s, aromatic C) and 174.1 (s); ν_{max}/cm^{-1} 3025, 2920, 2860, 1740, 1600, 1440, 1360, 1180, 1100, 890 and 820.

Preparation of (Z)-*Methyl* 9-*Mesyloxyoctadec*-12-*enoate* **4**.—A mixture of methane sulphonyl chloride (1.5 g, 13 mmol), triethylamine (2 cm^3), compound **1** (2.0 g, 6.4 mmol) and CH_2Cl_2 (25 cm^3) was stirred at 0 °C for 30 min. The reaction mixture was extracted with CH_2Cl_2 (2 × 30 cm^3), washed with dil. HCl 2 mol dm^{-3}, 10 cm^3), water (2 × 20 cm^3) and dried. Evaporation of the solvent under reduced pressure furnished compound **4** as a viscous oil (2.5 g, 98%) R_F 0.6 (40% Et_2O in light petroleum); δ_H(90 MHz; $CDCl_3$) 0.9 (3 H, t, *J* 7), 1.2–1.4 (16 H, m), 1.6 (4 H, m), 2.0 (4 H, m), 2.3 (2 H, t, *J* 7), 2.9 (3 H, s, CH_3 of OMs), 3.6 (3 H, s), 4.7 (1 H, quin, *J* 8), >*CH*–OMs), 5.4 (2 H, m, *CH*=*CH*); δ_C(90 MHz; $CDCl_3$) 14.0 (q), 22.6 (t), 22.9 (t, C-11), 24.8 (t, C-7), 24.9 (t, C-3), 27.3 (t, C-14), 29.0 (t, 2C), 29.2 (t), 29.3 (t), 31.6 (t), 34.0 (t, C-2), 34.5 (t, C-10), 34.6 (t), 38.7 (q, CH_3 of OMs), 51.2 (q), 83.4 (d, C-9), 128.0 (d, C-12), 131.3 (d, C-13) and 173.9 (s, C-1); ν_{max}/cm^{-1} 2960, 2850, 1740, 1710, 1580, 1440, 1355, 1180, 970, 900, 770 and 700; compound **5** was unstable for elemental and GC–MS analyses.

Preparation of (Z)-*Methyl* 9-*Azidooctadec*-12-*enoate* **5**.—A mixture of either compound **2**, **3** or **4** (14 mmol), sodium azide (1.0 g, 15.4 mmol) and *N*,*N*-dimethyl formamide (DMF) (40 cm^3) was stirred at 50 °C for 2 h. Water (50 cm^3) was added and the reaction mixture extracted with Et_2O (2 × 50 cm^3). The ethereal extract was washed with water (2 × 20 cm^3) and dried (Na_2SO_4). Silica gel column chromatography of the extract gave compound **5** [3.6 g, 79% from **2**; 4.5 g, 69% from **3** and 4.5 g, 95% from **4**]. R_F 0.7 (10% Et_2O in light petroleum); δ_H(90 MHz; $CDCl_3$) 0.9 (3 H, t, *J* 7), 1.2–1.8 (20 H, m), 1.8–2.2 (4 H, m), 2.3 (2 H, t, *J* 7), 3.2 (1 H, quin, *J* 8, >CH–N_3), 3.6 (3 H, s), 5.2–5.3 (2 H, m, *CH*=*CH*); δ_C(90 MHz; $CDCl_3$) 14.1 (q), 22.6 (t), 23.9 (t, C-11), 25.0 (t), 26.1 (t, C-7), 27.3 (t, C-14), 29.1 (t, 2C), 29.2 (t), 29.3 (t), 29.4 (t), 31.6 (t), 34.1 (t), 34.5 (t, C-8 and C-10), 51.4 (q), 62.5 (d, C-9), 128.2 (d, C-12), 131.2 (d, C-13) and 174.1 (s); ν_{max}/cm^{-1} 2950, 2860, 2100, 1740, 1440, 1230, 1190 and 1160; compound **5** was unstable for elemental analysis.

Preparation of Methyl 8-(5-*Hexyl*-2-*pyrrolin*-1-*yl*)*octanoate* **6**.—A mixture of any one of compounds **2**, **3** or **4** (2.7 mmol), sodium azide (0.3 g, 4.6 mmol) and DMF (25 cm^3) was stirred at 80 °C for 6 h. Water (50 cm^3) was added and the reaction mixture extracted with Et_2O (2 × 50 cm^3). The ethereal extract

was washed with water (2 × 20 cm^3) and dried (Na_2SO_4). Silica gel column chromatography of the extract with light petroleum–Et_2O (1:1) yielded *compound* **6** as an oil (0.6 g, 72% from **2**; 0.63 g, 75% from **3**; and 0.75 g, 90% from **4**) (Found: C, 73.7; H, 11.5; N, 4.8. $C_{19}H_{35}NO_2$ requires C, 73.7; H, 11.4; N, 4.5%); R_F 0.5 (60% Et_2O in light petroleum); ecl 18.4 (SE-30); δ_H(270 MHz; $CDCl_3$) 0.89 (3 H, t, *J* 7), 1.2–1.5 (14 H, m), 1.5–1.8 (6 H, m), 2.03 (2 H, m, ring CH_2, 10-H), 2.30 (4 H, t, *J* 7), 2.45 (2 H, q, *J* 7, ring CH_2, 11-H), 3.65 (3 H, s) and 3.90 (1 H, br m, ring C*H*–N); δ_C(270 MHz; $CDCl_3$) 14.05 (q), 22.60 (t), 25.00 (t), 26.62 (t, C-7 and C-14), 28.64 (t, C-10), 29.14 (t), 29.21 (t), 29.25 (t), 29.63 (t), 31.65 (t), 34.00 (t, C-2), 34.07 (t, C-13), 36.71 (t, C-8), 36.95 (t, C-11), 51.34 (q), 72.50 (d, C-9), 174.13 (s, C-1) and 177.07 (s, C-12); ν_{max}/cm^{-1} 2925, 2860, 1740, 1640, 1215 and 1190; *m/z* 278 ($M^+ - 31$).

When compound **5** (0.5 g, 1.5 mmol) was heated in DMF or cyclohexane (25 cm^3) at 80 °C for 8 h, isolation and purification by chromatography gave compound **6** (0.42 g, 90%).

Preparation of Methyl 9-Acetamido-12-oxooctadecanoate **7**.—A mixture of compound **6** (0.34 g, 1.1 mmol) and acetic anhydride (3.5 cm^3) was stirred at 90 °C for 1 h. The reaction mixture was cooled and ice–water (15 cm^3) was added. The precipitate was collected by suction filtration, washed with water (5 × 10 cm^3) and recrystallized from Et_2O–EtOAc (1:3) to give *compound* **7** as white needles (0.15 g, 37%), m.p. 103–104 °C (Found: C, 67.9; H, 10.3; N, 3.7. $C_{21}H_{39}NO_4$ requires C, 68.3; H, 10.6; N, 3.8%); R_F 0.5 (light petroleum–Et_2O–MeOH, 1:3:1); ecl 23.7 (SE-30); δ_H(90 MHz; $CDCl_3$) 0.9 (3 H, t, *J* 7), 1.2–1.5 (14 H, m), 1.5–1.8 (8 H, m), 2.0 (3 H, s, CH_3CONH–), 2.3 (2 H, t, *J* 7), 2.4 (2 H, t, *J* 7, –COCH_2–, 13-H), 2.5 (2 H, t, *J* 7, –COCH_2–, 11-H), 3.6 (3 H, s), 3.9 (1 H, m, >C*H*–NHCOCH$_3$) and 5.7 (1 H, d, *J* 9, –N*H*COCH$_3$); δ_C(90 MHz; $CDCl_3$) 14.0 (q), 22.5 (t), 23.3 (q, NHCO*C*H$_3$), 23.9 (t, C-14), 24.9 (t), 25.8 (t, C-7), 28.6 (t, C-10), 28.9 (t), 29.0 (t), 29.1 (t), 29.3 (t), 31.6 (t), 34.0 (t), 35.6 (t, C-8), 39.5 (t, C-11), 43.0 (t, C-13), 49.5 (d, C-9), 51.4 (q), 170.0 (s, NH*C*OCH$_3$), 174.3 (s, C-1) and 211.5 (s, C-12); ν_{max}/cm^{-1} 3250, 2960, 2860, 1740, 1700, 1640, 1440 and 1380; *m/z* 299 (2.4%), 278 (14), 252 (100), 242 (67), 228 (47), 212 (39), 200 (61), 186 (65), 170 (43), 152 (73), 113 (22), 55 (37), 43 (96) and 28 (99).

Preparation of Methyl 9-Benzamido-12-oxooctadecanoate **8**.—Benzoyl chloride (2 cm^3) was slowly added to a stirred mixture of compound **6** (0.6 g, 1.9 mmol) and dil. NaOH (5%, 20 cm^3). The reaction mixture was shaken vigorously for 15 min and cooled in ice. The precipitate was collected by suction filtration, washed with water (20 cm^3) and recrystallized from Et_2O–EtOAc (3:1) to give compound **8** as white needles (0.3 g, 37%), m.p. 91–91.5 °C (Found: C, 72.6; H, 9.7; N, 3.1. $C_{26}H_{41}NO_4$ requires C, 72.4; H, 9.6; N, 3.3%); R_F 0.4 (30% Et_2O in light petroleum); δ_H(90 MHz; $CDCl_3$) 0.9 (3 H, t, *J* 7), 1.2–1.5 (14 H, m), 1.5–1.8 (8 H, m), 2.3 (2 H, t, *J* 7), 2.4 (2 H, t, *J* 7, 13-H), 2.5 (2 H, t, *J* 7, 11-H), 3.6 (3 H, s), 4.1 (1 H, m, >C*H*NHCOPh), 6.2 (1 H, d, *J* 9, >CHN*H*COPh), 7.4 (3 H, m, aromatic H) and 7.8 (2 H, m, aromatic H); δ_C(90 MHz; $CDCl_3$) 14.0 (q), 22.4 (t), 23.8 (t, C-14), 24.9 (t), 25.9 (t, C-7), 28.4 (t, C-10), 28.8 (t), 29.0 (t), 29.1 (t), 29.3 (t), 31.5 (t), 34.1 (t), 35.9 (t, C-8), 39.6 (t, C-11), 43.1 (t, C-13), 50.0 (d, C-9), 51.4 (q), 126.8 (d, 2C, aromatic), 128.5 (d, 2C, aromatic), 131.3 (d, aromatic C), 134.5 (s, aromatic C), 167.0 (s, NH*C*OPh), 174.3 (s, C-1) and 211.9 (s, C-12); ν_{max}/cm^{-1} 3250, 2960, 2860, 1740, 1700, 1630, 1460, 1170, 1100, 760, 700 and 670; *m/z* 290 (13%), 258 (9), 152 (23), 122 (16), 113 (4), 105 (100), 77 (19) and 28 (25).

Reduction of Compound **6** *to Methyl 8-(5-Hexyl-2-pyrrolidinyl)octanoate* **9a**, **9b**.—A solution of $NaBH_4$ (0.2 g, 5.2 mmol) in MeOH (5 cm^3) was added to a cooled solution of **6** (1 g, 3.2 mmol) in MeOH (20 cm^3) at 0 °C. The reaction mixture was stirred for a further 20 min at 0–5 °C. The solvent was evaporated under reduced pressure and water (25 cm^3) was added to the residue. The aqueous mixture was extracted with Et_2O (2 × 30 cm^3) and the ethereal extract washed with water (2 × 20 cm^3) and dried (Na_2SO_4). Silica gel column chromatography of the extract gave compounds **9a** and **9b** as an oil (0.9 g, 90%); R_F 0.3 (light petroleum–Et_2O–MeOH, 2:2:1); ecl 19.4 (SE-30); δ_H(270 MHz; $CDCl_3$) 0.9 (3 H, t, *J* 7), 1.2–1.6 (22 H, m), 1.82 (2 H, m), 1.92 (3 H, m), 2.30 (2 H, t, *J* 7), 2.93 (2 H, m, ring C*H*, *Z*-isomer), 3.12 (2 H, m, ring CH, *E*-isomer) and 3.65 (3 H, s); δ_C(270 MHz; $CDCl_3$) 14.0 (q), 22.64 (t), 25.03 (t), 27.25 (t), 27.41 (t), 29.20 (t), 29.25 (t, 2C), 29.55 (t), 29.60 (t, 2C), 31.42 (t, C-10 and C-11, *Z*-isomer), 31.91 (t), 32.42 (t, C-10 and C-11, *E*-isomer), 34.13 (t), 36.76 (t, C-8 and C-13 *Z*-isomer), 36.86 (t, C-8 and C-13, *E*-isomer), 51.19 (q), 58.21 (d, C-9 and C-12, *E*-isomer), 59.48 (d, C-9 and C-12, *Z*-isomer) and 173.92 (s); ν_{max}/cm^{-1} 2940, 2860, 1740, 1460 and 1165; *m/z* 280 ($M^+ - 31$, 8%), 226 (87), 194 (17) and 154 (100); compounds **9a**, **9b** were unstable for elemental analysis.

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