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Manganese(III)-mediated facile synthesis of 3,4-dihydro-2(1*H*)-quinolinones: selectivity of the 6-*endo* and 5-*exo* cyclization

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ABSTRACT

The 4,4-bis(ethoxycarbonyl)-3,4-dihydro-2(1*H*)-quinolinones **2** were easily synthesized by the oxidative 6-*endo-trig* cyclization of 2-[2-(*N*-arylamino)-2-oxoethyl]malonates **1** with manganese(III) acetate in good to excellent yields. The same reaction of *N*-(2,4-dimethoxyphenyl)-substituted malonate **1t** exclusively produced the 5-*exo*-cyclized 4,4-bis(ethoxycarbonyl)-1-azaspiro[4,5]deca-6,9-diene-2,8-dione **5t** instead of the corresponding dihydroquinolinone. The regioselectivity during the cyclization could be explained by the difference in the activation energy of the transition state of the 6-*endo*/5-*exo* cyclization.

1. Introduction

The 2(1*H*)-quinolinone scaffold is widely found in various alkaloids[1a–e] and important as a characteristic building block for a series of significant biologically active compounds, such as endothelin receptor antagonists,[1f] angiotensin II receptor antagonists,[1g] farnesyl transferase inhibitors,[1h] and maxi-K channel opening agents.[1i] Several 2(1*H*)-quinolinone derivatives exhibit cytotoxic,[2a,b] antiplatelet,[2c] inotropic,[2d] antihypertensive,[2e,f] and antiviral (HIV) activities.[2g,h] Because of their interesting pharmacological properties, the development of an efficient method for the synthesis of 2(1*H*)-quinolinone derivatives represents a challenge in organic and medicinal chemistry. In recent years, we developed various manganese(III)-mediated oxidation reactions.[3] The characteristic of the oxidation is that the manganese(III) acetate can readily undergo a ligand-exchange reaction with β-dicarbonyl compounds to produce the manganese(III)–enolate complex in situ, followed by a one-electron oxidation of the enolate ligands, producing the corresponding α-dicarbonylalkyl radicals. The radicals are strongly electrophilic and undergo oxidative addition to the electron-rich carbon–carbon double bonds. This manganese(III)-based oxidation methodology has been used for the carbon–carbon bond formation and the generation of various important cyclic compounds in organic synthesis.[4] Among them, the oxidative intramolecular cyclization reaction is one of the most useful and efficient techniques to obtain the cyclization products, and the reaction has also been effectively applied to the synthesis of heterocyclic compounds.[5] Citterio et al. reported the manganese(III)-mediated intramolecular cyclization of malonates,[6] and Chuang et al. also showed a similar reaction using alkylsulfonylanilides, producing 2(1*H*)-quinolinones.[5a] However, to the best of our knowledge, the reaction using 2-[2-(*N*-arylamino)-2-oxoethyl]malonates **1**, readily prepared by the reaction of anilines with 2-haloacetyl halides followed by condensation with certain malonates, has never been examined. Accordingly, the growing importance for a practical route to biologically active 2(1*H*)-quinolinone derivatives and the readily available starting amidic malonates prompted us to investigate the oxidative intramolecular cyclization of the malonates **1** with manganese(III) acetate. In this paper, we report the facile synthesis of 3,4-dihydro-2(1*H*)-quinolinones **2** using the manganese(III)-mediated intramolecular cyclization of **1** and discuss the ratio of the 6-*endo*[7]/5-*exo-trig* cyclization mode during the reaction.

2. Results and discussion

2.1. Manganese(III)-mediated intramolecular cyclization of malonates 1a–y

Diethyl 2-[2-(*N*-methyl-*N*-phenylamino)-2-oxoethyl]malonate (**1a**) was prepared by the condensation of diethyl malonate with

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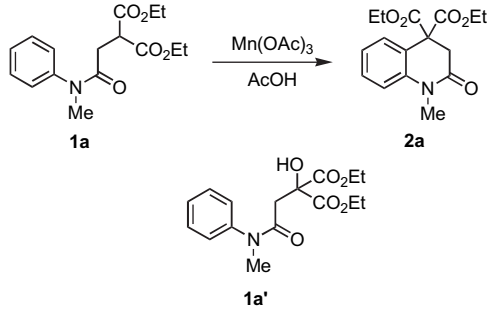
2-chloro-*N*-methylacetanilide, which was obtained by the reaction of *N*-methylaniline with 2-chloroacetyl chloride (two steps, 90% yield). With the malonate **1a** in hand, we examined the oxidation of **1a** with manganese(III) acetate under various reaction conditions. When the reaction of **1a** (0.5 mmol) with manganese(III) acetate (1.25 mmol) was carried out in glacial acetic acid (15 mL) at 80 °C, the desired 3,4-dihydro-2(1*H*)-quinolinone **2a** was fortunately obtained in a 60% yield together with a small amount of α-hydroxylated product **1a**′ of the malonate **1a** (Scheme 1 and Table 1, entry 1). The quinolinone **2a** was characterized by spectroscopic methods and elemental analysis (vide infra). The reaction was then optimized by dilution of the reaction mixture and the yield of **2a** was improved up to 97% (entry 6).



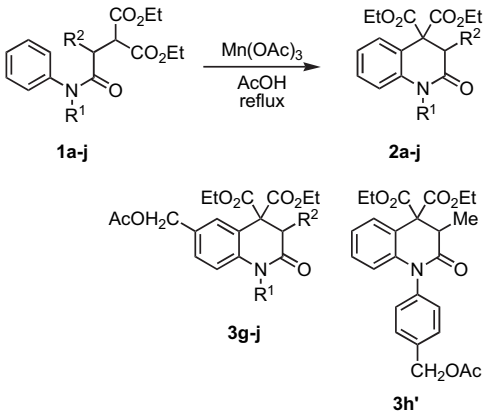
Scheme 1.

Table 1
Oxidation of malonate **1a** with $Mn(OAc)_3$[a]

Entry	**1a**: Mn(III)	AcOH (mL)	*T* (°C)	Time (min)	Product (yield/%)[b]	
1	1:2.5	15	80	240	**2a** (60)	**1a**′ (16)
2	1:2.5	15	100	60	**2a** (78)[c]	**1a**′ (6)
3	1:2.5	15	Reflux	18	**2a** (85)	
4	1:3.0	15	Reflux	30	**2a** (90)	
5[d]	1:3.0	15	Reflux	30	**2a** (90)	
6	1:3.0	30	Reflux	30	**2a** (97)	
7	1:3.0	50	Reflux	30	**2a** (91)	

[a] The reaction of malonate **1a** (0.5 mmol) was carried out in glacial acetic acid under ambient conditions.
[b] Isolated yield based on the amount of the malonate **1a** used.
[c] The malonate **1a** was recovered in 3% based on the ^1H NMR spectrum.
[d] The reaction was carried out under an argon atmosphere.

As we had an excellent yield from the reaction of **1a**, we applied the reaction to other diethyl 2-[2-(*N*-phenylamino)-2-oxoethyl]malonates **1b–j**. The malonates **1b–f** having a different substituent R^1 were prepared by the condensation of the corresponding 2-chloroacetanilides with diethyl malonate using the same reaction conditions for **1a**. The β-substituted malonates **1g–j** were prepared using the corresponding 2-bromoacetanilides at reflux temperature since the reaction using the corresponding 2-chloroacetanilides did not occur even under vigorous conditions. With the malonates **1b–j** in hand, a similar oxidation of **1b–j** was carried out under the optimized reaction conditions to give the desired 3,4-dihydro-2(1*H*)-quinolinones **2b–j** in excellent to moderate yields (Scheme 2 and Table 2). For the **1g–j** cases bearing either a methyl or a phenyl group at R^2, the reaction became very sluggish and a large excess amount of manganese(III) acetate was needed to completely consume the starting malonates **1g–j** (entries 10, 12, and 17). Probably, the substituent R^2 might hinder the cyclization. However, the cyclization actually occurred and, unfortunately, since an excess amount of the oxidant was used, the oxidation further proceeded and the acetoxymethylated dihydroquinolinones **3g–j** were also produced based on the electrophilic attack of carboxymethyl radical, $^{\bullet}CH_2CO_2H$, into the produced dihydroquinolinones **2g–j**.[3b,c] Therefore, the yield of the desired **2g–j** could not be improved any more (entries 7–18). The position of the acetoxymethyl group of **3g–j** was assigned by



Scheme 2.

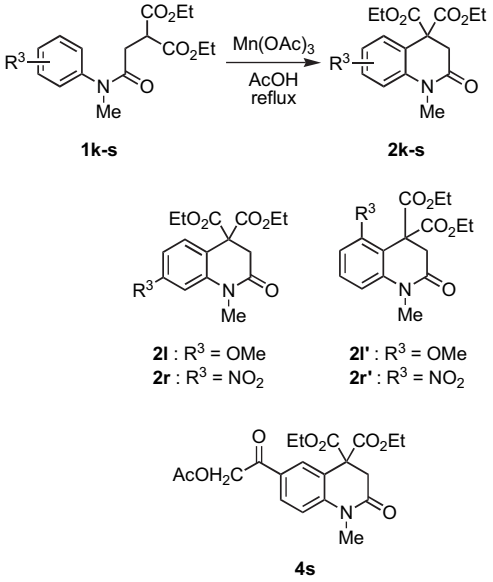
Table 2
Oxidation of malonates **1a–j** with $Mn(OAc)_3$[a]

Entry	Malonate			**1**:Mn(III)	Time (h)	Rec (%)	Product (yield/%)[b]	
		R^1	R^2					
1	**1a**	Me	H	1:3	0.5		**2a** (97)	
2	**1b**	Et	H	1:3	0.5		**2b** (98)	
3	**1c**	*i*-Pr	H	1:3	0.5		**2c** (93)	
4	**1d**	*n*-Bu	H	1:3	0.5		**2d** (92)	
5	**1e**	Ph	H	1:3	0.5		**2e** (100)	
6	**1f**	Bn	H	1:3	0.5		**2f** (93)	
7	**1g**	Me	Me	1:3	2.5	58	**2g** (32)	**3g** (trace)
8	**1g**	Me	Me	1:6	5	8	**2g** (65)	**3g** (18)
9	**1g**	Me	Me	1:8	5	5	**2g** (58)	**3g** (28)
10	**1g**	Me	Me	1:10	5		**2g** (61)	**3g** (28)
11	**1h**	Ph	Me	1:6	4	10	**2h** (65)	**3h**+**3h**′ (11+4)
12	**1h**	Ph	Me	1:8	5		**2h** (63)	**3h**+**3h**′ (15+7)
13	**1h**	Ph	Me	1:10	5		**2h** (58)	**3h**+**3h**′ (16+6)
14	**1i**	Me	Ph	1:10	5	16	**2i** (42)	**3i** (18)
15	**1i**	Me	Ph	1:15	6	8	**2i** (40)	**3i** (25)
16	**1i**	Me	Ph	1:20	8	5	**2i** (41)	**3i** (30)
17	**1i**	Me	Ph	1:25	9.5		**2i** (40)	**3i** (32)
18	**1j**	*i*-Pr	Ph	1:10	5	16	**2j** (44)	**3j** (18)

[a] The oxidation of the malonate **1** (0.5 mmol) was carried out in glacial acetic acid (30 mL) at reflux temperature under ambient conditions.
[b] Isolated yield based on the amount of the malonate **1** used.

the NOE experiment (see Experimental section). Although the malonates **1g–j** underwent the over-oxidation to give the minor acetoxymethylated dihydroquinolinones **3g–j**, which could be easily separated by silica gel chromatography, we convinced that the reaction must be convenient for the synthesis of dihydroquinolinone scaffold.

In order to examine the substituent effect on the *N*-phenyl group of **1**, we next explored the reaction of various diethyl 2-[2-(*N*-arylamino)-2-oxoethyl]malonates **1k–s**. As a result, the corresponding 3,4-dihydro-2(1*H*)-quinolinones **2k–s** were obtained in excellent to good yields (Scheme 3 and Table 3). In the case of **1l**, the two possible regioisomers **2l** and **2l′** were obtained in comparable yields (entry 2). The structures of **2l** and **2l′** were confirmed by the NOE experiment. Protection of the amide nitrogen using the *para*-methoxybenzyl (PMB) group instead of the methyl group had little influence on the reaction (entry 5 and footnote c). Surprisingly, the reaction of the nitro-substituted **1q** gave the desired **2q** in an excellent yield (entry 7). Furthermore, the regioisomer **1r** also yielded the corresponding regioisomeric quinolinones **2r** and **2r′** (entry 8). Considering the propensity of the electron-deficient malonyl radical intermediate (vide infra), it is quite interesting that the reaction of **1q** and **1r** containing the strong electron-withdrawing nitro group on the aromatic ring affords the corresponding nitrodihydroquinolinones **2q** and **2r** in significantly high yields. This could probably be attributed to the significant electron-donating effect of the amide moiety. Acetyl-substituted **1s** also afforded the dihydroquinolinone **2s** in a 61% yield together with an over-oxidation product **4s** (entry 9).



Scheme 3.

Unexpectedly, the reaction of the 2,4-dimethoxyphenyl-substituted malonate **1t** did not give any dihydroquinolinones, but a spirolactam **5t** was produced as the sole product (Table 4, entry 1). In order to scrutinize the relationship between the regioselectivity for the radical 6-*endo*/5-*exo* cyclization of the malonates **1** and the substituent R^3 on the aromatic ring, we examined the reaction of 2-methoxyphenyl-substituted malonate **1u**. As a result, the corresponding spirolactams **6u** and **7u** along with **5t** were preferentially produced besides the corresponding dihydroquinolinone **2u** in only a 23% yield (Table 4, entry 2). In addition, it was found that the spirolactams **6u** and **7u** were gradually transformed into **5t** in air for several days. The *ortho*-substituted analog **1v** also underwent the same reaction to afford the dihydroquinolinone **2v** and an inseparable mixture of the spirolactams **6v** and **7v**, each of which was formed as a single diastereoisomer (Table 4, entry 3). In contrast, the reaction of the bicyclic malonate **1w** quantitatively gave the tricyclic dihydroquinolinone **2w** (Table 4, entry 4). Furthermore, we also conducted the oxidative cyclization of **1x** and **1y** and obtained the dihydroquinolinones **2x** and **2y** in moderate yields (Table 4, entries 5 and 6). In both cases, the acetoxymethylated dihydroquinolinones **9x** and **9y** were also produced. The acetoxymethyl group was introduced at the 7-position of the formed dihydroquinolinones **2x** and **2y**, which was confirmed by the NOE experiments (see Experimental section). In addition, the spirolactam **10x** was also isolated from the reaction of **1x** (Table 4, entry 5).

Table 3
Oxidation of malonates **1k–s** with $Mn(OAc)_3$[a]

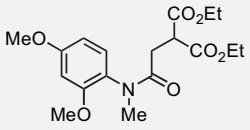
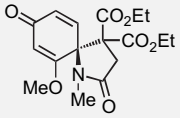
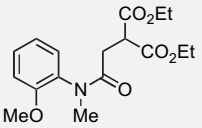
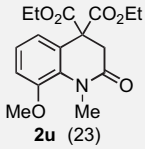
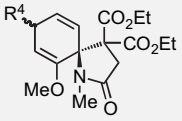
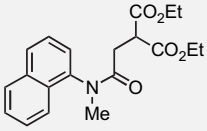
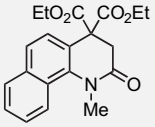
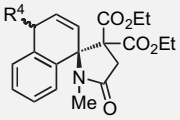
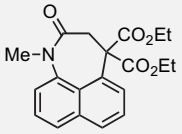
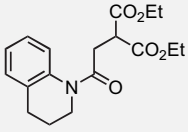
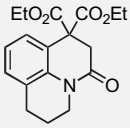
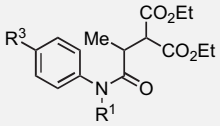
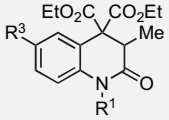
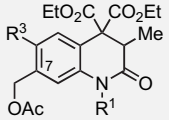
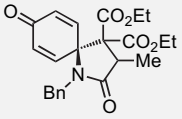
Entry	Malonate	R^3	**1**:Mn(III)	Time (min)	Product (yield/%)[b]	
1	**1k**	4-MeO	1:3	30	**2k** (97)	
2	**1l**	3-MeO	1:3	30	**2l** (46)	**2l′** (51)
3	**1m**	4-Me	1:4	30	**2m** (97)	
4	**1n**	4-Cl	1:4	30	**2n** (88)	
5[c]	**1o**	4-Cl	1:3	30	**2o** (85)	
6	**1p**	4-F	1:3	30	**2p** (95)	
7	**1q**	4-NO_2	1:3	30	**2q** (92)	
8	**1r**	3-NO_2	1:3.5	30	**2r** (76)	**2r′** (15)
9	**1s**	4-Ac	1:4	30	**2s** (61)	**4s** (28)

[a] The oxidation of the malonate **1** (0.5 mmol) was carried out in glacial acetic acid (30 mL) at reflux temperature under ambient conditions.
[b] Isolated yield based on the amount of the malonate **1** used.
[c] The *p*-methoxybenzyl group (PMB) was substituted on the amide nitrogen instead of the methyl group.

2.2. Structure determination of dihydroquinolinone 2a and spirolactam 5t

Comparing the ^{1}H NMR spectrum of the starting malonate **1a** with that of the product **2a**, the characteristic triplet methine proton (δ 3.96 ppm, J=7.3 Hz) of the malonate **1a** disappeared and a doublet of the methylene protons (δ 2.66 ppm, J=7.3 Hz) of **1a** collapsed into a sharp singlet (δ 3.23 ppm) in the ^{1}H NMR spectrum of **2a**. In addition, the aromatic protons of **2a** showed an ABCD splitting pattern. The corresponding methine carbon of **1a** changed into a quaternary carbon in the ^{13}C NMR spectrum of **2a**. Furthermore, the sp^2 carbon with no attached proton appeared at δ 122 ppm assigned to one of the aromatic carbons *ortho* to the amino group of **2a**. These spectroscopic data supported the fact that the structure of the product **2a** must be 4,4-bis(ethoxycarbonyl)-3,4-dihydro-2(1*H*)-quinolinone, and the combustion analysis was also identical to the structural formula $C_{16}H_{19}NO_5$. The NMR spectrum of the product **5t** was completely different from that of the 3,4-dihydro-2(1*H*)-quinolinone ring system. The doublet of the aromatic proton *ortho* to the amino group of **1t** remained as a doublet of the vinyl proton (δ 6.66 ppm, J=10.3 Hz), which was assigned by the NOE experiment in the ^{1}H NMR spectrum of **5t**. In addition, the characteristic triplet methine proton (δ 3.92 ppm, J=7.3 Hz) of **1t** disappeared and the two double-doublets of the methylene protons at δ 2.75 ppm (1H, J=17.2, 8.4 Hz) and δ 2.48 ppm (1H, J=17.2, 6.2 Hz) of **1t** collapsed into an AB quartet at δ 3.31 ppm (1H, J=17.2 Hz) and δ 2.84 ppm (1H, J=17.2 Hz) of **5t**. In the ^{13}C NMR spectrum of the product **5t**, the keto carbonyl carbon and the characteristic spirocarbon appeared at δ 185.6 and 66.4 ppm, respectively. In addition, four carbonyl groups appeared at ν 1740, 1719, 1670, and 1634 cm^{-1} in the IR spectrum. Accordingly, the product **5t** was determined to be 4,4-bis(ethoxycarbonyl)-6-methoxy-1-methyl-1-azaspiro[4,5]deca-6,9-diene-2,8-dione, and the combustion analysis also agreed with the structure.

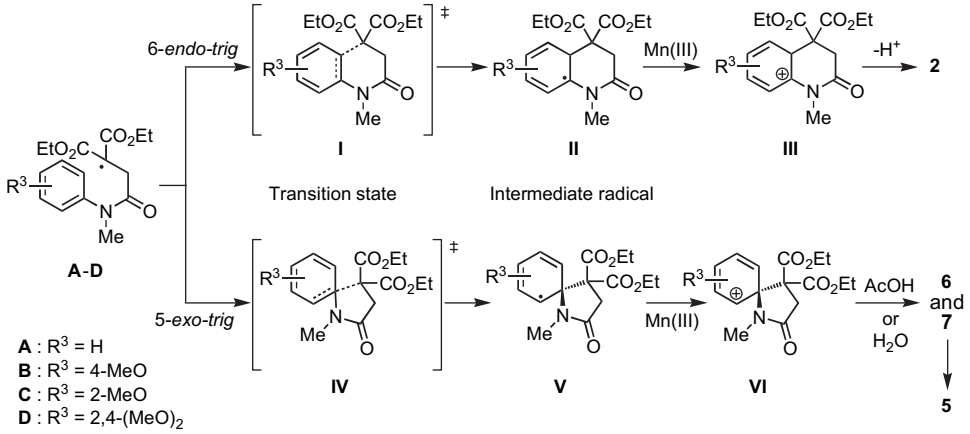
Table 4
Oxidation of malonates **1t–y** with $Mn(OAc)_3$[a]

Entry	1	1:Mn(III)	Time (h)	Product (yield/%)[b]		
1	 **1t**	1:3	0.5	 **5t** (85)		
2	 **1u**	1:3	0.5	 **2u** (23)	**5t** (6)	 **6u**: R^4 = OAc (21+11)[c] **7u**: R^4 = OH (24+12)[c]
3	 **1v**	1:3	0.5	 **2v** (61)	 **6v**: R^4 = OAc (4)[d] **7v**: R^4 = OH (6)[d]	 **8v** (24)
4	 **1w**	1:3	0.5	 **2w** (99)		
5	 **1x**: R^1 = Bn, R^3 = OMe	1:10	4.5	 **2x** (33)	 **9x** (16)	 **10x** (12)
6	**1y**: R^1=PMB, R^3=F	1:10	4.5	**2y** (40)	**9y** (28)	

[a] The oxidation of the malonate **1** (0.5 mmol) was carried out in glacial acetic acid (30 mL) at reflux temperature under ambient conditions.
[b] Isolated yield based on the amount of the malonate **1** used.
[c] Two diastereoisomers were isolated.
[d] The yield was determined by the integration of the ^1H NMR spectrum.

2.3. Reaction mechanism

The mechanism for the formation of the dihydroquinolinones **2** and the spirolactams **6** and **7** could be explained by the well-known oxidation mechanism outlined in Scheme 4.[4] In the case of the manganese(III) acetate oxidation, the ligand-exchange reaction of the acetate ligands with the malonates **1** must occur during the first stage followed by a one-electron oxidation to give the malonyl ligand radicals such as **A–D**.[3g] The 6-*endo-trig*[7] or 5-*exo-trig* cyclization of the malonyl radicals would be possible. For example, when the radical **C** from **1u** would cyclize according to the 6-*endo-trig* mode, the quinolinone intermediate radical **II** would be



Scheme 4.

produced and subsequently oxidized to give the dihydroquinolinone **2u** via deprotonation and aromatization. On the other hand, radical **C** would undergo the 5-*exo*-*trig* cyclization to afford the spirolactam intermediate radical **V**, which could be easily oxidized by manganese(III) species followed by attack of the solvent or water to finally give the spirolactams **6u** and **7u**. Although the intermediate cation **VI** might undergo anionotropic rearrangement to afford the cation **III**,[8] it should be ruled out for the different product formation and the difficulty of the rearrangement because of the sterically-crowded structure of **VI**.

In order to rationalize the 6-*endo*/5-*exo* regioselectivity of the oxidative cyclization of malonates **1**, the activation energy of each cyclization mode in **1a**, **1k**, **1u**, and **1t**, which led to the corresponding **A**–**D** radicals, respectively, was calculated by the UB3LYP/6-31G*//UHF/3-21G* method (Scheme 4, Table 5). All calculations were performed using the Spartan'06 program, and all stationary points were analyzed through computation of their vibrational

Table 5
Energies of intramolecular cyclization of malonyl radicals **A**–**D** calculated by UB3LYP/6-31G*//UHF/3-21G* method[a]

Reactant radical[b]	6-*endo*-*trig* Cyclization		5-*exo*-*trig* Cyclization	
	Transition state **I**	Intermediate radical **II**	Transition state **IV**	Intermediate radical **V**
A	9.12	−3.15	13.52	7.80
B	9.54	−3.12	12.68	6.53
C	8.22	−1.84	5.75	−0.64
D	12.11	2.01	8.11	3.37

[a] Energies are in kcal/mol.
[b] The reactant in the most stable conformation is taken as the reference.

frequencies. First of all, the activation energy of the 6-*endo* cyclization (**I**) was calculated using the radical **A** from **1a** and estimated to be 4.4 kcal/mol lower than that of the 5-*exo* cyclization (**IV**). In addition, it was found that the transition state of the 6-*endo* cyclization was the half-chair form because of the planar amide group (see Supplementary data). The transition state of the 6-*endo* cyclization (**I**) in the radical **B** from **1k** was ca. 3.1 kcal/mol more stable than that of the 5-*exo* cyclization (**IV**). These results indicate that the 6-*endo* cyclization of radicals **A** and **B** is kinetically preferred over the 5-*exo* cyclization, and furthermore, the resulting 6-*endo* intermediate radicals **II** are thermodynamically favored more than the 5-*exo* radicals **V**, which is in good agreement with the fact that the reaction of malonates, **1a** and **1k**, exclusively gave the dihydroquinolinones, **2a** and **2k**, respectively (Table 2, entry 1 and Table 3, entry 1).

We next calculated the transition state of the cyclization for radicals **C** and **D** from **1u** and **1t**, respectively. As a result, the energy barrier of the 5-*exo* cyclization (**IV**) is 2.5 and 4.0 kcal/mol, respectively, lower than that of the corresponding 6-*endo* cyclization (**I**). The data show that the introduction of a methoxy group *ortho* to the amino group on the aromatic ring changes the cyclization mode and the 5-*exo* cyclization becomes favored, probably because the 6-*endo* transition state **I** would be relatively destabilized by steric hindrance between the *ortho*-methoxy group of the aromatic ring and the methyl group attached to the amide nitrogen. As it is clear from the quantitative formation of the dihydroquinolinone **2w** from **1w** (Table 4, entry 4), the cyclic structure containing the nitrogen atom such as **1w** lead to **2w** through the 6-*endo* transition state **I**. Although the kinetic 6-*endo*/5-*exo* regioselectivity during the cyclization of radical **C** was predicted to be the ratio of 4:96 on the basis of the Boltzmann distribution from the difference in the activation energies, in fact, the dihydroquinolinone **2u** (6-*endo* product) and the spirolactams **5t**, **6u**, and **7u** (5-*exo* products) from radical **C** were obtained in the ratio of 24:76 (6-*endo*/5-*exo*) (Table 4, entry 2). Therefore, the thermodynamic control might reasonably contribute to the cyclization of radical **C**. It is known that the presence of two electron-withdrawing groups on the radical center such as α-dicarbonylalkyl radicals makes the cyclization reversible and change the regioselectivity from the kinetically favored 5-*exo* cyclization to the thermodynamically favored 6-*endo* cyclization since the radical is stabilized due to delocalization between the electron-withdrawing groups, and the cyclization is sterically hindered by the bulky electron-withdrawing groups.[9] For this reason, Citterio et al. deduced the presence of the reversible 5-*exo* cyclization process in the 6-*endo* cyclization reaction of the malonyl radicals onto the aromatic ring, however, unfortunately, the 5-*exo* cyclization product was not produced in their study.[6a] On the other hand, the reaction of the malonate **1t** gave the spirolactam **5t** as the sole product, which indicated that the reaction was thoroughly kinetically controlled (Table 4, entry 1). This is likely to be attributed to the ionization potential of the radical **D** having a 2,4-dimetoxyphenyl group, which must be lower than that of the radicals **B** and **C**. Therefore, once radical **D** undergoes the kinetically controlled 5-*exo* cyclization to produce the corresponding spiroradical **V**, which could be immediately subject to irreversible oxidation by the manganese(III) species followed by demethylation to exclusively give **5t**. This interpretation was supported by the fact that the reaction of **1x** gave the spirolactam **10x** besides the dihydroquinolonones **2x** and **9x**,[3b,c] whereas no spirolactams were obtained from the reaction of **1y** (Table 4, entries 6 and 5). This could also be attributed to the difference in the ionization potential of their intermediate radicals. The steric hindrance such as an *ortho*-alkyl substituent of the malonates **1** might also affect the 6-*endo*/5-*exo* cyclization mode. However, the most malonates **1** underwent the 6-*endo* cyclization under thermodynamic control to give the corresponding dihydroquinolinones **2** since the present cyclization was controlled by not only the steric hindrance of the *ortho*-substituent but also the ionization potential of the aromatic ring. Therefore, the spirolactamization might be specific for the methoxy-substituted **1t**, **1u**, **1x**, and the naphthyl-substituted **1v**.

3. Conclusion

We developed the manganese(III)-mediated convenient and useful synthesis of 4,4-bis(ethoxycarbonyl)-3,4-dihydro-2(1*H*)-quinolinones from the corresponding 2-[2-(*N*-arylamino)-2-oxoethyl]malonates **1**. It was found that the malonates **1** having not only electron-releasing but also electron-withdrawing groups on the aromatic ring of the aniline moiety efficiently underwent the oxidative cyclization to give the corresponding dihydroquinolinones **2**, **3**, **4**, and **9**. Furthermore, it was also possible to introduce the acetoxymethyl functionality into the dihydroquinolinone skeleton such as **3**, **4**, and **9** when an excess amount of the oxidant was used. The dihydroquinolinones **2**, **3**, **4**, and **9** could then be converted into the corresponding quinoline derivatives, which is currently underway. In addition, the oxidative cyclization of the *ortho*-substituted malonates having the relatively lower ionization potential, such as **1t**–**v** and **1x**, also led to the spirolactams **5**–**7** and **10**. The 6-*endo*/5-*exo* selectivity of the cyclization was interpreted to be due to the difference in the activation energy between the 6-*endo* and 5-*exo* cyclization.

4. Experimental

4.1. General

The NMR spectra were recorded in deuteriochloroform at 300 MHz for ^{1}H and at 75 MHz for ^{13}C, with tetramethylsilane as the internal standard. The chemical shifts are reported in δ values (ppm). The IR spectra were measured in chloroform or KBr, and expressed in cm^{-1}. The EIMS spectra were recorded at the ionizing voltage of 70 eV. Manganese(III) acetate dihydrate, $Mn(OAc)_3 \cdot 2H_2O$,

was prepared according to the method described in the literature.[3] The *N*-substituted 2-haloacetanilides were synthesized from the corresponding *N*-substituted anilines with 2-haloacetyl halides according to the method described in the literature.[10] 2-Bromophenylacetyl chloride was prepared by the bromination of phenylacetyl chloride.[11] *N*-Substituted anilines were prepared from a primary aniline and an aldehyde by the known route,[10b,12] except for *p*-acetyl-*N*-methylaniline, which was prepared from *p*-fluoroacetophenone according to the literature.[13]

4.2. General procedure for the preparation of diethyl 2-[2-(*N*-arylamino)-2-oxoethyl]malonates 1a–y

Diethyl malonate (20 mmol) and dry THF (50 mL) were placed in a 200 mL round-bottomed flask to which was carefully added sodium hydride (60% in mineral oil, 20 mmol) (*CAUTION*: H_2 gas evolution), which was then stirred at ambient temperature for 30 min. To the mixture was added a solution of the *N*-substituted 2-haloacetanilides (10 mmol) in dry THF (10 mL) and stirred for 2 h at ambient temperature or heated under reflux for 12 h until the starting acetanilides were completely consumed. The solvent was removed in vacuo and the residue was triturated with water followed by acidification with a 2 M HCl aqueous solution. The resulting aqueous solution was extracted with dichloromethane (30 mL×3) and the combined extract was washed with water. The organic layer was dried over anhydrous magnesium sulfate and concentrated to dryness. The obtained crude product was purified by silica gel flash column chromatography. The analytical samples were further purified by recrystallization from the solvent specified in parentheses except for the liquid products.

*4.2.1. Diethyl 2-[2-(N-methyl-N-phenylamino)-2-oxoethyl]malonate (**1a**).* R_f=0.45 (diethyl ether–hexane, 8:2 v/v); colorless oil; IR ($CHCl_3$) ν 1744, 1724, 1651 (C=O); ^{1}H NMR (300 MHz, $CDCl_3$) δ 7.48–7.22 (5H, m), 4.26–4.08 (4H, m), 3.96 (1H, t, J=7.3 Hz), 3.26 (3H, s), 2.66 (2H, d, J=7.3 Hz), 1.24 (6H, t, J=7.3 Hz); ^{13}C NMR (75 MHz, $CDCl_3$) δ 169.6, 169.0, 143.2, 129.8, 127.9, 127.2, 61.4, 48.1, 37.3, 33.3, 13.8. FAB HRMS (acetone–NBA) calcd for $C_{16}H_{22}NO_5$ 308.1498 (M+H). Found 308.1499.

*4.2.2. Diethyl 2-[2-(N-ethyl-N-phenylamino)-2-oxoethyl]malonate (**1b**).* R_f=0.44 (diethyl ether–hexane, 7:3 v/v); colorless oil; IR ($CHCl_3$) ν 1744, 1728, 1651 (C=O); ^{1}H NMR (300 MHz, $CDCl_3$) δ 7.49–7.21 (5H, m), 4.24–4.07 (4H, m), 3.96 (1H, t, J=7.3 Hz), 3.74 (2H, q, J=7.3 Hz), 2.62 (2H, d, J=7.3 Hz), 1.23 (6H, t, J=7.3 Hz), 1.10 (3H, t, J=7.3 Hz); ^{13}C NMR (75 MHz, $CDCl_3$) δ 169.6, 169.1, 141.7, 129.9, 128.5, 128.2, 61.4, 48.3, 44.2, 33.8, 14.0, 13.0. FAB HRMS (acetone–NBA) calcd for $C_{17}H_{24}NO_5$ 322.1654 (M+H). Found 322.1647.

*4.2.3. Diethyl 2-[2-oxo-2-(N-phenyl-N-isopropylamino)ethyl]malonate (**1c**).* R_f=0.44 (diethyl ether–hexane, 5:5 v/v); colorless microcrystals (from diethyl ether–hexane); mp 45 °C; IR ($CHCl_3$) ν 1744, 1728, 1651 (C=O); ^{1}H NMR (300 MHz, $CDCl_3$) δ 7.49–7.16 (5H, m), 5.06–4.89 (1H, m), 4.23–4.05 (4H, m), 3.96 (1H, t, J=7.3 Hz), 2.52 (2H, d, J=7.3 Hz), 1.22 (6H, t, J=7.3 Hz), 1.04 (6H, d, J=7.0 Hz); ^{13}C NMR (75 MHz, $CDCl_3$) δ 168.4, 168.3, 137.4, 129.7, 128.8, 127.9, 60.6, 47.5, 45.6, 33.7, 20.2, 13.3. FAB HRMS (acetone–NBA) calcd for $C_{18}H_{26}NO_5$ 336.1811 (M+H). Found 336.1812.

*4.2.4. Diethyl 2-[2-(N-butyl-N-phenylamino)-2-oxoethyl]malonate (**1d**).* R_f=0.43 (diethyl ether–hexane, 5:5 v/v); colorless oil; IR ($CHCl_3$) ν 1744, 1728, 1651 (C=O); ^{1}H NMR (300 MHz, $CDCl_3$) δ 7.49–7.21 (5H, m), 4.23–4.05 (4H, m), 3.97 (1H, t, J=7.3 Hz), 3.70 (2H, t, J=7.3 Hz), 2.63 (2H, d, J=7.3 Hz), 1.56–1.45 (2H, m), 1.37–1.14 (8H, m), 0.86 (3H, t, J=7.3 Hz); ^{13}C NMR (75 MHz, $CDCl_3$) δ 169.1, 168.9, 141.8, 129.7, 128.2, 127.9, 61.3, 49.0, 48.0, 33.6, 29.6, 19.7, 13.8, 13.6. FAB HRMS (acetone–NBA) calcd for $C_{19}H_{28}NO_5$ 350.1967 (M+H). Found 350.1925.

*4.2.5. Diethyl 2-[2-(N,N-diphenylamino)-2-oxoethyl]malonate (**1e**).* R_f=0.35 (diethyl ether–hexane, 5:5 v/v); colorless plates (from diethyl ether–hexane); mp 77 °C; IR ($CHCl_3$) ν 1744, 1728, 1668 (C=O); ^{1}H NMR (300 MHz, $CDCl_3$) δ 7.46–7.07 (10H, m), 4.25–4.09 (4H, m), 4.04 (1H, t, J=7.3 Hz), 2.85 (2H, d, J=7.3 Hz), 1.23 (6H, t, J=7.3 Hz); ^{13}C NMR (75 MHz, $CDCl_3$) δ 169.6, 168.7, 142.1, 129.7, 128.5, 127.9, 125.9, 61.3, 48.1, 34.3, 13.7. Anal. Calcd for $C_{21}H_{23}NO_5$: C, 68.28; H, 6.28; N, 3.79. Found: C, 68.12; H, 6.29; N, 3.69.

*4.2.6. Diethyl 2-[2-(N-benzyl-N-phenylamino)-2-oxoethyl]malonate (**1f**).* R_f=0.41 (diethyl ether–hexane, 6:4 v/v); colorless needles (from diethyl ether–hexane); mp 57–58 °C; IR ($CHCl_3$) ν 1744, 1728, 1655 (C=O); ^{1}H NMR (300 MHz, $CDCl_3$) δ 7.32–7.01 (10H, m), 4.87 (2H, s), 4.24–4.06 (4H, m), 4.03 (1H, t, J=7.3 Hz), 2.68 (2H, d, J=7.3 Hz), 1.21 (6H, t, J=7.3 Hz); ^{13}C NMR (75 MHz, $CDCl_3$) δ 169.3, 168.7, 141.3, 136.9, 129.3, 128.2, 128.0, 127.9, 127.0, 61.1, 52.8, 47.9, 33.4, 13.6. Anal. Calcd for $C_{22}H_{25}NO_5$: C, 68.91; H, 6.57; N, 3.65. Found: C, 68.75; H, 6.62; N, 3.58.

*4.2.7. Diethyl 2-[1-methyl-2-(N-methyl-N-phenylamino)-2-oxoethyl]malonate (**1g**).* R_f=0.40 (ethyl acetate–hexane, 3:7 v/v); colorless oil; IR ($CHCl_3$) ν 1744, 1726, 1647 (C=O); ^{1}H NMR (300 MHz, $CDCl_3$) δ 7.52–7.31 (5H, m), 4.29–4.05 (4H, m), 3.88 (1H, d, J=10.6 Hz), 3.26 (3H, s), 3.21–3.07 (1H, m), 1.31–1.17 (6H, m), 0.98 (3H, d, J=7.0 Hz); ^{13}C NMR (75 MHz, $CDCl_3$) δ 173.9, 168.5, 168.4, 143.4, 129.6, 127.7, 127.5, 61.2, 55.2, 37.5, 36.4, 15.5, 13.8. FAB HRMS (acetone–NBA) calcd for $C_{17}H_{24}NO_5$ 322.1654 (M+H). Found 322.1698.

*4.2.8. Diethyl 2-[2-(N,N-diphenylamino)-1-methyl-2-oxoethyl]malonate (**1h**).* R_f=0.35 (ethyl acetate–hexane, 2:8 v/v); colorless microcrystals (from diethyl ether–hexane); mp 62–63 °C; IR ($CHCl_3$) ν 1745, 1728, 1663 (C=O); ^{1}H NMR (300 MHz, $CDCl_3$) δ 7.60–7.05 (10H, m), 4.27–4.04 (4H, m), 3.94 (1H, d, J=11.0 Hz), 3.40–3.27 (1H, m), 1.22 (3H, t, J=7.3 Hz), 1.19 (3H, t, J=7.3 Hz), 1.13 (3H, d, J=7.0 Hz); ^{13}C NMR (75 MHz, $CDCl_3$) δ 174.4, 168.6, 142.9, 142.5, 129.8, 129.0, 128.9, 128.0, 126.6, 126.2, 61.5, 61.4, 55.5, 37.4, 15.7, 14.0. Anal. Calcd for $C_{22}H_{25}NO_5$: C, 68.91; H, 6.57; N, 3.65. Found: C, 68.98; H, 6.57; N, 3.79.

*4.2.9. Diethyl 2-[2-(N-methyl-N-phenylamino)-2-oxo-1-phenylethyl]malonate (**1i**).* R_f=0.26 (ethyl acetate–hexane, 2:8 v/v); colorless amorphous; IR ($CHCl_3$) ν 1744, 1728, 1651 (C=O); ^{1}H NMR (300 MHz, $CDCl_3$) δ 7.42–6.80 (10H, m), 4.34 (1H, d, J=11.7 Hz), 4.30–4.16 (3H, m), 3.76 (2H, q, J=7.3 Hz), 3.20 (3H, s), 1.28 (3H, t, J=7.3 Hz), 0.79 (3H, t, J=7.3 Hz); ^{13}C NMR (75 MHz, $CDCl_3$) δ 170.6, 168.2, 167.7, 142.7, 135.0, 129.2, 128.5, 128.0, 127.7, 127.3, 61.4, 60.8, 56.1, 48.7, 37.6, 13.8, 13.3. FAB HRMS (acetone–NBA) calcd for $C_{22}H_{26}NO_5$ 384.1811 (M+H). Found 384.1812.

*4.2.10. Diethyl 2-[2-oxo-1-phenyl-2-(N-phenyl-N-isopropylamino)ethyl]malonate (**1j**).* R_f=0.38 (ethyl acetate–hexane, 2:8 v/v); colorless oil; IR ($CHCl_3$) ν 1744, 1728, 1643 (C=O); ^{1}H NMR (300 MHz, $CDCl_3$) δ 7.54–6.81 (9H, m), 6.33–6.27 (1H, m), 5.02–4.87 (1H, m), 4.31 (1H, d, J=11.7 Hz), 4.23 (2H, q, J=7.3 Hz), 3.99 (1H, d, J=11.7 Hz), 3.75 (2H, q, J=7.3 Hz), 1.28 (3H, t, J=7.3 Hz), 1.02 (3H, d, J=7.0 Hz), 0.92 (3H, d, J=7.0 Hz), 0.79 (3H, t, J=7.3 Hz); ^{13}C NMR (75 MHz, $CDCl_3$) δ 169.9, 168.3, 167.9, 137.2, 135.4, 131.1, 130.9, 129.1, 128.6, 128.1, 128.0, 127.3, 61.4, 60.8, 56.4, 49.7, 46.3, 20.7, 20.3, 13.9, 13.4. FAB HRMS (acetone–NBA) calcd for $C_{24}H_{30}NO_5$ 412.2124 (M+H). Found 412.2106.

*4.2.11. Diethyl 2-{2-[N-methyl-N-(4-methoxyphenyl)amino]-2-oxoethyl}malonate (**1k**).* R_f=0.41 (diethyl ether–hexane, 8:2 v/v);

colorless oil; IR ($CHCl_3$) ν 1744, 1728, 1651 (C=O); ^{1}H NMR (300 MHz, $CDCl_3$) δ 7.23–7.14 (2H, m), 6.99–6.91 (2H, m), 4.26–4.07 (4H, m), 3.94 (1H, t, J=7.3 Hz), 3.82 (3H, s), 3.22 (3H, s), 2.66 (2H, d, J=7.3 Hz), 1.24 (6H, t, J=7.3 Hz); ^{13}C NMR (75 MHz, $CDCl_3$) δ 169.4, 168.6, 158.6, 135.6, 127.9, 114.5, 60.9, 54.9, 47.7, 36.9, 32.9, 13.4. FAB HRMS (acetone–NBA) calcd for $C_{17}H_{24}NO_6$ 338.1604 (M+H). Found 338.1606.

*4.2.12. Diethyl 2-{2-[N-methyl-N-(3-methoxyphenyl)amino]-2-oxoethyl}malonate (**1l**).* R_f=0.53 (diethyl ether–hexane, 8:2 v/v); colorless blocks (from diethyl ether–hexane); mp 56–57 °C; IR ($CHCl_3$) ν 1744, 1728, 1651 (C=O); ^{1}H NMR (300 MHz, $CDCl_3$) δ 7.39–7.28 (1H, m), 6.96–6.81 (3H, m), 4.26–4.05 (4H, m), 3.95 (1H, t, J=7.3 Hz), 3.80 (3H, s), 3.23 (3H, s), 2.72 (2H, d, J=7.3 Hz), 1.23 (6H, t, J=7.3 Hz); ^{13}C NMR (75 MHz, $CDCl_3$) δ 168.7, 168.2, 159.9, 143.8, 129.8, 118.7, 112.8, 112.4, 60.6, 54.5, 47.4, 36.4, 32.5, 13.1. FAB HRMS (acetone–NBA) calcd for $C_{17}H_{24}NO_6$ 338.1604 (M+H). Found 338.1606.

*4.2.13. Diethyl 2-{2-[N-methyl-N-(4-methylphenyl)amino]-2-oxoethyl}malonate (**1m**).* R_f=0.48 (ethyl acetate–hexane, 4:6 v/v); colorless microcrystals (from diethyl ether–hexane); mp 44 °C; IR ($CHCl_3$) ν 1744, 1728, 1651 (C=O); ^{1}H NMR (300 MHz, $CDCl_3$) δ 7.26–7.20 (2H, m), 7.17–7.10 (2H, m), 4.25–4.08 (4H, m), 3.95 (1H, t, J=7.3 Hz), 3.23 (3H, s), 2.66 (2H, d, J=7.3 Hz), 2.38 (3H, s), 1.24 (6H, t, J=7.3 Hz); ^{13}C NMR (75 MHz, $CDCl_3$) δ 169.5, 168.9, 140.5, 137.7, 130.2, 126.8, 61.2, 48.0, 37.1, 33.2, 20.7, 13.7. FAB HRMS (acetone–NBA) calcd for $C_{17}H_{24}NO_5$ 322.1654 (M+H). Found 322.1649.

*4.2.14. Diethyl 2-{2-[N-(4-chlorophenyl)-N-methylamino]-2-oxoethyl}malonate (**1n**).* R_f=0.40 (ethyl acetate–hexane, 4:6 v/v); colorless amorphous; IR ($CHCl_3$) ν 1744, 1724, 1655 (C=O); ^{1}H NMR (300 MHz, $CDCl_3$) δ 7.44–7.38 (2H, m), 7.25–7.20 (2H, m), 4.26–4.09 (4H, m), 3.95 (1H, t, J=7.3 Hz), 3.23 (3H, s), 2.64 (2H, d, J=7.3 Hz), 1.25 (6H, t, J=7.3 Hz); ^{13}C NMR (75 MHz, $CDCl_3$) δ 169.3, 168.8, 141.7, 133.6, 129.9, 128.6, 61.3, 47.9, 37.1, 33.2, 13.7. FAB HRMS (acetone–NBA) calcd for $C_{16}H_{21}ClNO_5$ 342.1108 (M+H). Found 342.1092.

*4.2.15. Diethyl 2-{2-[N-(4-chlorophenyl)-N-(4-methoxybenzyl)-amino]-2-oxoethyl}malonate (**1o**).* R_f=0.33 (diethyl ether–hexane, 5:5 v/v); colorless oil; IR ($CHCl_3$) ν 1744, 1728, 1655 (C=O); ^{1}H NMR (300 MHz, $CDCl_3$) δ 7.34–6.74 (8H, m), 4.78 (2H, s), 4.26–4.09 (4H, m), 4.01 (1H, t, J=7.3 Hz), 3.75 (3H, s), 2.62 (2H, d, J=7.3 Hz), 1.24 (6H, t, J=7.3 Hz); ^{13}C NMR (75 MHz, $CDCl_3$) δ 169.1, 168.7, 158.7, 139.8, 133.8, 129.8, 129.7, 128.7, 113.5, 61.3, 54.9, 52.1, 48.0, 33.4, 13.7. FAB HRMS (acetone–NBA) calcd for $C_{23}H_{27}ClNO_6$ 448.1527 (M+H). Found 448.1601.

*4.2.16. Diethyl 2-{2-[N-(4-fluorophenyl)-N-methylamino]-2-oxoethyl}malonate (**1p**).* R_f=0.54 (diethyl ether–hexane, 8:2 v/v); colorless oil; IR ($CHCl_3$) ν 1742, 1724, 1653 (C=O); ^{1}H NMR (300 MHz, $CDCl_3$) δ 7.32–7.25 (2H, m), 7.18–7.10 (2H, m), 4.26–4.08 (4H, m), 3.95 (1H, t, J=7.3 Hz), 3.24 (3H, s), 2.65 (2H, d, J=7.3 Hz), 1.25 (6H, t, J=7.3 Hz); ^{13}C NMR (75 MHz, $CDCl_3$) δ 169.8, 169.1, 162.0, 139.6, 129.4, 116.9, 61.6, 48.3, 37.5, 33.5, 14.0. FAB HRMS (acetone–NBA) calcd for $C_{16}H_{21}FNO_5$ 326.1404 (M+H). Found 326.1456.

*4.2.17. Diethyl 2-{2-[N-methyl-N-(4-nitrophenyl)amino]-2-oxoethyl}malonate (**1q**).* R_f=0.32 (ethyl acetate–hexane, 4:6 v/v); yellow oil; IR ($CHCl_3$) ν 1744, 1728, 1665 (C=O); ^{1}H NMR (300 MHz, $CDCl_3$) δ 8.34–8.28 (2H, m), 7.54–7.48 (2H, m), 4.29–4.11 (4H, m), 3.99 (1H, t, J=7.3 Hz), 3.36 (3H, s), 2.79 (2H, br d, J=7.3 Hz), 1.27 (6H, t, J=7.3 Hz); ^{13}C NMR (75 MHz, $CDCl_3$) δ 169.5, 168.9, 149.1, 146.6, 127.9, 125.2, 61.8, 48.2, 37.5, 33.6, 14.0. FAB HRMS (acetone–NBA) calcd for $C_{16}H_{21}N_2O_7$ 353.1349 (M+H). Found 353.1335.

*4.2.18. Diethyl 2-{2-[N-methyl-N-(3-nitrophenyl)amino]-2-oxoethyl}malonate (**1r**).* R_f=0.39 (ethyl acetate–hexane, 4:6 v/v); yellow amorphous; IR ($CHCl_3$) ν 1742, 1728, 1666 (C=O); ^{1}H NMR (300 MHz, $CDCl_3$) δ 8.30–8.14 (2H, m), 7.72–7.64 (2H, m), 4.28–4.11 (4H, m), 3.98 (1H, t, J=7.3 Hz), 3.34 (3H, br s), 2.68 (2H, br s), 1.27 (6H, t, J=7.3 Hz); ^{13}C NMR (75 MHz, $CDCl_3$) δ 169.6, 168.9, 149.0, 144.5, 133.8, 130.9, 122.9, 122.6, 61.8, 48.2, 37.6, 33.5, 14.0. FAB HRMS (acetone–NBA) calcd for $C_{16}H_{21}N_2O_7$ 353.1349 (M+H). Found 353.1299.

*4.2.19. Diethyl 2-{2-[N-(4-acetylphenyl)-N-methylamino]-2-oxoethyl}malonate (**1s**).* R_f=0.38 (ethyl acetate–hexane, 5:5 v/v); colorless oil; IR ($CHCl_3$) ν 1744, 1728, 1686, 1601 (C=O); ^{1}H NMR (300 MHz, $CDCl_3$) δ 8.09–8.02 (2H, m), 7.43–7.37 (2H, m), 4.27–4.10 (4H, m), 3.97 (1H, t, J=7.3 Hz), 3.31 (3H, s), 2.73 (2H, br s), 2.64 (3H, s), 1.26 (6H, t, J=7.3 Hz); ^{13}C NMR (75 MHz, $CDCl_3$) δ 197.0, 169.5, 169.0, 147.5, 136.3, 130.0, 127.4, 61.7, 48.2, 37.3, 33.6, 26.7, 14.0. FAB HRMS (acetone–NBA) calcd for $C_{18}H_{24}NO_6$ 350.1604 (M+H). Found 350.1569.

*4.2.20. Diethyl 2-[2-(2,4-dimethoxyphenyl)methylamino-2-oxoethyl]malonate (**1t**).* R_f=0.41 (ethyl acetate–hexane, 5:5 v/v); yellow oil; IR ($CHCl_3$) ν 1744, 1728, 1651 (C=O); ^{1}H NMR (300 MHz, $CDCl_3$) δ 7.17–7.08 (1H, m), 6.58–6.46 (2H, m), 4.28–4.06 (4H, m), 3.92 (1H, dd, J=8.4, 6.2 Hz), 3.83 (6H, s), 3.13 (3H, s), 2.75 (1H, dd, J=17.2, 8.4 Hz), 2.48 (1H, dd, J=17.2, 6.2 Hz), 1.32–1.19 (6H, m); ^{13}C NMR (75 MHz, $CDCl_3$) δ 170.6, 169.1, 160.4, 155.7, 129.3, 124, 104.5, 99.4, 61.2, 55.3, 48.0, 36.1, 32.6, 13.8. FAB HRMS (acetone–NBA) calcd for $C_{18}H_{26}NO_7$ 368.1709 (M+H). Found 368.1707.

*4.2.21. Diethyl 2-{2-[N-methyl-N-(2-methoxyphenyl)amino]-2-oxoethyl}malonate (**1u**).* R_f=0.47 (diethyl ether–hexane, 8:2 v/v); colorless oil; IR ($CHCl_3$) ν 1744, 1728, 1651 (C=O); ^{1}H NMR (300 MHz, $CDCl_3$) δ 7.38–6.96 (4H, m), 4.26–4.06 (4H, m), 3.93 (1H, dd, J=8.4, 6.6 Hz), 3.85 (3H, s), 3.16 (3H, s), 2.75 (1H, dd, J=16.9, 8.4 Hz), 2.50 (1H, dd, J=16.9, 6.6 Hz), 1.25 (3H, t, J=7.3 Hz), 1.23 (3H, t, J=7.3 Hz); ^{13}C NMR (75 MHz, $CDCl_3$) δ 169.9, 168.7, 154.7, 131.2, 129.3, 128.7, 120.9, 111.8, 61.0, 60.9, 55.1, 47.8, 35.7, 32.4, 13.5. FAB HRMS (acetone–NBA) calcd for $C_{17}H_{24}NO_6$ 338.1604 (M+H). Found 338.1602.

*4.2.22. Diethyl 2-{2-[N-methyl-N-(1-naphthyl)amino]-2-oxoethyl}-malonate (**1v**).* R_f=0.43 (ethyl acetate–hexane, 4:6 v/v); colorless blocks (from diethyl ether–hexane); mp 64–65 °C; IR ($CHCl_3$) ν 1744, 1728, 1655 (C=O); ^{1}H NMR (300 MHz, $CDCl_3$) δ 7.96–7.41 (7H, m), 4.21–4.05 (4H, m), 3.98 (1H, t, J=7.3 Hz), 3.35 (3H, s), 2.78 (1H, dd, J=16.9, 7.3 Hz), 2.40 (1H, dd, J=16.9, 7.3 Hz), 1.25–1.15 (6H, m); ^{13}C NMR (75 MHz, $CDCl_3$) δ 170.1, 168.8, 168.6, 139.1, 134.5, 129.7, 128.7, 128.4, 127.3, 126.5, 125.7, 125.5, 121.9, 61.2, 61.1, 47.8, 36.9, 32.8, 13.7. Anal. Calcd for $C_{20}H_{23}NO_5$: C, 67.21; H, 6.49; N, 3.92. Found: C, 67.26; H, 6.51; N, 3.87.

*4.2.23. Diethyl 2-[2-(3,4-dihydro-1(2H)-quinolinyl)-2-oxoethyl]-malonate (**1w**).* R_f=0.33 (diethyl ether–hexane, 5:5 v/v); colorless microcrystals (from diethyl ether–hexane); mp 71–72 °C; IR ($CHCl_3$) ν 1744, 1728, 1647 (C=O); ^{1}H NMR (300 MHz, $CDCl_3$) δ 7.59–6.98 (4H, m), 4.27–4.08 (4H, m), 4.01 (1H, t, J=7.3 Hz), 3.76 (2H, t, J=6.6 Hz), 3.09 (2H, d, J=7.3 Hz), 2.72 (2H, t, J=6.6 Hz), 1.94 (2H, quin, J=6.6 Hz), 1.25 (6H, t, J=7.3 Hz); ^{13}C NMR (75 MHz, $CDCl_3$) δ 169.0, 168.6, 138.1, 133.4, 128.2, 125.7, 125.1, 124.3, 61.1, 48.1, 42.8, 33.5, 26.2, 23.5, 13.6. Anal. Calcd for $C_{18}H_{23}NO_5$: C, 64.85; H, 6.95; N, 4.20. Found: C, 65.00; H, 6.97; N, 4.10.

*4.2.24. Diethyl 2-{1-methyl-2-[N-benzyl-N-(4-methoxyphenyl)-amino]-2-oxoethyl}malonate (**1x**).* R_f=0.33 (ethyl acetate–hexane, 2:8 v/v); colorless oil; IR ($CHCl_3$) ν 1745, 1726, 1647 (C=O); ^{1}H NMR (300 MHz, $CDCl_3$) δ 7.29–6.79 (9H, m), 4.90 (1H, d, J=14.6 Hz), 4.77 (1H, d, J=14.6 Hz), 4.24–4.07 (4H, m), 3.92 (1H, d, J=11.0 Hz), 3.77 (3H, s), 3.13 (1H, dq, J=11.0, 7.0 Hz), 1.25 (3H, t,

J=7.3 Hz), 1.21 (3H, t, J=7.3 Hz), 1.01 (3H, d, J=7.0 Hz); ^{13}C NMR (75 MHz, $CDCl_3$) δ 174.5, 168.8, 168.6, 158.9, 137.5, 134.4, 129.7, 128.6, 128.3, 127.2, 114.5, 61.5, 61.4, 55.4, 55.3, 53.3, 36.8, 15.7, 14.0. FAB HRMS (acetone–NBA) calcd for $C_{24}H_{30}NO_6$ 428.2073 (M+H). Found 428.2101.

*4.2.25. Diethyl 2-{1-methyl-2-[N-(4-fluorophenyl)-N-(4-methoxybenzyl)amino]-2-oxoethyl}malonate (**1y**).* R_f=0.49 (ethyl acetate–hexane, 3:7 v/v); colorless oil; IR ($CHCl_3$) ν 1746, 1726, 1647 (C=O); ^{1}H NMR (300 MHz, $CDCl_3$) δ 7.26–6.75 (8H, m), 4.87 (1H, d, J=14.3 Hz), 4.70 (1H, d, J=14.3 Hz), 4.24–4.05 (4H, m), 3.93 (1H, d, J=11.0 Hz), 3.76 (3H, s), 3.04 (1H, dq, J=11.0, 7.0 Hz), 1.26 (3H, t, J=7.3 Hz), 1.21 (3H, t, J=7.3 Hz), 1.00 (3H, d, J=7.0 Hz); ^{13}C NMR (75 MHz, $CDCl_3$) δ 173.9, 168.4, 161.7 (d, J=247.9 Hz), 158.7, 137.4 (d, J=3.1 Hz), 130.4, 129.8, 129.1, 116.1 (2C, d, J=22.4 Hz), 113.5, 61.3, 61.2, 55.2, 54.9, 52.3, 36.6, 15.5, 13.8. FAB HRMS (acetone–NBA) calcd for $C_{24}H_{29}FNO_6$ 446.1979 (M+H). Found 446.1974.

4.3. Manganese(III)-mediated oxidation of diethyl 2-[2-(*N*-arylamino)-2-oxoethyl]malonates 1a–y

To a mixture of the malonate **1** (0.5 mmol) and glacial acetic acid (30 mL) was added manganese(III) acetate dihydrate (1.5–12.5 mmol). The mixture was heated under reflux for 0.5–9.5 h in air. The solvent was removed in vacuo, and the residue was triturated with water followed by extraction with dichloromethane (10 mL×3). The combined extract was dried over anhydrous magnesium sulfate and then concentrated to dryness. The obtained product **2** was purified by silica gel TLC or flash column chromatography. The analytical samples were further purified by recrystallization from the solvent specified in parentheses except for the liquid products.

*4.3.1. 4,4-Bis(ethoxycarbonyl)-3,4-dihydro-1-methyl-2(1H)-quinolinone (**2a**).* R_f=0.47 (diethyl ether–hexane, 8:2 v/v); colorless prisms (from chloroform–hexane); mp 86–87 °C; IR (KBr) ν 1757, 1734, 1688 (C=O); ^{1}H NMR (300 MHz, $CDCl_3$) δ 7.40–7.29 (2H, m), 7.13–7.02 (2H, m), 4.35–4.19 (4H, m), 3.33 (3H, s), 3.23 (2H, s), 1.27 (6H, t, J=7.3 Hz); ^{13}C NMR (75 MHz, $CDCl_3$) δ 168.8, 166.5, 139.6, 129.2, 127.6, 122.9, 122.4, 115.1, 62.2, 56.7, 37.8, 29.4, 13.7. Anal. Calcd for $C_{16}H_{19}NO_5$: C, 62.94; H, 6.27; N, 4.59. Found: C, 62.90; H, 6.35; N, 4.62.

*4.3.2. Diethyl 2-hydroxy-2-[2-(N-methyl-N-phenylamino)-2-oxoethyl]malonate (**1a′**).* R_f=0.36 (diethyl ether–hexane, 8:2 v/v); colorless oil; IR ($CHCl_3$) ν 1740, 1697, 1643 (C=O); ^{1}H NMR (300 MHz, $CDCl_3$) δ 7.49–7.20 (6H, m), 4.24 (4H, q, J=7.3 Hz), 3.26 (3H, s), 2.89 (2H, s), 1.26 (6H, t, J=7.3 Hz); ^{13}C NMR (75 MHz, $CDCl_3$) δ 169.8, 169.5, 143.0, 130.0, 128.3, 127.2, 77.8, 62.5, 39.0, 37.3, 13.9. FAB HRMS (acetone–NBA) calcd for $C_{16}H_{22}NO_6$ 324.1447 (M+H). Found 324.1464.

*4.3.3. 4,4-Bis(ethoxycarbonyl)-1-ethyl-3,4-dihydro-2(1H)-quinolinone (**2b**).* R_f=0.36 (diethyl ether–hexane, 7:3 v/v); colorless oil; IR ($CHCl_3$) ν 1730, 1674 (C=O); ^{1}H NMR (300 MHz, $CDCl_3$) δ 7.40–7.27 (2H, m), 7.14–7.05 (2H, m), 4.35–4.18 (4H, m), 3.98 (2H, q, J=7.3 Hz), 3.21 (2H, s), 1.26 (6H, t, J=7.3 Hz), 1.20 (3H, t, J=7.3 Hz); ^{13}C NMR (75 MHz, $CDCl_3$) δ 169.0, 166.2, 138.7, 129.4, 128.0, 123.2, 123.1, 115.4, 62.4, 57.0, 38.2, 37.3, 14.0, 12.5. FAB HRMS (acetone–NBA) calcd for $C_{17}H_{21}NO_5$ 319.1420 (M). Found 319.1422.

*4.3.4. 4,4-Bis(ethoxycarbonyl)-3,4-dihydro-1-isopropyl-2(1H)-quinolinone (**2c**).* R_f=0.34 (diethyl ether–hexane, 5:5 v/v); colorless oil; IR ($CHCl_3$) ν 1732, 1674 (C=O); ^{1}H NMR (300 MHz, $CDCl_3$) δ 7.36–7.05 (4H, m), 4.59–4.43 (1H, m), 4.36–4.19 (4H, m), 3.14 (2H, s), 1.49 (6H, d, J=7.0 Hz), 1.28 (6H, t, J=7.3 Hz); ^{13}C NMR (75 MHz, $CDCl_3$) δ 168.7, 167.0, 139.7, 128.6, 126.7, 125.1, 123.1, 116.8, 62.1, 56.8, 49.4, 39.6, 19.7, 13.7. FAB HRMS (acetone–NBA) calcd for $C_{18}H_{23}NO_5$ 333.1576 (M). Found 333.1578.

*4.3.5. 4,4-Bis(ethoxycarbonyl)-1-butyl-3,4-dihydro-2(1H)-quinolinone (**2d**).* R_f=0.34 (diethyl ether–hexane, 5:5 v/v); colorless oil; IR ($CHCl_3$) ν 1732, 1674 (C=O); ^{1}H NMR (300 MHz, $CDCl_3$) δ 7.40–7.02 (4H, m), 4.35–4.17 (4H, m), 3.94 (2H, t, J=7.3 Hz), 3.22 (2H, s), 1.63–1.49 (2H, m), 1.40–1.20 (8H, m), 0.92 (3H, t, J=7.3 Hz); ^{13}C NMR (75 MHz, $CDCl_3$) δ 168.8, 166.2, 138.5, 129.0, 127.8, 123.0, 122.8, 115.3, 62.1, 56.8, 41.4, 37.9, 28.8, 19.7, 13.7, 13.5. FAB HRMS (acetone–NBA) calcd for $C_{19}H_{25}NO_5$ 347.1733 (M). Found 347.1701.

*4.3.6. 4,4-Bis(ethoxycarbonyl)-3,4-dihydro-1-phenyl-2(1H)-quinolinone (**2e**).* R_f=0.56 (diethyl ether–hexane, 8:2 v/v); colorless plates (from chloroform–hexane); mp 107–108 °C; IR (KBr) ν 1742, 1720, 1690 (C=O); ^{1}H NMR (300 MHz, $CDCl_3$) δ 7.51–7.03 (8H, m), 6.46–6.41 (1H, m), 4.39–4.24 (4H, m), 3.39 (2H, s), 1.30 (6H, t, J=7.3 Hz); ^{13}C NMR (75 MHz, $CDCl_3$) δ 168.9, 166.4, 141.1, 137.9, 129.8, 129.0, 128.9, 128.4, 127.4, 123.4, 122.7, 118.1, 62.5, 57.2, 38.7, 14.0. Anal. Calcd for $C_{21}H_{21}NO_5$: C, 68.65; H, 5.76; N, 3.81. Found: C, 68.57; H, 5.76; N, 3.79.

*4.3.7. 1-Benzyl-4,4-bis(ethoxycarbonyl)-3,4-dihydro-2(1H)-quinolinone (**2f**).* R_f=0.36 (diethyl ether–hexane, 6:4 v/v); colorless prisms (from chloroform–hexane); mp 96–97 °C; IR (KBr) ν 1755, 1726, 1680 (C=O); ^{1}H NMR (300 MHz, $CDCl_3$) δ 7.33–6.90 (9H, m), 5.16 (2H, s), 4.34–4.17 (4H, m), 3.62 (2H, s), 1.24 (6H, t, J=7.3 Hz); ^{13}C NMR (75 MHz, $CDCl_3$) δ 168.8, 166.6, 138.6, 136.2, 129.0, 128.4, 127.8, 126.9, 126.2, 123.0, 122.5, 116.0, 62.2, 56.8, 45.5, 37.8, 13.7. Anal. Calcd for $C_{22}H_{23}NO_5$: C, 69.28; H, 6.08; N, 3.67. Found: C, 69.06; H, 6.10; N, 3.64.

*4.3.8. 4,4-Bis(ethoxycarbonyl)-3,4-dihydro-1,3-dimethyl-2(1H)-quinolinone (**2g**).* R_f=0.60 (diethyl ether–hexane, 8:2 v/v); colorless plates (from diethyl ether–hexane); mp 60–61 °C; IR (KBr) ν 1757, 1730, 1674 (C=O); ^{1}H NMR (300 MHz, $CDCl_3$) δ 7.57–6.98 (4H, m), 4.33–4.11 (4H, m), 3.34 (3H, s), 3.31 (1H, q, J=7.3 Hz), 1.24 (3H, t, J=7.3 Hz), 1.23 (3H, t, J=7.3 Hz), 1.23 (3H, d, J=7.3 Hz); ^{13}C NMR (75 MHz, $CDCl_3$) δ 169.8, 168.9, 167.6, 139.5, 129.4, 129.1, 122.8, 121.4, 114.9, 62.0, 61.6, 60.5, 41.2, 29.7, 13.8, 13.7, 12.3. FAB HRMS (acetone–NBA) calcd for $C_{17}H_{21}NO_5$ 319.1420 (M). Found 319.1425.

*4.3.9. 6-Acetoxymethyl-4,4-bis(ethoxycarbonyl)-3,4-dihydro-1,3-dimethyl-2(1H)-quinolinone (**3g**).* R_f=0.47 (diethyl ether–hexane, 8:2 v/v); colorless oil; IR ($CHCl_3$) ν 1732, 1678 (C=O); ^{1}H NMR (300 MHz, $CDCl_3$) δ 7.57 (1H, d, J=1.80 Hz), 7.37 (1H, dd, J=8.41, 1.80 Hz), 7.00 (1H, d, J=8.41 Hz), 5.09 (2H, s), 4.35–4.12 (4H, m), 3.40–3.27 (1H, m), 3.31 (3H, s), 2.10 (3H, s), 1.38–1.13 (9H, m); ^{13}C NMR (75 MHz, $CDCl_3$) δ 170.8, 169.9, 168.8, 167.5, 139.6, 130.5, 129.9, 129.4, 121.5, 115.1, 65.7, 62.2, 61.8, 60.5, 41.2, 29.8, 20.9, 13.9, 13.8, 12.5. FAB HRMS (acetone–NBA) calcd for $C_{20}H_{25}NO_7$ 391.1631 (M). Found 391.1644.

The position of the acetoxymethyl group of **3g** was determined using a difference NOE technique as follows. When the singlet of *N*-methyl protons at δ 3.31 was irradiated, a signal of the aromatic proton at δ 7.00 (d, J=8.41 Hz) increased. The irradiation of the aromatic proton at δ 7.00 resulted in the increase of an aromatic proton at δ 7.37 (1H, dd, J=8.41 and 1.80 Hz). On the other hand, when the singlet of methylene protons of the acetoxymethyl group at δ 5.09 was irradiated, both aromatic protons at δ 7.37 and δ 7.57, respectively, increased. The irradiation of the aromatic protons at δ 7.37 and δ 7.57, respectively, also led to increase the methylene protons of the acetoxymethyl group. Since the aromatic protons showed an ABX splitting pattern and the aromatic proton at δ 7.00 should be assigned to be H-8 based on the above NOE experiment,

the acetoxymethyl group must be introduced at the 6 position of **3g**. The position of other acetoxymethylated products **3h–j** was also determined by the same technique.

*4.3.10. 4,4-Bis(ethoxycarbonyl)-3,4-dihydro-3-methyl-1-phenyl-2(1H)-quinolinone (**2h**).* R_f=0.60 (diethyl ether–hexane, 8:2 v/v); colorless oil; IR ($CHCl_3$) ν 1732, 1686 (C=O); ^{1}H NMR (300 MHz, $CDCl_3$) δ 7.62–7.02 (8H, m), 6.43–6.36 (1H, m), 4.38–4.19 (4H, m), 3.49 (1H, q, J=7.3 Hz), 1.35 (3H, d, J=7.3 Hz), 1.27 (6H, t, J=7.3 Hz); ^{13}C NMR (75 MHz, $CDCl_3$) δ 169.7, 169.1, 167.8, 140.7, 138.2, 129.8, 129.2, 128.9, 128.3, 123.2, 121.4, 117.5, 62.3, 61.9, 61.0, 41.8, 14.0, 12.4. FAB HRMS (acetone–NBA) calcd for $C_{22}H_{24}NO_5$ 382.1654 (M+H). Found 382.1649.

*4.3.11. 6-Acetoxymethyl-4,4-bis(ethoxycarbonyl)-3,4-dihydro-3-methyl-1-phenyl-2(1H)-quinolinone (**3h**).* R_f=0.49 (diethyl ether–hexane, 8:2 v/v); colorless oil; IR ($CHCl_3$) ν 1732, 1690 (C=O); ^{1}H NMR (300 MHz, $CDCl_3$) δ 7.60 (1H, d, J=1.80 Hz), 7.62–7.09 (5H, m), 7.43 (1H, dd, J=8.41, 1.80 Hz), 6.39 (1H, d, J=8.41 Hz), 5.06 (2H, s), 4.41–4.20 (4H, m), 3.49 (1H, q, J=7.3 Hz), 2.08 (3H, s), 1.38–1.24 (9H, m, CH_3); ^{13}C NMR (75 MHz, $CDCl_3$) δ 170.8, 169.7, 169.0, 167.7, 140.7, 138.1, 130.8, 129.9, 129.6, 129.1, 128.9, 128.4, 121.3, 117.7, 65.7, 62.4, 62.1, 60.9, 41.7, 21.0, 14.0, 12.5. FAB HRMS (acetone–NBA) calcd for $C_{25}H_{27}NO_7$ 453.1788 (M). Found 453.1797.

*4.3.12. 1-(4-Acetoxymethylphenyl)-4,4-bis(ethoxycarbonyl)-3,4-dihydro-3-methyl-2(1H)-quinolinone (**3h′**).* R_f=0.44 (diethyl ether–hexane, 8:2 v/v); colorless oil; IR ($CHCl_3$) ν 1732, 1692 (C=O); ^{1}H NMR (300 MHz, $CDCl_3$) δ 7.75–7.04 (7H, m), 6.44–6.37 (1H, m), 5.16 (2H, s), 4.40–4.16 (4H, m), 3.49 (1H, q, J=7.3 Hz), 2.14 (3H, s), 1.37–1.24 (9H, m); ^{13}C NMR (75 MHz, $CDCl_3$) δ 170.8, 169.8, 169.1, 167.8, 140.5, 138.1, 136.1, 129.7, 129.2, 129.1, 128.9, 123.4, 121.5, 117.6, 65.6, 62.3, 62.0, 61.0, 41.8, 21.0, 14.0, 12.5. FAB HRMS (acetone–NBA) calcd for $C_{25}H_{27}NO_7$ 453.1788 (M). Found 453.1805.

*4.3.13. 4,4-Bis(ethoxycarbonyl)-3,4-dihydro-1-methyl-3-phenyl-2(1H)-quinolinone (**2i**).* R_f=0.60 (diethyl ether–hexane, 8:2 v/v); colorless needles (from chloroform–hexane); mp 133–134 °C; IR (KBr) ν 1757, 1730, 1682 (C=O); ^{1}H NMR (300 MHz, $CDCl_3$) δ 7.87–6.99 (9H, m), 4.58 (1H, s), 4.26–3.95 (4H, m), 3.40 (3H, s), 1.14 (3H, t, J=7.3 Hz), 1.09 (3H, t, J=7.3 Hz); ^{13}C NMR (75 MHz, $CDCl_3$) δ 168.7, 167.4, 167.2, 140.1, 134.7, 131.2, 129.7, 128.8, 128.6, 128.3, 123.2, 119.6, 114.9, 62.3, 61.7, 60.7, 52.7, 29.9, 13.8, 13.7. Anal. Calcd for $C_{22}H_{23}NO_5 \cdot 1/4H_2O$: C, 68.47; H, 6.14; N, 3.63. Found: C, 68.48; H, 6.02; N, 3.61.

*4.3.14. 6-Acetoxymethyl-4,4-bis(ethoxycarbonyl)-3,4-dihydro-1-methyl-3-phenyl-2(1H)-quinolinone (**3i**).* R_f=0.44 (diethyl ether–hexane, 8:2 v/v); colorless oil; IR ($CHCl_3$) ν 1732, 1678 (C=O); ^{1}H NMR (300 MHz, $CDCl_3$) δ 7.85 (1H, d, J=1.80 Hz), 7.43 (1H, dd, J=8.41, 1.80 Hz), 7.18–7.00 (5H, m), 7.12 (1H, d, J=8.41 Hz), 5.11 (2H, s), 4.58 (1H, s), 4.27–3.94 (4H, m), 3.40 (3H, s), 2.09 (3H, s), 1.18–1.08 (6H, m); ^{13}C NMR (75 MHz, $CDCl_3$) δ 170.8, 168.5, 167.3, 167.0, 140.1, 134.5, 131.5, 130.8, 129.9, 128.7, 128.6, 128.3, 119.6, 115.1, 65.8, 62.4, 61.8, 60.6, 52.5, 29.9, 21.0, 13.8, 13.7. FAB HRMS (acetone–NBA) calcd for $C_{25}H_{27}NO_7$ 453.1788 (M). Found 453.1778.

*4.3.15. 4,4-Bis(ethoxycarbonyl)-3,4-dihydro-1-isopropyl-3-phenyl-2(1H)-quinolinone (**2j**).* R_f=0.67 (diethyl ether–hexane, 8:2 v/v); colorless plates (from chloroform–hexane); mp 105 °C; IR (KBr) ν 1755, 1732, 1674 (C=O); ^{1}H NMR (300 MHz, $CDCl_3$) δ 7.80–6.93 (9H, m), 4.71–4.55 (1H, m), 4.47 (1H, s), 4.25–4.00 (4H, m), 1.57 (3H, d, J=7.0 Hz), 1.50 (3H, d, J=7.0 Hz), 1.14 (6H, t, J=7.3 Hz); ^{13}C NMR (75 MHz, $CDCl_3$) δ 168.6, 167.9, 167.1, 140.2, 134.4, 130.6, 129.2, 129.1, 128.5, 128.0, 123.3, 122.1, 116.3, 62.2, 61.7, 61.1, 54.2, 49.8, 20.5, 19.5, 13.8. Anal. Calcd for $C_{24}H_{27}NO_5 \cdot 1/8H_2O$: C, 70.01; H, 6.67; N, 3.40. Found: C, 70.00; H, 6.67; N, 3.46.

*4.3.16. 6-Acetoxymethyl-4,4-bis(ethoxycarbonyl)-3,4-dihydro-1-isopropyl-3-phenyl-2(1H)-quinolinone (**3j**).* R_f=0.56 (diethyl ether–hexane, 8:2 v/v); colorless oil; IR ($CHCl_3$) ν 1732, 1676 (C=O); ^{1}H NMR (300 MHz, $CDCl_3$) δ 7.75 (1H, d, J=1.80 Hz), 7.40 (1H, dd, J=8.41, 1.80 Hz), 7.22 (1H, d, J=8.41 Hz), 7.23–6.89 (5H, m), 5.09 (2H, s), 4.72–4.56 (1H, m), 4.47 (1H, s), 4.26–4.02 (4H, m), 2.10 (3H, s), 1.60–1.46 (6H, m), 1.20–1.10 (6H, m); ^{13}C NMR (75 MHz, $CDCl_3$) δ 170.8, 168.4, 167.7, 167.0, 140.2, 134.3, 130.9, 130.7, 129.4, 129.0, 128.5, 128.1, 122.1, 116.4, 65.8, 62.3, 61.8, 60.9, 54.0, 49.8, 21.0, 20.4, 19.5, 13.8, 13.7. FAB HRMS (acetone–NBA) calcd for $C_{27}H_{32}NO_7$ 482.2179 (M+H). Found 482.2171.

*4.3.17. 4,4-Bis(ethoxycarbonyl)-3,4-dihydro-6-methoxy-1-methyl-2(1H)-quinolinone (**2k**).* R_f=0.43 (diethyl ether–hexane, 8:2 v/v); colorless oil; IR ($CHCl_3$) ν 1732, 1670 (C=O); ^{1}H NMR (300 MHz, $CDCl_3$) δ 6.99–6.87 (3H, m, arom. H), 4.33–4.22 (4H, m, O–CH_2CH_3×2), 3.79 (3H, s, O–CH_3), 3.31 (3H, s, N–CH_3), 3.20 (2H, s, H-3), 1.28 (6H, t, J=7.3 Hz, O–CH_2CH_3×2); ^{13}C NMR (75 MHz, $CDCl_3$) δ 168.9 (2C, C=O×2), 166.4 (C=O), 155.4, 133.5, 123.9 (arom. C), 116.3, 114.2, 113.8 (arom. *C*H), 62.5 (2C, O–CH_2CH_3×2), 57.0 (C-4), 55.6 (O–CH_3), 38.1 (C-3), 29.7 (N–CH_3), 14.0 (2C, O–CH_2CH_3×2). FAB HRMS (acetone–NBA) calcd for $C_{17}H_{21}NO_6$ 335.1369 (M). Found 335.1367.

*4.3.18. 4,4-Bis(ethoxycarbonyl)-3,4-dihydro-7-methoxy-1-methyl-2(1H)-quinolinone (**2l**).* R_f=0.45 (diethyl ether–hexane, 8:2 v/v); colorless microcrystals (from chloroform–hexane); mp 76–77 °C; IR (KBr) ν 1747, 1726, 1676 (C=O); ^{1}H NMR (300 MHz, $CDCl_3$) δ 7.27–7.23 (1H, m), 6.66–6.56 (2H, m), 4.34–4.18 (4H, m), 3.83 (3H, s), 3.31 (3H, s), 3.21 (2H, s), 1.27 (6H, t, J=7.3 Hz); ^{13}C NMR (75 MHz, $CDCl_3$) δ 169.3, 166.9, 160.4, 141.1, 129.0, 114.7, 107.2, 102.8, 62.4, 56.3, 55.4, 38.2, 29.6, 14.0. Anal. Calcd for $C_{17}H_{21}NO_6$: C, 60.89; H, 6.31; N, 4.18. Found: C, 60.76; H, 6.26; N, 4.19.

*4.3.19. 4,4-Bis(ethoxycarbonyl)-3,4-dihydro-5-methoxy-1-methyl-2(1H)-quinolinone (**2l′**).* R_f=0.36 (diethyl ether–hexane, 8:2 v/v); colorless oil; IR ($CHCl_3$) ν 1728, 1674 (C=O); ^{1}H NMR (300 MHz, $CDCl_3$) δ 7.35–7.28 (1H, m), 6.76–6.66 (2H, m), 4.31–4.15 (4H, m), 3.82 (3H, s), 3.31 (3H, s), 3.22 (2H, s), 1.26 (6H, t, J=7.3 Hz); ^{13}C NMR (75 MHz, $CDCl_3$) δ 169.7, 166.7, 157.3, 141.0, 130.0, 112.9, 108.6, 107.9, 62.0, 56.6, 54.4, 38.6, 30.0, 14.0. FAB HRMS (acetone–NBA) calcd for $C_{17}H_{21}NO_6$ 335.1369 (M). Found 335.1364.

*4.3.20. 4,4-Bis(ethoxycarbonyl)-3,4-dihydro-1,6-dimethyl-2(1H)-quinolinone (**2m**).* R_f=0.51 (diethyl ether–hexane, 8:2 v/v); colorless prisms (from diethyl ether); mp 83 °C; IR (KBr) ν 1732, 1676 (C=O); ^{1}H NMR (300 MHz, $CDCl_3$) δ 7.18–6.90 (3H, m), 4.35–4.20 (4H, m), 3.30 (3H, s), 3.21 (2H, s), 2.33 (3H, s), 1.28 (6H, t, J=7.3 Hz); ^{13}C NMR (75 MHz, $CDCl_3$) δ 169.1, 166.6, 137.5, 132.7, 129.9, 128.3, 122.5, 115.3, 62.4, 56.9, 38.2, 29.6, 20.8, 14.0. Anal. Calcd for $C_{17}H_{21}NO_5$: C, 63.94; H, 6.63; N, 4.39. Found: C, 63.72; H, 6.66; N, 4.35.

*4.3.21. 6-Chloro-4,4-bis(ethoxycarbonyl)-3,4-dihydro-1-methyl-2(1H)-quinolinone (**2n**).* R_f=0.55 (diethyl ether–hexane, 8:2 v/v); colorless prisms (from diethyl ether); mp 74 °C; IR (KBr) ν 1736, 1686 (C=O); ^{1}H NMR (300 MHz, $CDCl_3$) δ 7.37–7.28 (2H, m), 7.02–6.94 (1H, m), 4.37–4.20 (4H, m), 3.31 (3H, s), 3.21 (2H, s), 1.28 (6H, t, J=7.3 Hz); ^{13}C NMR (75 MHz, $CDCl_3$) δ 168.2, 166.0, 138.4, 129.1, 128.2, 127.7, 123.9, 116.4, 62.5, 56.4, 37.5, 29.5, 13.7. Anal. Calcd for $C_{16}H_{18}ClNO_5$: C, 56.56; H, 5.34; N, 4.12. Found: C, 56.42; H, 5.34; N, 4.14.

*4.3.22. 6-Chloro-4,4-bis(ethoxycarbonyl)-3,4-dihydro-1-(4-methoxybenzyl)-2(1H)-quinolinone (**2o**).* R_f=0.58 (diethyl ether–hexane, 8:2

v/v); colorless needles (from chloroform–hexane); mp 99 °C; IR (KBr) ν 1755, 1736, 1682 (C=O); ^{1}H NMR (300 MHz, $CDCl_3$) δ 7.33–6.77 (7H, m), 5.08 (2H, s), 4.36–4.19 (4H, m), 3.72 (3H, s), 3.32 (2H, s), 1.27 (6H, t, J=7.3 Hz); ^{13}C NMR (75 MHz, $CDCl_3$) δ 168.2, 166.2, 158.6, 137.3, 128.9, 128.2, 127.9, 127.7, 127.6, 124.0, 117.3, 113.9, 62.5, 56.4, 54.9, 44.9, 37.6, 13.7. Anal. Calcd for $C_{23}H_{24}ClNO_6$: C, 61.95; H, 5.43; N, 3.14. Found: C, 61.82; H, 5.49; N, 3.10.

*4.3.23. 4,4-Bis(ethoxycarbonyl)-6-fluoro-3,4-dihydro-1-methyl-2(1H)-quinolinone (**2p**).* R_f=0.52 (diethyl ether–hexane, 8:2 v/v); colorless prisms (from chloroform–hexane); mp 100–101 °C; IR (KBr) ν 1751, 1730, 1688 (C=O); ^{1}H NMR (300 MHz, $CDCl_3$) δ 7.12–6.97 (3H, m), 4.36–4.21 (4H, m), 3.33 (3H, s), 3.22 (2H, s), 1.28 (6H, t, J=7.3 Hz); ^{13}C NMR (75 MHz, $CDCl_3$) δ 168.5, 166.3, 158.4 (d, J=243.5 Hz), 136.3 (d, J=3.1 Hz), 124.3 (d, J=8.1 Hz), 116.6 (d, J=8.1 Hz), 115.9 (d, J=22.4 Hz), 115.2 (d, J=24.8 Hz), 62.7, 56.7 (d, J=1.2 Hz), 37.8, 29.8, 14.0. Anal. Calcd for $C_{16}H_{18}FNO_5$: C, 59.44; H, 5.61; N, 4.33. Found: C, 59.38; H, 5.72; N, 4.35.

*4.3.24. 4,4-Bis(ethoxycarbonyl)-3,4-dihydro-6-nitro-1-methyl-2(1H)-quinolinone (**2q**).* R_f=0.51 (ethyl acetate–hexane, 4:6 v/v); pale yellow plates (from diethyl ether); mp 89 °C; IR (KBr) ν 1755, 1732, 1699 (C=O); ^{1}H NMR (300 MHz, $CDCl_3$) δ 8.31–8.24 (2H, m), 7.23–7.18 (1H, m), 4.33 (4H, q, J=7.3 Hz), 3.42 (3H, s), 3.29 (2H, s), 1.32 (6H, t, J=7.3 Hz); ^{13}C NMR (75 MHz, $CDCl_3$) δ 168.0, 166.3, 145.3, 142.8, 125.3, 124.1, 123.0, 115.6, 63.1, 56.3, 37.3, 30.1, 14.0. Anal. Calcd for $C_{16}H_{18}N_2O_7$: C, 54.86; H, 5.18; N, 8.00. Found: C, 54.73; H, 5.21; N, 7.95.

*4.3.25. 4,4-Bis(ethoxycarbonyl)-3,4-dihydro-7-nitro-1-methyl-2(1H)-quinolinone (**2r**).* R_f=0.64 (diethyl ether–hexane, 8:2 v/v); pale yellow prisms (from chloroform–hexane); mp 106 °C; IR (KBr) ν 1761, 1735, 1690 (C=O), 1528, 1352 (NO_2); ^{1}H NMR (300 MHz, $CDCl_3$) δ 7.99–7.88 (2H, m), 7.57–7.52 (1H, m), 4.39–4.22 (4H, m), 3.43 (3H, s), 3.27 (2H, s), 1.30 (6H, t, J=7.3 Hz); ^{13}C NMR (75 MHz, $CDCl_3$) δ 167.8, 165.9, 148.4, 141.0, 129.0, 128.7, 117.5, 110.0, 62.8, 56.7, 37.1, 29.7, 13.7. Anal. Calcd for $C_{16}H_{18}N_2O_7$: C, 54.86; H, 5.18; N, 8.00. Found: C, 54.69; H, 5.15; N, 8.03.

*4.3.26. 4,4-Bis(ethoxycarbonyl)-3,4-dihydro-5-nitro-1-methyl-2(1H)-quinolinone (**2r′**).* R_f=0.29 (diethyl ether–hexane, 8:2 v/v); pale yellow prisms (from chloroform–hexane); mp 136 °C; IR (KBr) ν 1746, 1724, 1690 (C=O), 1535, 1358 (NO_2); ^{1}H NMR (300 MHz, $CDCl_3$) δ 7.76–7.30 (3H, m), 4.24 (4H, q, J=7.3 Hz), 3.37 (3H, s), 3.17 (2H, s), 1.26 (6H, t, J=7.3 Hz); ^{13}C NMR (75 MHz, $CDCl_3$) δ 167.3, 165.9, 149.1, 142.2, 129.6, 120.4, 120.3, 119.7, 62.8, 55.9, 39.7, 30.7, 13.9. Anal. Calcd for $C_{16}H_{18}N_2O_7$: C, 54.86; H, 5.18; N, 8.00. Found: C, 54.81; H, 5.17; N, 8.02.

*4.3.27. 6-Acetyl-4,4-bis(ethoxycarbonyl)-3,4-dihydro-1-methyl-2(1H)-quinolinone (**2s**).* R_f=0.33 (ethyl acetate–hexane, 4:6 v/v); colorless prisms (from diethyl ether); mp 114 °C; IR (KBr) ν 1746, 1722, 1680 (C=O); ^{1}H NMR (300 MHz, $CDCl_3$) δ 8.02–7.94 (2H, m), 7.15–7.08 (1H, m), 4.30 (4H, q, J=7.3 Hz), 3.38 (3H, s), 3.26 (2H, s), 2.58 (3H, s), 1.30 (6H, t, J=7.3 Hz); ^{13}C NMR (75 MHz, $CDCl_3$) δ 196.0, 168.4, 166.5, 143.6, 131.8, 129.9, 128.2, 122.4, 115.0, 62.5, 56.4, 37.6, 29.6, 26.2, 13.8. FAB HRMS (acetone–NBA) calcd for $C_{18}H_{21}NO_6$ 347.1369 (M). Found 347.1412.

*4.3.28. 6-(2-Acetoxyacetyl)-4,4-bis(ethoxycarbonyl)-3,4-dihydro-1-methyl-2(1H)-quinolinone (**4s**).* R_f=0.24 (ethyl acetate–hexane, 4:6 v/v); colorless oil; IR ($CHCl_3$) ν 1734, 1693 (C=O); ^{1}H NMR (300 MHz, $CDCl_3$) δ 8.00–7.89 (2H, m), 7.16–7.08 (1H, m), 5.30 (2H, s), 4.30 (4H, q, J=7.3 Hz), 3.38 (3H, s), 3.26 (2H, s), 2.23 (3H, s), 1.29 (6H, t, J=7.3 Hz); ^{13}C NMR (75 MHz, $CDCl_3$) δ 190.4, 170.5, 168.4, 166.6, 144.4, 129.5, 128.9, 128.0, 122.9, 115.4, 65.8, 62.8, 56.5, 37.7, 29.9, 20.6, 14.0. FAB HRMS (acetone–NBA) calcd for $C_{20}H_{23}NO_8$ 405.1424 (M). Found 405.1429.

*4.3.29. 4,4-Bis(ethoxycarbonyl)-6-methoxy-1-methyl-1-azaspiro-[4,5]deca-6,9-diene-2,8-dione (**5t**).* R_f=0.18 (diethyl ether); colorless prisms (from chloroform–hexane); mp 119 °C; IR (KBr) ν 1740, 1719, 1670, 1634 (C=O); ^{1}H NMR (300 MHz, $CDCl_3$) δ 6.66 (1H, d, J=10.3 Hz), 6.43 (1H, dd, J=10.3, 1.5 Hz), 5.71 (1H, d, J=1.5 Hz), 4.36–4.05 (4H, m), 3.70 (3H, s), 3.31 (1H, d, J=17.2 Hz), 2.84 (1H, d, J=17.2 Hz), 2.62 (3H, s), 1.29 (3H, t, J=7.3 Hz), 1.20 (3H, t, J=7.3 Hz); ^{13}C NMR (75 MHz, $CDCl_3$) δ 185.6, 173.0, 170.9, 168.5, 166.8, 140.3, 132.8, 104.8, 66.4, 62.9, 62.3, 61.3, 56.3, 38.5, 26.2, 13.9, 13.7. Anal. Calcd for $C_{17}H_{21}NO_7$: C, 58.11; H, 6.02; N, 3.99. Found: C, 58.12; H, 5.94; N, 4.09.

*4.3.30. 4,4-Bis(ethoxycarbonyl)-3,4-dihydro-8-methoxy-1-methyl-2(1H)-quinolinone (**2u**).* R_f=0.53 (diethyl ether–hexane, 8:2 v/v); colorless plates (from diethyl ether–hexane); mp 71 °C; IR ($CHCl_3$) ν 1744, 1720, 1680 (C=O); ^{1}H NMR (300 MHz, $CDCl_3$) δ 7.15–6.81 (3H, m), 4.36–4.19 (4H, m), 3.86 (3H, s), 3.32 (3H, s), 3.15 (2H, s), 1.28 (6H, t, J=7.3 Hz); ^{13}C NMR (75 MHz, $CDCl_3$) δ 168.9, 168.6, 150.1, 130.2, 128.0, 125.0, 118.7, 113.2, 62.4, 57.6, 55.9, 39.2, 34.7, 14.0. FAB HRMS (acetone–NBA) calcd for $C_{17}H_{21}NO_6$ 335.1369 (M). Found 335.1364.

*4.3.31. 8-Acetoxy-4,4-bis(ethoxycarbonyl)-6-methoxy-1-methyl-1-azaspiro[4,5]deca-6,9-diene-2-one (**6u**).* Major diastereoisomer; R_f=0.34 (diethyl ether); colorless oil; IR ($CHCl_3$) ν 1732, 1697 (C=O); ^{1}H NMR (300 MHz, $CDCl_3$) δ 6.22–6.15 (1H, m), 5.88–5.79 (2H, m), 5.12–5.07 (1H, m), 4.33–4.06 (4H, m), 3.50 (3H, s), 3.28 (1H, d, J=16.9 Hz), 2.76 (1H, d, J=16.9 Hz), 2.62 (3H, s), 2.11 (3H, s), 1.30–1.22 (6H, m); ^{13}C NMR (75 MHz, $CDCl_3$) δ 173.0, 170.5, 168.9, 167.3, 154.1, 131.2, 127.3, 97.8, 66.5, 65.5, 62.2, 61.7, 61.3, 54.7, 38.9, 29.5, 26.0, 21.1, 13.8. FAB HRMS (acetone–NBA) calcd for $C_{19}H_{26}NO_8$ 396.1658 (M+H). Found 396.1663. Minor diastereoisomer; R_f=0.30 (diethyl ether); colorless prisms (from diethyl ether); mp 115 °C; IR (KBr) ν 1738, 1711 (C=O); ^{1}H NMR (300 MHz, $CDCl_3$) δ 6.28–6.21 (1H, m), 5.91–5.81 (2H, m), 5.11–5.07 (1H, m), 4.34–4.07 (4H, m), 3.49 (3H, s), 3.32 (1H, d, J=16.9 Hz), 2.76 (1H, d, J=16.9 Hz), 2.53 (3H, s), 2.10 (3H, s), 1.32–1.24 (6H, m); ^{13}C NMR (75 MHz, $CDCl_3$) δ 173.0, 170.8, 169.4, 167.6, 155.2, 131.0, 128.0, 97.3, 66.2, 65.4, 62.4, 61.7, 61.2, 54.7, 39.1, 29.7, 25.7, 21.2, 13.9, 13.8. FAB HRMS (acetone–NBA) calcd for $C_{19}H_{26}NO_8$ 396.1658 (M+H). Found 396.1664.

*4.3.32. 4,4-Bis(ethoxycarbonyl)-8-hydroxy-6-methoxy-1-methyl-1-azaspiro[4,5]deca-6,9-diene-2-one (**7u**).* Major diastereoisomer; R_f=0.40 (ethyl acetate); colorless oil; IR ($CHCl_3$) ν 3600–3200 (OH), 1732, 1695 (C=O); ^{1}H NMR (300 MHz, $CDCl_3$) δ 6.41–6.34 (1H, m), 5.65–5.59 (1H, m), 5.27–5.22 (1H, m), 4.70–4.61 (1H, m), 4.29–4.13 (4H, m), 3.51 (3H, s), 3.21 (1H, d, J=16.9 Hz), 2.82–2.73 (1H, m), 2.78 (1H, d, J=16.9 Hz), 2.54 (3H, s), 1.28 (3H, t, J=7.3 Hz), 1.26 (3H, t, J=7.3 Hz); ^{13}C NMR (75 MHz, $CDCl_3$) δ 173.1, 169.0, 167.7, 153.9, 135.2, 126.3, 101.9, 65.7, 63.2, 62.4, 62.0, 61.3, 54.6, 38.6, 25.8, 14.0, 13.9. FAB HRMS (acetone–NBA) calcd for $C_{17}H_{24}NO_7$ 354.1553 (M+H). Found 354.1515. Minor diastereoisomer; R_f=0.33 (ethyl acetate); colorless oil; IR ($CHCl_3$) ν 3600–3200 (OH), 1734, 1693 (C=O); ^{1}H NMR (300 MHz, $CDCl_3$) δ 6.30–6.24 (1H, m), 5.71–5.65 (1H, m), 5.18–5.14 (1H, m), 4.83–4.76 (1H, m), 4.27–4.04 (4H, m), 3.50 (3H, s), 3.26 (1H, d, J=16.9 Hz), 2.73 (1H, d, J=16.9 Hz), 2.60 (3H, s), 2.47–2.38 (1H, m), 1.25 (6H, t, J=7.3 Hz); ^{13}C NMR (75 MHz, $CDCl_3$) δ 173.2, 169.1, 167.5, 152.5, 135.8, 125.0, 102.2, 65.8, 64.3, 62.3, 61.7, 61.6, 54.7, 39.0, 26.1, 14.0, 13.9. FAB HRMS (acetone–NBA) calcd for $C_{17}H_{24}NO_7$ 354.1553 (M+H). Found 354.1586.

*4.3.33. 4,4-Bis(ethoxycarbonyl)-3,4-dihydro-1-methyl-2(1H)-benzo[h]quinolinone (**2v**).* R_f=0.52 (diethyl ether–hexane, 8:2 v/v); colorless prisms (from diethyl ether–hexane); mp 79–80 °C; IR

(KBr) ν 1747, 1722, 1682 (C=O); ^{1}H NMR (300 MHz, $CDCl_3$) δ 7.94–7.38 (6H, m), 4.39–4.22 (4H, m), 3.49 (3H, s), 3.28 (2H, s), 1.29 (6H, t, J=7.3 Hz); ^{13}C NMR (75 MHz, $CDCl_3$) δ 169.8, 168.9, 138.0, 134.5, 128.4, 126.2, 125.8, 125.2, 124.9, 123.6, 123.5, 62.3, 57.6, 39.3, 37.8, 13.8. FAB HRMS (acetone–NBA) calcd for $C_{20}H_{21}NO_5$ 355.1420 (M). Found 355.1419.

*4.3.34. An inseparable mixture of 4-acetoxy-3′,3′-bis(ethoxycarbonyl)-1′-methylspiro[naphthalene-1(4H),2′-pyrrolidin]-5-one (**6v**) and 3′,3′-bis(ethoxycarbonyl)-4-hydroxy-1′-methylspiro[naphthalene-1(4H),2′-pyrrolidin]-5-one (**7v**).* Compound **6v**: R_f=0.27 (diethyl ether–hexane, 8:2 v/v); IR ($CHCl_3$) ν 1784, 1736, 1697 (C=O); ^{1}H NMR (300 MHz, $CDCl_3$) δ 7.42–6.01 (6H, m), 6.40–6.37 (1H, m), 4.38–3.57 (4H, m), 3.46 (1H, d, J=17.6 Hz), 2.87 (1H, d, J=17.6 Hz), 2.59 (3H, s), 2.24 (3H, s), 1.32–0.90 (6H, m); ^{13}C NMR (75 MHz, $CDCl_3$) δ 173.1, 171.9, 171.3, 170.9, 168.6, 167.1, 165.2, 135.8, 132.7, 132.4, 132.1, 130.3, 129.3, 128.8, 128.6, 128.5, 127.7, 126.8, 126.1, 124.9, 123.4, 66.3, 66.0, 63.6, 62.8, 62.3, 38.2, 26.5, 21.2, 13.9, 13.5.

Compound **7v**: R_f=0.27 (diethyl ether–hexane, 8:2 v/v); IR ($CHCl_3$) ν 3600–3200 (OH), 1736, 1697 (C=O); ^{1}H NMR (300 MHz, $CDCl_3$) δ 7.42–6.01 (6H, m), 5.61–5.58 (1H, m), 4.38–3.57 (4H, m), 3.48 (1H, d, J=17.6 Hz), 2.99 (1H, d, J=17.6 Hz), 2.77 (3H, s), 1.92 (1H, br s), 1.32–0.90 (6H, m); ^{13}C NMR (75 MHz, $CDCl_3$) δ 173.1, 171.9, 171.3, 170.9, 168.6, 167.1, 165.2, 135.8, 132.7, 132.4, 132.1, 130.3, 129.3, 128.8, 128.6, 128.5, 127.7, 126.8, 126.1, 124.9, 123.4, 80.2, 73.5, 62.8, 62.0, 60.4, 36.3, 26.8, 13.5, 13.4.

*4.3.35. 4,4-Bis(ethoxycarbonyl)-3,4-dihydro-1-methyl-2(1H)-naphth[1,8-bc]azepinone (**8v**).* R_f=0.41 (diethyl ether–hexane, 8:2 v/v); colorless oil; IR ($CHCl_3$) ν 1732, 1670 (C=O); ^{1}H NMR (300 MHz, $CDCl_3$) δ 7.89–7.24 (6H, m), 4.39–4.21 (4H, m), 3.48–3.39 (2H, m), 3.30 (3H, s), 1.30 (6H, t, J=7.3 Hz); ^{13}C NMR (75 MHz, $CDCl_3$) δ 171.1, 139.2, 135.7, 132.9, 129.8, 127.5, 127.1, 125.5, 125.4, 125.1, 120.9, 62.8, 62.4, 42.4, 38.5, 14.0. FAB HRMS (acetone–NBA) calcd for $C_{20}H_{22}NO_5$ 356.1498 (M+H). Found 356.1535.

*4.3.36. 1,1-Bis(ethoxycarbonyl)-1,2,6,7-tetrahydro-3(5H)-pyrido[3,2,1-ij]quinolinone (**2w**).* R_f=0.49 (diethyl ether–hexane, 8:2 v/v); colorless needles (from diethyl ether); mp 78–79 °C; IR (KBr) ν 1749, 1726, 1678 (C=O); ^{1}H NMR (300 MHz, $CDCl_3$) δ 7.17–6.96 (3H, m), 4.36–4.18 (4H, m), 3.86 (2H, t, J=6.2 Hz), 3.24 (2H, s), 2.82 (2H, t, J=6.2 Hz), 1.93 (2H, quin, J=6.2 Hz), 1.28 (6H, t, J=7.3 Hz); ^{13}C NMR (75 MHz, $CDCl_3$) δ 169.2, 166.0, 135.4, 129.9, 125.8, 122.7, 122.0, 62.4, 56.9, 40.8, 37.7, 27.4, 21.1, 14.0. Anal. Calcd for $C_{18}H_{21}NO_5$: C, 65.24; H, 6.39; N, 4.23. Found: C, 65.12; H, 6.42; N, 4.19.

*4.3.37. 1-Benzyl-4,4-bis(ethoxycarbonyl)-3,4-dihydro-6-methoxy-3-methyl-2(1H)-quinolinone (**2x**).* R_f=0.59 (diethyl ether–hexane, 8:2 v/v); colorless needles (from chloroform–hexane); mp 129 °C; IR (KBr) ν 1747, 1726, 1668 (C=O); ^{1}H NMR (300 MHz, $CDCl_3$) δ 7.32–6.68 (8H, m), 5.21 (1H, d, J=16.5 Hz), 5.05 (1H, d, J=16.5 Hz), 4.35–4.10 (4H, m), 3.76 (3H, s), 3.42 (1H, q, J=7.0 Hz), 1.35–1.19 (9H, m); ^{13}C NMR (75 MHz, $CDCl_3$) δ 169.8, 168.9, 167.6, 155.1, 136.9, 132.2, 128.6, 127.0, 126.4, 122.6, 116.6, 115.7, 114.1, 62.2, 61.8, 60.7, 55.4, 46.0, 41.4, 13.9, 12.6. Anal. Calcd for $C_{24}H_{27}NO_6$: C, 67.75; H, 6.40; N, 3.29. Found: C, 67.56; H, 6.42; N, 3.28.

*4.3.38. 7-Acetoxymethyl-1-benzyl-4,4-bis(ethoxycarbonyl)-3,4-dihydro-6-methoxy-3-methyl-2(1H)-quinolinone (**9x**).* R_f=0.50 (diethyl ether–hexane, 8:2 v/v); colorless oil; IR ($CHCl_3$) ν 1732, 1674 (C=O); ^{1}H NMR (300 MHz, $CDCl_3$) δ 7.33–7.16 (5H, m), 7.15 (1H, s), 6.87 (1H, s), 5.23 (1H, d, J=16.5 Hz), 5.03 (1H, d, J=16.5 Hz), 5.03 (2H, s), 4.36–4.06 (4H, m), 3.83 (3H, s), 3.43 (1H, q, J=7.0 Hz), 1.98 (3H, s), 1.32–1.19 (9H, m); ^{13}C NMR (75 MHz, $CDCl_3$) δ 170.6, 169.9, 168.7, 167.7, 152.5, 136.9, 132.0, 128.6, 127.1, 126.6, 125.1, 121.3, 116.3, 112.3, 62.2, 61.9, 60.9, 60.5, 55.8, 46.1, 41.4, 20.8, 13.9, 12.8. FAB HRMS (acetone–NBA) calcd for $C_{27}H_{31}NO_8$ 497.2050 (M). Found 497.2077.

The position of the acetoxymethyl group of **9x** was determined using a difference NOE technique similar to the determination of the acetoxymethylated products **3g–j**. Since the irradiation of the benzyl protons at δ 5.23 led to increase a singlet of the aromatic proton at δ 6.87, the aromatic proton should be assigned to be H-8. The irradiation of methylene protons of the acetoxymethyl group also led to increase the aromatic proton at δ 6.87. Therefore, the introduction of the acetoxymethyl group must be the position at C-7. The position of the acetoxymethylated product **9y** was also determined by the same method.

*4.3.39. 1-Benzyl-4,4-bis(ethoxycarbonyl)-1-azaspiro[4,5]deca-6,9-diene-2,8-dione (**10x**).* R_f=0.43 (diethyl ether–hexane, 8:2 v/v); colorless microcrystals (from diethyl ether–hexane); mp 117 °C; IR (KBr) ν 1740, 1701, 1676 (C=O); ^{1}H NMR (300 MHz, $CDCl_3$) δ 7.30–7.19 (5H, m), 6.94 (1H, dd, J=10.3, 2.9 Hz), 6.45 (1H, dd, J=9.9, 2.9 Hz), 6.33 (1H, dd, J=10.3, 1.5 Hz), 6.18 (1H, dd, J=9.9, 1.5 Hz), 4.61 (1H, d, J=16.5 Hz), 4.34–4.15 (4H, m), 4.09 (1H, d, J=16.5 Hz), 3.46 (1H, q, J=7.0 Hz), 1.36–1.19 (9H, m); ^{13}C NMR (75 MHz, $CDCl_3$) δ 184.0, 173.5, 166.6, 166.4, 145.0, 143.8, 137.2, 133.1, 131.6, 128.5, 128.4, 127.7, 66.6, 63.1, 62.4, 62.2, 45.0, 41.3, 14.0, 13.5, 11.2. FAB HRMS (acetone–NBA) calcd for $C_{23}H_{26}NO_6$ 412.1760 (M+H). Found 412.1764.

*4.3.40. 4,4-Bis(ethoxycarbonyl)-6-fluoro-3,4-dihydro-1-(4-methoxybenzyl)-3-methyl-2(1H)-quinolinone (**2y**).* R_f=0.59 (diethyl ether–hexane, 8:2 v/v); colorless oil; IR ($CHCl_3$) ν 1732, 1680 (C=O); ^{1}H NMR (300 MHz, $CDCl_3$) δ 7.39–6.76 (7H, m), 5.16 (1H, d, J=16.5 Hz), 5.00 (1H, d, J=16.5 Hz), 4.34–4.09 (4H, m), 3.75 (3H, s), 3.43 (1H, q, J=7.0 Hz), 1.32–1.18 (9H, m); ^{13}C NMR (75 MHz, $CDCl_3$) δ 169.9, 168.5, 167.3, 158.8, 158.3 (d, J=242.9 Hz), 134.9 (d, J=2.5 Hz), 128.5, 127.8, 123.1 (d, J=8.1 Hz), 117.2 (d, J=14.3 Hz), 117.0 (d, J=2.5 Hz), 115.8 (d, J=23.0 Hz), 114.1, 62.5, 62.1, 60.4, 55.2, 45.5, 41.3, 14.0, 13.9, 12.7. FAB HRMS (acetone–NBA) calcd for $C_{24}H_{26}FNNaO_6$ 466.1642 (M+Na). Found 466.1647.

*4.3.41. 7-Acetoxymethyl-4,4-bis(ethoxycarbonyl)-6-fluoro-3,4-dihydro-1-(4-methoxybenzyl)-3-methyl-2(1H)-quinolinone (**9y**).* R_f=0.45 (diethyl ether–hexane, 8:2 v/v); colorless oil; IR ($CHCl_3$) ν 1732, 1682 (C=O); ^{1}H NMR (300 MHz, $CDCl_3$) δ 7.42–6.76 (4H, m), 7.16 (1H, s), 6.86 (1H, s), 5.17 (1H, d, J=16.5 Hz), 5.09 (2H, s), 4.99 (1H, d, J=16.5 Hz), 4.35–4.10 (4H, m), 3.79 (3H, s), 3.43 (1H, q, J=7.0 Hz), 2.08 (3H, s), 1.31–1.18 (9H, m); ^{13}C NMR (75 MHz, $CDCl_3$) δ 170.9, 169.9, 168.5, 167.3, 158.3 (d, J=243.5 Hz), 156.7, 134.9 (d, J=2.5 Hz), 128.3, 128.0, 127.6, 124.6, 122.8 (d, J=7.5 Hz), 117.3 (d, J=24.8 Hz), 117.0 (d, J=8.1 Hz), 115.9 (d, J=22.4 Hz), 110.7, 62.4, 62.1, 61.6, 60.4, 55.5, 45.5, 41.2, 21.0, 14.0, 13.9, 12.8. FAB HRMS (acetone–NBA) calcd for $C_{27}H_{30}FNNaO_8$ 538.1853 (M+Na). Found 538.1855.

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Supplementary data

The calculation results of the energies of **A–D** (pp 1–22) as well as the copies of the ^{1}H NMR, ^{13}C NMR, IR, and/or MS spectra of the starting materials **1a–y** (pp 23–166) and the products **2–10**

(pp 167–406). Supplementary data associated with this article can be found in the online version, at doi:10.1016/j.tet.2009.08.068.

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