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β-Carboline-directed decarboxylative acylation of *ortho*-C(sp2)-H of aryl ring of aryl (β-carbolin-1-yl) methanones with α-ketoacids under Palladium catalysis

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A palladium-catalysed β-carboline directed decarboxylative acylation of *ortho*-C(sp2)-H of aryl ring of aryl (β-carbolin-1-yl) methanones using α-oxocarboxylic acid as the acyl ion equivalent to form (2-aroylaryl) (β-carbolin-2-yl)methanones is described. The utility of these products for preparing β-carboline-tethered phthalazine system is also demonstrated.

Introduction

Transition-metal-catalysed decarboxylative cross-coupling reactions have become an important tool for the formation of C-C bond.[1] A variety of carboxylic acids and their salts are used as coupling partners in such decarboxylative reactions. In particular, α-oxocarboxylic acids have received considerable attention as they affect acylation of the inactivated C-H bond under mild conditions. Goossen et al. first reported the Cu/Pd-catalysed decarboxylative cross-coupling reaction between aryl bromides and α-oxocarboxylates to form biaryl ketones.[2] Later Ge et al. reported the Pd-catalysed decarboxylative acylation of acetanilides and 2-aryl pyridines at the *ortho*-position of the phenyl ring with α-oxocarboxylic acids via ligand-assisted *ortho*-C(sp2)-H activation in the presence of an oxidant.[3] Subsequently different directing groups including azobenzenes,[4] azoxybenzenes,[5] carboxylic acids,[6] cyclic enamides,[7] O-methyl ketoximes,[8] O-phenyl carbamates,[9] phenylacetamides,[10] 2-aryloxypyridines,[11] pyridine-N-oxides,[12] indolines,[13] thioethers,[14] N-nitroso anilines,[15] tetrahydroquinolines[16] and indoles[17] have been used for performing the acylation via ligand-assisted activation of the *ortho*-C(sp2)-H bond leading to formation of biaryl ketones with high regioselectivities under mild reaction conditions.

β-Carboline, a privileged scaffold, is core unit of several natural alkaloids and bioactive compounds endowed with diverse pharmacological properties.[18] The first example of β-carboline-directed ruthenium-catalyzed arylation was reported by Gandhi et al.[19] Subsequently we reported $Pd(OAc)_2$-catalysed regioselective alkoxylation (C-O bond formation) of aryl (β-carbolin-1-yl) methanones employing β-carboline directed *ortho*-C(sp2)–H activation of an aryl ring under oxidative conditions.[20] Continuing with our efforts to study the scope of β-carboline directed C(sp2)-H activation for installing various functional groups, we now disclose a Pd-catalysed β-carboline directed decarboxylative acylation using α-oxocarboxylic acid as the acyl ion source to form (2-aroylaryl) (β-carbolin-2-yl)methanones.

Results and discussion

Our study began by heating phenyl (β-carbolin-2-yl)methanone **1a** (0.1 g, 0.367 mmol) with 1.5 equiv. of phenyl oxocarboxylic acid **2a**, 10 mol% of $Pd(OAc)_2$ and 1 equiv. of $(NH_4)_2S_2O_8$ as the oxidant in dichloroethane (DCE) as the solvent at 80 °C in air. After 16 h assessment of TLC indicated the formation of major product which upon column chromatographic purification gave a solid compound in 72% yield which was identified to be the required **3aa**. In order to improve the yield of **3aa**, an optimization study with respect to solvent, oxidant, Pd-catalyst and reaction temperature was carried out and the results are summarized in Table 1. Screening of different solvents like dioxane, THF and diglyme revealed that the yield of **3aa** was superior in DCE (compare entry 1 with entries 2-4). Investigating reaction with different oxidants including $Na_2S_2O_8$, $K_2S_2O_8$, $PhI(OAc)_2$ and $Cu(OAc)_2$ revealed that the yield of **3aa** was superior with $K_2S_2O_8$ (compare entry 6 with entries 5,7-8). Notably increasing the amount of $K_2S_2O_8$ from 1 equiv. to 2 equiv. enhanced the yield of **3aa** to 82% (entry 9) but further increase did not affect the output (entry 10). Lowering the catalyst loading from 10 mol% to 5 mol% had detrimental effect on the formation of **3aa** (entry 11). In the absence of a catalyst no product formation was observed (entry 12). Reaction in the presence of other Pd-catalysts like $PdCl_2$ gave lower yield of **3aa** whereas $Pd(TFA)_2$ afforded the product in comparable yield as obtained with $Pd(OAc)_2$ (entries 13-14). Varying the reaction temperature revealed that better yield of product was isolated when the reaction was

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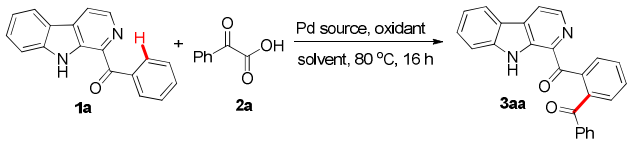
performed at 80°C as compared to 60°C or 100 °C (compare entry 9 with entries 15-16). Therefore, the

Table 1. Results of the optimization study[a]



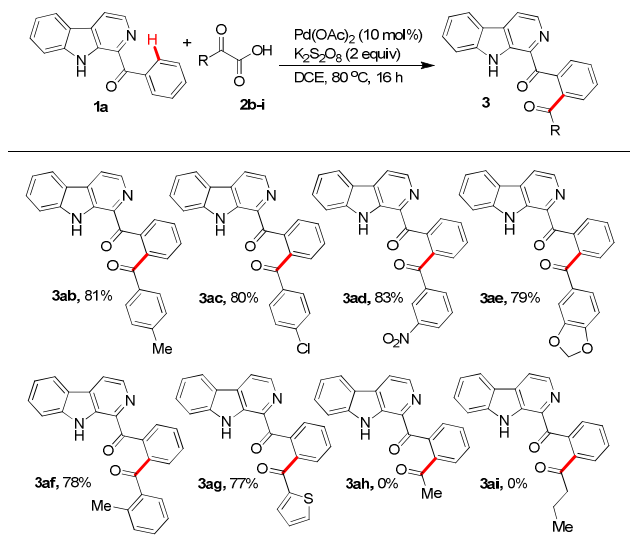
Entry	Pd source (mol%)	Oxidant (equiv)	Solvent	yield (%)[b]
1	$Pd(OAc)_2$ (10)	$(NH_4)_2S_2O_8$ (1)	DCE	72
2	$Pd(OAc)_2$ (10)	$(NH_4)_2S_2O_8$ (1)	Dioxane	46
3	$Pd(OAc)_2$ (10)	$(NH_4)_2S_2O_8$ (1)	THF	42
4	$Pd(OAc)_2$ (10)	$(NH_4)_2S_2O_8$ (1)	Diglyme	54
5	$Pd(OAc)_2$ (10)	$Na_2S_2O_8$ (1)	DCE	73
6	$Pd(OAc)_2$ (10)	$K_2S_2O_8$ (1)	DCE	74
7	$Pd(OAc)_2$ (10)	$PhI(OAc)_2$ (1)	DCE	68
8	$Pd(OAc)_2$ (10)	$Cu(OAc)_2$(1)	DCE	61
9	$Pd(OAc)_2$ (10)	$K_2S_2O_8$ (2)	DCE	82
10	$Pd(OAc)_2$ (10)	$K_2S_2O_8$ (3)	DCE	83
11	$Pd(OAc)_2$ (5)	$K_2S_2O_8$ (2)	DCE	55
12	-	$K_2S_2O_8$ (2)	DCE	0
13	$PdCl_2$ (10)	$K_2S_2O_8$ (2)	DCE	52
14	$Pd(TFA)_2$ (10)	$K_2S_2O_8$ (2)	DCE	80
15[c]	$Pd(OAc)_2$ (10)	$K_2S_2O_8$ (2)	DCE	71
16[d]	$Pd(OAc)_2$ (10)	$K_2S_2O_8$ (2)	DCE	81

[a]All reactions were performed using **1a** (0.1 g, 0.367 mmol) and **2a** (0.55 mmol) in a solvent (2 mL). [b]Isolated yield after column chromatography; [c]reaction at 60 °C; [d]reaction at 100 °C.

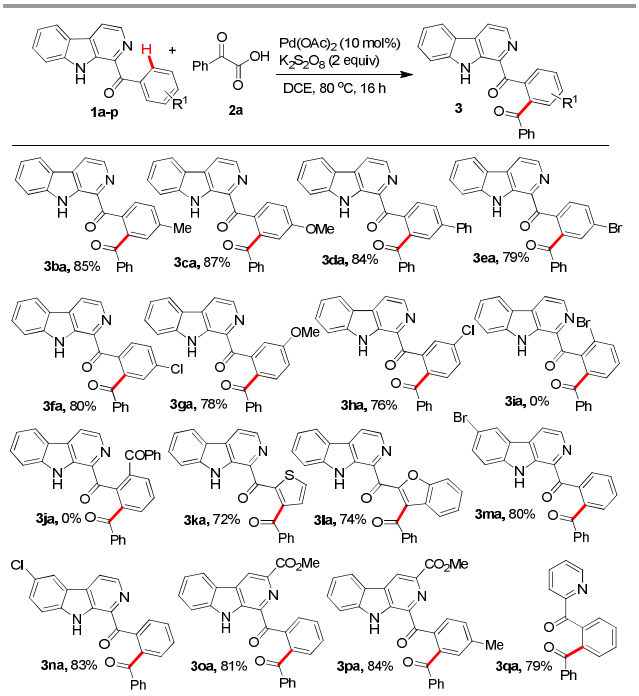
standardized conditions which suited the formation of **3aa** in our hands were heating **1a** (1.0 equiv.) with α-oxocarboxylic acid (1.5 equiv.) in the presence of 10 mol% of $Pd(OAc)_2$ and $K_2S_2O_8$ (2 equiv.) in DCE as the medium at 80 °C for 16 h.

With the optimized conditions in hands, we assessed the scope of the protocol with different α-oxocarboxylic acids and β-carbolines. Initially a variety of α-oxocarboxylic acids **(2b-i)** were investigated for their reactions with phenyl (β-carbolin-1-yl) methanone **(1a)** (Scheme 1). α-Oxocarboxylic acids **(2b-f)** bearing phenyl ring with electron donating or electron withdrawing groups reacted with **1a** affording the corresponding products **3ab-3af** in good to excellent yields. Treating α-oxocarboxylic acid bearing thiophene moiety **(2g)** with **1a** gave the product **3ag** in 77% yield. However, aliphatic α-oxocarboxylic acids **(2h-i)** failed to react with **1a** to yield the respective products **3ah-3ai**.

Next the reaction of **2a** was investigated with different starting aryl (β-carbolin-1-yl) methanones **(1b-p)** (Scheme 2). It was observed that the position of substituents on the aryl ring has direct bearing on the formation of the product. When the aryl ring was 3- or 4-substituted phenyl **(1b-h)**, the products **3ba-3ha**



Scheme 1. Scope of the protocol with different α-oxocarboxylic acids. All reactions were performed using **1a** (0.5 mmol) and **2b-i** (0.75 mmol) in 3 mL of solvent.

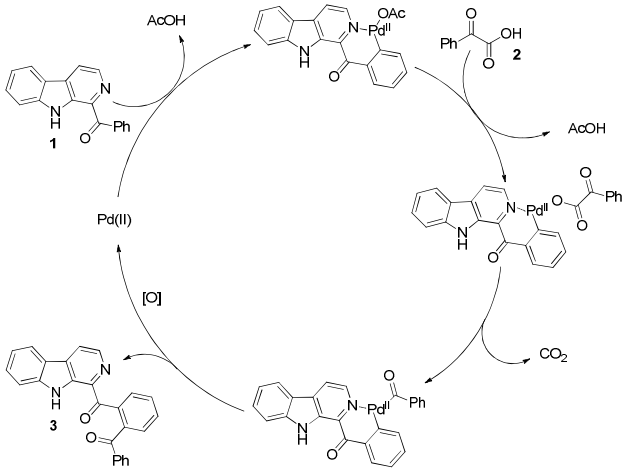


Scheme 2. Scope of the protocol with different aryl (β-carbolin-2-yl)methanones. All reactions were performed using **1b-n** (0.5 mmol) and **2a** (0.75 mmol) in 3 mL of solvent.

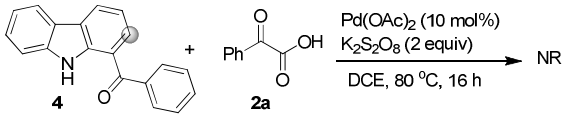
were isolated in 76-87 % yields. Interestingly, for the 3-substituted phenyl ring carrying substrate **(1g-h)** the reaction was found to be regioselective to yield **3ga-3ha**. However, substrates **1i-j** containing phenyl ring with *ortho*-substitution failed to give the required products **3ia-3ja**. Perhaps, this

failure is attributed to the steric hindrance due to the presence of substituent at the *ortho*-position in the phenyl ring. Further, the failure of reaction with **1j** inferred that the possibility of diacylation is ruled out. Even the heteroaryl (β-carbolin-1-yl) methanones **1k** and **1l** bearing thiophene and benzofuran units were found to undergo decarboxylative acylation with **2a** affording the corresponding products **3ka** and **3la** in 72% and 74% yields, respectively. Substrates **1m 1n 1o**, and **1p** bearing bromo and chloro substitutions at 6-position and methyl ester at 3-position of the β-carboline unit, were also investigated to obtain respective products **3ma**, **3na, 3oa** and **3pa** in excellent yields. Finally the scope of reaction was evaluated with phenyl (pyridin-2-yl)methanone **1q** and it too reacted with **2a** to give acylated product **3qa** in 79% yield.

As already reported, mechanism wise the pyridine ring of the β-carboline unit undergo chelation with the Pd-catalyst followed by coupling reaction as delineated in Scheme 3. Here too, for negating the role of carbonyl for the C-H functionalization,[21] we carried out reaction of (9*H*-carbazol-1-yl)(phenyl)methanone **4** under the optimized conditions (Scheme 4). It was found that the reaction was unsuccessful and **4** was recovered unreacted. This ascertained that the pyridine ring was involved in chelation with palladium.



Scheme 3. Plausible reaction mechanism

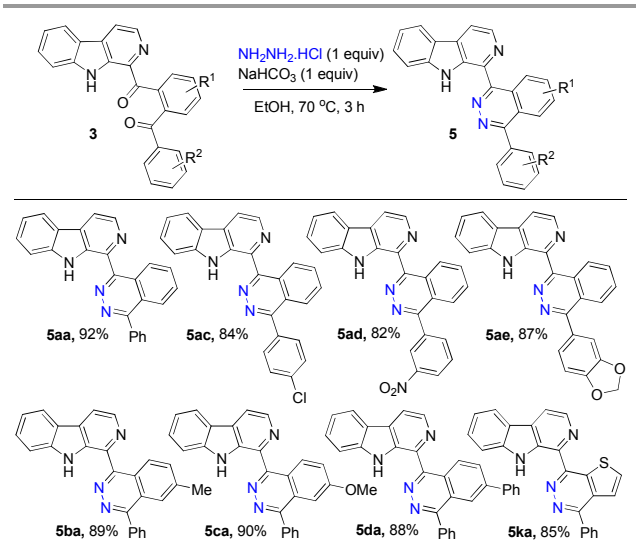


Scheme 4. Reaction with carbazole **4** under the standardized conditions

Finally, to demonstrate the utility of the isolated diaroyl-products belonging to **3**, a randomly selected set of substrates were treated with hydrazine hydrochloride in the presence of $NaHCO_3$ in ethanol as medium to prepare β-carboline tethered phthalazine derivatives **5** in 82-92% yields (Scheme 5). It may be noted the phthalizine pendant at the 3-position of β-carboline was prepared via Suzuki coupling between 3-chloro-β-carboline and phthalazine-1-boronic acid.[22]

Conclusions

In conclusion, we have demonstrated a Pd-catalysed decarboxylative acylation of aryl ring of aryl (β-carbolin-2-yl)methanones using α-oxocarboxylic acid as the acyl ion source



Scheme 5. Synthesis of β-carboline-tethered phthalazines **5**.

via β-carboline directed C(sp2)-H activation under oxidative conditions. The products (2-aroylaryl) (β-carbolin-2-yl)methanones which were efficiently prepared could be readily transformed into β-carboline tethered phthalazine by treating them with hydrazine hydrochloride.

Experimental

General experimental procedure for the acylation

To a round bottom flask containing DCE (3 mL) were added aryl (β-carbolin-1-yl) methanone **1** (0.5 mmol), α-oxocarboxylic acid **2** (0.75 mmol), $Pd(OAc)_2$ (0.05 mmol) and $K_2S_2O_8$ (1.0 mmol) in air. The reaction mixture was heated at 80 °C for 16 h. On completion of reaction (as assessed by TLC), the reaction mixture was diluted with water (25 mL) and extracted with methylene chloride (25 mL x 2). The organic layers were pooled, dried over anhydrous Na_2SO_4 and evaporated to obtain the crude product, which was purified by column chromatography over silica gel using hexanes/EtOAc (90:10, v/v) as eluent to obtain corresponding product **3**.

(2-(9*H*-Pyrido[3,4-*b*]indole-1-carbonyl)phenyl)(phenyl)methanone (3aa). Yield: 82% (0.113 g from 0.1 g); a yellow solid, mp 148-150 °C; R_f = 0.35 (Hexanes: EtOAc, 8:2, v/v). IR (KBr) ν_{max}: 769, 1168, 1220, 1455, 1580, 1651, 3022, 3431 cm^{-1}. ^{1}H NMR (400 MHz, $CDCl_3$): δ (ppm) = 7.22 (t, *J* = 7.7 Hz, 1H), 7.29 (t, *J* = 7.7 Hz, 2H), 7.39 (t, *J* = 7.3 Hz, 1H), 7.46-7.56 (m, 4H), 7.61-7.64 (m, 1H), 7.77 (d, *J* = 7.5 Hz, 2H), 7.86-7.88 (m, 2H), 7.99 (d, *J* = 7.9 Hz, 1H), 8.07 (d, *J* = 4.9 Hz, 1H), 10.22 (s, 1H). ^{13}C NMR (100 MHz, $CDCl_3$): δ (ppm) = 112.1, 118.7, 120.8, 121.9, 128.2, 129.2, 129.4, 130.1, 130.3, 131.1, 131.6, 132.6, 135.8, 136.4, 137.5, 138.1, 139.5, 140.9, 141.3, 196.6, 198.1.

MS (ESI+) m/z = 377.1. ESI-HRMS calculated for $C_{25}H_{16}N_2O_2$ $[MH]^+$: 377.1290, found: 377.1292.

(2-(9*H*-Pyrido[3,4-*b*]indole-1-carbonyl)phenyl)(p-tolyl)methanone (3ab). Yield: 81% (0.158 g from 0.136 g); a yellow solid, mp 126-128 ^oC; R_f = 0.39 (Hexanes: EtOAc, 8:2, v/v). IR (KBr) ν_{max}: 758, 1185, 1258, 1458, 1586, 1661, 3058, 3434 cm^{-1}. ^1H NMR (400 MHz, $CDCl_3$): δ (ppm) = 2.25 (s, 3H), 7.08 (d, *J* = 7.9 Hz, 2H), 7.22 (t, *J* = 7.0 Hz, 1H), 7.45-7.49 (m, 2H), 7.54 (t, *J* = 6.9 Hz, 2H), 7.59-7.62 (m, 1H), 7.65 (d, *J* = 8.1 Hz, 2H), 7.87 (d, *J* = 5.5 Hz, 2H), 8.00 (d, *J* = 7.9 Hz, 1H), 8.09 (d, *J* = 4.9 Hz, 1H), 10.21 (s, 1H). ^{13}C NMR (100 MHz, $CDCl_3$): δ (ppm) = 21.7, 112.0, 118.6, 120.8, 121.8, 128.9, 129.1, 129.3, 130.1, 130.3, 130.4, 131.9, 131.5, 134.9, 135.8, 136.4, 138.1, 139.4, 141.2, 143.4, 196.3, 198.1. MS (ESI+) m/z = 391.2. ESI-HRMS calculated for $C_{26}H_{18}N_2O_2$ $[MH]^+$: 391.1447, found: 391.1450.

(2-(9*H*-Pyrido[3,4-*b*]indole-1-carbonyl)phenyl)(4-chlorophenyl)methanone (3ac). Yield: 80% (0.164 g from 0.136 g); a yellow solid, mp 194-196 ^oC; R_f = 0.41 (Hexanes: EtOAc, 8:2, v/v). IR (KBr) ν_{max}: 772, 1185, 1225, 1456, 1591, 1659, 3013, 3433 cm^{-1}. ^1H NMR (400 MHz, $CDCl_3$): δ (ppm) = 7.21-7.25 (m, 1H), 7.29 (d, *J* = 8.4 Hz, 2H), 7.47-7.56 (m, 4H), 7.62-7.65 (m, 1H), 7.73 (d, *J* = 8.4 Hz, 2H), 7.87-7.89 (m, 2H), 7.99-8.04 (m, 2H), 10.24 (s, 1H). ^{13}C NMR (100 MHz, $CDCl_3$): δ (ppm) = 112.1, 118.8, 120.8, 120.9, 121.9, 128.6, 128.8, 129.4, 130.2, 130.5, 131.3, 131.7, 135.6, 135.8, 136.5, 138.1, 139.1, 139.3, 140.7, 141.3, 195.4, 197.8. MS (ESI+) m/z = 411.1. ESI-HRMS calculated for $C_{25}H_{15}ClN_2O_2$ $[MH]^+$: 411.0900, found: 411.0904.

(2-(9*H*-Pyrido[3,4-*b*]indole-1-carbonyl)phenyl)(3-nitrophenyl)methanone (3ad). Yield: 83% (0.175 g from 0.136 g); a yellow solid, mp 152-154 ^oC; R_f = 0.24 (Hexanes: EtOAc, 8:2, v/v). IR (KBr) ν_{max}: 756, 1125, 1285, 1425, 1587, 1659, 3052, 3435 cm^{-1}. ^1H NMR (400 MHz, $CDCl_3$): δ (ppm) = 7.22-7.26 (m, 1H), 7.49-7.54 (m, 4H), 7.59 (t, *J* = 7.6 Hz, 1H), 7.69 (t, *J* = 7.5 Hz, 1H), 7.88 (d, *J* = 4.9 Hz, 1H), 7.93 (d, *J* = 7.6 Hz, 1H), 7.99-8.03 (m, 2H), 8.10 (d, *J* = 7.7 Hz, 1H), 8.26 (dd, J_1 = 8.2 Hz, J_2 = 1.2 Hz, 1H), 8.64 (s, 1H), 10.23 (s, 1H). ^{13}C NMR (100 MHz, DMSO-d_6): δ (ppm) = 113.5, 119.6, 120.2, 120.8, 122.3, 124.4, 127.6, 128.8, 129.6, 130.7, 130.8, 131.5, 132.1, 135.4, 135.6, 136.1, 137.5, 138.5, 139.5, 139.8, 142.3, 148.0, 194.5, 196.4. MS (ESI+) m/z = 422.1. ESI-HRMS calculated for $C_{25}H_{15}N_3O_4$ $[MH]^+$: 422.1141, found: 422.1144.

(2-(9*H*-Pyrido[3,4-*b*]indole-1-carbonyl)phenyl)(benzo[d][1,3]dioxol-5-yl)methanone (3ae). Yield: 79% (0.166 g from 0.136 g); a yellow solid, mp 188-190 ^oC; R_f = 0.21 (Hexanes: EtOAc, 8:2, v/v). IR (KBr) ν_{max}: 726, 1025, 1155, 1224, 1455, 1581, 1649, 3026, 3432 cm^{-1}. ^1H NMR (400 MHz, $CDCl_3$): δ (ppm) = 5.78 (s, 2H), 6.67 (d, *J* = 8.1 Hz, 1H), 7.15 (d, *J* = 1.3 Hz, 1H), 7.22-7.25 (m, 1H), 7.31 (dd, J_1 = 8.1 Hz, J_2 = 1.4 Hz, 1H), 7.47-7.64 (m, 5H), 7.88 (d, *J* = 7.5 Hz, 1H), 7.92 (d, *J* = 4.9 Hz, 1H), 8.03 (d, *J* = 7.8 Hz, 1H), 8.15 (d, *J* = 4.9 Hz, 1H), 10.18 (s, 1H). ^{13}C NMR (100 MHz, $CDCl_3$): δ (ppm) = 101.8, 107.5, 109.4, 112.1, 118.7, 120.8, 120.8, 121.9, 127.0, 129.0, 129.3, 130.3, 130.4, 130.8, 131.5, 132.3, 135.9, 136.4, 138.2, 139.3, 141.1, 141.2, 147.8, 151.5, 194.9, 197.9. MS (ESI+) m/z = 421.1. ESI-HRMS calculated for $C_{26}H_{16}N_2O_4$ $[MH]^+$: 421.1188, found: 421.1191.

(2-(9*H*-Pyrido[3,4-b]indole-1-carbonyl)phenyl)(o-tolyl)methanone (3af). Yield: 78% (0.152 g from 0.136 g); a yellow solid, mp 188-190 oC; Rf = 0.38 (Hexanes: EtOAc, 8:2, v/v). IR (KBr) vmax: 725, 1185, 1221, 1432, 1592, 1655, 3021, 3434 cm-1. 1H NMR (400 MHz, CDCl3): δ (ppm) = 2.27 (s, 3H), 7.09-7.15 (m, 2H), 7.22-7.26 (m, 2H), 7.47 (dd, J1 = 6.6 Hz, J2 = 1.3 Hz, 2H), 7.52 (d, J = 3.6 Hz, 2H), 7.59-7.65 (m, 2H), 7.71 (d, J = 7.1 Hz, 1H), 7.93 (d, J = 4.9 Hz, 1H), 8.04 (d, J = 7.8 Hz, 1H), 8.23 (d, J = 4.9 Hz, 1H), 10.29 (s, 1H). 13C NMR (100 MHz, $CDCl_3$): δ (ppm) = 112.13, 118.6, 120.8, 120.9, 121.9, 125.1, 129.3, 129.4, 129.8, 130.3, 130.8, 131.1, 131.2, 131.6, 132.0, 136.1, 136.3, 137.5, 138.3, 138.6, 140.5, 141.1, 141.3, 198.2, 199.5. MS (ESI+) m/z = 391.1. ESI-HRMS calculated for $C_{26}H_{18}N_2O_2$ [MH]+: 391.1447, found: 391.1450.

(2-(9*H*-Pyrido[3,4-*b*]indole-1-carbonyl)phenyl)(thiophen-2-yl)methanone (3ag). Yield: 77% (0.147 g from 0.136 g); a yellow solid, mp 142-144 ^oC; R_f = 0.37 (Hexanes: EtOAc, 8:2, v/v). IR (KBr) ν_{max}: 758, 1058, 1152, 1282, 1425, 1596, 1658, 3025, 3432 cm^{-1}. ^1H NMR (400 MHz, $CDCl_3$): δ (ppm) = 7.99 (d, *J* = 4.0 Hz, 1H), 7.23 (t, *J* = 6.9 Hz, 1H), 7.49-7.63 (m, 6H), 7.74-7.77 (m, 1H), 7.88 (d, *J* = 7.5 Hz, 1H), 7.91 (d, *J* = 4.7 Hz, 1H), 8.02 (d, *J* = 7.6 Hz, 1H), 8.11(d, *J* = 4.6 Hz, 1H), 10.25 (s, 1H). ^{13}C NMR (100 MHz, $CDCl_3$): δ (ppm) = 112.2, 118.8, 120.9, 121.9, 127.9, 128.7, 129.4, 130.5, 130.6, 131.1, 131.7, 133.6, 134.2, 134.9, 135.7, 136.5, 138.1, 139.1, 140.7, 141.3, 144.2, 188.3, 197.8. MS (ESI+) m/z = 383.1. ESI-HRMS calculated for $C_{23}H_{14}N_2O_2S$ $[MH]^+$: 383.0854, found: 383.0852.

(2-Benzoyl-4-methylphenyl)(9*H*-pyrido[3,4-*b*]indol-1-yl)methanone (3ba). Yield: 85% (0.192 g from 0.166 g); a yellow solid, mp 188-190 ^oC; R_f = 0.39 (Hexanes: EtOAc, 8:2, v/v). IR (KBr) ν_{max}: 778, 1159, 1222, 1412, 1591, 1652, 3015, 3436 cm^{-1}. ^1H NMR (400 MHz, $CDCl_3$): δ (ppm) = 2.41 (s, 3H), 7.20-7.29 (m, 3H), 7.36-7.52 (m, 5H), 7.74 (d, *J* = 1.4 Hz, 1H), 7.76 (d, *J* = 1.2 Hz, 1H), 7.83 (d, *J* = 7.8 Hz, 1H), 7.88 (dd, J_1 = 4.9 Hz, J_2 = 0.5 Hz, 1H), 7.99-8.02 (m, 1H), 8.11 (d, *J* = 4.9 Hz, 1H), 10.19 (s, 1H). ^{13}C NMR (100 MHz, $CDCl_3$): δ (ppm) = 21.6, 112.0, 118.6, 120.8, 121.8, 128.2, 129.3, 129.7, 130.1, 130.7, 131.5, 132.5, 135.9, 136.4, 136.5, 137.6, 138.0, 140.9, 141.2, 141.2, 196.8, 197.6. MS (ESI+) m/z = 391.1. ESI-HRMS calculated for $C_{26}H_{18}N_2O_2$ $[MH]^+$: 391.1447, found: 391.1445.

(2-Benzoyl-4-methoxyphenyl)(9*H*-pyrido[3,4-*b*]indol-1-yl)methanone (3ca). Yield: 87% (0.177 g from 0.151 g); a yellow solid, mp 144-146 ^oC; R_f = 0.25 (Hexanes: EtOAc, 8:2, v/v). IR (KBr) ν_{max}: 758, 1187, 1281, 1421, 1589, 1660, 3033, 3432 cm^{-1}. ^1H NMR (400 MHz, $CDCl_3$): δ (ppm) = 3.84 (s, 3H), 7.04 (d, *J* = 2.5 H, 1H), 7.10 (dd, J_1 = 8.6 Hz, J_2 = 2.6 Hz, 1H), 7.16-7.28 (m, 3H), 7.34-7.38 (m, 1H), 7.43-7.51 (m, 2H), 7.75 (d, *J* = 1.4 Hz, 1H), 7.77 (d, *J* = 0.8 Hz, 1H), 7.89 (d, *J* = 4.9 Hz, 1H), 8.01 (d, *J* = 7.8 Hz, 1H), 8.08 (d, *J* = 8.5 Hz, 1H), 8.15 (d, *J* = 4.9 Hz, 1H), 10.15 (s, 1H). ^{13}C NMR (100 MHz, DMSO-d_6): δ (ppm) = 56.3, 113.5, 114.7, 115.3, 119.2, 120.3, 120.7, 122.2, 128.8, 129.4, 130.0, 131.2, 131.3, 133.4, 133.8, 135.6, 136.3, 137.1, 137.4, 142.2, 143.5, 161.3, 194.7, 195.9. MS (ESI+) m/z = 407.1. ESI-HRMS calculated for $C_{26}H_{18}N_2O_3$ $[MH]^+$: 407.1396, found: 407.1395.

(4-(9*H*-Pyrido[3,4-*b*]indole-1-carbonyl)-[1,1'-biphenyl]-3-yl)(phenyl)methanone (3da). Yield: 84% (0.190 g from 0.174 g); a yellow solid, mp 182-184 ^oC; R_f = 0.39 (Hexanes: EtOAc, 8:2, v/v). IR (KBr) ν_{max}: 660, 773, 1155, 1234, 1442, 1575, 1653, 3052, 3436 cm^{-1}. ^1H NMR (400 MHz, $CDCl_3$): δ (ppm) = 7.22-7.26 (m, 1H), 7.29-7.35 (m, 3H), 7.38-7.42 (m, 3H), 7.47-7.52 (m, 2H), 7.56 (s, 1H), 7.58 (d, *J*

= 1.3 Hz, 1H), 7.75 (d, *J* = 1.6 Hz, 1H), 7.80 (d, *J* = 1.3 Hz, 1H), 7.82-7.85 (m, 2H), 7.89 (d, *J* = 4.9 Hz, 1H), 7.99-8.03 (m, 2H), 8.11 (d, *J* = 4.9 Hz, 1H), 10.29 (s, 1H). ^{13}C NMR (100 MHz, $CDCl_3$): *δ* (ppm) = 112.1, 118.7, 120.8, 120.9, 121.9, 127.5, 127.8, 128.3, 128.4, 129.2, 129.4, 129.4, 130.3, 131.2, 131.6, 132.7, 135.8, 136.5, 137.4, 137.9, 138.1, 139.7, 141.2, 141.8, 143.4, 196.6, 197.5. MS (ESI+) m/z = 453.2. ESI-HRMS calculated for $C_{31}H_{20}N_2O_2$ $[MH]^+$: 453.1603, found: 453.1605.

(2-Benzoyl-4-bromophenyl)(9*H*-pyrido[3,4-*b*]indol-1-yl)methanone (3ea). Yield: 79% (0.179 g from 0.175 g); a yellow solid, mp 152-154 ^oC; R_f = 0.42 (Hexanes: EtOAc, 8:2, v/v). IR (KBr) ν_{max}: 755, 1147, 1287, 1467, 1588, 1649, 3032, 3434 cm^{-1}. ^{1}H NMR (400 MHz, $CDCl_3$): *δ* (ppm) = 7.31-7.35 (m, 1H), 7.42 (t, *J* = 7.8 Hz, 2H), 7.51-7.54 (m, 1H), 7.56-7.66 (m, 3H), 7.77 (d, *J* = 1.6 Hz, 1H), 7.84-7.90 (m, 3H), 7.99 (d, *J* = 8.0 Hz, 1H), 8.11 (d, *J* = 7.9 Hz, 1H), 8.17 (d, *J* = 4.9 Hz, 1H), 10.27 (s, 1H). ^{13}C NMR (100 MHz, $CDCl_3$): *δ* (ppm) = 112.1, 118.9, 120.8, 120.9, 121.9, 124.9, 128.4, 129.5, 130.2, 131.8, 132.1, 132.6, 133.0, 133.9, 135.4, 136.5, 136.8, 137.9, 138.1, 141.3, 142.8, 195.0, 196.7. MS (ESI+) m/z = 455.0. ESI-HRMS calculated for $C_{25}H_{15}BrN_2O_2$ $[MH]^+$: 455.0395, found: 455.0392.

(2-Benzoyl-4-chlorophenyl)(9*H*-pyrido[3,4-*b*]indol-1-yl)methanone (3fa). Yield: 80% (0.164 g from 0.153 g); a yellow solid, mp 192-194 ^oC; R_f = 0.41 (Hexanes: EtOAc, 8:2, v/v). IR (KBr) ν_{max}: 669, 771, 1157, 1216, 1403, 1599, 1654, 3019, 3435 cm^{-1}. ^{1}H NMR (400 MHz, $CDCl_3$): *δ* (ppm) = 7.22-7.26 (m, 1H), 7.32 (t, *J* = 7.8 Hz, 2H), 7.43 (t, *J* = 7.5 Hz, 1H), 7.46-7.52 (m, 3H), 7.59 (dd, J_1 = 8.2 Hz, J_2 = 2.0 Hz, 1H), 7.76 (d, *J* = 7.2 Hz, 2H), 7.86-7.89 (m, 2H), 8.01 (d, *J* = 7.8 Hz, 1H), 8.07 (d, *J* = 4.9 Hz, 1H), 10.17 (s, 1H). ^{13}C NMR (100 MHz, $CDCl_3$): *δ* (ppm) = 112.1, 118.9, 120.8, 120.9, 121.9, 128.4, 128.9, 129.5, 130.2, 130.9, 131.7, 131.9, 133.0, 135.4, 136.5, 136.7, 136.9, 137.5, 138.1, 141.2, 142.7, 195.2, 196.6. MS (ESI+) m/z = 411.1. ESI-HRMS calculated for $C_{25}H_{15}ClN_2O_2$ $[MH]^+$: 411.0900, found: 411.0904.

(2-Benzoyl-5-methoxyphenyl)(9*H*-pyrido[3,4-*b*]indol-1-yl)methanone (3ga). Yield: 78% (0.158 g from 0.151 g); a yellow solid, mp 196-198 ^oC; R_f = 0.25 (Hexanes: EtOAc, 8:2, v/v). IR (KBr) ν_{max}: 799, 1185, 1225, 1324, 1434, 1579, 1664, 3032, 3434 cm^{-1}. ^{1}H NMR (400 MHz, $CDCl_3$): *δ* (ppm) = 3.87 (s, 3H), 6.99 (dd, J_1 = 8.6 Hz, J_2 = 2.6 Hz, 1H), 7.21-7.25 (m, 1H), 7.27-7.31 (m, 3H), 7.39 (t, *J* = 7.3 Hz, 1H), 7.50-7.55 (m, 3H), 7.71 (d, *J* = 7.2 Hz, 2H), 7.88 (d, *J* = 4.9 Hz, 1H), 8.01 (d, *J* = 7.8 Hz, 1H), 8.11 (d, *J* = 4.9 Hz, 1H), 10.25 (s, 1H). ^{13}C NMR (100 MHz, $CDCl_3$): *δ* (ppm) = 55.8, 112.1, 114.8, 115.3, 118.6, 120.8, 120.8, 121.8, 128.1, 129.3, 130.1, 131.6, 131.9, 132.2, 132.9, 135.9, 136.2, 137.9, 138.2, 141.3, 142.4, 162.2, 195.7, 198.6. MS (ESI+) m/z = 407.1. ESI-HRMS calculated for $C_{26}H_{18}N_2O_3$ $[MH]^+$: 407.1396, found: 407.1399.

(2-Benzoyl-5-chlorophenyl)(9*H*-pyrido[3,4-*b*]indol-1-yl)methanone (3ha). Yield: 76% (0.156 g from 0.153 g); a yellow solid, mp 184-186 ^oC; R_f = 0.41 (Hexanes: EtOAc, 8:2, v/v). IR (KBr) ν_{max}: 745, 1057, 1285, 1423, 1586, 1650, 3045, 3436 cm^{-1}. ^{1}H NMR (400 MHz, $CDCl_3$): *δ* (ppm) = 7.22 (t, *J* = 7.7 Hz, 1H), 7.28-7.34 (m, 2H), 7.42 (t, *J* = 7.2 Hz, 1H), 7.48-7.54 (m, 4H), 7.74 (d, *J* = 7.6 Hz, 2H), 7.82 (s, 1H), 7.88 (d, *J* = 4.8 Hz, 1H), 8.01 (d, *J* = 7.8 Hz, 1H), 8.06 (d, *J* = 4.9 Hz, 1H), 10.19 (s, 1H). ^{13}C NMR (100 MHz, $CDCl_3$): *δ* (ppm) = 112.1, 118.9, 120.7, 120.9, 121.9, 128.3, 129.5, 129.9, 130.2, 130.4, 130.5, 131.7, 132.8, 135.2, 136.4, 137.2, 137.6, 138.2, 139.2, 141.2, 141.3, 195.6, 196.6. MS (ESI+) m/z = 411.1. ESI-HRMS calculated for $C_{25}H_{15}ClN_2O_2$ $[MH]^+$: 411.0900, found: 411.0901.

(2-(9*H*-Pyrido[3,4-*b*]indole-1-carbonyl)thiophen-3-yl)(phenyl)methanone (3ka). Yield: 72% (0.137 g from 0.139 g); a yellow solid, mp 168-170 ^oC; R_f = 0.38 (Hexanes: EtOAc, 8:2, v/v). IR (KBr) ν_{max}: 758, 1024, 1185, 1258, 1425, 1587, 1645, 3054, 3438 cm^{-1}. ^{1}H NMR (400 MHz, $CDCl_3$): *δ* (ppm) = 7.14 (d, *J* = 5. Hz, 1H), 7.23 (t, *J* = 7.2 Hz, 1H), 7.34-7.40 (m, 3H), 7.47 (dd, J_1 = 16.2 Hz, J_2 = 7.8 Hz, 2H), 7.78 (d, *J* = 5.0 Hz, 1H), 7.85 (d, *J* = 1.3 Hz, 1H), 7.87 (s, 1H), 8.03-8.07 (m, 2H), 8.46 (d, *J* = 4.9 Hz, 1H), 10.14 (s, 1H). ^{13}C NMR (100 MHz, $CDCl_3$): *δ* (ppm) = 112.1, 119.2, 120.7, 120.9, 121.9, 127.2, 128.7, 129.4, 129.5, 131.8, 133.3, 134.7, 135.6, 136.6, 137.1, 137.3, 137.5, 141.1, 148.6, 184.7, 195.0. MS (ESI+) m/z = 383.1. ESI-HRMS calculated for $C_{23}H_{14}N_2O_2S$ $[MH]^+$: 383.0854, found: 383.0856.

(2-(9*H*-Pyrido[3,4-*b*]indole-1-carbonyl)benzofuran-3-yl)(phenyl)methanone (3la). Yield: 74% (0.154 g from 0.156 g); a yellow solid, mp 212-214 ^oC; R_f = 0.39 (Hexanes: EtOAc, 8:2, v/v). IR (KBr) ν_{max}: 852, 1042, 1167, 1258, 1402, 1592, 1661, 3052, 3432 cm^{-1}. ^{1}H NMR (400 MHz, $CDCl_3$): *δ* (ppm) = 7.23-7.29 (m, 4H), 7.34 (t, *J* = 7.1 Hz, 1H), 7.47 (t, *J* = 8.2 Hz, 1H), 7.52-7.53 (m, 3H), 7.67 (d, *J* = 8.4 Hz, 1H), 7.87-7.89 (m, 4H), 8.0 (d, *J* = 7.8 Hz, 1H), 10.18 (s, 1H). ^{13}C NMR (100 MHz, $CDCl_3$): *δ* (ppm) = 112.3, 112.6, 119.5, 120.7, 121.1, 121.9, 123.0, 124.5, 127.5, 128.4, 128.5, 128.7, 129.3, 129.6, 131.8, 132.9, 134.3, 136.5, 137.0, 138.5, 141.2, 148.2, 154.7, 183.7, 189.9. MS (ESI+) m/z = 417.1. ESI-HRMS calculated for $C_{27}H_{16}N_2O_3$ $[MH]^+$: 417.1239, found: 417.1240.

(2-Benzoylphenyl)(6-bromo-9*H*-pyrido[3,4-*b*]indol-1-yl)methanone (3ma). Yield: 80% (0.182 g from 0.175 g); a yellow solid, mp 158-160 ^oC; R_f = 0.36 (Hexanes: EtOAc, 8:2, v/v). IR (KBr) ν_{max}: 712, 1157, 1254, 1401, 1597, 1671, 3020, 3431 cm^{-1}. ^{1}H NMR (400 MHz, $CDCl_3$): *δ* (ppm) = 7.30-7.35 (m, 3H), 7.43 (t, *J* = 7.5 Hz, 1H), 7.54-7.58 (m, 3H), 7.62-7.66 (m, 1H), 7.76-7.81 (m, 3H), 7.85 (d, *J* = 7.7 Hz, 1H), 8.07 (d, *J* = 4.9 Hz, 1H), 8.10 (d, *J* = 1.3 Hz, 1H), 10.27 (s, 1H). ^{13}C NMR (100 MHz, $CDCl_3$): *δ* (ppm) = 113.5, 113.6, 118.7, 122.5, 124.5, 128.3, 129.3, 130.2, 130.3, 130.4, 131.3, 132.0, 132.7, 136.1, 136.4, 137.4, 138.3, 139.4, 139.7, 140.9, 196.7, 198.0. MS (ESI+) m/z = 455.0. ESI-HRMS calculated for $C_{25}H_{15}BrN_2O_2$ $[MH]^+$: 455.0395, found: 455.0397.

(2-Benzoylphenyl)(6-chloro-9*H*-pyrido[3,4-*b*]indol-1-yl)methanone (3na). Yield: 83% (0.151 g from 0.136 g); a yellow solid, mp 138-140 ^oC; R_f = 0.41 (Hexanes: EtOAc, 8:2, v/v). IR (KBr) ν_{max}: 728, 1186, 1231, 1445, 1597, 1658, 3028, 3438 cm^{-1}. ^{1}H NMR (400 MHz, $CDCl_3$): *δ* (ppm) = 7.29-7.35 (m, 3H), 7.39-7.42 (m, 2H), 7.52-7.54 (m, 2H), 7.60-7.64 (m, 1H), 7.76-7.78 (m, 3H), 7.84 (d, *J* = 7.5 Hz, 1H), 7.91 (d, *J* = 1.6 Hz, 1H), 8.04 (d, *J* = 4.9 Hz, 1H), 10.28 (s, 1H). ^{13}C NMR (100 MHz, $CDCl_3$): *δ* (ppm) = 113.2, 118.7, 121.5, 121.9, 126.3, 128.3, 129.3, 129.5, 130.2, 130.3, 130.3, 130.6, 131.2, 132.7, 136.1, 136.6, 137.4, 138.3, 139.4, 139.5, 140.9, 196.6, 198.0. MS (ESI+) m/z = 411.1. ESI-HRMS calculated for $C_{25}H_{15}ClN_2O_2$ $[MH]^+$: 411.0900, found: 411.0904.

Methyl 1-(2-benzoylbenzoyl)-9*H*-pyrido[3,4-*b*]indole-3-carboxylate (3oa). Yield: 81% (0.176 g from 0.165 g); a yellow solid, mp 144-146 ^oC; R_f = 0.29 (Hexanes: EtOAc, 8:2, v/v). IR (KBr) ν_{max}: 798, 1054,

1263, 1404, 1575, 1668, 1716 3017, 3437 cm^{-1}. ^1H NMR (400 MHz, $CDCl_3$): δ (ppm) = 3.83 (s, 3H), 7.27-7.33 (m, 3H), 7.42 (t, *J* = 7.4 Hz, 1H), 7.49-7.56 (m, 4H), 7.64-7.68 (m, 1H), 7.79 (d, *J* = 7.5 Hz, 2H), 7.98 (d, *J* = 7.6 Hz, 1H), 8.05 (d, *J* = 7.8 Hz, 1H), 8.74 (s, 1H), 10.50 (s, 1H). ^{13}C NMR (100 MHz, $CDCl_3$): δ (ppm) =52.4, 112.5, 120.9, 121.1, 121.6, 121.9, 128.1, 129.8, 130.2, 130.6, 130.8, 131.6, 131.9, 132.8, 135.6, 136.7, 136.9, 137.3, 139.6, 140.6, 141.5, 165.8, 196.7, 198.0. MS (ESI+) m/z = 435.1. ESI-HRMS calculated for $C_{27}H_{18}N_2O_4$ $[MH]^+$: 435.1345, found: 435.1348.

Methyl 1-(2-benzoyl-4-methylbenzoyl)-9*H*-pyrido[3,4-*b*]indole-3-carboxylate (3pa). Yield: 84% (0.245 g from 0.224 g); a yellow solid, mp 158-160 °C; R_f = 0.31 (Hexanes: EtOAc, 8:2, v/v). IR (KBr) ν_{max}: 789, 1059, 1272, 1409, 1571, 1662, 1717 3011, 3439 cm^{-1}. ^1H NMR (400 MHz, $CDCl_3$): δ (ppm) = 2.41 (s, 3H), 3.86 (s, 3H), 7.27-7.47 (m, 6H), 7.49-7.54 (m, 2H), 7.77 (d, *J* = 7.6 Hz, 2H), 8.01-8.07 (m, 2H), 8.76 (s, 1H), 10.47 (s, 1H). ^{13}C NMR (100 MHz, $CDCl_3$): δ (ppm) = 21.7, 52.5, 112.5, 120.8, 121.1, 121.6, 122.0, 128.1, 128.6, 129.8, 130.2, 130.4, 131.3, 131.9, 132.7, 133.7, 135.8, 136.5, 136.6, 137.1, 137.4, 141.2, 141.5, 165.9, 196.9, 197.3. MS (ESI+) m/z = 449.1. ESI-HRMS calculated for $C_{28}H_{20}N_2O_4$ $[MH]^+$: 449.1501, found: 449.1505.

(2-Benzoylphenyl)(pyridin-2-yl)methanone (3qa). Yield: 79% (0.113 g from 0.091 g); a white solid, mp 116-118 °C; R_f = 0.45 (Hexanes: EtOAc, 8:2, v/v). IR (KBr) ν_{max}: 1430, 1467, 1598, 1662, 2925 cm^{-1}. ^1H NMR (400 MHz, $CDCl_3$): δ (ppm) = 7.18-7.21 (m, 1H), 7.32 (t, *J* = 7.7 Hz, 2H), 7.45 (t, *J* = 7.5 Hz, 1H), 7.51 (d, *J* = 4.1 Hz, 2H), 7.57-7.61 (m, 1H), 7.66-7.75 (m, 4H), 7.99 (d, *J* = 7.9 Hz, 1H), 8.22-8.23 (m, 1H). ^{13}C NMR (100 MHz, $CDCl_3$): δ (ppm) = 123.4, 126.6, 128.3, 129.3, 130.2, 130.3, 130.4, 131.2, 132.7, 137.0, 137.4, 139.3, 140.6, 148.6, 153.7, 195.7, 196.6. MS (ESI+) m/z = 288.1. ESI-HRMS calculated for $C_{19}H_{13}NO_2$ $[MH]^+$: 288.1025, found: 288.1030.

General experimental procedure for the synthesis of compoud 5

To a round bottom flask containing ethanol (3 ml) were added (2-aroylaryl) (β-carbolin-2-yl)methanone **3** (0.25 mmol), hydrazine hydrochloride (0.25 mmol) and $NaHCO_3$ (0.25 mmol). The reaction mixture was heated at 70 °C for 3 h. On completion of reaction (as monitored by TLC), the solvent was evaporated to get a residue, which was purified by column chromatography over silica gel using hexanes/EtOAc (90:10, v/v) as eluent to obtain appropriate product **5**.

(1-(4-Phenylphthalazin-1-yl)-9*H*-pyrido[3,4-*b*]indole (5aa). Yield: 92% (0.085 g from 0.094 g); a yellow solid, mp 170-172 °C; R_f = 0.38 (Hexanes: EtOAc, 8:2, v/v). IR (KBr) ν_{max}: 658, 781, 1045, 1285, 1485, 3085, 3395 cm^{-1}. ^1H NMR (400 MHz, $CDCl_3$): δ (ppm) = 7.19-7.25 (m, 1H), 7.48 (d, *J* = 3.6 Hz, 2H), 7.51-7.54 (m, 4H), 7.75-7.78 (m, 2H), 7.91 (t, *J* = 7.3 Hz, 1H), 8.01 (d, *J* = 5.0 Hz, 1H), 8.05-8.10 (m, 2H), 8.61 (d, *J* = 5.0 Hz, 1H), 10.03 (d, *J* = 8.4 Hz, 1H), 11.16 (s, 1H). ^{13}C NMR (100 MHz, $CDCl_3$): δ (ppm) = 112.2, 115.9, 120.2, 121.7, 126.6, 126.7, 128.8, 128.9, 129.6, 129.9, 130.3, 130.9, 132.0, 132.6, 133.0, 134.3, 136.2, 136.5, 137.8, 138.7, 140.9, 155.4, 159.6. MS (ESI+) m/z = 373.1. ESI-HRMS calculated for $C_{25}H_{16}N_4$ $[MH]^+$: 373.1453, found: 373.1455.

1-(4-(4-Chlorophenyl)phthalazin-1-yl)-9*H*-pyrido[3,4-*b*]indole (5ac). Yield: 84% (0.086 g from 0.103 g); a yellow solid, mp 184-186 °C; R_f = 0.43 (Hexanes: EtOAc, 8:2, v/v). IR (KBr) ν_{max}: 667, 768, 1022, 1242, 1461, 3041, 3392 cm^{-1}. ^1H NMR (400 MHz, $CDCl_3$): δ (ppm) = 7.23-7.28 (m, 1H), 7.51-7.55 (m, 4H), 7.73 (d, *J* = 8.2 Hz, 2H), 7.83 (t, *J* = 7.2 Hz, 1H), 7.96 (t, *J* = 7.2 Hz, 1H), 8.03-8.07 (m, 2H), 8.13 (d, *J* = 7.8 Hz, 1H), 8.65 (d, *J* = 5.0 Hz, 1H), 10.07 (d, *J* = 8.5 Hz, 1H), 11.11 (s, 1H). ^{13}C NMR (100 MHz, $CDCl_3$): δ (ppm) = 112.2, 116.0, 120.3, 121.5, 121.7, 126.2, 126.6, 128.9, 129.1, 129.2, 131.0, 131.6, 132.3, 132.8, 134.9, 136.0, 136.2, 137.9, 138.5, 140.9, 155.7, 158.6. MS (ESI+) m/z = 407.1. ESI-HRMS calculated for $C_{25}H_{15}ClN_4$ $[MH]^+$: 407.1063, found: 407.1065.

1-(4-(3-Nitrophenyl)phthalazin-1-yl)-9*H*-pyrido[3,4-*b*]indole (5ad). Yield: 82% (0.085 g from 0.105 g); a yellow solid, mp 172-174 °C; R_f = 0.23 (Hexanes: EtOAc, 8:2, v/v). IR (KBr) ν_{max}: 663, 768, 1012, 1289, 1412, 3082, 3395 cm^{-1}. ^1H NMR (400 MHz, $CDCl_3$): δ (ppm) = 7.22-7.26 (m, 1H), 7.49 (d, *J* = 3.6 Hz, 2H), 7.73 (t, *J* = 7.9 Hz, 1H), 7.85 (t, *J* = 7.6 Hz, 1H), 7.97 (t, *J* = 8.7 Hz, 2H), 8.05 (d, *J* = 5.0 Hz, 1H), 8.12 (d, *J* = 7.7 Hz, 2H), 8.39 (d, *J* = 8.2 Hz, 1H), 8.63-8.66 (m, 2H), 10.09 (d, *J* = 8.5 Hz, 1H), 11.07 (s, 1H). ^{13}C NMR (100 MHz, $CDCl_3$): δ (ppm) = 112.2, 116.2, 120.4, 121.5, 121.8, 124.5, 125.3, 125.5, 126.3, 126.6, 128.9, 129.6, 129.9, 131.2, 132.7, 133.2, 136.2, 136.3, 138.0, 138.2, 140.9, 148.6, 156.2, 157.4. MS (ESI+) m/z = 418.1. ESI-HRMS calculated for $C_{25}H_{15}N_5O_2$ $[MH]^+$: 418.1304, found: 418.1308.

1-(4-(Benzo[*d*][1,3]dioxol-5-yl)phthalazin-1-yl)-9*H*-pyrido[3,4-*b*]indole (5ae). Yield: 87% (0.09 g from 0.105 g); a yellow solid, mp 164-166 °C; R_f = 0.23 (Hexanes: EtOAc, 8:2, v/v). IR (KBr) ν_{max}: 666, 762, 1068, 1211, 1412, 3015, 3398 cm^{-1}. ^1H NMR (400 MHz, $CDCl_3$): δ (ppm) = 6.01 (s, 2H), 6.94 (d, *J* = 8.3 Hz, 1H), 7.17-7.24 (m, 3H), 7.47 (d, *J* = 3.8 Hz, 2H), 7.77 (t, *J* = 7.9 Hz, 1H), 7.86-7.90 (m, 1H), 7.99 (d, *J* = 5.0 Hz, 1H), 8.08 (dd, J_1 = 7.8 Hz, J_2 = 4.3 Hz, 2H), 8.59 (d, *J* = 5.0 Hz, 1H), 9.97 (d, *J* = 8.4 Hz, 1H), 11.13 (s, 1H). ^{13}C NMR (100 MHz, $CDCl_3$): δ (ppm) = 101.7, 108.6, 110.6, 112.2, 115.8, 120.2, 121.5, 121.7, 124.7, 126.5, 126.6, 128.7, 128.9, 130.3, 130.9, 131.9, 132.6, 136.1, 137.8, 138.7, 140.9, 148.1, 148.9, 155.2, 159.0. MS (ESI+) m/z = 417.1. ESI-HRMS calculated for $C_{26}H_{16}N_4O_2$ $[MH]^+$: 417.1352, found: 417.1355.

1-(6-Methyl-4-phenylphthalazin-1-yl)-9*H*-pyrido[3,4-*b*]indole (5ba). Yield: 89% (0.086 g from 0.098 g); a yellow solid, mp 152-154 °C; R_f = 0.42 (Hexanes: EtOAc, 8:2, v/v). IR (KBr) ν_{max}: 668, 768, 1063, 1218, 1409, 3019, 3397 cm^{-1}. ^1H NMR (400 MHz, $CDCl_3$): δ (ppm) = 2.50 (s, 3H), 7.22-7.26 (m, 1H), 7.51-7.58 (m, 5H), 7.75-7.78 (m, 3H), 7.84 (s, 1H), 8.05 (d, *J* = 5.1 Hz, 1H), 8.13 (d, *J* = 7.8 Hz, 1H), 8.64 (d, *J* = 5.0 Hz, 1H), 9.95 (d, *J* = 8.7 Hz, 1H), 11.19 (s, 1H). ^{13}C NMR (100 MHz, $CDCl_3$): δ (ppm) = 112.2, 115.8, 120.2, 121.6, 121.7, 124.9, 125.5, 127.0, 128.8, 128.8, 129.5, 130.3, 130.9, 134.6, 136.2, 136.8, 137.8, 138.9, 140.9, 142.8, 155.4, 159.4. MS (ESI+) m/z = 387.2. ESI-HRMS calculated for $C_{26}H_{18}N_4$ $[MH]^+$: 387.1610, found: 387.1615.

1-(6-Methoxy-4-phenylphthalazin-1-yl)-9*H*-pyrido[3,4-*b*]indole (5ca). Yield: 90% (0.09 g from 0.101 g); a yellow solid, mp 146-148 °C; R_f = 0.28 (Hexanes: EtOAc, 8:2, v/v). IR (KBr) ν_{max}: 664, 768, 1068, 1214, 1408, 3017, 3395 cm^{-1}. ^1H NMR (400 MHz, $CDCl_3$): δ (ppm) = 3.76 (s, 3H), 7.17-7.21 (m, 1H), 7.29 (d, *J* = 2.4 Hz, 1H), 7.45-7.53 (m, 6H), 7.75-7.77 (m, 2H), 7.97 (d, *J* = 5.0 Hz, 1H), 8.07 (d, *J* = 7.8 Hz, 1H), 8.57 (d, *J* = 5.0 Hz, 1H), 9.97 (d, *J* = 9.4 Hz, 1H), 11.21 (s, 1H). ^{13}C NMR (100 MHz, $CDCl_3$): δ (ppm) = 55.7, 112.2, 115.8, 120.2, 121.5, 121.7, 121.9, 123.9, 128.8, 128.8, 129.0, 129.6, 129.7, 130.0,

130.9, 131.2, 136.2, 136.9, 137.8, 138.9, 140.9, 154.9, 159.0. MS (ESI+) m/z = 403.2. ESI-HRMS calculated for $C_{26}H_{18}N_4O$ $[MH]^+$: 403.1559, found: 403.1562.

1-(4,6-Diphenylphthalazin-1-yl)-9*H*-pyrido[3,4-*b*]indole (5da). Yield: 88% (0.098 g from 0.113 g); a yellow solid, mp 170-172 ^oC; R_f = 0.43 (Hexanes: EtOAc, 8:2, v/v). IR (KBr) ν_{max}: 651, 712, 1012, 1281, 1415, 3084, 3397 cm^{-1}. ^1H NMR (400 MHz, $CDCl_3$): δ (ppm) = 7.25 (s, 1H), 7.36-7.42 (m, 3H), 7.52-7.58 (m, 7H), 7.83 (d, J = 5.7 Hz, 2H), 8.06 (d, J = 3.8 Hz, 1H), 8.16 (dd, J_1 = 19.3 Hz, J_2 = 7.6 Hz, 2H), 8.25 (s, 1H), 8.66 (d, J = 4.3 Hz, 1H), 10.14 (d, J = 8.7 Hz, 1H), 11.21 (s, 1H). ^{13}C NMR (100 MHz, $CDCl_3$): δ (ppm) = 112.2, 115.9, 120.2, 121.5, 121.7, 124.0, 125.6, 127.2, 127.7, 128.7, 128.8, 128.9, 129.3, 129.6, 129.7, 130.3, 130.9, 131.9, 136.2, 136.6, 137.9, 139.6, 140.9, 144.6, 155.3, 159.8. MS (ESI+) m/z = 449.2. ESI-HRMS calculated for $C_{31}H_{20}N_4$ $[MH]^+$: 449.1766, found: 449.1765.

4-Phenyl-7-(9*H*-pyrido[3,4-*b*]indol-1-yl)thieno[2,3-*d*]pyridazine (5ka). Yield: 85% (0.081 g from 0.096 g); a yellow solid, mp 124-126 ^oC; R_f = 0.39 (Hexanes: EtOAc, 8:2, v/v). IR (KBr) ν_{max}: 684, 781, 1015, 1242, 1412, 3042, 3398 cm^{-1}. ^1H NMR (400 MHz, $CDCl_3$): δ (ppm) = 7.21-7.28 (m, 1H), 7.52-7.59 (m, 5H), 7.69 (d, J = 5.5 Hz, 1H), 7.95-7.99 (m, 3H), 8.14 (d, J = 7.9 Hz, 1H), 8.66 (d, J = 5.0 Hz, 1H), 10.14 (s, 1H), 11.41 (s, 1H). ^{13}C NMR (100 MHz, $CDCl_3$): δ (ppm) = 112.3, 116.1, 120.3, 121.3, 121.8, 122.5, 128.9, 129.0, 129.6, 129.8, 130.6, 135.1, 135.7, 136.8, 137.2, 137.2, 137.7, 128.3, 141.2, 154.3, 155.2. MS (ESI+) m/z = 379.1. ESI-HRMS calculated for $C_{23}H_{14}N_4S$ $[MH]^+$: 379.1017, found: 379.1015.

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β-Carboline-directed decarboxylative acylation of *ortho*-C(sp2)-H of aryl ring of aryl (β-carbolin-1-yl) methanones with α-ketoacids under Palladium catalysis

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A Pd-catalysed β-carboline assisted decarboxylative acylation of *ortho*-C(sp2)-H of aryl ring of aryl (β-carbolin-1-yl) methanones using α-oxocarboxylic acid as the acyl ion source to form (2-aroylaryl) (β-carbolin-2-yl)methanones is demonstrated.