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A Convenient Approach to the Synthesis of Dialkyl 5-Oxo-1,2-dihydro-5*H*-chromeno [4,3-*b*]pyridine-2,3-dicarboxylates

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Abstract: Coumarin and its analogs are considered privileged scaffolds in the current synthetic and pharmacological research. The chemical behavior of enaminocarbaldehydes of the coumarin moiety under intramolecular Wittig reaction conditions in the presence of triphenylphosphine and dimethyl or diethyl acetylenedicarboxylates has been studied, resulting in the isolation of a series of dimethyl and diethyl 5-oxo-1,2-dihydro-5*H*-chromeno[4,3-*b*]pyridine-2,3-dicarboxylates in good to high yields.

Keywords: Annelated ring system, coumarin, enaminoaldehydes, Wittig reaction

INTRODUCTION

As well-established pharmacophores, coumarins or pyridine-benzopyran fused systems are ubiquitous backbone subunits in many compounds of natural or synthetic origin with remarkable pharmacological action such as anticoagulant (warfarin-like), antibacterial, anti-allergic, wound-healing, or broncho-dilatating activity.[1] Remarkably wide spectra of chromen-2-one annelated ring systems of various types have been synthesized in the past years as *N*-containing analogs of naturally occurring substances[2] or as fluorescent dyes.[3] The continuing studies on the biologically active ingredients of

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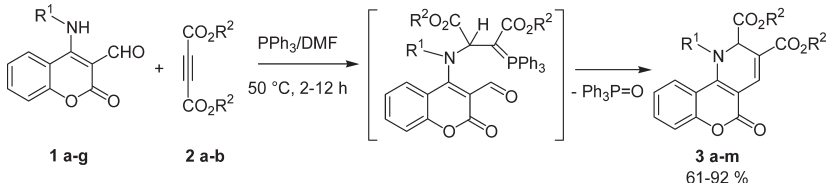

Scheme 1.

Cannabis sativa L., and in particular tetrahydrocannabinol, should also be mentioned.[4]

Most of the known methods for insertion of *N*-atom into the phenantrene skeleton are based on well-established reactions, for example, Kröhnke pyridine synthesis, Pechmann condensation, Skraup synthesis, Diels–Alder, or Vilsmeier–Haak.[5] One of them, the Wittig reaction, has turned into a standard tool for the preparative synthesis.[5g] Its intramolecular variant has been applied for the synthesis of numerous four- five- six- and seven-membered carbo- and heterocycles. Another successful synthesis of bezopyrano[4,3-*b*]pyridine-5-ones has also been realized through intermediate coumarin-acetamidines containing a formyl group.[6]

We report here on the application of coumarinic enaminoaldehydes as useful starting materials to produce hitherto unknown 5-oxo-1,2-dihydro-5*H*-chromeno[4,3-*b*]pyridine-2,3-dicarboxylates in good to excellent yields by using symmetrical acetylene dicarboxylates (Scheme 1). The enaminones **1a**–**g**, utilized in this study, are readily available. Upon treating 4-hydroxycoumarin with various amines in acidic media, the corresponding 4-aminocoumarines were formed, which were then formylated under Vilsmeier–Haack reaction conditions to give the desired enaminoaldehydes **1a**–**g**.[7]

RESULTS AND DISCUSSION

In a recent work,[8] we demonstrated 4-aminocoumarin-3-carbaldehydes **1a**–**g** to be handy intermediates for the synthesis of 2*H*-chromeno[4,3-*b*]pyridine-2,5(1*H*)-diones. Earlier studies in our labaratory have shown that these aminoladehydes react in the presence of triphenylphosphine in terms of the Wittig reaction, resulting in the isolation of some 1-alkyl-1*H*-chromeno[4,3-*b*]pyridine-2,5-diones.[5f] A recent report extended the application of the intramolecular Wittig reaction to the heterocyclization of 4-hydroxycoumarin-3-carbaldehyde or indole-7-carbaldehyde with different symmetrical acetylene dicarboxylic esters.[9] Hence, we initially attempted the synthesis of 5-oxo-1,2-dihydro-5*H*-chromeno[4,3-*b*]pyridine-2,3-dicarboxylates by reacting equimolar amounts of 4-aminocoumarin-3-carbaldehyde (**1a**), triphenyl phosphine, and dimethyl acetylendicarboxylate **2a** (CH_2Cl_2 as solvent) at

room temperature for 12 hours. This trial was unsuccessful because of incomplete conversion of the starting material into the product even after prolonging the reaction time by 6 hours. However, optimizing the reaction conditions by using dimethylformamide (DMF) as reaction medium of higher polarity, increasing the reaction temperature up to 50 °C, and adding 0.5 equivalents of both Ph_3P and dimethylacetylendicarboxylate **2a** in one portion after 1 h, proved to be crucial for the completion of the reaction in 2 h. Upon conjugate addition of Ph_3P to the activated acetylene **2a**, consequent formation of phosphonium salt and phosphorane, and following intermolecular Wittig transformation, the desired product **3a** was formed (Scheme 1) and isolated in 71% yield by removal of the solvent under vacuum and successive flash chromatography of the solid residue. A similar type of intermolecular processes have already been observed and discussed by authors working on various other systems.[9]

Further experiments proved that the described procedure is applicable to a variety of similar enaminones. All of the utilized starting compounds were readily converted into the corresponding dialkyl 5-oxo-1,2-dihydro-5*H*-chromeno[4,3-*b*]pyridine-2,3-dicarboxylates (**3a**–**m**) (Table 1). As expected, increasing the bulkiness of the *N*-substituent (R^1) in the series (e.g., Table 1, entries **3e**–**g** and **3k**–**m**) resulted in longer reaction times. The structure of the synthesized diaklyl 1-alkyl-5-oxo-1,2-dihydro-5*H*-chromeno[4,3-*b*]pyridine-1,2-dicarboxylates (**3a**–**m**) was successfully and unambiguously assigned on the basis of ^1H and ^{13}C NMR spectral data. The signals of the characteristic methine protons at C-2 and C-4 positions

Table 1. Substitution pattern, reaction times, and isolated yields for the newly synthesized compounds **3a**–**m**

Product	R^1	R^2	Reaction time (h)	Yield (%)[a]
3a	H	CH_3	2	71
3b	CH_3	CH_3	3	87
3c	C_2H_5	CH_3	6	93
3d	C_3H_7	CH_3	7	90
3e	C_4H_9	CH_3	12	61
3f	$CH_2C_6H_5$	CH_3	10	92
3g	$CH_2CH{=}CH_2$	CH_3	9	86
3h	H	C_2H_5	2.5	84
3i	CH_3	C_2H_5	3	85
3j	C_2H_5	C_2H_5	5	91
3k	C_3H_7	C_2H_5	10	90
3l	$CH_2C_6H_5$	C_2H_5	12	88
3m	$CH_2CH{=}CH_2$	C_2H_5	10	85

[a]Yields of isolated products after flash chromatography (see the Experimental section).

appeared at $\delta = 5.18-5.34$ and $\delta = 7.56-7.84$, respectively, in the ^{1}H NMR spectrum of compounds **3a–m**. Supplemental mass spectra (MS) spectra and elemental microanalyses are in good agreement with the expected values.

In summary, we have demonstrated a useful approach to the synthesis of 1,2-dihydro-chromeno[4,3-*b*]pyridine-2,3-dicarboxylates in good to high yields by a type of intramolecular Wittig reaction starting from easily obtainable *N*-substituted 4-aminocoumarins.

EXPERIMENTAL

The thin-layer chromatography (TLC) was performed on pre coated silica-gel Merck 60 F_{254} plates. ^{1}H NMR and ^{13}C NMR spectra were recorded on a 360-MHz Bruker AMX instrument at 360 and 90 MHz, respectively. Low-resolution mass spectra (LRMS) were obtained on an HP 1100 LC/MS instrument using atmospheric pressure chemical ionisation (APCI) technique (positive or negative mode). Column chromatography was performed on silica gel (Merck 60H), using the dry-flash method.

General Procedure for the Synthesis of Dialkyl 1-Alkyl-5-oxo-1,2-dihydro-5*H*-chromeno[4,3-*b*]pyridine-2,3-dicarboxylates (3a–m)

The corresponding 4-aminocoumarin-3-carbaldehyde **1a–f** (1 mmol), triphenyl phosphine (262 mg, 1.0 mmol), and 10 mL of DMF were stirred at room temperature for 10 min in a 10-mL round-bottom flask. Dimethyl acetylene dicarboxylate **2a** (1.0 mmol) (or diethyl ester **2b**) was added dropwise for another 10 min, and the dark-orange colored solution thus obtained was heated at 50 °C. A second portion of 0.5 eq. of PPh_3 was added after 1 h, instantly followed by an additional 0.5 eq. of acetylene dicarboxylate **2a** or **2b**. The reaction continued until no starting material could be detected by TLC. After removing the reaction medium under reduced pressure, the products **3a–k** were isolated by dry flash chromatography on silica gel (eluted by petroleum ether–ethylacetate 1:1).

Dimethyl 5-Oxo-1,2-dihydro-5*H*-chromeno[4,3-*b*]pyridine-2,3-dicarboxylate (3a)

Reaction time 2 h, yield 71%, bright yellow crystals, mp 258–260 °C (2-propanol). ^{1}H NMR (DMSO-d_6): $\delta = 3.64$ (s, 3H), 3.74 (s, 3H), 5.31 (s, 1H), 7.37 (d, $J = 8.31$, 1H), 7.42 (t, $J = 7.65$, 1H), 7.56 (s, 1H), 7.69 (t, $J = 7.76$, 1H), 8.11 (d, $J = 7.92$, 1H), 9.38 (br s, 1H); ^{13}C NMR (DMSO-d_6): δ 51.7 (2 C), 52.52, 92.96, 111.75, 112.36, 117.18, 123.02, 124.1, 131.3, 133.57, 150.4, 152.88, 158.8, 164.43, 170.23; MS (pos. APCI) m/z (%) 316

(15, M + 1), 315 (100, M), 255 (15, M − 1). Anal. calcd. for $C_{16}H_{13}NO_6$: C, 60.95%; H, 4.16%; N, 4.44%. Found: C, 60.85%; H, 4.05%; N, 4.37%.

Dimethyl 1-Methyl-5-oxo-1,2-dihydro-5*H*-chromeno[4,3-*b*]pyridine-2,3-dicarboxylate (3b)

Reaction time 3 h, yield 87%, bright yellow crystals, mp 204–206 °C (ethanol). ^{1}H NMR (DMSO-d_6): $\delta = 3.68$ (s, 3H), 3.72 (s, 3H), 3.84 (s, 3H), 5.19 (s, 3H), 7.26–7.35 (m, 2H), 7.54 (t, $J = 7.22$, 1H), 7.62 (t, $J = 7.24$, 1H), 7.85 (s, 1H), 8.03 (d, $J = 7.51$, 1H), 8.13 (d, $J = 7.51$, 1H); ^{13}C NMR (DMSO-d_6): δ 45.23, 52.08, 52.85, 62.01, 101.44, 112.56, 114.93, 118.37, 123.72, 126.31, 130.87, 132.71, 152.57, 154.18, 159.98, 165.53, 170.44; MS (pos. APCI) m/z (%) 330 (20, M + 1), 329 (100, M), 314 (10, M − 16). Anal. calcd. for $C_{17}H_{15}NO_6$: C, 62.00%; H, 4.59%; N, 4.25%. Found: C, 62.05%; H, 4.55%; N, 4.22%.

Dimethyl 1-Ethyl-5-oxo-1,2-dihydro-5*H*-chromeno[4,3-*b*]pyridine-2,3-dicarboxylate (3c)

Reaction time 6 h, yield 93%, bright yellow crystals, mp 197–200 °C (2-propanol). ^{1}H NMR (DMSO-d_6): $\delta = 1.46$ (t, $J = 7.06$, 3H), 3.66 (s, 3H), 3.74–3.85 (m, 4H), 3.99 (m, $J = 7.06$, 1H), 5.32 (s, 1H), 7.27–7.39 (m, 2H), 7.54 (t, $J = 7.24$, 1H), 7.84 (s, 1H), 7.89 (d, $J = 8.15$, 1H); ^{13}C NMR ($CDCl_3$): δ 14.91, 49.90, 52.14, 52.82, 57.48, 103.93, 113.74, 115.13, 118.32, 123.96, 125.63, 130.72, 132.61, 152.89, 154.03, 160.02, 165.59, 170.69; MS (pos. APCI) m/z (%) 343 (100, M). Anal. calcd. for $C_{18}H_{17}NO_6$: C, 62.97%; H, 4.99%; N, 4.08%. Found: C, 63.01%; H, 4.96%; N, 4.12%.

Dimethyl 5-Oxo-1-propyl-1,2-dihydro-5*H*-chromeno[4,3-*b*]pyridine-2,3-dicarboxylate (3d)

Reaction time 7 h, yield 90%, bright yellow crystals, mp 194–196 °C (2-propanol). ^{1}H NMR ($CDCl_3$): δ 0.87 (t, $J = 7.36$, 3H), 1.72–1.94 (m, 2H), 3.65 (s, 3H), 3.81 (t, $J = 7.62$, 2H), 3.85 (s, 3H), 5.34 (s, 1H), 7.27–7.34 (m, 2H), 7.51–7.56 (t, $J = 7.79$, 1H), 7.83 (s, 1H), 7.89 (d, $J = 8.16$, 1H); ^{13}C NMR ($CDCl_3$): δ 10.86, 23.05, 52.15, 52.82, 57.05, 57.49, 103.74, 113.70, 115.12, 118.32, 123.94, 125.83, 130.64, 132.59, 153.06, 154.06, 160.08, 165.59, 170.69; MS (neg. APCI) m/z (%) 357 (100, M), 314 (55, M − 43), 284 (10, M − 73). Anal. calcd. for $C_{19}H_{19}NO_6$: C, 63.86%; H, 5.36%; N, 3.92%. Found: C, 63.78%; H, 5.33%; N, 3.88%.

Dimethyl 1-Butyl-5-oxo-1,2-dihydro-5*H*-chromeno[4,3-*b*]pyridine-2,3-dicarboxylate (3e)

Reaction time 12 h, yield 61%, bright yellow crystals, mp 166–168 °C (methanol). ^{1}H NMR ($CDCl_3$): δ 0.91 (t, $J = 7.35$, 3H), 1.26–1.32 (m, 2H), 1.73–1.89 (m, 2H), 3.67 (s, 3H), 3.84–3.90 (m, 5H), 5.39 (s,1H), 7.27–7.35 (m, 2H), 7.54 (t, $J = 7.76$, 1H), 7.84 (s, 1H), 7.91 (d, $J = 8.17$, 1H); ^{13}C NMR ($CDCl_3$): δ 13.59, 19.70, 31.63, 52.12, 52.83, 55.13, 57.55, 103.70, 113.62, 115.12, 118.33, 123.91, 125.81, 130.66, 132.60, 153.04, 154.04, 160.08, 165.59, 170.71; MS (neg. APCI) m/z (%) 371 (100, M), 314 (39, M − 57). Anal. calcd. for $C_{20}H_{21}NO_6$: C, 64.68%; H, 5.70%; N, 3.77%. Found: C, 64.55%; H, 5.48%; N, 3.69%.

Dimethyl 1-Allyl-5-oxo-1,2-dihydro-5*H*-chromeno[4,3-*b*]pyridine-2,3-dicarboxylate (3g)

Reaction time 9 h, yield 86%, bright yellow crystals, mp 129–131 °C (2-propanol). ^{1}H NMR ($CDCl_3$): δ 3.66 (s, 3H), 3.85 (s, 3H), 4.33–4.39 (m, 1H), 4.48–4.54 (m, 1H), 5.33 (s, 1H), 5.44 (d, $J = 10.22$, 1H), 5.68 (d, $J = 17.11$, 1H), 5.89–6.00 (m, 1H), 7.27–7.35 (m, 2H), 7.55 (t, $J = 7.76$, 1H), 7.84 (s, 1H), 7.93 (d, $J = 8.07$, 1H); ^{13}C NMR (90 MHz, DMSO-d_6): δ 52.14, 52.77, 57.18, 57.54, 104.41, 114.22, 115.10, 118.23, 120.75, 124.07, 125.72, 130.55, 132.45, 132.74, 153.16, 154.02, 160.00, 165.40, 170.58; MS (pos. APCI) m/z (%): 355 (100, M). Anal. calcd. for $C_{19}H_{17}NO_6$: C, 64.22; H, 4.82; N, 3.94. Found: C, 64.19; H, 4.76; N, 3.98.

Dimethyl 1-Benzyl-5-oxo-1,2-dihydro-5*H*-chromeno[4,3-*b*]pyridine-2,3-dicarboxylate (3f)

Reaction time 10 h, yield 92%, bright yellow crystals, mp 178–180 °C (methanol). ^{1}H NMR ($CDCl_3$): δ 3.66 (s, 3H), 3.74 (s, 3H), 4.98 (d, $J = 15.43$, 1H), 5.13 (d, $J = 15.45$, 1H), 5.22 (s, 1H), 7.23 (t, $J = 7.65$, 1H), 7.34–7.45 (m, 5H), 7.56 (t, $J = 7.78$, 1H), 7.82 (s, 1H), 8.00 (d, $J = 8.05$, 1H); ^{13}C NMR ($CDCl_3$): δ 52.01, 52.78, 57.35, 58.56, 104.85, 114.84, 115.25, 118. 28, 124.16, 125.61, 127.01, 127.59, 128.55, 129.14, 129.41, 130.35, 132.77, 135.77, 153.56, 154.10, 160.04, 164.99, 170.55; MS (pos. APCI) m/z (%) 406 (20, M + 1), 405 (100, M). Anal. calcd. for $C_{23}H_{19}NO_6$: C, 68.14%; H, 4.72%; N, 3.45%. Found: C, 68.23%; H, 4.76%; N, 3.52%.

Diethyl 5-Oxo-1,2-dihydro-5*H*-chromeno[4,3-*b*]pyridine-2,3-dicarboxylate (3h)

Reaction time 2.5 h, yield 84%, bright yellow crystals, mp 245–246 °C (ethanol). ^{1}H NMR (DMSO-d_6): δ 1.13 (t, $J = 7.07$, 3H), 1.26 (t, $J = 7.07$, 3H), 4.07 (m, $J = 7.07$, 2H), 4.17–4.26 (m, 2H), 5.28 (d, $J = 3.53$, 1H), 7.38 (d, $J = 8.32$, 1H), 7.46, (t, $J = 7.59$, 1H), 7.55 (s, 1H), 7.74 (t, $J = 7.82$, 1H), 8.12 (d, $J = 7.98$, 1H), 9.33 (d, $J = 3.48$ H); ^{13}C NMR (DMSO-d_6): δ 14.37, 14.65, 52.61, 60.86, 61.88, 93.56, 113.12, 117.89, 123.71, 124.80, 131.59, 134.23, 151.10, 153.61, 159.51, 164.70, 170.40; MS (pos. APCI) m/z (%) 344 (25, M + 1), 343 (100, M), 270 (36, M − 74). Anal. calcd. for $C_{18}H_{17}NO_6$: C, 62.97%; H, 4.99%; N, 4.08%. Found: C, 63.01%; H, 4.85%; N, 4.16%.

Diethyl 1-Methyl-5-oxo-1,2-dihydro-5*H*-chromeno[4,3-*b*]pyridine-2,3-dicarboxylate (3i)

Reaction time 3 h, yield 88%, bright yellow crystals, mp 186–188 °C (ethanol). ^{1}H NMR ($CDCl_3$): δ 1.20 (t, $J = 7.12$, 3H), 1.35 (t, $J = 7.12$, 3H), 3.73 (s, 3H), 4.13 (m, $J = 7.06$, 2H), 4.30 (q, $J = 7.12$, 2H), 5.18 (s, 1H), 7.27–7.35 (m, 2H), 7.55 (t, $J = 7.77$, 1H), 7.86 (s, 1H), 8.04 (d, $J = 8.23$, 1H); ^{13}C NMR ($CDCl_3$): δ 14.01, 14.34, 45.26, 61.00, 62.91, 62.11, 101.36, 113.39, 115.01, 118.36, 123.68, 126.26, 130.27, 132.61, 152.50, 154.16, 160.11, 165.17, 169.94; MS (pos. APCI) m/z (%) 358 (21, M + 1), 357 (100, M), 283 (11, M − 74). Anal. calcd. for $C_{19}H_{19}NO_6$: C, 63.86%; H, 5.36%; N, 3.92%. Found: C, 63.75%; H, 5.41%; N, 4.06%.

Diethyl 1-Ethyl-5-oxo-1,2-dihydro-5*H*-chromeno[4,3-b]pyridine-2,3-dicarboxylate (3j)

Reaction time 5 h, yield 91%, bright yellow crystals, mp 148–150 °C (ethanol). ^{1}H NMR ($CDCl_3$): δ 1.18 (t, $J = 7.11$, 3H), 1.35 (t, $J = 7.12$, 3H), 1.46 (t, $J = 7.08$, 3H), 3.78 (m, 1H), 4.00 (m, 1H), 4.10 (quartet, $J = 7.10$, 2H), 4.27–4.35 (m, 2H), 5.30 (s, 1H), 7.27–7.35 (m, 2H), 7.54 (t, $J = 7.22$, 1H), 7.83 (s, 1H), 7.89 (d, $J = 8.13$, 1H); ^{13}C NMR ($CDCl_3$): δ 13.95, 14.32, 14.92, 49.91, 57.60, 61.02, 61.80, 103.80, 114.57, 115.20, 118.28, 123.92, 125.58, 130.10, 132.50, 152.81, 153.98, 160.16, 165.22, 170.18; MS (pos. APCI) m/z (%) 372 (19, M + 1), 371 (100, M), 325 (10, M − 46), 297 (15, M − 74). Anal. calcd. for $C_{19}H_{19}NO_6$: C, 64.68%; H, 5.70%; N, 3.77%. Found: C, 64.59%; H, 5.65%; N, 3.68%.

Diethyl 5-Oxo-1-propyl-1,2-dihydro-5*H*-chromeno[4,3-*b*]pyridine-2,3-dicarboxylate (3k)

Reaction time 12 h, yield 90%, bright yellow crystals, mp 104–106 °C (ethanol). ^{1}H NMR ($CDCl_3$): δ 0.87 (t, $J = 7.34$, 3H), 1.71 (t, $J = 7.10$, 3H), 1.34 (t, $J = 7.12$, 3H), 1.71–1.96 (m, 2H), 3.81 (t, $J = 7.55$, 2H), 4.09 (t, $J = 7.07$, 2H), 4.26–4.35 (m, 2H), 5.32 (s, 1H), 7.27–7.34 (m, 2H), 7.53 (t, $J = 7.55$, 1H), 7.82 (s, 1H), 7.89 (d, $J = 8.04$, 1H); ^{13}C NMR ($CDCl_3$): δ 10.86, 13.97, 14.32, 23.03, 57.06, 57.63, 61.02, 61.79, 103.68, 114.57, 115.21, 118.29, 123.88, 125.77, 130.00, 132.47, 152.97, 154.03, 160.18, 165.22, 170.17; MS (neg. APCI) m/z (%) 386 (29, M + 1), 385 (100, M), 342 (54, M − 43). Anal. calcd. for $C_{21}H_{23}NO_6$: C, 65.44%; H, 6.02%; N, 3.63%. Found: C, 65.35%; H, 5.97%; N, 3.71%.

Diethyl 1-Benzyl-5-oxo-1,2-dihydro-5*H*-chromeno[4,3-*b*]pyridine-2,3-dicarboxylate (3l)

Reaction time 12 h, yield 89%, bright yellow crystals, mp 121–123 °C (ethanol). ^{1}H NMR ($CDCl_3$): δ 1.17 (t, $J = 7.12$, 3H), 1.26 (t, $J = 7.11$, 3H), 4.10 (quartet, $J = 7.10$, 2H), 4.19–4.23 (m, 2H), 4.97 (d, $J = 15.38$, 1H), 5.14 (d, $J = 15.40$, 1H), 5.19 (s, 1H), 7.27 (t, $J = 7.67$, 1H), 7.33–7.37 (m, 6H), 7.55, (t, $J = 7.34$, 1H), 7.81 (s, 1H), 7.99 (d, $J = 7.69$, 1H); ^{13}C NMR ($CDCl_3$): δ 13.93, 14.23, 57.47, 58.64, 60.84, 61.77, 104.78, 115.34, 115.71, 118.25, 124.09, 125.59, 127.61 (2 C), 128.50, 129.09 (2 C), 129.72, 132.65, 135.92, 153.46, 154.07, 160.13, 164.59, 170.05; MS (neg. APCI) m/z (%) 434 (20, M + 1), 433 (100, M), 342 (37, M − 91). Anal. calcd. for $C_{21}H_{23}NO_6$: C, 69.27%; H, 5.35%; N, 3.23%. Found: C, 69.38%; H, 5.43%; N, 3.32%.

Diethyl 1-Allyl-5-Oxo-1,2-dihydro-5*H*-chromeno[4,3-*b*]pyridine-2,3-dicarboxylate (3m)

Reaction time 10 h, yield 85%, bright yellow crystals, mp 110–112 °C (2-propanol).^{1}H-NMR (360-MHz, $CDCl_3$): δ 1.18 (t, $J = 7.12$ Hz, 3H), 1.35 (t, $J = 7.13$ Hz, 3H), 4.10 (q, $J = 7.11$ Hz, 2H), 4.24–4.35 (m, 2H), 4.37 (d, $J = 5.13$ Hz, 1H), 4.48–4.54 (m, 1H), 5.31 (s, 1H), 5.44 (dd, $^1J = 0.94$, $^2J = 10.27$, 1H), 5.57 (dd, $^1J = 0.91$, $^2J = 17.10$, 1H), 5.90–6.01 (m, 1H), 7.27–7.36 (m, 2H), 7.52–7.57 (m, 1H), 7.83 (s, 1H), 7.93 (dd, $^1J = 1.18$, $^2J = 8.17$, 1H); ^{13}C NMR (90-MHz, DMSO-d_6): δ 13.94, 14.30, 57.34, 57.58, 61.02, 61.79, 104.35, 115.06, 115.19, 118.21, 120.62, 124.03, 125.68, 129.91, 132.58, 132.63, 153.09, 153.99, 160.13, 165.05, 170.08; MS (pos. APCI) m/z (%): 383 (100, M). Anal. Calcd. for $C_{21}H_{21}NO_6$: C, 65.79; H, 5.52; N, 3.65. Found: C, 65.80; H, 5.53; N, 3.60.

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