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Reaction Between Alkyl Isocyanides and Cyclic 1,3-Diketones: A Convenient Synthesis of Functionalized 4*H*-Pyrans

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Summary. Alkyl isocyanides react with dialkyl acetylendicarboxylates in the presence of CH-acids such as cyclopentane-1,3-dione, cyclohexane-1,3-dione, or 5,5-dimethylcyclohexane-1,3-dione to afford highly functionalized 4*H*-pyrans in fairly high yields. In the case of reaction between dimethyl acetylenedicarboxylate and 5,5-dimethylcyclohexane-1,3-dione in the presence of cyclohexyl isocyanide or benzyl isocyanide tetrahydro-cyclopenta[*b*]pyran derivatives were isolated in addition to the 4*H*-pyran system. The free energy barrier (96.9 kJ mol^{-1}) for restricted rotation around the polarized double bond of the enaminone moiety in dimethyl 2-[cyclohexylamino-(4,4-dimethyl-2,6-dioxocyclohexylidene)methyl]but-2-enedioate was determined by dynamic NMR spectroscopy.

Keywords. 1,3-Diketones; Alkyl isocyanides; CH-Acids; 4*H*-Pyrans; Three-component reaction; *Ugi* reaction.

Introduction

Six-membered oxygen heterocyclic compounds occupy an important position in natural product chemistry. They occur in plant life, most notably as flavenoids, and in marine environment where they form a part of the wide range of macrocyclic molecules [1]. The presence of oxacyclic units in polyether and macrolide antibiotics [2–4] has stimulated intense synthetic activity in pyran chemistry because of the significant pharmacological activity shown by these systems. Substituted 2-amino-4*H*-pyrans are significant in a number of practical applications. Some have been shown to exhibit biological activity [5] and they also serve as convenient starting materials for synthesis of condensed heterocycles [6, 7]. Synthesis of substituted 2-amino-4*H*-pyrans is usually a two-step process that is carried out

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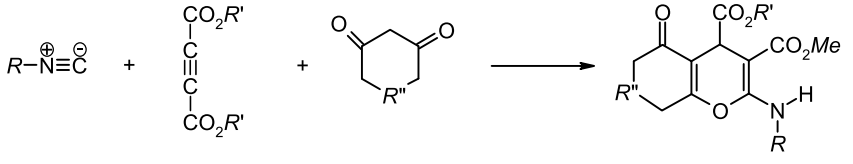
in the presence of a base as catalyst. The first step is the formation and isolation of an α,β-unsaturated nitrile that is subsequently reacted with a 1,3-dicarbonyl compound to form the 2-amino-4*H*-pyran [8, 9]. However, this method does not always succeed [10]. We previously reported [11, 12] the synthesis of 4*H*-pyrano[3,2-*d*]pyrimidine derivatives from the reaction of alkyl isocyanides with dimethyl acetylendicarboxylate (*DMAD*) and *N*,*N*-dimethylbarbituric acid. In the present work it will be shown that a one-pot three-component reaction can produce the desired substituted 2-amino-4*H*-pyran in good yield by reaction of alkyl isocyanides and cyclic 1,3-diketones in the presence of dialkyl acetylendicarboxylates.

Results and Discussion

The reaction of alkyl isocyanides **1** with acetylenic esters **2** in the presence of cyclic 1,3-diketones **3** affords product **4** in good yields (Scheme 1). The structures of **4a**–**4l** were deduced from their IR, ^{1}H NMR, and ^{13}C NMR spectra. The mass spectra of these compounds are fairly similar and display molecular ion peaks.

Although we have not yet established the mechanism of the reaction between alkyl isocyanides and acetylenic esters in the presence of 1,3-diketones in an experimental manner, a possible explanation is proposed in Scheme 2. On the basis of the well-established chemistry of isocyanides [13–16] it is reasonable to assume that **4** results from an initial addition of the alkyl isocyanide to the acetylenic ester and subsequent protonation of the 1:1 adduct by the CH-acid. Then, the positively charged ion might be attacked by the enolate anion of the CH-acid to produce the keteneimine **6**. Such an addition product may isomerize, under the reaction conditions employed, to produce the fused heterocyclic system **4** (Scheme 2).

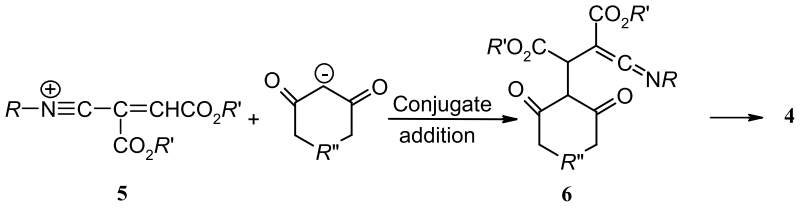
From the reaction of *DMAD* with 5,5-dimethylcyclohexane-1,3-dione in the presence of benzyl isocyanide or cyclohexyl isocyanide, in addition to the 4*H*-pyran derivative **4j** or **4l**, enaminones **7a** or **7b** were isolated. These enaminone



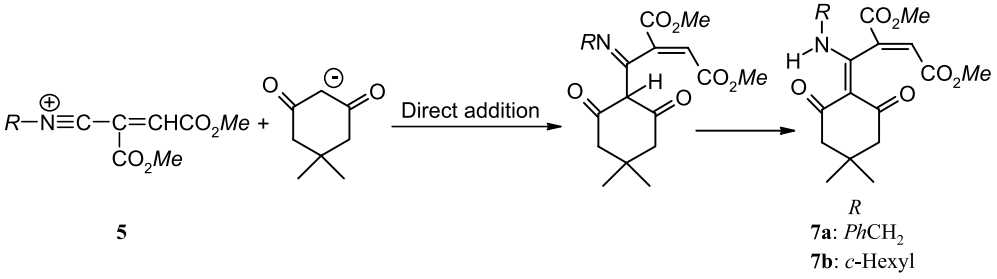
	R	*R'*	*R"*
1a:	*Bu*^{t}		
1b:	*c*-Hexyl		
1c:	*Ph*CH$_2$		
2a:		*Me*	
2b:		*Et*	
2c:		*Bu*^{t}	
3a:			-
3b:			CH$_2$
3c:			C*Me*$_2$

	R	*R'*	*R"*
4a:	*Bu*^{t}	*Me*	-
4b:	*c*-Hexyl	*Me*	-
4c:	*Bu*^{t}	*Me*	CH$_2$
4d:	*Bu*^{t}	*Et*	CH$_2$
4e:	*Bu*^{t}	*Bu*^{t}	CH$_2$
4f:	*c*-Hexyl	*Bu*^{t}	CH$_2$
4g:	*Bu*^{t}	*Me*	C*Me*$_2$
4h:	*Bu*^{t}	*Et*	C*Me*$_2$
4i:	*Bu*^{t}	*Bu*^{t}	C*Me*$_2$
4j:	*c*-Hexyl	*Me*	C*Me*$_2$
4k:	*c*-Hexyl	*Bu*^{t}	C*Me*$_2$
4l:	*Ph*CH$_2$	*Me*	C*Me*$_2$

Scheme 1



Scheme 2



Scheme 3

systems are produced by direct addition of the enolate anion to the positively charged ion **5** (see Scheme 3). This addition product undergoes an imine-to-enamine tautomerism to generate the enaminone system **7**. The (*E*) configuration of the carbon–carbon double bound in **7** is based on the chemical shift of the olefinic proton [17]. The methylene protons of benzyl group in **7a** are diasterotopic and exhibit an ABX ($J_{AB} = 15$ Hz, $J_{AX} = J_{BX} = 5$ Hz, $\delta_A = 4.36$, $\delta_B = 4.42$ ppm) system.

The ^{1}H NMR spectrum of **7a** in 1,2-dichlorobenzene at ambient temperature displayed four single resonances due to the C–Me (0.96 and 0.98 ppm) and methoxy (3.52 and 3.59 ppm) protons. At about 100°C, the resonances arising from the C–Me protons were appreciably broadened when compared to the corresponding signals at room temperature, whereas the methoxy resonance remained unchanged. The C–Me protons coalesced near 150°C and appeared as a fairly broad symmetrical line at 180°C. From the coalescence of the C–Me proton resonances using the expression $k = \pi \Delta\nu/\sqrt{2}$ we calculated the first order rate constant (k) for the C=C bond rotation in **7a** to be $10\,s^{-1}$ at 150°C. Application of the absolute rate theory with a transmission coefficient of 1 gives a free energy of activation ($\Delta G^{\#}$) of $96.9 \pm 2\,kJ\,mol^{-1}$, where all known sources of errors were estimated and included [18]. The experimental data available were not suitable for obtaining meaningful values of $\Delta H^{\#}$ and $\Delta S^{\#}$, even though the errors in $\Delta G^{\#}$ were not large [19]. The process, which led to the coalescence of the two C–Me signals at 150°C is attributed to restricted rotation about the highly polarized carbon–carbon double bond of the enaminone moiety in **7a** [20, 21].

In conclusion, the three-component reaction of alkyl isocyanides with electron deficient acetylenic esters in the presence of cyclic 1,3-diketones provides a simple one-pot entry into the synthesis of polyfunctional 4*H*-pyran derivatives of potential synthetic interest. This procedure has the advantages of high yields, mild reaction conditions, and simple experimental and work-up conditions.

Experimental

Dialkyl acetylenedicarboxylates, alkyl isocyanides, and cyclic 1,3-diketones were obtained from Fluka (Buchs, Switzerland) and were used without further purification. Melting points were measured on an Electrothermal 9100 apparatus. Elemental analyses (C, H, N) were performed using a Heraeus CHN-O-Rapid analyzer; the results agreed favourably with the calculated values. IR spectra were measured on a Shimadzu IR-460 spectrometer. ^{1}H and ^{13}C NMR spectra were measured with a Bruker DRX-500 AVANCE instrument with $CDCl_3$ as solvent at 500.1 and 125.7 MHz. Dynamic ^{1}H NMR spectra were measured on a JEOL-90 MHz NMR instrument. Mass spectra were recorded on a Finnigan-Matt 8430 mass spectrometer operating at an ionization potential of 70 eV.

General Procedure (*Examplified by* ***4a***)

To a magnetically stirred solution of 0.20 g of cyclopentane-1,3-dione (2 mmol) and 0.28 g of *DMAD* (2 mmol) in 10 cm^3 of $CHCl_3$ a mixture of 0.17 g of *tert*-butyl isocyanide (2 mmol) in 3 cm^3 of $CHCl_3$ was added dropwise at 0°C over 5 min. After 24 h stirring at rt, the solvent was removed under reduced pressure. The oily residue was separated by silica (Merck 230–400 mesh) column chromatography using *n*-hexane:ethyl acetate mixture as eluent. The first compound was eluted using a 5:1 mixture of *n*-hexane:ethyl acetate and was identified as **4a**.

Dimethyl 2-tert-butylamino-5-oxo-4,5,6,7-tetrahydrocyclopenta[b]pyran-3,4-dicarboxylate (**4a**, $C_{16}H_{21}NO_6$)

Pale yellow crystals, yield 0.63 g (98%); mp 180–182°C; IR (KBr): $\bar{\nu} = 3230$ (NH), 1729 and 1680 (C=O), 1592 (C=C) cm^{-1}; ^{1}H NMR: $\delta = 1.43$ (s, CMe_3), 2.54–2.72 (m, $2CH_2$), 3.66 and 3.69 (2s, 2OMe), 4.27 (s, CH), 9.00 (br s, NH···O=C) ppm; ^{13}C NMR: $\delta = 24.88$ and 33.39 ($2CH_2$), 30.33 (CMe_3), 35.38 (CH), 50.98 and 52.24 (2OMe), 52.77 (N–CMe_3), 72.32 (N–C=*C*), 115.68 (O–C=*C*), 160.48 (O–*C*=C), 169.68 and 173.18 (2C=O, ester), 176.00 (N–*C*=C), 200.70 (C=O) ppm; MS: m/z (%) = 323 (M^+, 3), 307 (25), 250 (100), 218 (63).

Dimethyl 2-cyclohexylamino-5-oxo-4,5,6,7-tetrahydrocyclopenta[b]pyran-3,4-dicarboxylate (**4b**, $C_{18}H_{23}NO_6$)

Pale yellow crystals, yield 0.67 g (96%); mp 121–123°C; IR (KBr): $\bar{\nu} = 3225$ (NH), 1729 and 1686 (C=O), 1593 (C=C) cm^{-1}; ^{1}H NMR: $\delta = 1.22$–1.90 (m, $5CH_2$), 2.46–2.67 (m, $2CH_2$), 3.60 and 3.63 (2s, 2OMe), 3.66 (m, N–CH), 4.20 (s, CH), 8.76 (d, $J = 8$ Hz, NH···O=C) ppm; ^{13}C NMR: $\delta = 20.85$, 21.41, 21.63 ($5CH_2$), 29.78 and 31.88 ($2CH_2$), 29.99 (CH), 46.21 (N–*C*H), 47.27 and 48.57 (2OMe), 68.00 (N–C=*C*), 112.18 (O–C=*C*), 155.64 (O–*C*=C), 165.98 and 169.62 (2C=O, ester), 172.88 (N–*C*=C), 197.10 (C=O) ppm; MS: m/z (%) = 349 (M^+, 3), 291 (64), 208 (63), 176 (100).

Dimethyl 2-tert-butylamino-5-oxo-5,6,7,8-tetrahydro-4H-chromene-3,4-dicarboxylate (**4c**, $C_{17}H_{23}NO_6$)

Pale yellow crystals, yield 0.65 g (96%); mp 93–94°C; IR (KBr): $\bar{\nu} = 3235$ (NH), 1727 and 1666 (C=O), 1600 (C=C) cm^{-1}; ^{1}H NMR: $\delta = 1.28$ (s, CMe_3), 2.20–2.60 (m, $3CH_2$), 3.50 and 3.55 (2s, 2OMe), 4.35 (s, CH), 8.60 (s, NH) ppm; ^{13}C NMR: $\delta = 16.23$, 23.16, and 32.68 ($3CH_2$), 26.60 (CMe_3), 30.55 (CH), 47.01 (CMe_3), 48.28 and 48.70 (2OMe), 69.47 (N–C=*C*), 109.43 (O–C=*C*), 156.12 (O–*C*=C), 160.77 and 165.73 (2C=O, ester), 169.94 (N–*C*=C), 192.13 (C=O) ppm; MS: m/z (%) = 337 (M^+, 3), 279 (26), 222 (100), 189 (56).

Diethyl 2-tert-butylamino-5-oxo-5,6,7,8-tetrahydro-4H-chromene-3,4-dicarboxylate (**4d**, $C_{19}H_{27}NO_6$)

Pale yellow powder, yield 0.66 g (90%); mp 109°C, IR (KBr): $\bar{\nu} = 3220$ (NH), 1717 and 1678 (C=O), 1598 (C=C) cm^{-1}; ^1H NMR: $\delta = 1.21$ and 1.26 (2t, J = 7 Hz, $2CH_3$), 1.39 (s, CMe_3), 2.20–2.55 (m, $3CH_2$), 4.00 and 4.20 (2q, $J = 7$ Hz, $2OCH_2$), 4.45 (s, CH), 8.70 (s, br, N–H···O=C); ^{13}C NMR: $\delta = 14.20$ and 14.50 ($2CH_3$), 20.20, 27.12, and 28.20 ($3CH_2$), 30.50 (CMe_3), 36.70 (CH), 52.50 (CMe_3), 59.60 and 60.90 ($2OCH_2$), 73.40 (N–C=*C*), 113.44 (O–C=*C*), 160.01 (O–*C*=C), 164.64 and 169.40 (2C=O, ester), 173.77 (N–*C*=C), 196.28 (C=O) ppm; MS: m/z (%) = 365 (M^+, 3), 292 (100), 235 (100), 207 (30).

Di-tert-butyl 2-tert-butylamino-5-oxo-5,6,7,8-tetrahydro-4H-chromene-3,4-dicarboxylate (**4e**, $C_{23}H_{35}NO_6$)

Pale yellow powder, yield 0.72 g (85%); mp 107°C, IR (KBr): $\bar{\nu} = 3225$ (NH), 1717 and 1676 (C=O), 1602 (C=C) cm^{-1}; ^1H NMR: $\delta = 1.40$, 1.43, and 1.50 (3s, $3CMe_3$), 2.10–2.69 (m, $3CH_2$), 4.43 (s, CH), 8.64 (br s, N–H···O=C); ^{13}C NMR: $\delta = 27.09$, 27.79, and 28.28 ($3CH_2$), 28.05, 28.50 and 30.00 ($3CMe_3$), 36.00 (CH), 52.28 ($NCMe_3$), 75.00 (N–C=*C*), 79.41 and 80.30 ($2OCMe_3$), 113.93 (O–C=*C*), 159.70 (O–*C*=C), 164.40 and 169.09 (2C=O, ester), 173.15 (N–*C*=C), 196.00 (C=O) ppm; MS: m/z (%) = 421 (M^+, 20), 320 (100), 263 (100), 236 (50), 162 (30).

Di-tert-butyl 2-cyclohexylamino-5-oxo-5,6,7,8-tetrahydro-4H-chromene-3,4-dicarboxylate (**4f**, $C_{25}H_{37}NO_6$)

Pale yellow powder, yield 0.82 g (92%); mp 122–124°C, IR (KBr): $\bar{\nu} = 3220$ (NH), 1713 and 1678 (C=O), 1597 (C=C) cm^{-1}; ^1H NMR: $\delta = 1.42$ and 1.49 (2s, $2CMe_3$), 1.50, 1.80 and 2.00 (m, $3CH_2$), 2.30–2.50 (m, $5CH_2$), 3.50 (NCH), 4.30 (CH), 8.40 (br s, N–H···O=C); ^{13}C NMR: $\delta = 20.26$, 24.70, 25.50, 27.00, 27.60 and 27.85 ($8CH_2$), 28.00 and 28.50 ($2CMe_3$), 36.74 (CH), 50.14 (NCH), 74.14 (N–C=*C*), 80.37 and 81.87 ($2CMe_3$), 113.97 (O–C=*C*), 158.56 (O–*C*=C), 164.77 and 169.00 (2C=O, ester), 173.30 (N–*C*=C), 196.10 (C=O) ppm; MS: m/z (%) = 447 (M + 1, 20), 365 (10), 346 (100), 308 (10), 289 (100).

Dimethyl 2-tert-butylamino-7,7-dimethyl-5-oxo-5,6,7,8-tetrahydro-4H-chromene-3,4-dicarboxylate (**4g**, $C_{19}H_{27}NO_6$)

White crystals, yield 0.71 g (97%); mp 163–165°C; IR (KBr): $\bar{\nu} = 3235$ (NH), 1717 and 1657 (C=O), 1589 (C=C) cm^{-1}; ^1H NMR: $\delta = 1.13$ and 1.14 (2s, CMe_2), 1.40 (s, CMe_3), 2.33 and 2.48 (2s, $2CH_2$), 3.64 and 3.70 (2s, 2OMe), 4.50 (s, CH), 8.70 (s, NH···O=C) ppm; ^{13}C NMR: $\delta = 23.37$ and 25.60 (2Me), 28.60 (CMe_2), 26.77 (CMe_3), 30.45 (CH), 37.02 and 48.47 ($2CH_2$), 47.25 (CMe_3), 46.80 and 48.90 (2OMe), 69.61 (N–C=*C*), 108.59 (O–C=*C*), 156.5 (O–*C*=C), 159.38 and 166.02 (2C=O, ester), 169.98 (N–*C*=C), 192.40 (C=O) ppm; MS: m/z (%) = 365 (M^+, 3), 307 (25), 250 (100), 218 (63).

Diethyl 2-tert-butylamino-7,7-dimethyl-5-oxo-5,6,7,8-tetrahydro-4H-chromene-3,4-dicarboxylate (**4h**, $C_{21}H_{31}NO_6$)

Pale yellow powder, yield 0.75 g (95%); mp 102°C, IR (KBr): $\bar{\nu} = 3225$ (NH), 1719 and 1690 (C=O) cm^{-1}; ^1H NMR: $\delta = 1.10$ (s, CMe_2), 1.18 and 1.24 (t, $J = 7$ Hz, $2CH_3$), 1.36 (s, CMe_3), 2.26 and 2.44 (2s, $2CH_2$), 4.00–4.10 (m, $2OCH_2$), 4.44 (s, CH), 8.67 (br s, N–H···O=C); ^{13}C NMR: $\delta = 14.30$ and 14.67 (2Me), 27.23 and 29.50 (CMe_2), 30.04 (CMe_3), 32.49 (CMe_2) 34.55 and 40.93 ($2CH_2$), 34.59

(CH), 50.7 (CMe_3), 59.70 and 60.96 ($2OCH_2$), 73.68 (N–C=*C*), 112.54 (O–C=*C*), 160.27 (O–*C*=C), 163.18 and 169.60 (2C=O, ester), 172.48 (N–*C*=C), 196.35 (C=O) ppm; MS: m/z (%) = 393 (M^+, 8), 320 (100), 263 (90), 235 (50).

Di-tert-butyl 2-tert-butylamino-7,7-dimethyl-5-oxo-5,6,7,8-tetrahydro-4H-chromene-3,4-dicarboxylate (**4i**, $C_{25}H_{39}NO_6$)

Colorless crystals, yield 0.88 g (98%); mp 150–151°C; IR (KBr): $\bar{\nu}$ = 3220 (NH), 1709 and 1661 (C=O), 1597 (C=C) cm^{-1}; ^1H NMR: δ = 1.09 and 1.10 (2s, CMe_2), 1.37, 1.38, and 1.46 (3s, $3CMe_3$), 2.27 and 2.42 (2s, $2CH_2$), 4.27 (s, CH), 8.60 (br, NH···O=C) ppm; ^{13}C NMR: δ = 26.97 and 29.42 (2Me), 28.02 and 28.59 ($2O–CMe_3$), 30.60 ($N–CMe_3$), 32.23 (CMe_2), 36.04 (CH), 40.85 and 52.29 ($2CH_2$), 50.76 ($NCMe_3$), 75.20 (N–C=*C*), 79.43 and 80.27 ($2OCMe_3$), 112.73 (O–C=*C*), 159.83 (O–*C*=C), 162.92 and 169.14 (2C=O, ester), 172.62 (N–*C*=C), 195.93 (C=O) ppm; MS: m/z (%) = 452 (M + 2, 1), 451 (M + 1, 3), 450 (M^+, 15), 348 (35), 292 (100), 218 (60).

Dimethyl 2-cyclohexylamino-7,7-dimethyl-5-oxo-5,6,7,8-tetrahydro-4H-chromene-3,4-dicarboxylate (**4j**, $C_{21}H_{29}NO_6$)

Yellow crystals, yield 0.61 g (78%); mp 136–138°C; IR (KBr): $\bar{\nu}$ = 3240 (NH), 1726 and 1675 (C=O), 1596 (C=C) cm^{-1}; ^1H NMR: δ = 1.06 and 1.07 (2s, 2Me), 1.18–1.89 (m, $5CH_2$), 2.25 and 2.40 (2s, $2CH_2$), 3.58 and 3.63 (2s, 2OMe), 3.60 (m, N–CH), 4.41 (s, CH), 8.5 (d, NH···O=C, J = 7 Hz) ppm; ^{13}C NMR: δ = 24.38, 24.41, 25.40, 33.49, and 33.76 ($5CH_2$), 27.16 and 29.26 (2Me), 32.30 (CMe_2), 34.40 (CH), 40.68 and 50.86 ($2CH_2$), 49.96 (N–CH), 50.51 and 52.14 (2OMe), 72.31 (N–C=*C*), 112.25 (O–C=*C*), 158.90 (O–*C*=C), 163.32 and 169.65 (2C=O, ester), 173.85 (N–*C*=C), 195.15 (C=O) ppm; MS: m/z (%) = 391 (M^+, 2), 333 (100), 251 (42), 218 (62), 52 (21).

Di-tert-butyl 2-cyclohexylamino-7,7-dimethyl-5-oxo-5,6,7,8-tetrahydro-4H-chromene-3,4-dicarboxylate (**4k**, $C_{27}H_{41}NO_6$)

Pale yellow powder, yield 0.86 g (90%); mp 126–128°C, IR (KBr): $\bar{\nu}$ = 3220 (NH), 1715 and 1675 (C=O), 1598 (C=C) cm^{-1}; ^1H NMR: δ = 1.09 and 1.11 (2s, CMe_2), 1.32 and 1.47 (2s, $2CMe_3$), 1.60–1.80 (m, $5CH_2$), 2.25 and 2.41 (2s, $2CH_2$), 3.30–3.40 (m, NCH), 4.27 (s, CH), 8.45 (br s, N–H···O=C); ^{13}C NMR: δ = 24.70, 25.40, and 33.70 ($5CH_2$), 25.49 and 26.95 (CMe_2), 27.70 and 29.38 ($2CMe_3$), 32.10 (CMe_2), 33.99 (CH), 40.77 and 50.11 ($2CH_2$), 50.73 (NCH), 74.15 (N–C=*C*), 79.31 and 80.27 ($2CMe_3$), 112.70 (O–C=*C*), 158.50 (O–*C*=C), 163.23 and 169.11 (2C=O, ester), 172.48 (N–*C*=C), 196.07 (C=O) ppm; MS: m/z (%) = 479 (M^+, 3), 420 (3), 374 (35), 318 (100), 236 (20).

Dimethyl 2-benzylamino-7,7-dimethyl-5-oxo-5,6,7,8-tetrahydro-4H-chromene-3,4-dicarboxylate (**4l**, $C_{22}H_{25}NO_6$)

White crystals, yield 0.54 g (68%); mp 169–171°C; IR (KBr): $\bar{\nu}$ = 3255 (NH), 1715 and 1676 (C=O), 1596 (C=C) cm^{-1}; ^1H NMR: δ = 0.96 and 0.98 (2s, 2Me), 2.16 (AB quartet, $\Delta\delta$ = 0.05, J_{AB} = 17 Hz, CH_2), 2.23 (AB quartet, $\Delta\delta$ = 0.10, J_{AB} = 18 Hz, CH_2), 3.52 and 3.58 (2s, 2OMe), 4.39 (ABX, J_{AB} = 15 Hz, $J_{AX} = J_{BX}$ = 6 Hz, δ_A = 4.36, δ_B = 4.42, CH_2Ph), 4.40 (s, CH), 7.14–7.27 (m, C_6H_5), 8.81 (t, NH···O=C, J = 5 Hz) ppm; ^{13}C NMR: δ = 27.00 and 28.98 (2Me), 32.19 (CMe_2), 34.40 and 44.93 ($2CH_2$), 40.35 (CH), 50.37 (CH_2Ph), 50.91 and 52.06 (2OMe), 73.51 (N–C=*C*), 112.23 (O–C=*C*), 126.97, 127.26, 128.66, and 138.24 (C_6H_5), 159.28 (O–*C*=C), 163.27 and 169.39 (2C=O, ester), 173.48 (N–*C*=C), 195.91 (C=O) ppm; MS: m/z (%) = 399 (M^+, 10), 339 (100), 249 (10), 91 (50).

Dimethyl 2-[benzylamino(4,4-dimethyl-2,6-dioxo-cyclohexylidene)methyl]but-2-enedioate (**7a**, $C_{22}H_{25}NO_6$)

White crystals, yield 0.22 g (28%); mp 113–115°C; IR (KBr): $\bar{\nu} = 3254$ (NH), 1716 and 1632 (C=O), 1556 (C=C) cm^{-1}; ^1H NMR: $\delta = 1.01$ and 1.03 (2s, 2Me), 2.25 (AB quartet, $\Delta\delta = 0.03$, $J_{AB} = 17$ Hz, CH_2), 2.40 (AB quartet, $\Delta\delta = 0.03$, $J_{AB} = 17$ Hz, CH_2), 3.62 and 3.77 (2s, 2OMe), 4.39 (ABX, $J_{AB} = 15$ Hz, $J_{AX} = J_{BX} = 5$ Hz, $\delta_A = 4.36$, $\delta_B = 4.42$, CH_2Ph), 6.88 (s, CH), 7.24–7.35 (m, C_6H_5), 13.4 (br, NH···O=C) ppm; ^{13}C NMR: $\delta = 27.75$ and 28.72 (2Me), 29.69 (*C*Me_2), 48.67 (*C*H_2Ph), 51.64 and 51.78 (2OMe), 52.19 and 53.01 (2CH_2), 107.84 (N–C=*C*), 125.11 (C=*C*H), 127.85, 128.19, 128.95, and 135.21 (C_6H_5), 140.41 (*C*=CH), 162.84 and 165.93 (2C=O, ester), 164.28 (N–*C*=C), 195.65 and 199.17 (2C=O) ppm; MS: m/z (%) = 399 (M^+, 6), 339 (70), 249 (22), 91 (100).

Dimethyl 2-[cyclohexylamino-(4,4-dimethyl-2,6-dioxo-cyclohexylidene)-methyl]-but-2-enedioate (**7b**, $C_{21}H_{29}NO_6$)

White powder, yield 0.14 g (18%); mp 107–109°C; IR (KBr): $\bar{\nu} = 3225$ (NH), 1717 and 1629 (C=O), 1561 (C=C) cm^{-1}; ^1H NMR: $\delta = 1.03$ and 1.04 (2s, 2Me), 1.16–1.87 (m, 5CH_2), 2.25 and 2.45 (m, 2CH_2), 3.35 (m, N–CH), 3.68 and 3.71 (2s, 2OMe), 6.85 (s, CH), 13.30 (br, NH···O=C) ppm; ^{13}C NMR: $\delta = 20.11$ (2Me), 21.32, 23.81, 25.18, 27.09, and 29.44 (5CH_2), 28.80 (*C*Me_2), 47.85 and 48.04 (2CH_2), 48.42 and 49.30 (2OMe), 50.15 (N–*C*H), 103.56 (N–C=*C*), 120.97 (C=*C*H), 136.64 (N–C–*C*=C), 159.42 (N–*C*=C), 160.53 and 160.66 (2C=O, ester), 191.74 and 195.08 (2C=O) ppm; MS: m/z (%) = 391 (M^+, 3), 333 (92), 251 (30), 218 (100), 52 (30).

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