Pergamon

Tetrahedron 56 (2000) 2941–2951

TETRAHEDRON

Formation of Isoquinoline and 1-Azetine Derivatives via Novel Photocyclization of Substituted α-Dehydrophenylalanines

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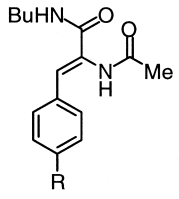
Received 2 December 1999; accepted 2 March 2000

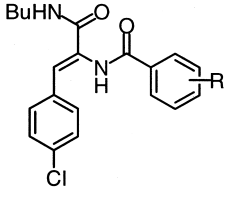
Abstract—The irradiation of substituted *N*-acetyl α-dehydrophenylalanines in MeOH with Pyrex-filtered light was found to give isoquinoline and 1-azetine derivatives in relatively good yields, which may be formed via intramolecular cyclization reactions from the (*Z*)- and (*E*)-isomers, respectively. Solvent viscosity effects on the product distribution and composition strongly suggested the minor role of a radical pair mechanism. In the presence of benzophenone as a triplet sensitizer, the starting (*Z*)-isomer underwent an exclusive isomerization into the corresponding (*E*)-isomer without yielding any cyclization products, being consistent with the occurrence of the novel photocyclization reactions from the excited singlet-state isomers. On the other hand, the irradiation of *N*-substituted benzoyl α-dehydrophenylalanines in MeOH afforded selectively 1-azetine derivatives without forming any isoquinolines. It was suggested that the stereoelectronic effects of bulky aromatic acyl groups are responsible for the complete suppression of the cyclization reactions, which eventually afford isoquinoline derivatives via the excited singlet-state (*Z*)-isomers.

Introduction

Synthetic organic photochemistry has continued to contribute to the development of efficient and selective transformations for the preparation of natural products as well as complicated molecules, which could not have been synthesized by conventional methods.[1] It is well-known that many of the naturally occurring α,β-unsaturated-α-amino acids (α-dehydroamino acids) and α-dehydropeptides possess a variety of biological activities,[2] allowing us to expect the potential pharmacological and physiological usefulness of these dehydroamino acid-derived products. Efficient synthetic routes to α-dehydroamino acids and their derivatives have been discovered,[3] whereas there has been only limited preliminary investigation of the photochemistry of these dehydroamino acid derivatives.[4] In this sense, the photochemistry of substituted α-dehydroamino acids is an unexplored field of research. Accordingly, systematic study is required to characterize the photochemical processes of α-dehydroamino acids. Taking into account the fact that aromatic olefins such as styrene and stilbene derivatives show diverse excited-state reactivities of synthetic utility, our attention is focused on the photoreactivity of aromatic α-dehydroamino acids. This paper reports the novel photocyclization reactions of (*Z*)-2-acylamino-*N*-butyl-3-(4-substituted phenyl)-2-propenamides **1a**–**k** obtained by the ring-opening reactions of (*Z*)-2-methyl-*N*-butyl-4-(4-substituted benzylidene)-5(4*H*)- and (*Z*)-2-aryl-*N*-butyl-4-(4-chlorobenzylidene)-5(4*H*)-oxazolones with butylamine.[5]



1a (R= OMe); **1b** (R= Me); **1c** (R= H);
1d (R= Cl); **1e** (R= CF_3)



1f (R= 4-Me); **1g** (R= H); **1h** (R= 4-Cl);
1i (R= 3-Cl); **1j** (R= 2-Cl); **1k** (R= 4-CF_3)

Results and Discussion

N-Acetyl α-dehydrophenylalanine derivatives 1a–e

The irradiation of a nitrogen-purged MeOH solution of **1d**

Keywords: amino acid and derivatives; photochemistry; isoquinolines; 1-azetines.
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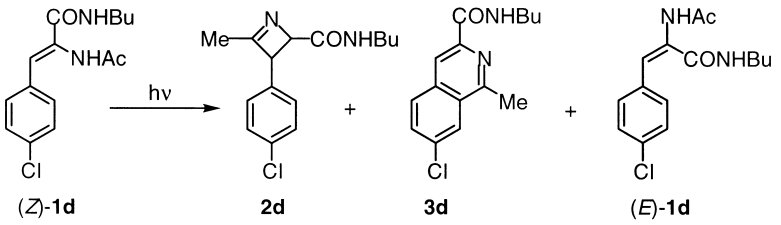
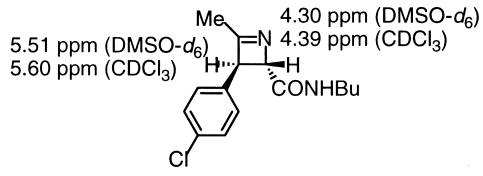


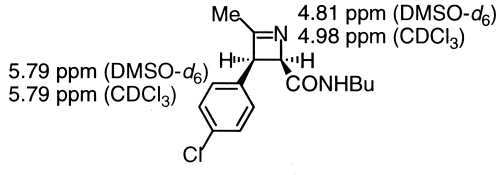
Scheme 1.

(1.0×10^{-2} mol dm^{-3}) with Pyrex-filtered light (>280 nm) from a 400 W high-pressure Hg lamp for 24 h at room temperature gave product mixtures with R_f values of 0.26, 0.40, 0.70 and 0.86 on a silica gel TLC plate (EtOAc). Column chromatography of the reaction mixtures over silica gel allowed us to isolate (*E*)-isomer of **1d** [(*E*)-**1d**; R_f=0.26], the starting **1d** [(*Z*)-**1d**; R_f=0.40], *trans*-2-methyl-3-(4-chlorophenyl)-4-butylaminocarbonyl-1-azetine monohydrate (**2d**; R_f=0.70) and 1-methyl-3-butylaminocarbonyl-7-chloroisoquinoline (**3d**; R_f=0.86) in 0.4, 6.8, 21 and 19% yields, respectively (Scheme 1). The structures of the isolated products were determined based on their spectroscopic and physical properties. The much lower yield of (*E*)-**1d** than that expected from a ^{1}H NMR analysis of the mixtures may be due to, in part, conversion into the thermodynamically more stable (*Z*)-**1d** during work-up.

The NMR analysis also revealed that there was formation of the *cis*-azetine isomer, the isolation of which was unsuccessful, having the vicinal coupling constants ($J_{3,4}$) (between protons on the azetine ring) of 9.4 (DMSO-d_6) and 10.9 Hz ($CDCl_3$), along with the isolated *trans*-azetine [$J_{3,4}$=7.2 (DMSO-d_6) and 7.6 Hz ($CDCl_3$)]. In order to calculate the magnitude of $J_{3,4}$ for these two isomers, we first performed MM2 calculations of the model azetine: 2-methyl-3-phenyl-1-azetine and then obtained the dihedral angles of 134.8° for the *trans*-isomer and 0.8° for the *cis*. The combined use of these dihedral angles and the Karplus equation[6] made it possible to estimate the $J_{3,4}$ values as 4.4 and 8.2 Hz for the *trans*- and *cis*-isomers, respectively. It is, thus, reasonable to assign the azetine with larger $J_{3,4}$ value to the *cis*-isomer and that having the smaller value to the *trans*. The structure of **2d** was verified also by ^{1}H–^{1}H and ^{13}C–^{1}H COSY spectra. When the *trans*-azetine isomer was allowed to stand for a few weeks at room temperature, there was indication of the appearance of azetine-derived decomposition product(s) (^{1}H NMR analysis). It is likely that the *cis*-isomer, which should be less stable, is mainly converted into either the thermodynamically more stable *trans*-isomer or the decomposition product(s).



trans -**2d**



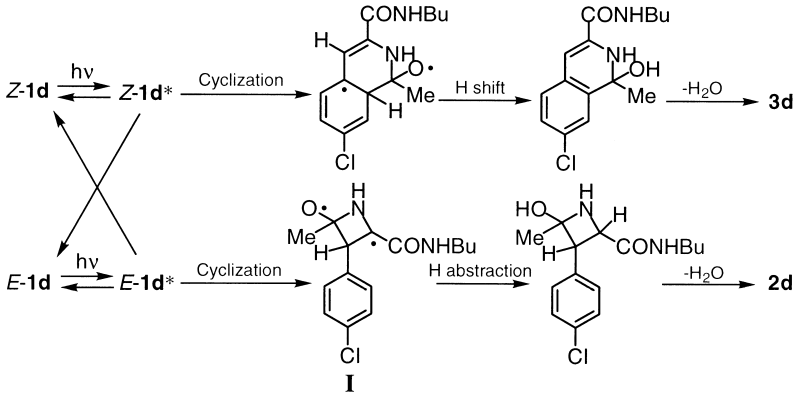
cis -**2d**

The finding that ^{1}H NMR spectrum obtained after 24 h irradiation can be explained in terms of overlapping of the spectra of **1d** (*Z* and *E*), **2d** (*trans* and *cis*) and **3d** enabled us to monitor the reaction by means of ^{1}H NMR spectroscopy. As seen from Table 1, after 0.5 h irradiation (*E*)-**1d** was detected in 16% yield without leading to either **2d** or **3d**. Additionally, its yield went up to 25% and then gradually decreased as the reaction proceeded, indicating that the isomerization of (*Z*)-**1d** to (*E*)-**1d** must take place prior to the formation of **2d** and **3d**. In addition to the principle of least motion,[7] Chem 3D modeling of **1d** suggests that the (*Z*)- and (*E*)-isomers adopt most suitable conformations for the intramolecular cyclization reactions that eventually give substituted isoquinoline **3d** and 1-azetine **2d**, respectively. Thus, we were led to propose Scheme 2 to explain the observed product distribution.

Interestingly, the irradiation of **1d** in MeOD or CD_3OD under similar conditions resulted in an incorporation of

Table 1. Relation between irradiation time and composition (%) of each compound in MeOH and MeCN

Compound	Solvent	Time (h)							
		0	0.5	1	3	6	12	18	24
(*Z*)-**1d**	MeOH	100	84	78	71	56	44	31	20
	(MeCN)	(100)	(89)	(87)	(83)	(75)	(61)	(47)	(33)
(*E*)-**1d**	MeOH		16	19	20	25	22	18	14
	(MeCN)		(11)	(11)	(13)	(14)	(16)	(17)	(16)
trans-**2d**	MeOH			1.1	3.9	10	16	27	34
	(MeCN)			(0.1)	(0.5)	(1.6)	(4.8)	(7.8)	(12)
cis-**2d**	MeOH			0.3	1.2	2.7	5.0	7.0	8.0
	(MeCN)				(0.3)	(0.8)	(2.7)	(4.9)	(6.9)
3d	MeOH			1.3	3.5	6.8	12	18	24
	(MeCN)			(1.2)	(4.0)	(8.0)	(16)	(24)	(32)



Scheme 2.

deuterium at the 4-position on the azetine ring but did not into the isoquinoline ring. Since the oxyl radical in the assumed biradical intermediate **I** is considered to abstract at first the methyl hydrogen from MeOH and then to abstract the hydroxy hydrogen of solvent-derived hydroxymethyl radical affording eventually the 1-azetine **2d** and formaldehyde, this finding provides a piece of evidence for the proposed Scheme 2. Table 1 also shows that the change in solvent from MeOH to MeCN results in a decrease of the composition for (*E*)-**1d** and **2d** with an increase of that for (*Z*)-**1d** and **3d**. Because the latter solvent has a lower reactivity toward hydrogen abstraction than the former, this demonstrates that suppression of both the isomerization into (*E*)-**1d** and the hydrogen abstraction by the biradical **I**, the precursor of **2d**, causes an increase in the relative composition of the isoquinoline **3d** to the 1-azetine **2d**, being consistent with a mechanism shown in Scheme 2. The great hydrogen-bonding solvation ability of MeOH may be a factor determining this relative composition. On the other hand, the irradiation of (*Z*)-**1d** in 2-propanol (having a much smaller polarity than MeOH) under the same conditions gave **3d** in preference to **2d** (composition ratio, **3d/2d**≈1.5 at 12 h irradiation) but side reactions occurred appreciably on prolonged irradiation. This finding implies that the solvent polarity as well as the reactivity of a given solvent toward hydrogen abstraction plays a major role in determining the product composition and also in controlling the undesirable side reactions.

The fact that the photo-Fries rearrangements[8] as well as acyloxy photomigrations[9] proceed mainly through a caged singlet radical pair intermediate forces us to discuss the remaining possibility of the acetyl migration by a radical pair mechanism. It was previously found that the direct photolysis of *N*,*O*-diacyl-*N*-phenylhydroxylamines affords 1,3- and 1,5-acyloxy-migrated products along with fragmentation products, and that the quantum yields of these rearrangement and fragmentation products are subject to great solvent viscosity effects.[9] Thus, we can expect the appearance of both acetyl-rearranged and fragmented products and then the observation of viscosity effects on these product compositions, when (degassed and sealed) CD_3OD and CD_3OD-glycerol-d_8 (3:2 v/v) solutions of (*Z*)-**1d** are irradiated with Pyrex-filtered light. The obtained results are presented in Table 2 and clearly show that there are negligible products other than (*E*)-**1d**, *trans*- and *cis*-**2d** and **3d**. Additionally, the composition of each product underwent solvent viscosity effects to only a negligible extent, suggesting the minor role of a radical pair mechanism.

It is an important issue to elucidate the spin multiplicity of the excited state from which the intramolecular cyclization of **1** takes place forming eventually two different types of heterocyclic rings. For this purpose we chose (*Z*)-**1d** as the starting material and benzophenone (BP) as a triplet sensitizer,[9,10] and a nitrogen-purged MeCN solution of this material containing BP was irradiated for a given period of time with light of wavelengths longer than 340 nm, which permitted selective excitation of the sensitizer. An inspection of Table 3 reveals that the triplet BP accelerates only the isomerization without forming any 1-azetine and isoquinoline derivatives. Because a ^{1}H NMR analysis of the reaction mixtures showed no sign of the appearance of BP-derived product(s), this finding strongly suggests that the novel photocyclization reaction of **1** proceeds preferentially through its excited singlet state.

In order to obtain further information regarding factors that control the selectivity of the observed photocyclization reaction, we examined substituent effects on the product

Table 2. Viscosity effects on the composition of each compound obtained by the irradiation of the starting (*Z*)-**1d** (1×10^{-2} mol dm^{-3}) for 6 h at room temperature

Solvent	Composition (%)				
	(*Z*)-**1d**	(*E*)-**1d**	*trans*-**2d**	*cis*-**2d**	**3d**
CD_3OD	34	22	16	2.0	26
CD_3OD-glycerol-d_8 (3:2 v/v)	33	23	14	3.1	27

Table 3. The composition of each compound obtained by the BP (4.0×10^{-2} mol dm^{-3})-sensitized reaction of (*Z*)-**1d** (4.0×10^{-3} mol dm^{-3}) in nitrogen-saturated MeCN at room temperature

Irradiation time (h)	Composition (%)				
	(*Z*)-**1d**	(*E*)-**1d**	*trans*-**2d**	*cis*-**2d**	**3d**
0	100	0	0	0	0
1	55	45	0	0	0
3	50	50	0	0	0
6	49	51	0	0	0

Table 4. Substituent effects on the composition of each compound obtained by the irradiation of **1a–e** (1.0×10^{-2} mol dm^{-3}) in nitrogen-purged MeOH at room temperature

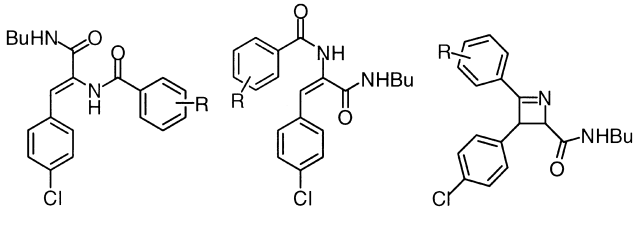
Compound	Irradiation time (h)	Composition (%)					**3/2**
		(*Z*)-**1**	(*E*)-**1**	*trans*-**2**	*cis*-**2**	**3**	
1a (R=OMe)	0.5	74	24	0.9	0.3	0.8	
	24	26	12	11	8.0	43	2.3
1b (R=Me)	0.5	82	18	0	0	0	
	24	22	12	16	8.0	42	1.8
1c (R=H)	0.5	81	16	0.8	0.3	1.6	
	24	20	10	22	7.0	41	1.4
1d (R=Cl)	0.5	84	16	0	0	0	
	24	20	14	34	8.0	24	0.6
1e (R=CF_3)	0.5	91	9	0	0	0	
	24	55	15	7.0	1.0	22	2.8

composition as well as on the composition ratio **3/2**. As shown in Table 4, the introduction of the strong electron-withdrawing trifluoromethyl group lowers not only the relative rate for the isomerization into (*E*)-form but also the reactivity of the excited singlet-state **1**. Interestingly, both the methoxy (**1a**) and trifluoromethyl (**1e**) substituents have a tendency to enhance the selectivity for the isoquinoline derivative **3**. The substituents attached at the 4-position on the benzene ring of (*Z*)-**1** are considered to exert their electronic effects on the excited-state reactivity in a rather complicated manner.

Although there are extensive synthetic routes to isoquinoline[11] and 1-azetine[12] derivatives, convenient photochemical routes to these derivatives are scarcely known.[13] The procedure for preparing the starting **1** is very simple and is easily applicable to its related compounds. The photoreaction of substituted *N*-acetyl α-dehydrophenylalanines described above should, therefore, find application in the simultaneous synthesis of various kinds of isoquinoline and 1-azetine derivatives.

N-Substituted benzoyl α-dehydrophenylalanine derivatives 1f–k

In the preceding section we demonstrated that the photoreaction of *N*-acetyl α-dehydrophenylalanine derivatives constitutes a new method for the preparation of substituted isoquinolines and 1-azetines. As an extension of our study on the photochemistry of α-dehydroamino acids, we designed and synthesized (*Z*)-2-substituted benzoylamino-*N*-butyl-3-(4-chlorophenyl)-2-propenamides (**1f–k**) in order to investigate the effects of aromatic acyl groups on the product distribution and composition derived from the irradiation of **1a–e** in MeOH.



(*Z*)-**1f–k** (*E*)-**1f–k** **2f–k**

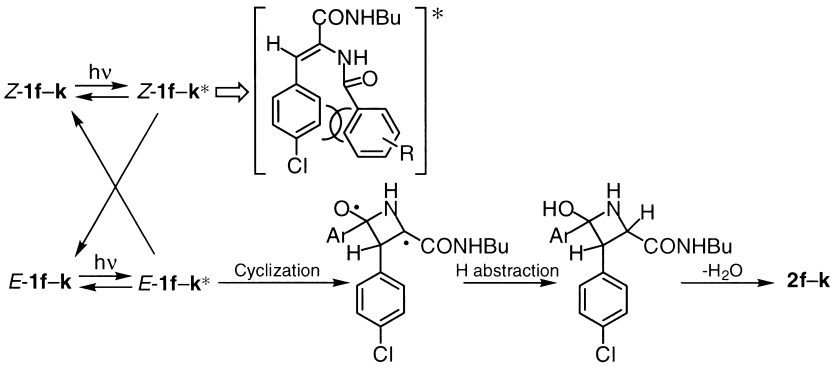
f (R= 4-Me); **g** (R= H); **h** (R= 4-Cl); **i** (R= 3-Cl); **j** (R= 2-Cl); **k** (R= 4-CF_3)

After a nitrogen-purged MeOH solution of **1f** (4.0×10^{-3} mol dm^{-3}) was irradiated with Pyrex-filtered light (>280 nm) from a 400 W high-pressure Hg lamp for 20 h at room temperature, the product mixture obtained was subjected to column chromatography over silica gel, which allowed us to isolate the starting **1f** [(*Z*)-**1f**, 49%], (*E*)-**1f** (9.1%) and *trans*-2-(4-tolyl)-3-(4-chlorophenyl)-4-butylaminocarbonyl-1-azetine (*trans*-**2f**, 18%). The structure of *trans*-**2f** was confirmed by comparison of its spectroscopic property with that of *trans*-2-methyl-3-(4-chlorophenyl)-4-butylaminocarbonyl-1-azetine (**2d**). ^{1}H–^{1}H and ^{13}C–^{1}H COSY spectra also substantiated our structure determination. A careful ^{1}H NMR analysis of the product mixture revealed that there was a minor formation of the *cis*-azetine isomer (*cis*-**2f**), though its isolation was unsuccessful, with a negligible amount of the expected isoquinoline derivative. When a DMSO-d_6 solution of the *trans*-**2f** and *cis*-**2f** was allowed to stand for several days at room temperature, there was indication of the faster appearance of the *cis*-**2f**-derived decomposition product(s) than that of the *trans*-**2f**-derived one(s) (^{1}H NMR analysis). It is, thus, likely that the *cis*-isomer of lower stability is subjected to either decomposition or isomerization (into the *trans*) during the work-up.

On the basis of MM2 calculations and the Karplus equation[6] described in the preceding section, we were able to assign the azetine with larger vicinal coupling constant ($J_{3,4}$=10.8 Hz) to the *cis*-isomer and that having the smaller $J_{3,4}$ value of 7.0 Hz to the *trans*, as shown below. In addition, PM3 calculations of the model azetine: 2,3-diphenyl-4-methylaminocarbonyl-1-azetine allowed us to estimate the heat of formation for the *trans*-azetine and the *cis* as 231 and

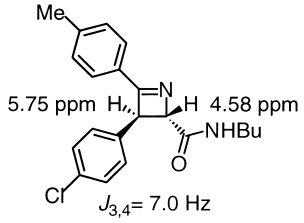
Table 5. Relation between irradiation time and composition (%) of each compound in MeOH

Compound	Time (h)					
	0	2	4	6	8	20
(*Z*)-**1f**	100	85	81	79	75	58
[(*Z*)-**1j**]	[100]	[75]	[71]	[68]	[65]	[51]
(*E*)-**1f**		13	14	14	14	13
[(*E*)-**1j**]		[22]	[23]	[25]	[25]	[27]
trans-**2f**		1.7	3.4	5.2	7.4	20
[*trans*-**2j**]		[2.4]	[4.2]	[5.9]	[7.9]	[16]
cis-**2f**		0.7	2.0	2.6	3.8	9.7
[*cis*-**2j**]		[0.7]	[1.3]	[1.6]	[2.3]	[6.2]

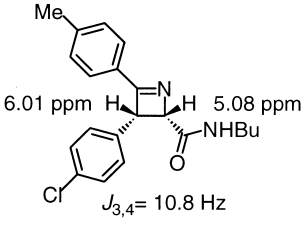


Scheme 3.

243 kJ mol^{-1}, respectively, showing that the *trans*-isomer is thermodynamically more stable. Thus, our calculations are consistent with the preferential formation of *trans*-**2f**.



trans-**2f** (DMSO-d_6)



cis-**2f** (DMSO-d_6)

^{1}H NMR spectra measured after 20 h irradiation clearly showed that the reaction mixtures consisted of (*Z*)-**1**, (*E*)-**1**, *trans*-**2** and *cis*-**2**, and then contained negligible amounts of isoquinoline derivatives, so that we attempted to monitor the reactions by means of the ^{1}H NMR spectroscopy. As typically shown in Table 5, the fast isomerization of (*Z*)-**1** should occur (prior to the production of **2**) giving the (*E*)-**1** that is a likely precursor of **2**. In the preceding section it was suggested that the isoquinoline is formed via the intramolecular cyclization reaction from the excited singlet-state (*Z*)-isomer while the cyclization from the (*E*)-isomer is responsible for the appearance of the 1-azetine. If we adopt this mechanism for the simultaneous formation of these two products, the much larger steric bulkiness of aromatic acyl groups as compared with that of acetyl is considered to suppress completely the attack of the acyl carbonyl carbon upon the phenyl carbon resulting in an exclusive deactivation of the excited-state (*Z*)-**1** (Scheme 3).[14] The stronger electron-withdrawing ability of aroyl groups than acetyl may also play a role in causing such a deactivation of the (*Z*)-isomer in the excited singlet state.

Significantly, the results shown in Fig. 1 confirm that there is a good correlation between the relative rates at which (*E*)-**1** and **2** are generated. The increased rate for the isomerization has a propensity to accelerate the reaction that eventually gives the azetine **2**, being consistent with the (*E*)-isomer, which serves as the precursor of **2**. Because (*Z*)-**1f**–**k** exhibit the first absorption bands with almost the same maximum wavelengths (λ_{max}=282–283 nm) and molar extinction coefficients (ϵ_{max}=2.2–2.3×10^4 dm^3 mol^{-1} cm^{-1}), it may be concluded that the isomerization of (*Z*)-**1** to (*E*)-**1** takes place in a higher efficiency on introducing a stronger electron-donating substituent and a more bulky one at the 4- and 2-positions on the benzene ring of aromatic acyl group, respectively. No attempt could be made to compare the isomerization efficiency between **1g** and **1f**, **h**–**k** under the same reaction conditions, owing to

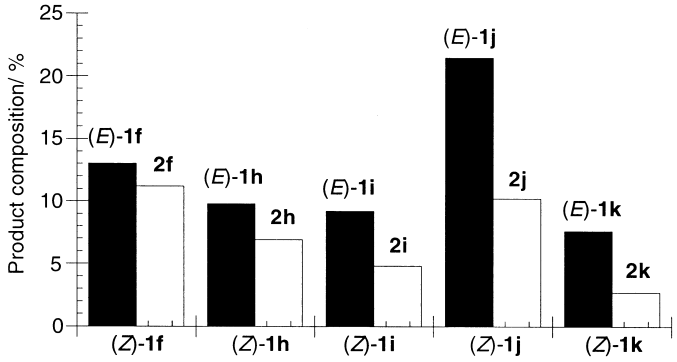


Fig. 1. Correlation between the compositions of (*E*)-**1** and **2** (*trans*+*cis*) obtained after 2 h [(*E*)-**1**] and 8 h (**2**) irradiations.

the poor solubility of **1g**, the 20 h irradiation of which (4.0×10^{-4} mol dm^{-3}) afforded *trans*-**2g** (14%), *cis*-**2g** (8.7%) and (*E*)-**1g** (15%) along with (*Z*)-**1g** (62%) without forming any other products (^{1}H NMR analysis).

In conclusion, the photoreaction of the *N*-substituted benzoyl α-dehydrophenylalanine derivatives in MeOH provides a convenient route to the substituted 1-azetines.

Experimental

General

^{1}H and ^{13}C NMR and IR spectra were taken with a JEOL JNM-500 spectrometer and a Hitachi 270-30 infrared spectrometer, respectively. Chemical shifts were determined using tetramethylsilane as an internal standard. UV absorption spectra were recorded on a Shimadzu UV-2200 spectrophotometer. A cell with a 10-mm pathlength was used. MeOH and MeCN were purified according to the standard procedures[15] and freshly distilled prior to use. 2-Propanol was of spectroscopic grade and was used without further purification. All other reagents used were obtained from commercial sources and were of the highest grade available. MM2 and PM3 calculations were accomplished by using the Mac SPARTAN *Plus* available from Wavefunction, Inc.

General procedure for the synthesis of (*Z*)-2-methyl-4-(4-substituted benzylidene)-5(4*H*)- and (*Z*)-2-substituted phenyl-4-(4-chlorobenzylidene)-5(4*H*)-oxazolones

N-Acylglycine (0.13 mol), 4-substituted benzaldehyde (0.15 mol) and sodium acetate (0.10 mol) were added to acetic anhydride (150 mL) and the resulting mixture was heated at 70–85°C for 1–2 h with stirring. The mixture was cooled with ice and then poured into ice-water (200 mL). The solid separated out was collected by filtration with suction and washed with small amounts of cold EtOH. After the crude product had been air-dried at room temperature, it was recrystallized from CCl_4 to give yellow crystals (40–60%).

(*Z*)-2-Methyl-4-(4-methoxybenzylidene)-5(4*H*)-oxazolone. Mp 109.5–110.0°C. IR (KBr): 1800, 1776, 1662, 1263 cm^{-1}. ^{1}H NMR (500 MHz, $CDCl_3$): δ 2.39 (3H, s), 3.87 (3H, s), 6.96 (2H, d, *J*=8.5 Hz), 7.11 (1H, s), 8.06 (2H, d, *J*=8.5 Hz).

(*Z*)-2-Methyl-4-(4-methylbenzylidene)-5(4*H*)-oxazolone. Mp 135.0–136.0°C. IR (KBr): 1809, 1776, 1656, 1266 cm^{-1}. ^{1}H NMR (500 MHz, $CDCl_3$): δ 2.38 (3H, s), 2.39 (3H, s), 7.11 (1H, s), 7.23 (2H, d, *J*=8.3 Hz), 7.96 (2H, d, *J*=8.3 Hz).

(*Z*)-2-Methyl-4-benzylidene-5(4*H*)-oxazolone. Mp 152.0–152.5°C. IR (KBr): 1779, 1659, 1266 cm^{-1}. ^{1}H NMR (500 MHz, $CDCl_3$): δ 2.38 (3H, s), 7.13 (1H, s), 7.39–7.44 (3H, m), 8.04–8.09 (2H, m).

(*Z*)-2-Methyl-4-(4-chlorobenzylidene-5(4*H*)-oxazolone. Mp 143.0–144.0°C. IR (KBr): 1800, 1773, 1659, 1260 cm^{-1}. ^{1}H NMR (500 MHz, $CDCl_3$): δ 2.40 (3H, s), 7.05 (1H, s), 7.39 (2H, d, *J*=8.3 Hz), 8.01 (2H, d, *J*=8.3 Hz).

(*Z*)-2-Methyl-4-[4-(trifluoromethyl)benzylidene]-5(4*H*)-oxazolone. Mp 110.0–112.0°C. IR (KBr): 1806, 1779, 1665, 1257 cm^{-1}. ^{1}H NMR (500 MHz, $CDCl_3$): δ 2.43 (3H, s), 7.12 (1H, s), 7.68 (2H, d, *J*=8.3 Hz), 8.18 (2H, d, *J*=8.3 Hz).

(*Z*)-2-(4-Tolyl)-4-(4-chlorobenzylidene-5(4*H*)-oxazolone. Mp 209.0–210.0°C. IR (KBr): 1791, 1644, 1227 cm^{-1}. ^{1}H NMR (500 MHz, $CDCl_3$): δ 2.46 (3H, s), 7.15 (1H, s), 7.34 (2H, d, *J*=7.9 Hz), 7.44 (2H, d, *J*=8.6 Hz), 8.06 (2H, d, *J*=7.9 Hz), 8.14 (2H, d, *J*=8.6 Hz).

(*Z*)-2-Phenyl-4-(4-chlorobenzylidene-5(4*H*)-oxazolone. Mp 192.5–193.5°C. IR (KBr): 1797, 1770, 1656, 1236 cm^{-1}. ^{1}H NMR (500 MHz, $CDCl_3$): δ 7.19 (1H, s), 7.43–7.63 (5H, m), 8.13–8.21 (4H, m).

(*Z*)-2-(4-Chlorophenyl)-4-(4-chlorobenzylidene)-5(4*H*)-oxazolone. Mp 254.0–255.0°C. IR (KBr): 1788, 1775, 1650, 1224 cm^{-1}. ^{1}H NMR (500 MHz, $CDCl_3$): δ 7.21 (1H, s), 7.46 (2H, d, *J*=8.5 Hz), 7.53 (2H, d, *J*=8.5 Hz), 8.12 (2H, d, *J*=8.5 Hz), 8.14 (2H, d, *J*=8.5 Hz).

(*Z*)-2-(3-Chlorophenyl)-4-(4-chlorobenzylidene)-5(4*H*)-oxazolone. Mp 181.0–182°C. IR (KBr): 1791, 1767, 1653, 1233 cm^{-1}. ^{1}H NMR (500 MHz, $CDCl_3$): δ 7.21 (1H, s), 7.45–7.50 (3H, m) 7.58–7.60 (1H, m), 8.03 (1H, d, *J*=7.9 Hz), 8.13 (2H, d, *J*=8.6 Hz) 8.15 (1H, m).

(*Z*)-2-(2-Chlorophenyl)-4-(4-chlorobenzylidene)-5(4*H*)-oxazolone. Mp 194.0–195.0°C. IR (KBr): 1788, 1647, 1230 cm^{-1}. ^{1}H NMR (500 MHz, $CDCl_3$): δ 7.26 (1H, s), 7.44 (1H, ddd, *J*=1.2, 7.3, 7.9 Hz), 7.46 (2H, d, *J*=8.5 Hz), 7.52 (1H, ddd, *J*=1.8, 7.3, 7.9 Hz), 7.59 (1H, dd, *J*=1.2, 7.9 Hz), 8.10 (1H, dd, *J*=1.8, 7.9 Hz), 8.18 (2H, d, *J*=8.5 Hz).

(*Z*)-2-[4-(Trifluoromethyl)phenyl]-4-(4-chlorobenzylidene)-5(4*H*)-oxazolone. Mp 254.0–255.0°C. IR (KBr): 1788, 1761, 1653, 1230 cm^{-1}. ^{1}H NMR (500 MHz, $CDCl_3$): δ 7.26 (1H, s), 7.47 (2H, d, *J*=8.5 Hz), 7.80 (2H, d, *J*=8.5 Hz), 8.15 (2H, d, *J*=8.5 Hz), 8.29 (2H, d, *J*=8.5 Hz).

General procedure for the synthesis of (*Z*)-2-acylamino-*N*-butyl-3-(4-substituted phenyl)-2-propenamides [(*Z*)-1a–k]

(*Z*)-2-Methyl-4-(4-substituted benzylidene)-5(4*H*)-oxazolone or (*Z*)-2-(substituted phenyl)-4-(4-chlorobenzylidene)-5(4*H*)-oxazolone (0.020 mol) was added to dry CH_2Cl_2 (200 mL) containing butylamine (0.021 mol) and the resulting solution was refluxed for 2–4 h. The reaction mixture was washed successively with, 1 mol dm^{-3} HCl (50 mL), H_2O (100 mL), 5 wt% $NaHCO_3$ (50 mL) and H_2O (100 mL), and then dried over anhydrous Na_2SO_4. After removal of the solvent under reduced pressure, the solid residue obtained was recrystallized from EtOH–hexane or EtOAc affording colorless crystals (60–70%).

(*Z*)-2-Acetylamino-*N*-butyl-3-(4-methoxyphenyl)-2-propenamide [(*Z*)-1a]. Mp 144.5–146.0°C. IR (KBr): 3328, 3208, 1653, 1608 cm^{-1}. ^1H NMR (500 MHz, DMSO-d_6): δ 0.88 (3H, t, *J*=6.8 Hz), 1.23–1.43 (4H, m), 200 (3H, s), 3.13 (2H, m), 3.77 (3H, s), 6.95 (2H, d, *J*=8.3 Hz), 7.02 (1H, s), 7.50 (2H, d, *J*=8.3 Hz), 7.89 (1H, br s), 9.29 (1H, s). ^{13}C NMR (125.7 MHz, DMSO-d_6): δ 13.7, 19.5, 22.9, 31.3, 38.7, 55.1, 113.9, 126.7, 127.6, 128.1, 130.9, 159.3, 164.9, 169.2. Anal. Calcd (Found) for $C_{16}H_{22}N_2O_3$: C, 66.19 (66.51); H, 7.64 (7.42); N, 9.65% (9.63%).

(*Z*)-2-Acetylamino-*N*-butyl-3-(4-tolyl)-2-propenamide [(*Z*)-1b]. Mp 148.0–149.0°C. IR (KBr): 3322, 3208, 1653, 1617 cm^{-1}. ^1H NMR (500 MHz, DMSO-d_6): δ 0.88 (3H, t, *J*=7.0 Hz), 1.27–1.43 (4H, m), 1.99 (3H, s), 2.30 (3H, s), 3.13 (2H, m), 6.99 (1H, s), 7.18 (2H, d, *J*=8.3 Hz), 7.42 (2H, d, *J*=8.3 Hz), 7.93 (1H, br, s), 9.31 (1H, s). ^{13}C NMR (125.7 MHz, DMSO-d_6): δ 13.7, 19.5, 20.8, 22.8, 31.2, 38.7, 127.4, 129.0, 129.2, 129.5, 131.4, 137.9, 164.8, 169.2. Anal. Calcd (Found) for $C_{16}H_{22}N_2O_2$: C, 70.04 (70.36); H, 8.08 (7.77); N, 10.21% (10.11%).

(*Z*)-2-Acetylamino-*N*-butyl-3-phenyl-2-propenamide [(*Z*)-1c]. Mp 147.0–148°C. IR (KBr): 3448, 1644, 1614 cm^{-1}. ^1H NMR (500 MHz, DMSO-d_6): δ 0.88 (3H, t, *J*=7.1 Hz), 1.20–1.48 (4H, m), 1.99 (3H, s), 3.14 (2H, dt, *J*=6.4, 6.4 Hz), 7.00 (1H, s), 7.35–7.53 (5H, m), 7.99 (1H, t, *J*=6.4 Hz), 9.38 (1H, s), 9.38 (1H, s). ^{13}C NMR (125.7 MHz, DMSO-d_6): δ 13.7, 19.5, 22.8, 31.2, 38.8, 127.2, 128.3, 128.4, 129.2, 130.4, 134.2, 164.8, 169.3. Anal. Calcd (Found) for $C_{15}H_{20}N_2O_2$: C, 69.21 (69.54); H, 7.74 (7.45); N, 10.76% (10.88%).

(*Z*)-2-Acetylamino-*N*-butyl-3-(4-chlorphenyl)-2-propenamide [(*Z*)-1d]. Mp 153–154.5°C. IR (KBr): 3448, 1650, 1616 cm^{-1}. ^1H NMR (500 MHz, DMSO-d_6): δ 0.88 (3H, t, *J*=7.3 Hz), 1.29 (2H, tq, *J*=7.3, 7.3 Hz), 1.43 (2H, tt, *J*=6.5, 7.3 Hz), 1.98 (3H, s), 3.13 (2H, dt, *J*=6.5, 6.5 Hz), 6.95 (1H, s), 7.43 (2H, d, *J*=8.5 Hz), 7.53 (2H, d, *J*=8.5 Hz), 7.99 (1H, t, *J*=6.5 Hz), 9.36 (1H, s). ^{13}C NMR (125.7 MHz, DMSO-d_6): δ 13.7, 19.5, 22.8, 31.2, 38.8, 125.6, 128.4, 130.8, 131.0, 132.6, 133.2, 164.6, 169.2. Anal. Calcd (Found) for $C_{15}H_{19}ClN_2O_2$: C, 61.12 (60.90); H, 6.50 (6.40); N, 9.50% (9.40%).

(*Z*)-2-Acetylamino-*N*-butyl-3-[4-(trifluoromethyl)phenyl]-2-propenamide [(*Z*)-1e]. Mp 158.0–159.0°C. IR (KBr): 3304, 1660, 1626 cm^{-1}. ^1H NMR (500 MHz, DMSO-d_6): δ 0.92 (3H, t, *J*=7.3 Hz), 1.30 (2H, tq, *J*=7.3, 7.3 Hz), 1.45 (2H, tt, *J*=7.3, 7.3 Hz), 1.99 (3H, s), 3.15 (2H, dt, *J*=5.8, 7.3 Hz), 6.98 (1H, s), 7.70 (2H, d, *J*=8.5 Hz), 7.73 (2H, d, *J*=8.5 Hz), 8.10 (1H, t, *J*=5.8 Hz), 9.48 (1H, s). ^{13}C NMR (125.7 MHz, DMSO-d_6): δ 13.7, 19.5, 22.9, 31.2, 38.8, 124.1 (q, *J*=272 Hz), 124.6, 125.2 (q, *J*=4 Hz), 127.8 (q, *J*=32 Hz), 129.7, 132.7, 138.7, 164.5, 169.2. Anal. Calcd (Found) for $C_{16}H_{19}F_3N_2O_2$: C, 58.53 (58.65); H, 5.83 (5.74); N, 8.53% (8.35%).

(*Z*)-2-(4-Toluoylamino)-*N*-butyl-3-(4-chlorphenyl)-2-propenamide [(*Z*)-1f]. Mp 176.0–177.0°C. IR (KBr): 3238, 1632, 1527 cm^{-1}. ^1H NMR (500 MHz, DMSO-d_6): δ 0.88 (3H, t, *J*=7.3 Hz), 1.30 (2H, tq, *J*=7.3, 7.3 Hz), 1.44 (2H, tt, *J*=7.3, 7.3 Hz), 2.38 (3H, s), 3.15 (2H, dt, *J*=5.8, 7.3 Hz), 7.13 (1H, s), 7.31 (2H, d, *J*=8.2 Hz), 7.39 (2H, d, *J*=8.5 Hz), 7.55 (2H, d, *J*=8.5 Hz), 7.89 (2H, d, *J*=8.2 Hz), 8.15 (1H, t, *J*=5.8 Hz), 9.85 (1H, s). ^{13}C NMR (125.7 MHz, DMSO-d_6): δ 13.7, 19.6, 21.0, 31.2, 38.9, 126.8, 127.9, 128.4, 128.8, 130.8, 130.9, 131.3, 132.7, 133.5, 141.6, 164.8, 165.6. Anal. Calcd (Found) for $C_{21}H_{23}ClN_2O_2$: C, 68.01 (68.19); H, 6.25 (6.45); N, 7.55% (7.52%).

(*Z*)-2-Benzoylamino-*N*-butyl-3-(4-chlorophenyl)-2-propenamide [(*Z*)-1g]. Mp 217.0–219°C. IR (KBr): 3256, 1644, 1566 cm^{-1}. ^1H NMR (500 MHz, DMSO-d_6): δ 0.88 (3H, t, *J*=6.8 Hz), 1.24–1.45 (4H, m), 3.15 (2H, dt, *J*=6.2, 6.8 Hz), 7.14 (1H, s), 7.38–7.99 (9H, m), 8.16 (1H, t, *J*=6.2 Hz), 9.89 (1H, s). ^{13}C NMR (125.7 MHz, DMSO-d_6): δ 13.7, 19.5, 31.1, 38.8, 126.9, 127.8, 128.2, 128.4, 130.7, 131.1, 131.6, 132.7, 133.3, 133.4, 164.6, 165.7. Anal Calcd (Found) for $C_{20}H_{21}ClN_2O_2$: C, 67.32 (67.17); H, 5.93 (5.87); N, 7.85% (7.57%).

(*Z*)-2-(4-Cholorobenzoylamino)-*N*-butyl-3-(4-chlorophenyl)-2-propenamide [(*Z*)-1h]. Mp 187.0–189.0°C. IR (KBr): 3238, 1632, 1560 cm^{-1}. ^1H NMR (500 MHz, DMSO-d_6): δ 0.88 (3H, t, *J*=7.3 Hz), 1.30 (2H, tq, *J*=7.3, 7.5 Hz), 1.46 (2H, tt, *J*=7.3, 7.5 Hz), 3.15 (2H, dt, *J*=5.6, 7.3 Hz), 7.17 (1H, s), 7.40 (2H, d, *J*=8.5 Hz), 7.55 (2H, d, *J*=8.5 Hz), 7.59 (2H, d, *J*=8.5 Hz), 8.00 (2H, d, *J*=8.5 Hz), 8.18 (1H, t, *J*=5.6 Hz), 9.98 (1H, s). ^{13}C NMR (125.7 MHz, DMSO-d_6): δ 13.7, 19.5, 31.2, 38.9, 127.2, 128.3, 128.5, 129.8, 130.1, 131.9, 132.4, 132.0, 133.3, 136.5, 164.6, 164.8. Anal. Calcd (Found) for $C_{20}H_{20}Cl_2N_2O_2$: C, 61.39 (61.38); H, 5.15 (5.24); N, 7.16% (7.16%).

(*Z*)-2-(3-Chlorobenzoylamino)-*N*-butyl-3-(4-chlorophenyl)-2-propenamide [(*Z*)-1i]. Mp 174.0–175.0°C. IR (KBr): 3268, 1632, 1554 cm^{-1}. ^1H NMR (500 MHz, DMSO-d_6): δ 0.88 (3H, t, *J*=7.6 Hz), 1.30 (2H, tq, *J*=7.3, 7.6 Hz), 1.45 (2H, tt, *J*=6.7, 7.3 Hz), 3.11 (2H, dt, *J*=5.8, 6.7 Hz), 7.16 (1H, s), 7.41 (2H, d, *J*=8.9 Hz), 7.54 (2H, d, *J*=8.9 Hz), 7.56 (1H, dd, *J*=6.7, 7.6 Hz), 7.66 (1H, d, *J*=6.7 Hz), 7.93 (1H, d, *J*=7.6 Hz), 8.05 (1H, s), 8.19 (1H, t, *J*=5.8, Hz), 10.00 (1H, s). ^{13}C NMR (125.7 MHz, DMSO-d_6): δ 13.7, 19.6, 31.2, 38.9, 126.6, 127.4, 127.8, 128.5, 130.3, 130.8, 131.5, 132.9, 133.1, 133.3, 135.6, 164.42, 164.45. Anal. Calcd (Found) for $C_{20}H_{20}Cl_2N_2O_2$: C, 61.39 (60.98); H, 5.15 (5.25); N, 7.16% (6.87%).

(*Z*)-2-(2-Chlorobenzoylamino)-*N*-butyl-3-(4-chlorophenyl)-2-propenamide [(*Z*)-1j]. Mp 186.0–188.0°C. IR (KBr): 3340, 1614, 1512 cm^{-1}. ^1H NMR (500 MHz, DMSO-d_6): δ 0.89 (3H, t, *J*=7.2 Hz), 1.33 (2H, tq, *J*=7.2, 7.5 Hz), 1.48 (2H, tt, *J*=7.2, 7.5 Hz), 3.21 (2H, dt, *J*=5.7, 7.2 Hz), 7.09 (1H, s), 7.45–7.63 (8H, m), 7.94 (1H, t, *J*=5.7 Hz), 10.00 (1H, s). ^{13}C NMR (125.7 MHz, DMSO-d_6): δ 13.7, 19.5, 31.2, 38.9, 126.8, 127.3, 128.4, 129.2, 129.7, 130.0, 130.4, 131.0, 131.2, 132.9, 133.1, 135.8, 164.5, 165.7. Anal. Calcd (Found) for $C_{20}H_{20}Cl_2N_2O_2$: C, 61.39 (61.68); H, 5.15 (5.31); N, 7.16% (6.92%).

(*Z*)-2-[4-(Trifluoromethyl) benzoylamino]-*N*-butyl-3-(4-chlorophenyl)-2-propenamide [(*Z*)-1k]. Mp 175.0–176°C. IR (KBr): 3244, 1635, 1527 cm^{-1}. ^1H NMR (500 MHz, DMSO-d_6): δ 0.88 (3H, t, *J*=7.3 Hz), 1.31 (2H, tq, *J*=7.3, 7.5 Hz), 1.45 (2H, tt, *J*=7.2, 7.5 Hz), 3.17

(2H, dt, *J*=5.5, 7.2 Hz), 7.21 (1H, s), 7.41 (2H, d, *J*=8.6 Hz), 7.57 (2H, d, *J*=8.6 Hz), 7.91 (2H, d, *J*=7.9 Hz), 8.20 (2H, d, *J*=7.9 Hz), 8.21 (1H, t, *J*=5.5 Hz), 10.12 (1H, s). ^{13}C NMR (125.7 MHz, DMSO-d_6): δ 13.7, 19.5, 31.2, 38.9, 123.9 (q, *J*=272 Hz), 125.3 (q, *J*=3 Hz), 127.6, 128.5, 128.8, 130.7, 130.8, 131.5 (q, *J*=31 Hz), 132.9, 133.2, 137.4, 164.4, 164.6. Anal. Calcd (Found) for $C_{21}H_{20}ClF_3N_2O_2$: C, 59.36 (59.50); H, 4.75 (5.11); N, 6.60% (6.26%).

General procedure for the irradiation of (*Z*)-1a–k

A solution of (*Z*)-**1** (0.40–1.0×10^{-2} mol dm^{-3}) in MeOH (500 mL), placed in a Pyrex vessel, was irradiated for a given period of time under nitrogen with Pyrex-filtered light from a 400 W high-pressure Hg lamp at room temperature. At regular time intervals, an appropriate amount of the solution (5 mL) being irradiated was pipetted off and concentrated to dryness in vacuo giving the residue which was subjected to ^{1}H NMR analysis in DMSO-d_6. The composition was estimated from the area ratio of a given ^{1}H NMR signal for each compound. After 24 h (**1a**–**e**) or 20 h (**1f**–**k**) irradiation the remaining solution was concentrated to dryness under reduced pressure and the resulting residue was subjected to column chromatography over silica gel (230 mesh, Merck) eluting with EtOAc–hexane. For the purpose of isolating and purifying the photoproducts, preparative TLC plate (silica gel) was also used. Physical and spectroscopic properties of the isolated isomers (*E*)-**1a**–**k**, substituted 1-azetines **2a**–**k** and isoquinolines **3a**–**e** are as follows.

(*E*)-1a. Mp 126.0–127.0°C. IR (KBr): 3328, 3274, 1650, 1611 cm^{-1}. ^{1}H NMR (500 MHz, DMSO-d_6): δ 0.81 (3H, t, *J*=7.3 Hz), 1.24 (2H, tq, *J*=7.3, 7.3 Hz), 1.31 (2H, tt, *J*=7.3, 7.3 Hz), 1.93 (3H, s), 3.02 (2H, dt, *J*=6.1, 7.3 Hz), 3.73 (3H, s), 6.71 (1H, s), 6.83 (2H, d, *J*=8.6 Hz), 7.16 (2H, d, *J*=8.6 Hz), 7.97 (1H, t, *J*=6.1 Hz), 9.47 (1H, s). ^{13}C NMR (125.7 MHz, DMSO-d_6): δ 13.6, 19.5, 23.3, 30.3, 38.4, 54.9, 113.4, 115.0, 127.6, 129.1, 132.1, 158.0, 164.7, 167.9. Anal. Calcd (Found) for $C_{16}H_{22}N_2O_3$: C, 66.19 (65.97); H, 7.64 (7.50); N, 9.65% (9.50%).

(*E*)-1b. Mp 149.0–150.0°C. IR (KBr): 3334, 3274, 1650, 1640 cm^{-1}. ^{1}H NMR (500 MHz, DMSO-d_6): δ 0.88 (3H, t, *J*=7.3 Hz), 1.13 (2H, tq, *J*=7.3, 7.3 Hz), 1.31 (2H, tt, *J*=7.3, 7.3 Hz), 1.94 (3H, s), 2.26 (3H, s), 3.01 (2H, dt, *J*=6.1, 7.3 Hz), 6.76 (1H, s), 7.06 (2H, d, *J*=8.2 Hz), 7.12 (2H, d, *J*=8.2 Hz), 7.98 (1H, t, *J*=6.1 Hz), 9.50 (1H, s). ^{13}C NMR (125.7 MHz, DMSO-d_6): δ 13.6, 19.5, 20.6, 23.3, 30.2, 38.5, 114.8, 127.8, 128.5, 132.4, 133.1, 135.7, 164.6, 168.0. Anal. Calcd (Found) for $C_{16}H_{22}N_2O_2$: C, 70.04 (69.73); H, 8.08 (8.04); N, 10.21% (10.05%).

(*E*)-1c. Mp 131.0–132.0°C. IR (KBr): 3298, 1660, 1632 cm^{-1}. ^{1}H NMR (500 MHz, DMSO-d_6): δ 0.80 (3H, t, *J*=7.3 Hz), 1.13 (2H, tq, *J*=7.3, 7.3 Hz), 1.30 (2H, tt, *J*=7.3, 7.3 Hz), 1.95 (3H, s), 3.00 (2H, dt, *J*=6.1, 7.3 Hz), 6.81 (1H, s), 7.17 (1H, dd, *J*=6.7, 6.7 Hz), 7.22–7.27 (4H, m), 8.31 (1H, t, *J*=6.1 Hz), 9.56 (1H, s). ^{13}C NMR (125.7 MHz, DMSO-d_6): δ 13.6, 19.5, 23.3, 30.2, 38.4, 114.5, 126.4, 127.8, 127.9, 133.8, 135.3, 164.5, 168.1. Anal. Calcd (Found for $C_{15}H_{20}N_2O_2$: C, 69.21 (69.18); H, 7.74 (7.80); N, 10.76% (10.93%).

(*E*)-1d. Mp 143.0–144.0°C. IR (KBr): 3334, 3262, 1644, 1630 cm^{-1}. ^{1}H NMR (500 MHz, DMSO-d_6): δ 0.80 (3H, t, *J*=7.3 Hz), 1.10 (2H, tq, *J*=7.3, 7.3 Hz), 1.29 (2H, tt, *J*=7.3, 7.3 Hz), 1.95 (3H, s), 3.01 (2H, dt, *J*=7.3, 6.0 Hz), 6.82 (1H, s), 7.22 (2H, d, *J*=8.4 Hz), 7.31 (2H, d, *J*=8.4 Hz), 8.10 (1H, t, *J*=6.0 Hz), 9.62 (1H, s). ^{13}C NMR (125.7 MHz, DMSO-d_6): δ 13.5, 19.5, 23.3, 30.2, 38.4, 113.0, 127.9, 129.5, 130.8, 134.4, 134.5, 164.3, 165.2. Anal. Calcd (Found for $C_{15}H_{19}ClN_2O_2$: C, 61.12 (60.79); H, 6.50 (6.49); N, 9.50% (9.19%).

(*E*)-1e. Mp 154.0–155.0°C. IR (KBr): 3340, 3274, 1650, 1640 cm^{-1}. ^{1}H NMR (500 MHz, DMSO-d_6): δ 0.78 (3H, t, *J*=7.3 Hz), 1.06 (2H, tq, *J*=7.3, 7.3 Hz), 1.27 (2H, tt, *J*=7.0, 7.3 Hz) 1.97 (3H, s), 3.01 (2H, dt, *J*=5.8, 7.0 Hz), 6.93 (1H, s), 7.40 (2H, d, *J*=8.2 Hz), 7.60 (2H, d, *J*=8.2 Hz), 8.17 (1H, t, *J*=5.8 Hz), 9.78 (1H, s). ^{13}C NMR (125.7 MHz, DMSO-d_6): δ 13.5, 19.5, 23.4, 30.2, 38.5, 112.4, 124.4 (q, *J*=271 Hz), 124.8 (q, *J*=4 Hz), 126.6 (q, *J*=32 Hz), 128.0, 136.1, 140.0, 164.2, 168.5. Anal. Calcd (Found) for $C_{16}H_{19}F_3N_2O_2$: C, 58.53 (58.22); H, 5.83 (5.56); N, 8.53% (8.33%).

(*E*)-1f. Mp 140.0–141.0°C. IR (KBr): 3298, 1641, 1539 cm^{-1}. ^{1}H NMR (500 MHz, DMSO-d_6): δ 0.81 (3H, t, *J*=7.3 Hz), 1.18 (2H, tq, *J*=7.3, 7.3 Hz), 1.42 (2H, tt, *J*=7.2, 7.3 Hz), 2.38 (3H, s), 3.04 (2H, dt, *J*=5.8, 7.2 Hz), 6.69 (1H, s), 7.29 (2H, d, *J*=8.2 Hz), 7.32 (2H, d, *J*=8.5 Hz), 7.34 (2H, d, *J*=8.5 Hz), 7.83 (2H, d, *J*=8.2 Hz), 8.08 (1H, t, *J*=5.8 Hz), 10.02 (1H, s). ^{13}C NMR (125.7 MHz, DMSO-d_6): δ 13.6, 19.6, 21.0, 30.3, 38.6, 116.0, 127.8, 128.0, 128.9, 129.8, 131.0, 131.2, 134.2, 134.7, 141.8, 164.3, 164.7. Anal. Calcd (Found) for $C_{21}H_{23}ClN_2O_2$: C, 68.01 (67.78); H, 6.25 (6.63); N, 7.55% (7.20%).

(*E*)-1g. Mp 144.0–145.0°C. IR (KBr): 3274, 1626, 1521 cm^{-1}. ^{1}H NMR (500 MHz, DMSO-d_6): δ 0.82 (3H, t, *J*=7.3 Hz), 1.14 (2H, tq, *J*=7.3, 7.3 Hz), 1.33 (2H, tt, *J*=7.3, 7.3 Hz), 3.05 (2H, dt, *J*=5.5, 7.3 Hz), 6.71 (1H, s), 7.30 (2H, d, *J*=8.5 Hz), 7.35 (2H, dd, *J*=7.3, 7.3 Hz), 7.58 (1H, dd, *J*=7.3, 7.3 Hz), 7.91 (2H, d, *J*=7.3 Hz), 8.11 (1H, t, *J*=5.5 Hz), 10.12 (1H, s). ^{13}C NMR (125.7 MHz, DMSO-d_6): δ 13.6, 19.5, 30.2, 38.5, 116.1, 127.6, 127.9, 128.2, 129.7, 131.2, 131.6, 133.7, 134.0, 164.0, 164.7. Anal. Calcd (Found) for $C_{20}H_{21}ClN_2O_2$: C, 67.32 (67.30); H, 5.93 (6.63); N, 7.85% (7.95%).

(*E*)-1h. Mp 185.0–186.0°C. IR (KBr): 3292, 1644, 1539 cm^{-1}. ^{1}H NMR (500 MHz, DMSO-d_6): δ 0.82 (3H, t, *J*=7.3 Hz), 1.15 (2H, tq, *J*=7.3, 7.3 Hz), 1.33 (2H, tt, *J*=7.0, 7.3 Hz), 3.05 (2H, dt, *J*=5.8, 7.0 Hz), 6.71 (1H, s), 7.30 (2H, d, *J*=8.6 Hz), 7.35 (2H, d, *J*=8.6 Hz), 7.59 (2H, d, *J*=8.6 Hz), 7.94 (2H, d, *J*=8.6 Hz), 8.11 (1H, t, *J*=5.8 Hz), 10.18 (1H, s). ^{13}C NMR (125.7 MHz, DMSO-d_6): δ 13.6, 19.5, 30.2, 38.5, 116.5, 128.0, 128.4, 129.6, 129.8, 131.3, 132.5, 133.9, 134.3, 136.5, 163.8, 164.0. Anal. Calcd (Found) for $C_{20}H_{21}Cl_2N_2O_2$: C, 61.39 (61.53); H, 5.15 (5.03); N, 7.16% (7.13%).

(*E*)-1i. Mp 119.0–121.0°C. IR (KBr): 3304, 1626, 1527 cm^{-1}. ^{1}H NMR (500 MHz, DMSO-d_6): δ 0.82 (3H, t, *J*=7.3 Hz), 1.15 (2H, tq, *J*=7.3, 7.3 Hz), 1.33 (2H, tt, *J*=7.0, 7.3 Hz), 3.06 (2H, dt, *J*=5.8, 7.0 Hz), 6.72 (1H, s), 7.31 (2H,

d, J=8.5 Hz), 7.36 (2H, d, J=8.5 Hz), 7.55 (1H, dd, J=7.9, 7.9 Hz), 7.66 (1H, d, J=7.9 Hz), 7.87 (1H, d, J=7.9 Hz), 7.97 (1H, s), 8.15 (1H, t, J=5.8 Hz), 10.24 (1H, s). ^{13}C NMR (125.7 MHz, DMSO-d_6): δ 13.6, 19.6, 30.3, 38.5, 116.8, 126.5, 127.5, 128.0, 129.8, 130.4, 131.4, 131.5, 133.1, 133.9, 134.2, 135.8, 163.4, 163.9 Anal. Calcd (Found) for $C_{20}H_{20}Cl_2N_2O_2$: C, 61.39 (61.28); H, 5.15 (5.49); N, 7.16% (7.18%).

(*E*)-1j. Mp 139.0–141.0°C. IR (KBr): 3236, 1638, 1524 cm^{-1}. ^{1}H NMR (500 MHz, DMSO-d_6): δ 0.82 (3H, t, J=7.3 Hz), 1.14 (2H, tq, J=7.3, 7.3 Hz), 1.33 (2H, tt, J=7.3, 7.3 Hz), 3.04 (2H, dt, J=6.1, 7.3 Hz), 6.80 (1H, s), 7.30 (2H, d, J=8.6 Hz), 7.35 (2H, d, J=8.6 Hz), 7.38–7.54 (4H, m), 8.19 (1H, t, J=6.1 Hz), 10.26 (1H, s). ^{13}C NMR (125.7 MHz, DMSO-d_6): δ 13.6, 19.6, 30.2, 38.5, 115.1, 127.0, 128.0, 129.1, 129.6, 129.7, 130.1, 131.2, 131.3, 134.0, 134.3, 136.0, 163.8, 164.6. Anal. Calcd (Found) for $C_{20}H_{20}Cl_2N_2O_2$: C, 61.39 (61.05); H, 5.15 (5.38); N, 7.16% (7.04%).

(*E*)-1k. Mp 234.0–236.0°C. IR (KBr): 3256, 1644, 1539 cm^{-1}. ^{1}H NMR (500 MHz, DMSO-d_6): δ 0.82 (3H, t, J=7.3 Hz), 1.15 (2H, tq, J=7.3, 7.3 Hz), 1.33 (2H, tt, J=7.0, 7.3 Hz), 3.06 (2H, dt, J=5.5, 7.0 Hz), 6.75 (1H, s), 7.31 (2H, d, J=8.6 Hz), 7.36 (2H, d, J=8.6 Hz), 7.90 (2H, d, J=8.2 Hz), 8.11 (2H, d, J=8.2 Hz), 8.17 (1H, t, J=5.5 Hz), 10.35 (1H, s). ^{13}C NMR (125.7 MHz, DMSO-d_6): δ 13.6, 19.5, 30.3, 38.5, 116.9, 123.9 (q, J=275 Hz), 125.3 (q, J=3 Hz) 128.0, 128.6, 129.8, 131.2 (q, J=32 Hz), 131.4, 133.9, 134.1, 137.6, 163.7, 163.9. Anal. Calcd (Found) for $C_{21}H_{20}ClF_3N_2O_2$: C, 59.36 (59.22); H, 4.75 (4.60); N, 6.60% (6.50%).

***trans*-2-Methyl-3-(4-methoxyphenyl)-4-butylaminocarbonyl-1-azetine (*trans*-2a).** Oily liquid. IR (neat): 3316, 1640, 1611 cm^{-1}. ^{1}H NMR (500 MHz, DMSO-d_6): δ 0.82 (3H, t, J=7.3 Hz), 1.26 (2H, tq, J=7.3, 7.3 Hz), 1.40 (2H, tt, J=7.0, 7.3 Hz), 2.03 (3H, d, J=1.2 Hz), 3.13 (2H, dt, J=6.0, 7.0 Hz), 3.76 (3H, s), 4.31 (1H, dd, J=1.2, 7.3 Hz), 5.44 (1H, d, J=7.3 Hz), 6.95 (2H, d, J=8.6 Hz), 7.23 (2H, d, J= 8.6 Hz), 7.89 (1H, br s). ^{13}C NMR (125.7 MHz, DMSO-d_6): δ 13.6 (2C), 19.4, 31.1, 38.2, 55.1, 76.6, 82.7, 114.1, 127.2, 131.2, 132.2, 164.8, 164.9. Anal. Calcd (Found) for $C_{16}H_{22}N_2O_2{\cdot}H_2O$: C, 65.73 (65.91); H, 8.27 (7.94); N, 9.58% (9.22%).

***trans*-2-Methyl-3-(4-tolyl)-4-butylaminocarbonyl-1-azetine (*trans*-2b).** Oily liquid. IR (neat): 3322, 1653, 1590 cm^{-1}. ^{1}H NMR (500 MHz, DMSO-d_6): δ 0.87 (3H, t, J=7.3 Hz), 1.26 (2H, tq, J=7.3, 7.3 Hz), 1.40 (2H, tt, J=7.0, 7.3 Hz), 2.04 (3H, d, J=1.2 Hz), 2.30 (3H, s), 3.09 (2H, dt, J=5.8, 7.0 Hz), 4.29 (1H, dd, J=1.2, 7.3 Hz), 5.45 (1H, d, J= 7.3 Hz), 7.18 (2H, d, J=8.3 Hz), 7.21 (2H, d, J=8.3 Hz), 7.98 (1H, t, J=5.8 Hz). ^{13}C NMR (125.7 MHz, DMSO-d_6): δ 13.5, 13.6, 19.5, 20.7, 31.1, 38.3, 76.8, 82.7, 125.5, 129.2, 137.4, 137.5,164.9, 169.9. Anal. Calcd (Found) for $C_{16}H_{22}N_2O{\cdot}H_2O$: C, 69.53 (69.14); H, 8.75 (8.69); N, 10.14% (10.30%).

***trans*-2-Methyl-3-phenyl-4-butylaminocarybonyl-1-azetine (*trans*-2c).** Oily liquid. IR (neat): 3310, 1656, 1590 cm^{-1}. ^{1}H NMR (500 MHz, DMSO-d_6): δ 0.87 (3H, t J=7.3 Hz) 1.27 (2H, tq, J=7.3, 7.3 Hz), 1.41 (2H, tt, J=7.0, 7.3 Hz), 2.06 (3H, s), 3.10 (2H, dt, J=5.8, 7.0 Hz), 4.32 (1H, d, J= 7.3 Hz), 5.50 (1H, d, J=7.3 Hz), 7.30 (2H, d, J=7.6 Hz), 7.34 (1H, dd, J=7.3, 7.3 Hz), 7.40 (2H, dd, J=7.3, 7.6 Hz), 7.91 (1H, br s). ^{13}C NMR (125.7 MHz, DMSO-d_6) δ 13.5, 13.6, 19.5, 31.1, 38.3, 76.9, 82.6, 125.5, 128.2, 128.7, 140.4, 164.9, 169.8. This azetine was slowly decomposed so that we could not obtain the satisfactory result of elemental analysis.

***trans*-2-Methyl-3-(4-chlorophenyl)-4-butylaminocarbonyl-1-azetine (*trans*-2d).** Mp 42.0–43.0°C. IR (KBr): 3310, 1677, 1617 cm^{-1}. ^{1}H NMR (500 MHz, DMSO-d_6): δ 0.87 (3H, t, J=7.4 Hz), 1.26 (2H, tq, J=7.4, 7.4 Hz), 1.40 (2H, tt, J=7.0, 7.4 Hz), 2.06 (3H, d, J=1.4 Hz), 3.10 (2H, dt, J=6.0, 7.0 Hz), 4.30 (1H, dd, J=1.4, 7.2 Hz), 5.51 (1H, d, J= 7.2 Hz), 7.34 (2H, d, J=8.3 Hz), 7.47 (2H, d, J=8.3 Hz), 7.90 (1H, t, J=6.0 Hz). ^{13}C NMR (125.7 MHz, DMSO-d_6): δ 13.5, 13.6, 19.5, 31.1, 38.3, 76.8, 81.9, 127.4, 128.7, 132.7, 139.4, 164.9, 169.7. EI-MS: m/z (%) 296 (M^+, 0.36), 298 (M^++2, 0.10). Anal. Calcd (Found) for $C_{15}H_{19}ClN_2O{\cdot}H_2O$: C, 60.70 (60.70); H, 7.13 (7.13); N, 9.44% (9.43%).

***trans*-2-Methyl-3-[4-(trifluoromethyl)phenyl]-4-butylaminocarbonyl-1-azetine (*trans*-2e).** Oily liquid. IR (neat): 3322, 1653, 1595 cm^{-1}. ^{1}H NMR (500 MHz, DMSO-d_6): δ 0.87 (3H, t, J=7.3 Hz), 1.27 (2H, tq, J=7.3, 7.3 Hz), 1.42 (2H, tt, J=7.0, 7.3 Hz), 2.09 (3H, d, J=1.2 Hz), 3.08–3.18 (2H, m), 4.34 (1H, dd, J=1.2, 7.3 Hz), 5.62 (1H, d, J= 7.3 Hz), 7.55 (2H, d, J=8.2 Hz), 7.78 (2H, d, J=8.2 Hz), 7.92 (1H, t, J=5.5 Hz). ^{13}C NMR (125.7 MHz, DMSO-d_6): δ 13.5, 13.6, 19.5, 31.1, 38.3, 76.8, 81.8, 124.0 (q, J=272 Hz), 125.6 (q, J=4 Hz), 126.2, 128.6 (q, J=32 Hz), 145.1, 164.9, 169.6. Anal. Calcd (Found) for $C_{16}H_{19}F_3N_2O{\cdot}H_2O$: C, 58.17 (58.49); H, 6.41 (6.06); N, 8.48% (8.46%).

***trans*-2-(4-Tolyl)-3-(4-chlorophenyl)-4-butylaminocarbonyl-1-azetine (*trans*-2f)**. Oily liquid. IR (neat): 3400, 1650, 1615 cm^{-1}. ^{1}H NMR (500 MHz, DMSO-d_6): δ 0.88 (3H, t, J=7.3 Hz), 1.28 (2H, tq, J=7.3, 7.6 Hz), 1.43 (2H, tt, J=7.2, 7.6 Hz), 2.39 (3H, s), 3.14 (2H, dt, J=5.5, 7.2 Hz), 4.58 (1H, d, J=7.0 Hz), 5.75 (1H, d, J=7.0 Hz), 7.34 (2H, d, J=8.2 Hz), 7.39 (2H, d, J=8.5 Hz), 7.49 (2H, d, J=8.5 Hz), 7.88 (2H, d, J=8.2 Hz), 8.06 (1H, t, J=5.5 Hz), ^{13}C NMR (125.7 MHz, DMSO-d_6): δ 13.6, 19.5, 21.1, 31.1, 38.4, 76.8, 82.1, 123.9, 127.4, 128.2, 128.8, 129.2, 132.8, 139.3, 142.1, 163.3, 169.5. Anal. Calcd (Found) for $C_{21}H_{23}ClN_2O{\cdot}H_2O$: C, 67.64 (67.89); H, 6.76 (6.36); N, 7.51% (7.15%).

***trans*-2-Phenyl-3-(4-chorophenyl)-4-butylaminocarbonyl-1-azetine (*trans*-2g).** Oily liquid. IR (neat): 3310, 1644, 1610 cm^{-1}. ^{1}H NMR (500 MHz, DMSO-d_6): δ 0.87 (3H, t, J=7.3 Hz), 1.28 (2H, tq, J=7.3, 7.3 Hz), 1.43 (2H, tt, J=7.0, 7.3 Hz), 3.11 (2H, dt, J=5.8, 7.0 Hz), 4.60 (1H, d, J=7.3 Hz), 5.76 (1H, d, J=7.3 Hz), 7.39 (2H, d, J=8.5 Hz), 7.48 (2H, d, J=8.5 Hz), 7.52 (2H, dd, J=7.6, 7.6 Hz), 7.61 (1H, dd, J=7.6, 7.6 Hz), 7.98 (2H, d, J=7.6 Hz), 8.05 (1H, t, J=5.8 Hz). ^{13}C NMR (125.7 MHz, DMSO-d_6): δ 13.6, 19.5, 31.1, 38.4, 76.8, 82.3, 126.6, 127.5, 128.2, 128.7, 128.8, 132.1, 132.9, 139.2, 163.3, 169.5. Anal. Calcd (Found) for

$C_{20}H_{21}ClN_2O·H_2O$: C, 66.94 (66.58); H, 6.46 (6.12); N, 7.81% (7.50%).

***trans*-2-(4-Chlorophenyl)-3-(4-chlorophenyl)-4-butylaminocarbonyl-1-azetine (*trans*-2h).** Mp 107.0–109.0°C. IR (KBr): 3292, 1644, 1596 cm^{-1}. ^1H NMR (500 MHz, DMSO-d_6): δ 0.88 (3H, t, J=7.3 Hz), 1.27 (2H, tq, J=7.3, 7.6 Hz), 1.43 (2H, tt, J=7.3, 7.6 Hz), 3.13 (2H, dt, J=5.8, 7.3 Hz), 4.62 (1H, d, J=7.3 Hz), 5.78 (1H, d, J=7.3 Hz), 7.40 (2H, d, J=8.5 Hz), 7.49 (2H, d, J=8.5 Hz), 7.61 (2H, d, J=8.8 Hz), 8.00 (2H, d, J=8.8 Hz), 8.08 (1H, t, J=5.8 Hz), ^{13}C NMR (125.7 MHz, DMSO-d_6): δ 13.6, 19.4, 31.0, 38.4, 76.8, 82.6, 125.5, 127.5, 128.8, 128.9, 130.0, 132.9, 136.9, 138.9, 162.4, 169.3. Anal. Calcd (Found) for $C_{20}H_{20}Cl_2N_2O·H_2O$: C, 61.08 (61.25); H, 5.64 (5.29); N, 7.12% (6.86%).

***trans*-2-(3-Chlorophenyl)-3-(4-chlorophenyl)-4-butylaminocarbonyl-1-azetine (*trans*-2i).** Mp 73.0–74.0°C. IR (KBr): 3272, 1648, 1600 cm^{-1}. ^1H NMR (500 MHz, DMSO-d_6): δ 0.88 (3H, t, J=7.3 Hz), 1.28 (2H, tq, J=7.3, 7.3 Hz), 1.44 (2H, tt, J=6.7, 7.3 Hz), 3.11 (2H, dt, J=5.8, 6.7 Hz), 4.64 (1H, d, J=7.3 Hz), 5.79 (1H, d, J=7.3 Hz), 7.42 (2H, d, J=8.5 Hz), 7.49 (2H, d, J=8.5 Hz), 7.58 (1H, dd, J=7.9, 8.1 Hz), 7.70 (1H, dd, J=1.5, 8.1 Hz), 7.93 (1H, dd, J=1.5, 7.9 Hz), 8.01 (1H, dd, J=1.5, 1.5 Hz), 8.10 (1H, t, J=5.8, Hz). ^{13}C NMR (125.7 MHz, DMSO-d_6): δ 13.6, 19.5, 31.1, 38.4, 76.7, 82.7, 126.8, 127.6, 127.8, 128.6, 128.8, 130.8, 131.9, 133.0, 133.4, 138.9, 162.1, 169.3. Anal. Calcd (Found) for $C_{20}H_{20}Cl_2N_2O·0.5H_2O$: C, 62.51 (62.32); H, 5.51 (5.52); N, 7.26% (7.29%).

***trans*-2-(2-Chlorophenyl)-3-(4-chlorophenyl)-4-butylaminocarbonyl-1-azetine (*trans*-2j).** Oily liquid. IR (neat): 3396, 1642, 1592 cm^{-1}. ^1H NMR (500 MHz, DMSO-d_6): δ 0.88 (3H, t, J=7.3 Hz), 1.30 (2H, tq, J=7.3, 7.6 Hz), 1.44 (2H, tt, J=7.0, 7.6 Hz), 3.16 (2H dt, J=5.5, 7.0 Hz), 4.59 (1H, d, J=7.6 Hz), 5.79 (1H, d, J=7.6, Hz), 7.45 (2H, d, J=8.6, Hz), 7.49 (1H, dd, J=1.3, 7.3 Hz), 7.51 (2H, d, J=8.6, Hz), 7.57–7.64 (2H, m), 7.91 (1H, dd, J=1.5, 7.8 Hz), 8.02 (1H, t, J=5.5 Hz). ^{13}C NMR (125.7 MHz, DMSO-d_6): δ 13.6, 19.4, 31.0, 38.4, 76.7, 82.5, 126.3, 127.3, 127.6, 128.8, 130.6, 131.7, 132.2, 132.7, 133.0, 138.9, 162.1, 169.2. Anal. Calcd (Found) for $C_{20}H_{20}Cl_2N_2O·H_2O$: C, 61.08 (61.39); H, 5.64 (5.44); N, 7.12% (7.08%).

***trans*-2-[4-(Trifluoromethyl)phenyl]-3-(4-chlorophenyl)-4-butylaminocarbonyl-1-azetine (*trans*-2k).** Mp 63.0–65.0°C. IR (KBr): 3292, 1650, 1600 cm^{-1}. ^1H NMR (500 MHz, DMSO-d_6): δ 0.88 (3H, t, J=7.3 Hz), 1.30 (2H, tq, J=7.3, 7.3 Hz), 1.44 (2H, tt, J=7.3, 7.3 Hz), 3.15 (2H, dt, J=5.8, 7.3 Hz), 4.68 (1H, d, J=7.3 Hz), 5.84 (1H, d, J=7.3 Hz), 7.43 (2H, d, J=8.5 Hz), 7.50 (2H, d, J=8.5 Hz), 7.91 (2H, d, J=8.2 Hz), 8.14 (1H, t, J=5.8 Hz), 8.20 (2H, d, J=8.2 Hz). ^{13}C NMR (125.7 MHz, DMSO-d_6): δ 13.6, 19.5, 31.0, 38.4, 76.8, 82.8, 125.7 (q, J=3 Hz), 126.2 (a, J=273 Hz), 127.6, 128.8, 129.1, 130.5, 131.8 (q, J=32 Hz), 133.0, 138.8, 162.2, 169.1. Anal. Calcd (Found) for $C_{20}H_{20}ClF_3N_2O·0.5H_2O$: C, 60.36 (60.44); H, 5.07 (5.24); N, 6.70% (6.35%).

***cis*-2i.** We succeeded in isolating a slight amount of *cis*-**2i** (oily liquid) whose ^1H and ^{13}C NMR spectra were consistent with the proposed structure, although the *cis*-isomer isolated was contaminated with the azetine-derived decomposition product(s): ^1H NMR (500 MHz, DMSO-d_6): δ=0.73 (3H, t, J=7.0 Hz), 0.90–0.97 (4H, m), 2.70–2.79 (2H, m), 5.12 (1H, d, J=10.7 Hz), 6.07 (1H, d, J=10.7 Hz), 7.25 (2H, d, J=8.2, Hz), 7.36 (2H, d, J=8.5, Hz), 7.59 (1H, dd, J=7.6, 8.2 Hz), 7.69–7.73 (2H, m), 7.94 (1H, d, J=7.6 Hz), 8.01 (1H, br s). ^{13}C NMR (125.7 MHz, DMSO-d_6): δ 13.6, 19.4, 30.9, 37.9, 73.7, 82.4, 126.8, 127.7, 127.8, 128.5, 129.9, 130.8, 131.9, 132.6, 133.4, 135.3, 163.3, 167.0.

3-Butylaminocarbonyl-7-methoxy-1-methylisoquinoline (3a). Mp 105.0–106.0°C. IR (KBr): 3376, 1656 cm^{-1}. ^1H NMR (500 MHz, DMSO-d_6): δ 0.92 (3H, t, J=7.3, Hz), 1.37 (2H, tq, J=7.3, 7.3 Hz), 1.56 (2H, tt, J=7.0, 7.3 Hz), 2.94 (3H, s), 3.37 (2H, dt, J=6.1, 7.0 Hz), 3.98 (3H, s), 7.48 (1H, dd, J=2.4, 8.8 Hz), 7.51 (1H, d, J=2.4 Hz), 8.08 (1H, d, J=8.8 Hz), 8.31 (1H, s), 8.66 (1H, t, J=6.1 Hz). ^{13}C NMR (125.7 MHz, DMSO-d_6): δ 13.7, 19.7, 22.3, 31.5, 38.4, 55.6, 104.4, 118.0, 123.1, 129.3, 130.3, 130.8, 140.8, 156.0, 159.2, 164.2. Anal. Calcd (Found) for $C_{16}H_{20}N_2O_2$: C, 70.56 (70.23); H, 7.40 (7.07); N, 10.29% (10.64%).

3-Butylaminocarbonyl-7-methyl-1-methylisoquinoline (3b). Mp 67.0–69.0°C. IR (KBr): 3436, 1658 cm^{-1}. ^1H NMR (500 MHz, DMSO-d_6): δ 0.92 (3H, t, J=7.3 Hz), 1.35 (2H, tq, J=7.3, 7.6 Hz), 1.54 (2H, tt, J=7.3, 7.6 Hz), 2.57 (3H, s), 2.94 (3H, s), 3.35 (2H, dt, J=6.1, 7.3 Hz), 7.68 (1H, dd, J=1.2, 8.5 Hz), 8.04 (1H, dd, J=8.5 Hz), 8.06 (1H, d, J=1.2 Hz), 8.32 (1H, s), 8.69 (1H, t, J=6.1 Hz). ^{13}C NMR (125.7 MHz, DMSO-d_6): δ 13.7, 19.6, 21.6, 22.1, 31.5, 38.4, 118.0, 124.7, 128.0, 128.4, 132.8, 133.7, 138.7, 141.8, 156.8, 164.1. Anal. Calcd (Found) for $C_{16}H_{20}N_2O$: C, 74.97 (75.21); H, 7.86 (7.83); N, 10.93% (11.04%).

3-Butylaminocarbonyl-1-methylisoquinoline (3c). Mp 66.0–67.0°C. IR (KBr) 3310, 1656 cm^{-1}. ^1H NMR (500 MHz, DMSO-d_6): δ 0.92 (3H, t, J=7.3 Hz), 1.35 (2H, tq, J=7.3, 7.3 Hz), 1.57 (2H, t, J=7.0, 7.3 Hz), 2.98 (3H, s), 3.37 (2H, dt, J=6.1, 7.0 Hz), 7.78 (1H, ddd, J=1.2, 7.0, 8.2 Hz), 7.85 (1H, ddd, J=1.2, 7.0, 8.2 Hz), 8.15 (1H, d, J=8.2 Hz), 8.29 (1H, d, J=8.2 Hz), 8.38 (1H, s), 8.75 (1H, t, J=6.1 Hz). ^{13}C NMR (125.7 MHz, DMSO-d_6): δ 13.7, 19.6, 22.1, 31.4, 38.4, 118.1, 125.9, 127.8, 128.6, 128.8, 130.8, 135.5, 142.5, 157.7, 163.9. Anal. Calcd (Found) for $C_{15}H_{18}N_2O$: C, 74.35 (74.16); H, 7.49 (7.34); N, 11.56% (11.64%).

3-Butylaminocarbonyl-7-chloro-1-methylisoquinoline (3d). Mp 91.0–92.0°C. IR (KBr): 3400, 1668 cm^{-1}. ^1H NMR (500 MHz, DMSO-d_6): δ 0.92 (3H, t, J=7.3 Hz), 1.34 (2H, tq, J=7.3, 7.3 Hz), 1.56 (2H, tt, J=6.7, 7.3 Hz), 2.96 (3H, s), 3.35 (2H, dt, J=6.1, 6.7 Hz), 7.87 (1H, dd, J=2.0, 8.7 Hz), 8.22 (1H, d, J=8.7 Hz), 8.35 (1H, d, J=2.0 Hz), 8.41 (1H, s), 8.76 (1H, t, J=6.1 Hz). ^{13}C NMR (125.7 MHz, DMSO-d_6): δ 13.7, 19.6, 22.2, 31.4, 38.5, 117.8, 125.0, 128.5, 130.9, 131.4, 133.2, 134.1, 143.0, 157.3, 163.7. Anal. Calcd (Found) for $C_{15}H_{17}ClN_2O$: C, 65.10 (65.47); H, 6.19 (6.16); N, 10.12% (10.03%).

3-Butylaminocarbonyl-7-trifluoromethyl-1-methylisoquinoline (3e). Mp 104.0–105.0°C. IR (KBr): 3384,

1662 cm^{-1}. ^1H NMR (500 MHz, DMSO-d_6): δ 0.93 (3H, t, J=7.3 Hz), 1.36 (2H, tq, J=7.3, 7.6 Hz), 1.57 (2H, tt, J=7.3, 7.6 Hz), 3.06 (3H, s), 3.37 (2H, dt, J=6.1, 7.3 Hz), 8.10 (1H, dd, J=1.2, 8.5 Hz), 8.40 (1H, d, J=8.5 Hz), 8.49 (1H, d, J=1.2, Hz), 8.62 (1H, s), 8.85 (1H, t, J=6.1, Hz). ^{13}C NMR (125.7 MHz, DMSO-d_6): δ 13.7, 19.9, 22.2, 31.4, 38.6, 117.8, 123.87 (q, J=4 Hz), 123.88 (q, J=272 Hz), 126.0, 126.8, 128.4 (q, J=32 Hz), 130.5, 137.4, 144.5, 159.3, 163.5. Anal. Calcd (Found) for $C_{16}H_{17}F_3N_2O$: C, 61.93 (61.85); H, 5.52 (5.50); N, 9.03% (9.43%).

Viscosity and sensitization effects on the photoreactivity of (*Z*)-1d

For the purpose of examining sensitization effects on the product distribution and composition, an MeCN solution (40 mL) of (*Z*)-**1d** (4.0×10^{-3} mol dm^{-3}) containing BP (4.0×10^{-2} mol dm^{-3}), placed in a Pyrex vessel, was irradiated under nitrogen at room temperature with light of wavelengths longer than 340 nm (Corning 0–52 glass filter) from a 450 W high-pressure Hg lamp. At suitable time intervals, an aliquot (5 mL) of the solution was pipetted off and concentrated to dryness in vacuo. The resulting residue was dissolved in DMSO-d_6 and subjected to ^1H NMR analysis. On the other hand, we employed a ^1H NMR tube instead of a Pyrex vessel in order to investigate viscosity effects on the photoreactivity. A CD_3OD or a CD_3OD-glycerol-d_8 (3:2 v/v) solution of (*Z*)-**1d** (1×10^{-2} mol dm^{-3}) was placed in an NMR tube and sealed after the solution was degassed with nitrogen. This degassed and sealed solution was irradiated for 6 h at room temperature with Pyrex-filtered light from a 450 W high-pressure Hg lamp.

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