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Palladium Catalyzed Pyridine Group Directed Regioselective Oxidative C-H Acylation of Carbazoles Using Aldehydes as the Acyl Source

Subhadip Maiti[a], Laxminarayana Burgula[a], Gargi Chakraborti[a], and Jyotirmayee Dash[a]*

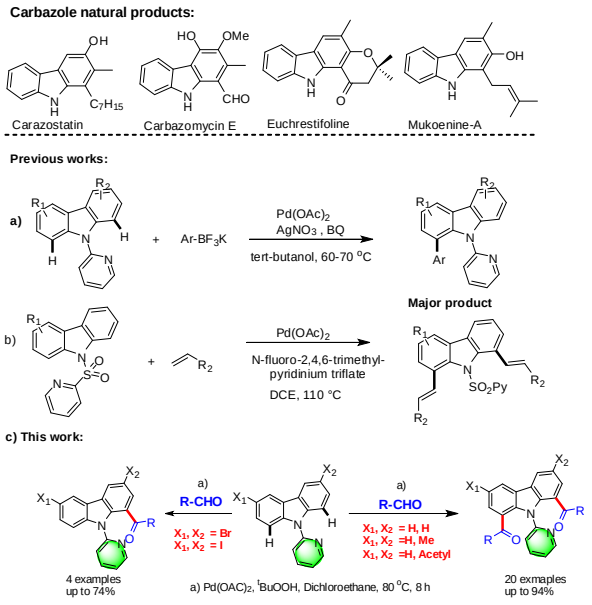
Dedication ((optional))

Abstract: We herein report the first example of a highly regioselective palladium catalyzed oxidative acylation of carbazole derivatives with various aromatic and aliphatic aldehydes as acyl source. The carbazole derivatives are N-protected with easily removable pyridine moiety that directs the Pd-catalyzed ortho-acylation of carbazoles at C1 and C8 positions. The reaction of dibromo and diiodo substituted N-pyridinyl carbazole derivatives with aryl aldehydes provides the 1-acylated product. A mechanism is proposed for the chelation-directed C-H acylation of carbazoles. The method has a broad substrate scope.

Introduction

In the last decade, transition-metal-catalyzed (Rh, Ru, Pd, Cu, Fe, *etc*.) protocols have been developed for carbon−hydrogen (C−H) bond activation and functionalization to access a remarkable diverse classes of organic compounds.[1-5] And therefore, the C-H activation is recently emerged as one of the most powerful tools for building the carbon−carbon (C−C) bonds and carbon−heteroatom (C−X, X = N, O, S, B, Si) bonds.[1] The contribution of Suzuki-Miyaura,[2] Buchwald and Hartwig,[3] Yu[4] and others[5] is remarkable in this promising field.

The carbazole alkaloids and its derivatives are present in natural products (Scheme 1),[6] pharmaceuticals,[7] and optoelectronic materials.[8] Recently we have developed a novel synthetic route for the synthesis of various carbazole alkaloids[9] and evaluated their biological activities by proper functional group modification.[10] The metal-catalyzed cyclization of diarylamine derivatives[11] or 2-aminobiphenyl derivatives[12] is a versatile and well known practical method for the synthesis of different substituted carbazoles. Substituted carbazoles can also be synthesized by following other literature protocols.[13] Due to the intrinsic inertness of carbazoles, a direct C-H functionalization on simple carbazoles is very difficult.[14] The development of efficient methods to substitute carbazoles would enable relatively straightforward access to a variety of synthetic analogues. To the best of our knowledge, only a few examples of the ortho arylation and olefination of carbazoles using pyrimidinyl protecting group have been reported.[15,16] Very recently, Chu, Wu and co-workers reported the Pd (II)-catalyzed direct 1-arylation of carbazoles using pyridine as an ortho directing group with potassium aryltrifluoroborates (Scheme 1a).[15a] Arrayas , Carretero and co workers have reported the Pd (II)-catalyzed 1,8-di-olefination of carbazoles directed by the protecting N-(2-pyridyl)sulfonyl group (Scheme 1b).[15b] The direct ortho acylation (at C1 and C8) of carbazole is quite challenging as the traditional method such as a Friedel-Crafts acylation could offer acylation at C3 and C6 positions.[17] In this protocol, we have reported, the first example of palladium (II) catalyzed direct 1,8- di-acylation of carbazoles using various aldehydes as the acyl source (Scheme 1c) bearing pyridine as a directing group.



Scheme 1. Carbazole natural products and Pd (II)-catalyzed direct ortho-arylation of carbazoles.

Results and Discussion

Initially, the acylation of 9-(pyridin-2-yl)-9H-carbazole **1** was investigated in the presence of $Pd(OAc)_2$ (10 mol%), ^tBuOOH (4 eq) with 1 eq of 4-chlorobenzaldehyde **2b** in dichloroethane at 80 °C for 8 h. This acylation reaction provided a mixture of 1,8-diacylated (**3b**) and 1-acylated (**4**) carbazole derivatives at 67:33 ratio with 50% overall yield (Table 1, entry 1). By increasing the amount of aldehyde from 2-3 eq, the regioselectivity for the

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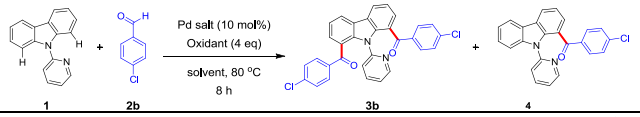
formation of 1,8- diacylated product **3b** was improved (Table 1, entries 2-3). Finally, the di-acylation product **3b** was exclusively obtained by using 4 eq of aldehyde (Table 1, entry 4). Next, the reaction was screened with different solvents.

Table 1. Screening for the optimal conditions.[a]



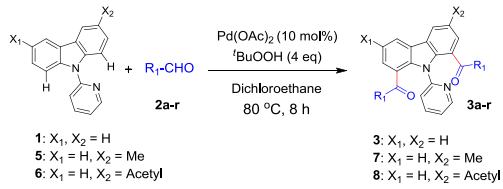
1 2b 3b 4

Entry	Catalyst (mol%)	Oxidant	Aldehyde (eq.)	Solvent	Time (h)	Yield of **3b**[b] (%)
1	$Pd(OAc)_2$	^{t}BuOOH	1 eq	DCE	8	34 (67:33)[c]
2	$Pd(OAc)_2$	^{t}BuOOH	2 eq	DCE	8	48 (80:20)[c]
3	$Pd(OAc)_2$	^{t}BuOOH	3 eq	DCE	8	76 (89:11)[c]
4	$Pd(OAc)_2$	^{t}BuOOH	4 eq	DCE	8	94 (98:2)[c]
5	$Pd(OAc)_2$	^{t}BuOOH	4 eq	Toluene	15	55
6	$Pd(OAc)_2$	^{t}BuOOH	4 eq	DMF	24	NR[d]
7	$Pd(OAc)_2$	^{t}BuOOH	4 eq	THF	20	NR[d]
8	$Pd(OAc)_2$	^{t}BuOOH	4 eq	Dioxane	20	NR[d]
9	$Pd(OAc)_2$	^{t}BuOOH	4 eq	Chloro benzene	15	90
10	$Pd(OAc)_2$	^{t}BuOOH	4 eq	DMSO	24	NR[d]
11	$Pd(OAc)_2$	^{t}BuOOH	4 eq	DCM	20	65
12	$Pd(OAc)_2$	^{t}BuOOH	4 eq	ACN	24	NR[d]
13	$Pd(OAc)_2$	$K_2S_2O_8$	4 eq	DCE	24	NR[d]
14	$Pd(OAc)_2$	O_2	4 eq	DCE	24	trace
15	$PdCl_2$	^{t}BuOOH	4 eq	DCE	24	20
16	$Pd(PPh_3)_2Cl_2$	^{t}BuOOH	4 eq	DCE	24	trace
17	$Pd(OAc)_2$	-	4 eq	DCE	24	NR[d]
18	-	^{t}BuOOH	4 eq	DCE	24	NR[d]
19[e]	$Pd(OAc)_2$	^{t}BuOOH	4 eq	DCE	8	NR[d]

[a]N-pyridinyl carbazole (0.25 mmol), 4-chlorobenzaldehyde, Pd (II) salt (10 mol%), oxidant (4 eq), dry solvent (2 mL), 80 °C; [b]all yields are isolated yields; [c]ratio of **3b** and **4**; [d] no reaction; [e] reaction performed at room temperature.

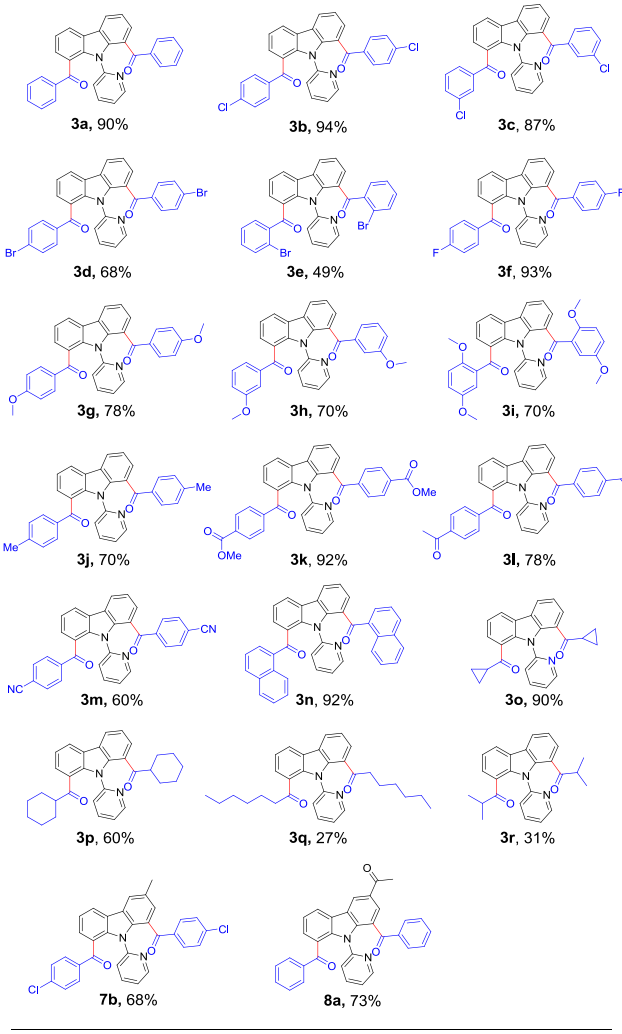
The reaction was equally effective in dichloroethane and chlorobenzene to provide the diacylated product **3b** in 94% and 90% isolated yields respectively (Table 1; entries 4 and 9). Toluene and dichloromethane were partially effective for the reaction producing **3b** in 55% and 65% as isolated yields respectively (Table 1, entries 5 and 11). The remaining solvents were ineffective for the di-acylation reaction (Table 1, entries 6, 7, 8, 10 and 8). Further, the catalytic activity of different Pd-sources were evaluated and $Pd(OAc)_2$ remained far superior compared to $PdCl_2$ and $Pd(PPh_3)_2Cl_2$ (Table 1, entries 4, 15 and 16). The reaction was also screened with several oxidants such as *tert*-butyl hydro peroxide (^{t}BuOOH), $K_2S_2O_8$ and O_2. Among them, ^{t}BuOOH produced best result while remaining oxidants failed to produce the desired product (Table 1; entries 13 and 14). In the absence of either ^{t}BuOOH or $Pd(OAc)_2$, the reaction failed to give the expected product **3b** (Table 1, entries 17 and 18). The reaction did not occur at room temperature (Table 1, entry 19). Finally, it was evident from the optimisation studies that, $Pd(OAc)_2$, ^{t}BuOOH and dichloroethane were the best catalyst, oxidant and solvent respectively for the direct diacylation of N-pyridyl carbazole **1**.

Table 2. Acylation of unsubstituted and substituted N-pyridyl carbazole with various aromatic and aliphatic aldehydes[a,b]



1: X_1, X_2 = H
5: X_1 = H, X_2 = Me
6: X_1 = H, X_2 = Acetyl

3: X_1, X_2 = H
7: X_1 = H, X_2 = Me
8: X_1 = H, X_2 = Acetyl

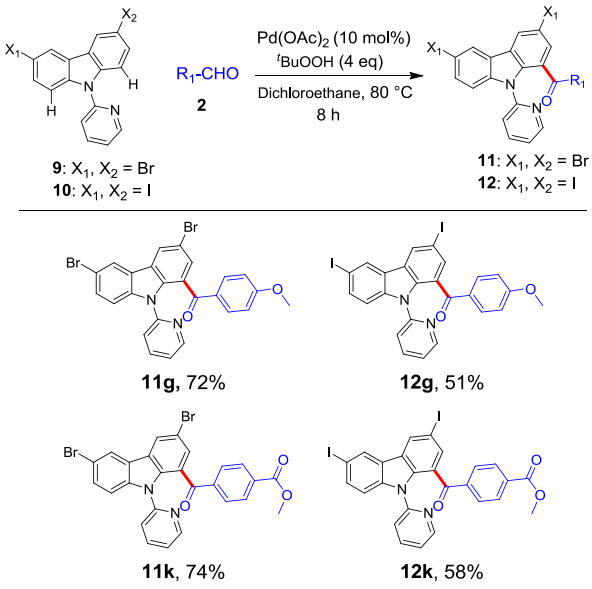


[a]N-pyridinyl carbazole (0.25 mmol), aldehyde (1 mmol), $Pd(OAC)_2$ (10 mol%), ^{t}BuOOH (4 eq), dry dichloroethane (2 mL), 80 °C, 8 h. [b]All yields are isolated yields.

With the optimized reaction conditions in hand (4 equiv of ^{t}BuOOH, 10 mol % of $Pd(OAc)_2$, at 80 °C for 8 h), we have carried out the reaction with a variety of aryl and aliphatic aldehydes. Benzaldehydes with *p*-substituted halogen groups such as Cl, F, Br took part in the reaction effectively affording the desired products **3b**, **3d** and **3f** in 94%, 68% and 93% isolated yields respectively. The *p*-chlorobenzaldehyde exhibited enhanced reactivity compared to the *m*-chlorobenzaldehyde affording the desired products **3b** and **3c** in 94% and 87% isolated yields, respectively. Similarly, the reaction with *p*-bromobenzaldehyde produced better yield than *o*-bromobenzaldehyde providing **3d**, **3e** in 68% and 49% yields respectively. Benzaldehydes with *p*-substituted electron-donating groups such as OMe, Me also participated in the reaction very efficiently affording **3g**, **3j** in 78%, 70% isolated

yields respectively. The reaction of **1** with *p*-methoxybenzaldehyde **2g** generated the desired product **3g** in better isolated yield than m-methoxybenzaldehyde. Substituted benzaldehydes containing electron withdrawing groups (such as CO_2Me, COMe and CN) took part in the reaction efficiently to afford **3k**, **3l** and 3m in 92%, 78% and 60% yields respectively. Unsubstituted aromatic aldehydes such as benzaldehyde, naphthaldehyde produced corresponding di-acylated carbazole derivatives in excellent yields. (Table 2, 3a and 3n). Disubstituted benzaldehyde such as 2,5-dimethoxybenzaldehyde also afforded the desired product **3i** in good yield. It is worth mentioning that aliphatic aldehydes also participated in the reaction. To our delight, cyclopropanecarboxaldehyde and cyclohexanecarboxaldehyde afforded the desired products **3o** and **3p** in 90% and 60% isolated yields where as heptaldehyde and isobutaraldehyde afforded **3q** and **3r** in relatively lower yields (27%, 31%). We have also performed the diacylation reaction of substituted carbazole derivatives, such as 3-methyl-9-(pyridin-2-yl)-9H-carbazole (5) with 4-chlorobenzaldehyde afforded 7 in 68% isolated yield and 1-(9-(pyridin-2-yl)-9H-carbazol-3-yl)ethanone (6) with benzaldehyde produced the desired product 8 in 73% isolated yield.

Table 3. Acylation of halogen substituted N-pyridinyl carbazole with aldehydes[a,b]



[a]Halogen substituted N-pyridinyl carbazole (0.25 mmol), aldehyde (1 mmol), $Pd(OAC)_2$ (10 mol%), ^tBuOOH (4 eq), dry dichloroethane (2 mL), 80 °C, 8 hrs. [b]all yields are isolated yields.

Next the acylation of halogen substituted N-pyridyl carbazole derivatives **9** and **10** with two aromatic aldehydes (**2g** and **2k**) were tested under similar conditions. Surprisingly, in each case the 1-acylated product was formed. The dibromo substituted N-pyridyl carbazole derivative **9** with electron rich aldehyde such as *p*-methoxy benzaldehyde (**2g**) produced better result compared to the diiodo substituted N-pyridinyl carbazole derivative **10** (Table 3, **11g** and **12g**). The dibromo substituted N-pyridyl carbazole derivative **9** with electron defficient aldehyde like methyl 4-formylbenzoate (**2k**) also afforded the desired product **11k** in better isolated yield than the diiodo substituted N-pyridinyl carbazole **10** (Table 3, **11k** and **12k**). However, the limitation of this methodology is that hydroxy substituted benzaldehyde, 4-pyridine carboxaldehyde and pivaldehyde did not provide the desired product.

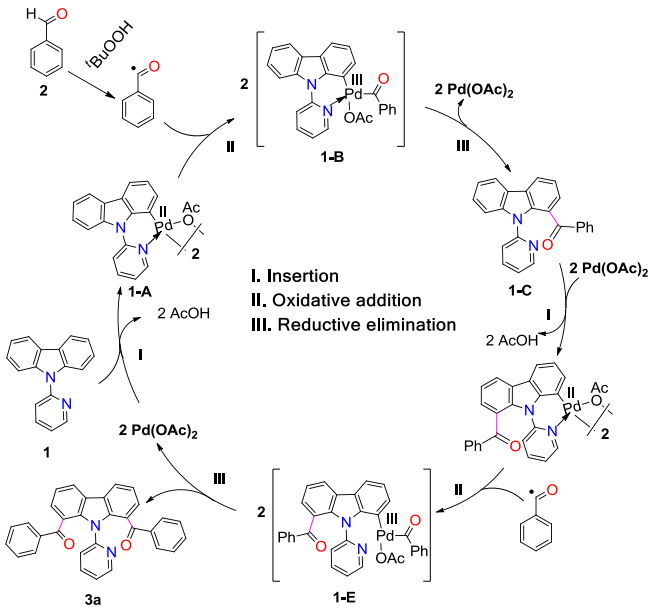
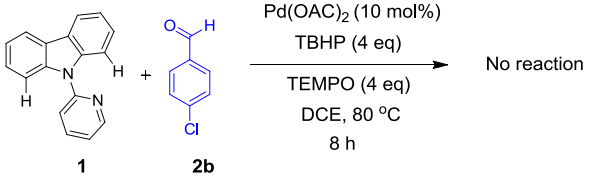


Figure 1. Proposed catalytic cycle of formation 1,8-di-acylated carbozole derivatives.

Based on these results a plausible mechanism has been proposed for the directed 1,8- di-acylation of carbazole **1** (Figure 1). In the first step, with the help of chelation-directed C-H activation, Pd(II) forms a palladacycle **1-A** by ortho-cyclometalation with **1**, while the aldehyde **2** forms acyl radical in presence of ^tBuOOH. In the 2nd step, the acyl radical reacts with intermediate **1-A** to produce oxidative addition product **1-B** and the reductive elimination of **1-B** to afford monoacylated carbazole derivative **1-C** in the third step. Subsequently, **1-C** undergoes ortho-cyclometalation, oxidative addition, reductive elimination successively as mentioned above, to produce the 1,8-di-acylated carbazole derivative 3a while Pd(II) gets regenerated.[18,19] Absense of any desired product, when the reaction was performed in the presence of radical inhibitor TEMPO (2,2,6,6-Tetramethylpiperidin-1-yl)oxyl), further confirms the participation of acyl radical in the proposed catalytic cycle (Scheme 2).



Scheme 2. Acylation reaction of carbazole derivative **1** in the presence of TEMPO.

From the crystal structure of the compound **3g** (Figure 2),[20] we observed that pyridine group is almost perpendicular to the carbazole ring and parallel with aryl rings from aldehyde. To examine whether pyridine ring is acting as a directing group, we

performed reactions of N-methyl carbazole and N-phenyl carbazole with 4-chlorobenzaldehyde under similar optimized conditions. Those reactions did not proceed to give the corresponding acylated product indicates that the pyridine motif acts as a directing group.

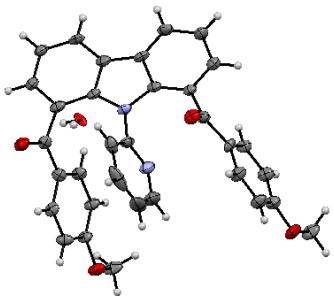
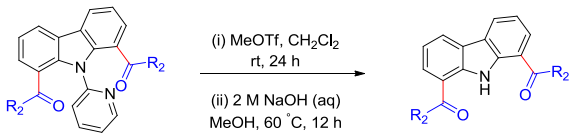


Figure 2. Crystal structure of compound **3g**.



3f: R_2 = 4-fluorophenyl
3o: R_2 = cyclopropyl

3ff: R_2 = 4-fluorophenyl
3oo: R_2 = cyclopropyl

Scheme 3. Removal of the pyridinyl directing group.

To confirm whether pyridinyl goup can act not only as a directing group but also a removable group, we performed depyridination reaction of **3f** and **3o** as the model substrates (Scheme 3). The reactions were carried out using methyl trifluoromethanesulfonate (MeOTf) in dichloromethane and sodium hydroxide in methanol[21] to provide N-H free carbazole derivatives **3ff** and **3oo** in 60 % and 70% isolated yields respectively.

Conclusions

In conclusion, we have demonstrated a palladium catalyzed regioselective synthesis of 1,8- di-acylated carbazole derivatives using aldehydes as acyl source. The main advantages of the present method are high regioselectivity, mild reaction conditions, shorter reaction time and compatibility with a wide range of substrates resulting in high to moderate yields of the desired products.

Experimental Section

All experiments were carried out under an inert atmosphere of argon in Oven-dried flasks, sealed tubes. Solvents were dried using standard procedures. All starting materials were obtained from commercial suppliers and used as received. Products were purified by flash chromatography on silica gel (100-200 mesh, Merck). Unless otherwise stated, yields refer to analytical pure samples. NMR spectra were recorded in $CDCl_3$ unless otherwise stated. **^{1}H NMR** spectra were recorded at 500 MHz and 400 MHz instruments at 298 K. Signals are quoted as δ values in ppm using residual protonated solvent signals as internal standard ($CDCl_3$: δ 7.26 ppm). Data is reported as follows: chemical shift, integration, multiplicity (s = singlet, d = doublet, t = triplet, q = quartet, p = pentet, br = broad, m = multiplet), and coupling constants (Hz). **^{13}C NMR** spectra were recorded on 100 MHz or a 125 MHz with complete proton decoupling. Chemical shifts (δ) are reported in ppm downfield from tetramethylsilane with the solvent as the internal reference ($CDCl_3$: δ 77.16 ppm). **HRMS** analyses were performed with Q-TOF high resolution instruments by +ve mode electro-spray ionization.

Synthesis of 9-pyridinyl carbazole derivative 1

Using the following literature,[22] 9H carbazole (167.2 mg, 1.0 mmol) was taken in an oven-dried 5 mL vial with a magnetic stirrer bar. To this vial, Cs_2CO_3 (325.8, 1.0 mmol), 2-bromopyridine (105 µL, 1.1 mmol), CuI (19 mg, 10 mol%), 2 mL dry DMF were added. Then the vial was sealed with a cap and irradiated for 45 min at 220 °C in a microwave reactor and then cooled to room temperature. The reaction mixture was diluted with saturated aqueous ammonium chloride and product was isolated by extraction with ethyl acetate. The organic layer was dried over sodium sulphate and concentrated under reduced pressure. The product was purified by silica gel column chromatography using hexane/ethyl acetate as eluent to give 222.3 mg (91%) of pyridinyl carbazole **1** as a white solid.

Synthesis of 3-methyl substituted 9-pyridinyl carbazole derivative 5

Following a literature procedure,[22] 3-methyl-9H-carbazole (1.0 mmol), Cs_2CO_3 (1.0 mmol), 2-bromopyridine (1.1 mmol), CuI (0.1 mmol), and dry DMF (2 mL) were added to a 5-mL vial. The vial was sealed with a crimp cap and placed in a Biotage initiator microwave cavity. After irradiation at 220 °C for 45 min and subsequent cooling, the reaction mixture was diluted with saturated aqueous ammonium chloride, extracted with ethyl acetate. The organic layer was dried over anhydrous sodium sulfate, filtered, and concentrated. The residue was purified by silica gel column chromatography using hexane/ethyl acetate as eluent to give 3-methyl-9-(pyridin-2-yl)-9H-carbazole **5** (236 mg, 86%) as a yellow solid. ^{1}H NMR (400 MHz): 8.75 (1H, dd, *J* = 1.2 Hz, 4.8 Hz), 8.14 (1H, d, *J* = 7.7 Hz), 7.96 (1H, s), 7.93-7.89 (2H, m), 7.79 (1H, d, *J* = 8.4 Hz), 7.65 (1H, d, *J* = 8.1Hz), 7.50-7.46 (1H, m), 7.37-7.27 (3H, m), 2.60 (3H, m); ^{13}C NMR (100 MHz): 152.1, 149.6, 139.9, 138.4, 137.9, 130.4, 127.6, 126.1, 124.6, 124.3, 121.0, 120.9, 120.3, 120.2, 118.8, 111.3, 111.0, 21.5; HRMS (ESI) calcd for $C_{18}H_{15}N_2$ $[M+H]^+$: 259.1235; Found: 259.1232.

Synthesis of 3-acetyl substituted 9-pyridinyl carbazole derivative 6:

Following a literature procedure [23], a mixture of **1** (5 mmol) and acetic anhydride (5 mmol) in boron trifluoride diethyl etherate ($BF_3.Et_2O$) (13 mL) was stirred at room temperature in a round bottom flask for 4 h. Then the mixture was hydrolyzed by adding a mixture of ice cold water (50 mL) containing concentrated

hydrochloric acid (0.2 mL) to the reaction mixture with stirring. Then diethyl ether was removed by distillation. The residue was purified by silica gel column chromatography using hexane/ethyl acetate as eluent to give 1-(9-(pyridin-2-yl)-9H-carbazol-3-yl)ethanone **6** (573 mg, 40%) as a white solid. ^{1}H NMR (400 MHz): 8.76-8.75 (2H, m), 8.19 (1H, d, *J* = 7.7 Hz), 8.10 (1H, dd, *J* = 1.6 Hz, 8.7 Hz), 7.98 (1H, dt, *J* = 1.8 Hz, 7.9 Hz), 7.84-7.79 (2H, m), 7.65 (1H, d, *J* = 8.1 Hz), 7.49 (1H, t, *J* = 7.5 Hz), 7.40-7.36 (2H, m), 2.74 (3H, s); ^{13}C NMR (100 MHz): 197.8, 151.3, 150.0, 142.6, 140.5, 138.9, 130.8, 127.1, 127.0, 124.4, 124.3, 122.2, 121.9, 121.6, 120.6, 119.5, 111.5, 111.0, 26.8; HRMS (ESI) calcd for $C_{19}H_{15}N_2O$ $[M+H]^+$: 287.1184; Found: 287.1181.

Synthesis of dibromo 9-pyridinyl carbazole derivative 9

Following literature [24], 9-(pyridin-2-yl)-9H-carbazole **1** (444.6 mg, 2 mmol) in dichlomethane (25 mL), containing silica (100-200 mesh, Merck, 8 gm), a solution of NBS (712 mg, 4 mmol in 25 mL dichloromethane) was added drop wise. The reaction mixture was stirred for 4.5 h in the absence of light at 18 °C until TLC indicated that reaction was completed. The reaction mixture was filtered and the silica was washed with dichloromethane. The combined extracts were washed with water (100 mL) and organic layer was dried and evaporated. The residue was purified by silica gel column chromatography using hexane/ethyl acetate as eluent to give 3,6-dibromo-9-(pyridin-2-yl)-9H-carbazole **9** (563 mg, 70%) as a white solid. ^{1}H NMR (400 MHz): 8.72 (1H, d, *J* = 4.9 Hz), 8.18 (2H, d, *J* = 1.8 Hz), 7.96 (1H, dt, *J* = 7.9, 1.7 Hz), 7.71 (2H, d, *J* = 8.5 Hz), 7.59-7.53 (3H, m), 7.35 (1H, dd, *J* = 7.1, 5.1 Hz); ^{13}C NMR (100 MHz): 151.2, 150.0, 138.9, 138.7, 129.8, 125.1, 123.3, 122.0, 119.1, 114.2, 113.0; HRMS (ESI) calcd for $C_{17}H_{11}Br_2N_2$ $[M+H]^+$: 402.9269; Found: 402.9262.

Synthesis of di-iodo 9-pyridinyl carbazole derivative 10

Following literature[25], 10 mL glacial acetic acid was taken in a 50 mL round bottom flask equipped with a magnetic stir bar and boiled. To this boiled acetic acid, 9-(pyridin-2-yl)-9H-carbazole **1** (444.6 mg, 2 mmol), KI (431.6 mg, 2.6 mmol) were added. Then the mixture was cooled, potassium iodate (642.0 mg, 3 mmol) was added and the reaction mixture was again boiled until a clear straw-colour was observed. The hot solution mixture was decanted from un-dissolved potassium iodate then diluted with saturated sodium thiosulphate solution and the product was isolated by the extraction into ethyl acetate. The crude product was purified by silica gel column chromatography using hexane/ethyl acetate as eluent to provide 3,6-diiodo-9-(pyridin-2-yl)-9H-carbazole **10** (397.0 mg, 40%) as a white solid. ^{1}H NMR (500 MHz): 8.72 (1H, d, *J* = 4.0 Hz), 8.37 (2H, d, *J* = 1.1 Hz), 7.97-7.93 (1H, m), 7.71-7.69 (2H, m), 7.60-7.55 (3H, m), 7.34 (1H, dd, *J* = 7.1, 5.1 Hz); ^{13}C NMR (100 MHz): 151.3, 150.1, 139.1, 139.0, 135.4, 129.5, 125.6, 122.1, 119.2, 113.5, 84.3; HRMS (ESI) calcd for $C_{17}H_{11}I_2N_2$ $[M+H]^+$: 496.9012; Found: 496.9009.

General procedure for the C-H acylation of carbazole derivatives

The carbazole derivatives **1, 5, 6, 9, 10** (0.25 mmol), aldehyde **2** (1.0 mmol), $Pd(OAc)_2$ (10 mol %) in dry DCE (2 mL) were placed in an oven-dried vial with a magnetic stirrer bar. The vial was sealed with a Teflon coated cap and *tert*-butyl hydroperoxide (5.0–6.0 M in decane; 1 mmol) was added to the sealed tube drop wise with syringe through the cap. The whole reaction mixture was kept in a pre-heated oil bath at 80 °C for 8 h. The progress of the reaction was monitored by TLC. The reaction mixture was cooled to room temperature after the consumption of starting material. The reaction mixture was extracted by dichloromethane (3 x 15 mL). The organic layer was washed with saturated sodium bicarbonate solution and dried over Na_2SO_4. The whole organic phase was concentrated under reduced pressure. The products **3, 7, 8, 11, 12** were purified by silica gel column chromatography using hexane/ethyl acetate as eluent. The structure of the product was confirmed by ^{1}H, ^{13}C NMR spectroscopy and mass spectrometry.

(9-(Pyridin-2-yl)-9H-carbazole-1,8 diyl)bis(phenylmethanone) (3a): White solid (90%); 1H NMR (500 MHz): 8.26-8.23 (2H, m), 7.60-7.58 (1H, m), 7.38-7.35 (4H, m), 7.32-7.29 (7H, m), 7.14-7.11 (4H, m), 6.95-6.92 (1H, m), 6.70-6.66 (1H, m); 13C NMR (100 MHz): 195.8, 151.9, 149.3, 138.3, 138.2, 137.2, 132.9, 130.1, 128.1, 127.6, 124.9, 124.4, 123.7, 123.1, 122.5, 120.3; HRMS (ESI) calcd for $C_{31}H_{21}N_2O_2$ [M+H]+: 453.1603; Found: 453.1597.

(9-(Pyridin-2-yl)-9H-carbazole-1,8-diyl)bis((4-chlorophenyl)methanone) (3b): Yellow solid (94%); ^{1}H NMR (500 MHz): 8.34 (2H, dd, *J* = 6.5, 2.4 Hz), 7.73(1H, d, *J* = 4.8 Hz), 7.42-7.38 (9H, m), 7.21 (4H, d, *J* = 8.5 Hz), 7.07 (1H, d, *J* = 7.9 Hz,), 6.85 (1H, dd, *J* = 7.0, 5.3 Hz); ^{13}C NMR (100 MHz): 194.5, 151.9, 149.2, 139.5, 138.4, 138.1, 135.5, 131.4, 128.5, 127.6, 124.9, 123.9, 123.6, 123.3, 122.7, 120.4; HRMS (ESI) calcd for $C_{31}H_{19}Cl_2N_2O_2$ $[M+H]^+$: 521.0823; Found: 521.0826.

(9-(Pyridin-2-yl)-9H-carbazole-1,8-diyl)bis((3-chlorophenyl)methanone) (3c): White solid (87%); ^{1}H NMR (400 MHz): 8.37-8.33 (2H, m), 7.74 (1H, d, *J* = 3.0 Hz), 7.45-7.35 (9H, m), 7.26 (2H, d, *J* = 7.3 Hz), 7.15 (2H, t, *J* = 7.8 Hz), 7.04 (1H, d, *J* = 7.9 Hz), 6.93 (1H, dd, *J* = 7.3, 5.0 Hz); ^{13}C NMR (100 MHz): 194.4, 151.8, 149.3, 138.8, 138.5, 138.1, 134.5, 132.8, 129.5, 129.3, 128.4, 127.7, 124.9, 123.7, 123.4, 123.1, 122.9, 120.5; HRMS (ESI) calcd for $C_{31}H_{18}Cl_2N_2O_2Na$ $[M+Na]^+$: 543.0643; Found: 543.0641.

(9-(Pyridin-2-yl)-9H-carbazole-1,8-diyl)bis((4-bromophenyl)methanone) (3d): Brown solid (68%); ^{1}H NMR (500 MHz): 8.34 (2H, dd, *J* = 6.4, 2.5 Hz) 7.73 (1H, d, *J* = 4.7 Hz), 7.43-7.37 (9H, m), 7.32 (4H, d, *J* = 7.9 Hz), 7.06 (1H, d, *J* = 8.2 Hz), 6.85 (1H, dd, *J* = 7.3, 5.0 Hz); ^{13}C NMR (100 MHz): 194.6, 151.9, 149.3, 138.4, 138.1, 135.9, 131.5, 131.4, 128.2, 127.6, 124.9, 123.8, 123.5, 123.3, 122.7, 120.4; HRMS (ESI) calcd for $C_{31}H_{18}Br_2N_2O_2Na$ $[M+Na]^+$: 632.9612; Found: 632.9612.

(9-(Pyridin-2-yl)-9H-carbazole-1,8-diyl)bis((2-bromophenyl)methanone) (3e): Yellow solid (49%); ^{1}H NMR (400 MHz): 8.33 (2H, dd, *J* = 7.3, 1.1 Hz), 8.18 (1H, dd, *J* = 4.7, 1.2 Hz), 7.76 (1H, dt, *J* = 7.8, 1.8 Hz), 7.62-7.58 (3H, m), 7.51-7.48 (2H, m), 7.36-7.28 (8H, m), 7.08 (1H, dd, *J* = 7.2, 5.0 Hz); ^{13}C NMR (100 MHz): 194.0, 153.3, 148.9, 139.4, 138.8, 138.5,

134.1, 132.3, 132.2, 129.6, 127.2, 125.4, 124.9, 123.9, 123.6, 123.5, 121.1, 120.2; HRMS (ESI) calcd for $C_{31}H_{19}Br_2N_2O_2$ $[M+H]^+$: 610.9793; Found: 610.9791.

(9-(Pyridin-2-yl)-9H-carbazole-1,8-diyl)bis((4-fluorophenyl)methanone) (3f): White solid (93%); ^{1}H NMR (500 MHz): 8.34 (2H, dd, *J* = 9.0, 2.5 Hz), 7.72-7.70 (1H, m), 7.49-7.46 (4H, m), 7.42-7.38 (5H, m), 7.07 (1H, dd, *J* = 7.7, 2.1 Hz), 6.92-6.88 (4H, m), 6.83 (1H, dd, *J* = 7.1, 4.7 Hz); ^{13}C NMR (125 MHz): 194.3, 166.6, 164.6, 151.9, 149.2, 138.3, 138.1, 133.6, 132.7, 132.6, 127.5, 124.9, 124.1,123.7, 123.2, 122.6, 120.4, 115.4, 115.2; HRMS (ESI) calcd for $C_{31}H_{19}F_2N_2O_2$ $[M+H]^+$: 489.1415; Found: 489.1406.

(9-(Pyridin-2-yl)-9H-carbazole-1,8-diyl)bis((4-methoxyphenyl)methanone) (3g): White solid (78%); ^{1}H NMR (500 MHz): 8.29 (2H, d, *J* = 3.4 Hz), 7.72 (1H, s), 7.43-7.33 (9H, m), 7.03-6.98 (1H, m), 6.78 (1H, d, *J* = 3.8 Hz), 6.70-6.64 (4H, m), 3.77-3.74 (6H, m);^{13}C NMR (100 MHz):194.5, 163.5, 151.9, 149.1, 138.2, 137.9, 132.4, 130.5, 127.2, 124.8, 124.7, 123.9, 123.1, 122.1, 120.2, 113.3, 55.5; HRMS (ESI) calcd for $C_{33}H_{25}N_2O_4$ $[M+H]^+$: 513.1814; Found: 513.1807.

(9-(Pyridin-2-yl)-9H-carbazole-1,8-diyl)bis((3-methoxyphenyl)methanone) (3h): Yellow solid (70%); ^{1}H NMR (500 MHz): 8.32 (2H, dd, *J* = 6.8, 1.6 Hz), 7.78 (1H, d, *J* = 4.9 Hz), 7.41-7.34 (5H, m), 7.13 (2H, t, *J* = 7.8 Hz), 7.05-7.01 (5H, m), 6.96 (2H, dd, *J* = 8.2, 2.3 Hz), 6.84 (1H, dd, *J* = 7.4, 5.1 Hz), 3.73 (6H, s); ^{13}C NMR (125 MHz): 195.6, 159.4, 151.9, 149.1, 138.6, 138.4, 138.3, 129.2, 127.8, 124.9, 124.4, 123.7, 123.6, 122.9, 122.5, 120.3, 119.8, 113.4, 55.5; HRMS (ESI) calcd for $C_{33}H_{25}N_2O_4$ $[M+H]^+$: 513.1814; Found: 513.1809.

(9-(Pyridin-2-yl)-9H-carbazole-1,8-diyl)bis((2,5-dimethoxyphenyl)methanone) (3i): White solid (70%); ^{1}H NMR (400 MHz): 8.26 (2H, dd, *J* = 7.4, 0.9 Hz), 8.08 (1H, d, *J* = 3.5 Hz), 7.49 (1H, dt, *J* = 7.7, 1.8 Hz), 7.35-7.28 (5H, m), 6.96-6.92 (5H, m), 6.78 (2H, dd, *J* = 7.5, 2.0 Hz), 3.70 (6H, s), 3.48 (6H, s); ^{13}C NMR (100 MHz): 194.3, 153.3, 153.2, 153.1, 149.0, 138.1, 137.8, 128.5, 127.6, 127.4, 124.9, 122.9, 122.6, 122.4, 120.0, 119.9, 115.5, 113.9, 56.5, 55.9; HRMS (ESI) calcd for $C_{35}H_{29}N_2O_6$ $[M+H]^+$: 573.2026; Found: 573.2021.

(9-(Pyridin-2-yl)-9H-carbazole-1,8-diyl)bis(p-tolylmethanone) (3j): White solid (70%); ^{1}H NMR (500 MHz): 8.25-8.22 (2H, m), 7.63 (1H, s), 7.30-7.22 (9H, m), 6.96-6.94 (5H, m), 6.72-6.69 (1H, m), 2.24 (6H, d, *J* = 3.6 Hz) ; ^{13}C NMR (100 Hz): 195.5, 151.9, 149.1, 143.7, 138.3, 138.0, 134.8, 130.3, 128.8, 127.5, 124.9, 124.6, 123.8, 123.1, 122.2, 120.1, 21.7; HRMS (ESI) calcd for $C_{33}H_{25}N_2O_2$ $[M+H]^+$: 481.1916; Found: 481.1912.

Dimethyl 4,4'-(9-(pyridin-2-yl)-9H-carbazole-1,8-dicarbonyl)dibenzoate (3k): White solid (92%); ^{1}H NMR (500 MHz): 8.37 (2H, dd, *J* = 6.9, 2.1 Hz), 7.89 (4H, d, *J* = 8.4 Hz), 7.62 (1H, d, *J* = 3.4 Hz), 7.51 (4H, d, *J* = 8.4 Hz), 7.44-7.35 (5H, m), 7.06 (1H, dd, *J* = 7.5, 3.0 Hz), 6.81 (1H, td, *J* = 7.6, 3.9 Hz), 3.91 (6H, d, *J* = 3.5 Hz); ^{13}C NMR (125 MHz): 195.1, 166.4, 151.7, 149.4, 140.4, 138.5, 138.2, 133.7, 130.0, 129.4, 127.8, 125.0, 123.9, 123.3, 123.2, 122.9, 120.5, 52.6; HRMS (ESI) calcd for $C_{35}H_{24}N_2O_6Na$ $[M+Na]^+$: 591.1532; Found: 591.1534.

1,1'-((9-(Pyridin-2-yl)-9H-carbazole-1,8-dicarbonyl)bis(4,1-phenylene))diethanone (3l): Yellow solid (78%); ^{1}H NMR (500 MHz): 8.37 (2H, dd, *J* = 7.1, 1.8 Hz), 7.81 (4H, d, *J* = 8.4 Hz), 7.61 (1H, dd, *J* = 4.7, 1.1 Hz), 7.55 (4H, d, *J* = 8.4 Hz), 7.44-7.38 (5H, m), 7.08 (1H, d, *J* = 7.9 Hz), 6.82 (1H, dd, *J* = 7.0, 5.0 Hz), 2.58 (6H, s); ^{13}C NMR (100 MHz): 197.6, 194.9, 152.1, 149.3, 140.3, 139.9, 138.5, 138.1, 130.2, 128.0, 127.8, 125.0, 123.9, 123.3, 123.2, 123.0, 120.5, 27.0; HRMS (ESI) calcd for $C_{35}H_{25}N_2O_4$ $[M+H]^+$: 537.1814; Found: 537.1807.

4,4'-(9-(Pyridin-2-yl)-9H-carbazole-1,8-dicarbonyl)dibenzonitrile (3m): White solid (60%); ^{1}H NMR (500 MHz): 8.39 (2H, d, *J* = 7.6 Hz), 7.63(1H, d, *J* = 4.5 Hz), 7.55 (8H, s), 7.50-7.43 (3H, m), 7.40 (2H, d, *J* = 7.3 Hz), 7.12 (1H, d, *J* = 7.9 Hz), 6.86 (1H, dd, *J* = 7.4, 4.9 Hz); ^{13}C NMR (100 MHz): 194.1, 152.1, 149.4, 140.1, 138.8, 137.9, 132.1, 130.3, 127.9, 125.0, 123.4, 123.2, 123.1, 120.8, 118.0, 116.2, 114.2 ; HRMS (ESI) calcd for $C_{33}H_{19}N_4O_2$ $[M+H]^+$: 503.1508; Found: 503.1515.

(9-(Pyridin-2-yl)-9H-carbazole-1,8-diyl)bis(naphthalen-1-ylmethanone) (3n): White solid (92%); ^{1}H NMR (500 MHz): 8.50 (2H, d, *J* =9.1 Hz), 8.25 (2H, d, *J* = 7.7 Hz), 7.73 (2H, d, *J* = 8.1 Hz), 7.68-7.64 (2H, m), 7.41 (2H, d, *J* = 7.2 Hz), 7.37-7.33 (7H, m), 7.28-7.24 (2H, m), 7.18-7.16 (2H, m), 7.01 (1H, d, *J* = 7.6 Hz), 6.84 (1H, t, *J* = 7.5 Hz), 5.84 (1H, dd, *J* = 7.2, 4.8 Hz); ^{13}C NMR (125 MHz): 197.1, 152.4, 149.2, 138.6, 138.2, 134.2, 133.8, 133.4, 132.9, 130.8, 129.1, 128.3, 127.9, 126.6, 126.5, 126.3, 125.1, 124.3, 122.9, 122.4, 121.8, 120.4; HRMS (ESI) calcd for $C_{39}H_{24}N_2O_2Na$ $[M+Na]^+$: 575.1735; Found: 575.1738.

(9-(Pyridin-2-yl)-9H-carbazole-1,8-diyl)bis(cyclopropylmethanone) (3o): White solid (90%); ^{1}H NMR (500 MHz): 8.57 (1H, d, *J* = 4.0 Hz), 8.24 (2H, d, *J* = 7.6 Hz), 7.89-7.86 (1H, m), 7.61 (2H, d, *J* = 7.4 Hz), 7.39-7.31 (4H, m), 2.26-2.21 (2H, m), 0.86-0.79 (8H, m); ^{13}C NMR (100 MHz): 203.9,153.5, 149.3, 139.1, 136.8,127.3, 126.5, 125.1, 123.2, 122.9, 122.6, 120.4, 21.9, 12.6; HRMS (ESI) calcd for $C_{25}H_{21}N_2O_2$ $[M+H]^+$: 381.1603; Found: 381.1597.

(9-(Pyridin-2-yl)-9H-carbazole-1,8-diyl)bis(cyclohexylmethanone) (3p): Colorless oil (60%); ^{1}H NMR (400 MHz): 8.53 (1H, dd, *J* = 4.6, 1.1 Hz), 8.21 (2H, d, *J* = 8.0 Hz), 7.87 (1H, dt, *J* = 7.7, 1.8 Hz), 7.47 (2H, d, *J* = 7.1 Hz), 7.37-7.29 (4H, m), 2.69-2.62 (2H, m), 1.70-1.58 (10H, m)1.13 (10H, d, *J* = 3.9 Hz) ; ^{13}C NMR (100 MHz): 206.8, 153.5, 149.1, 139.2, 137.9, 126.9, 126.4, 125.7, 123.0, 122.9, 122.5, 120.7, 49.9, 29.1, 26.1, 25.9; HRMS (ESI) calcd for $C_{31}H_{33}N_2O_2$ $[M+H]^+$: 465.2542; Found: 465.2535.

1,1'-(9-(Pyridin-2-yl)-9H-carbazole-1,8-diyl)bis(heptan-1-one) (3q): Colorless oil (27%); ^{1}H NMR (500 MHz): 8.53 (1H, d, *J* = 4.2 Hz), 8.22 (2H, d, *J* = 7.7 Hz), 7.86 (1H, dt, *J* = 7.9, 1.6 Hz), 7.45 (2H, d, *J* = 7.4 Hz), 7.35-7.32 (4H, m), 2.62 (4H, t, *J* = 7.5 Hz), 1.40-1.33 (4H, m), 1.29-1.20 (12 H, m), 0.87 (6H, t, *J* = 7.0 Hz); ^{13}C NMR (100 MHz): 204.4, 153.7, 149.2, 139.1, 137.2, 127.2, 126.0, 125.3, 123.3, 122.7, 122.5, 120.5, 43.0, 31.7, 28.9, 24.1, 22.6, 14.2; HRMS (ESI) calcd for $C_{31}H_{37}N_2O_2$ $[M+H]^+$: 469.2855; Found: 469.2850.

1,1'-(9-(Pyridin-2-yl)-9H-carbazole-1,8-diyl)bis(2-methylpropan-1-one) (3r): Colorless oil (31%) ^{1}H NMR (500 MHz): 8.51 (1H, d, *J* = 4.5 Hz), 8.23 (2H, d, *J* = 7.6 Hz), 7.86 (1H, t, *J* = 7.6 Hz), 7.49 (2H, d, *J* = 7.4 Hz), 7.38-7.29 (4H, m), 3.06-3.01 (2H, m), 0.94 (12H, d, *J* = 7.1 Hz) ; ^{13}C NMR (100 MHz): 207.3, 153.4, 149.1, 138.9, 138.2, 126.7, 126.2, 125.7, 123.4,

123.2, 122.6, 120.6, 39.8, 18.7; HRMS (ESI) calcd for $C_{25}H_{24}N_2O_2Na$ $[M+Na]^+$: 407.1735; Found: 407.1735.

(4-chlorophenyl)(9-(pyridin-2-yl)-9H-carbazol-1-yl)methanone (4): Yellow solid; ^{1}H NMR (500 MHz): 8.21 (1H, d, J = 7.6 Hz), 8.07 (1H, d, J = 7.7 Hz), 8.03-8.02 (1H, m), 7.68-7.65 (1H, m), 7.44-7.41 (4H, m), 7.34-7.24 (4H, m), 7.20-7.16 (2H, m), 7.01 (1H, dd, J = 5.1 Hz, 7.4 Hz); ^{13}C NMR (100 MHz): 194.7, 152.4, 149.3, 140.9, 139.1, 138.7, 137.7, 136.0, 134.7, 131.3, 128.9, 128.5, 127.7, 127.0, 126.0, 123.9, 123.7, 122.2, 121.5, 120.5, 120.4, 110.3; HRMS (ESI) calcd for $C_{24}H_{16}ClN_2O$ $[M+H]^+$: 383.0951; Found: 383.0954.

(3-Methyl-9-(pyridin-2-yl)-9H-carbazole-1,8-diyl)bis((4-chlorophenyl)methanone) (7b): Yellow solid (68%); ^{1}H NMR (500 MHz): 8.30 (1H, dd, *J* = 2.9 Hz, 6.1 Hz), 8.13 (1H, s), 7.71 (1H, d, *J* = 3.8 Hz), 7.40-7.36 (7H, m), 7.21-7.19 (5H, m), 7.03 (1H, d, *J* = 7.8 Hz), 6.82 (1H, dd, *J* = 5.1 Hz, 7.2 Hz) 2.56 (3H, s); ^{13}C NMR (125 MHz): 194.8, 194.6, 152.1, 149.3, 139.4, 138.3, 136.5, 135.6, 131.5, 131.4, 130.2, 128.6, 128.5, 127.5, 125.1, 128.8, 123.8, 123.7, 123.4, 123.1, 122.8, 122.7, 120.3, 21.3; HRMS (ESI) calcd for $C_{32}H_{21}Cl_2N_2O_2$ $[M+H]^+$: 535.0980; Found: 535.0974.

3-Acetyl-9-(pyridin-2-yl)-9H-carbazole-1,8-diyl)bis(phenylmethanone) (8a): Yellow solid (73%); ^{1}H NMR (400 MHz): 8.97 (1H, d, *J* = 1.3 Hz), 8.41 (1H, dd, *J* = 2.5 Hz, 6.4 Hz), 8.02 (1H, d, *J* = 1.3 Hz), 7.67 (1H, dd, *J* = 1.2 Hz, 4.7 Hz), 7.47-7.40 (7H, m), 7.35 (1H, dt, *J* = 1.8 Hz, 7.7 Hz), 7.27-7.23 (5H, m), 7.05 (1H, d, *J* = 7.9 Hz), 6.82 (1H, dd, *J* = 4.9 Hz, 7.3 Hz), 2.73 (3H, s); ^{13}C NMR (100 MHz): 197.0, 195.4, 195.0, 151.3, 149.4, 140.7, 138.9, 138.3, 137.0, 136.7, 133.3, 133.2, 130.1, 129.9, 128.3, 128.2, 127.8, 125.0, 124.9, 124.1, 123.6, 123.0, 122.7, 121.2, 26.9; HRMS (ESI) calcd for $C_{33}H_{23}N_2O_3$ $[M+H]^+$: 495.1708; Found: 495.1704.

3,6-Dibromo-9-(pyridin-2-yl)-9H-carbazol-1-yl)(4-methoxyphenyl)methanone) (11g): White solid (72%); ^{1}H NMR (500 MHz): 8.32 (1H, d, *J* = 1.6 Hz), 8.23 (1H, d, *J* = 1.6 Hz), 8.08-8.07 (1H, m), 7.77 (1H, dt, *J* = 7.6, 1.5 Hz), 7.61-7.58 (3H, m), 7.51 (1H, dd, *J* = 8.6, 1.7 Hz), 7.33 (2H, dd, *J* = 8.6, 1.7 Hz), 7.11 (1H, dd, *J* = 7.3, 4.9 Hz), 6.82 (2H, d, *J* = 8.7 Hz), 3.86 (3H, s); ^{13}C NMR (100 MHz): 192.9, 163.8, 151.4, 149.5, 139.9, 138.8, 136.8, 132.4, 130.3, 129.9, 126.5, 126.4, 125.4, 124.6, 123.4, 120.7, 120.5, 114.5, 113.7, 113.3, 112.1, 55.7; HRMS (ESI) calcd for $C_{25}H_{17}Br_2N_2O_2$ $[M+H]^+$: 536.9636; Found: 536.9633.

(3,6-Diiodo-9-(pyridin-2-yl)-9H-carbazol-1-yl)(4-methoxyphenyl)methanone (12g): White solid (51%); ^{1}H NMR (500 MHz): 8.50 (1H, d, *J* = 1.5 Hz), 8.41 (1H, d, *J* = 1.4 Hz), 8.07 (1H, dd, *J* = 4.7, 1.1 Hz), 7.77-7.74 (2H, m), 7.67 (1H, dd, *J* = 8.6, 1.5 Hz), 7.57 (2H, d, *J* = 8.8 Hz), 7.30 (1H, d, *J* = 7.9 Hz), 7.24 (1H, d, *J* = 8.7 Hz), 7.11 (1H, dd, *J* = 7.0, 5.0 Hz), 6.82 (2H, d, *J* = 8.8 Hz), 3.85 (3H, s); ^{13}C NMR (125 MHz): 192.8, 163.7, 151.3, 149.4, 140.2, 138.8, 136.9, 135.8, 135.6, 132.3, 131.4, 129.9, 129.5, 126.7, 124.9, 122.7, 120.5, 113.7, 112.4, 84.4, 82.9, 55.6; HRMS (ESI) calcd for $C_{25}H_{17}I_2N_2O_2$ $[M+H]^+$: 630.9379; Found: 630.9376.

Methyl 4-(3,6-dibromo-9-(pyridin-2-yl)-9H-carbazole-1-carbonyl)benzoate (11k): White solid (74%); ^{1}H NMR (500 MHz): 8.35 (1H, d, *J* = 2.5 Hz), 8.22 (1H, d, *J* = 1.6 Hz,), 8.03-7.98 (3H, m), 7.76 (1H, dt, *J* = 7.9, 1.7 Hz), 7.65 (2H, d, *J* = 8.3 Hz), 7.60 (1H, d, *J* = 2.5 Hz), 7.52 (1H, dd, *J* = 9.1, 1.5 Hz), 7.36 (1H, d, *J* = 8.4 Hz), 7.30 (1H, d, *J* = 7.6 Hz), 7.11 (1H, dd, *J* = 7.3, 5.0 Hz) 3.95 (3H, s); ^{13}C NMR (100 MHz): 193.5, 166.3, 151.4, 149.4, 140.2, 139.8, 139.1, 136.7, 133.9, 130.5, 130.4, 129.7, 129.6, 126.7, 126.1, 125.5, 124.6, 123.5, 122.8, 120.2, 114.8, 113.4, 111.9, 52.6; HRMS (ESI) calcd for $C_{26}H_{17}Br_2N_2O_3$ $[M+H]^+$: 586.9405; Found: 586.9407.

Methyl 4-(3,6-diiodo-9-(pyridin-2-yl)-9H-carbazole-1-carbonyl)benzoate (12k): White solid (58%); ^{1}H NMR (500 MHz): 8.46 (1H, d, *J* = 5.3 Hz), 8.34 (1H, d, *J* = 5.2 Hz), 7.95-7.91 (3H, m), 7.69-7.66 (2H, m), 7.61-7.54 (3H, m), 7.22-7.15 (2H, m), 7.04-7.01 (1H, m), 3.86 (3H, d, *J* = 5.3 Hz); ^{13}C NMR (125 MHz): 193.4, 166.3, 151.4, 149.4, 140.2, 140.1, 139.0, 136.9, 135.9, 135.8, 133.4, 132.2, 129.7, 129.6, 126.9, 125.9, 124.9, 122.7, 120.2, 112.4, 84.7, 82.9, 52.6; HRMS (ESI) calcd for $C_{26}H_{17}I_2N_2O_3$ $[M+H]^+$: 658.9329; Found: 658.9325.

9H-carbazole-1,8-diyl)bis((4-fluorophenyl)methanone) (3ff): White solid (60%); ^{1}H NMR (400 MHz): 11.97 (1H, s), 8.40 (2H, d, J = 7.7 Hz), 7.92-7.85 (6H, m), 7.37 (2H, t, J = 7.7 Hz), 7.27-7.21 (4H, m); ^{13}C NMR (125 MHz): 195.6, 166.1, 164.1, 140.5, 135.1, 132.2, 132.1, 130.9, 126.0, 124.3, 119.7, 119.1, 115.7, 115.6; HRMS (ESI) calcd for $C_{26}H_{16}F_2NO_2$ $[M+H]^+$: 412.1149; Found: 412.1141.

(9H-carbazole-1,8-diyl)bis(cyclopropylmethanone) (3oo): White solid (70%); ^{1}H NMR (400 MHz): 12.31 (1H, s), 8.32 (2H, d, *J* = 7.6 Hz), 8.23 (2H, d, *J* = 7.7 Hz), 7.36 (2H, t, *J* = 7.7 Hz), 2.91-2.84 (2H, m), 1.38-1.35 (4H, m), 1.10-1.05 (4H, m); ^{13}C NMR (125 MHz): 200.7, 139.4, 127.7, 125.7, 123.9, 120.8, 119.2, 16.9, 11.5; HRMS (ESI) calcd for $C_{20}H_{18}NO_2$ $[M+H]^+$: 304.1337; Found: 304.1333.

Radical quenching experiment

A mixture of 9-(pyridin-2-yl)-9H-carbazole **1** (0.25 mmol), 4-chlorobenzaldehyde **2b** (1.0 mmol), $Pd(OAc)_2$ (10 mol %), TEMPO (1 mmol), dry DCE (2 mL) was placed in an oven-dried vial with a magnetic stirrer bar. The vial was sealed with a Teflon coated cap and *tert*-butyl hydroperoxide (5.0–6.0 M in decane, 1 mmol) was added to the sealed tube drop wise with syringe through the cap. The whole reaction mixture was kept in a preheated oil bath at 80 °C for 8 h. No product formation was observed.

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Keywords: Palladium catalyst · Regioselective · C-H acylation · Carbazole ·

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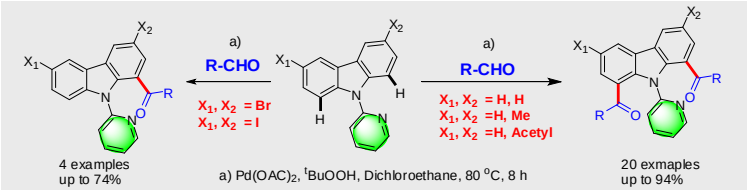

The pyridinyl group directed regioselective C-H acylation of carbazoles using aldehydes as acyl source is reported. The reaction provides C1 and C8 diacylated products in good to high yields. The dihalogenated carbazoles afford the 1-acylated products. Moreover, the pyridinyl directing group is easily removable.

C-H acylation of carbazoles*

*Subhadip Maiti, Laxminarayana Burgula and Jyotirmayee Dash**

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Title

Palladium Catalyzed Pyridine Group Directed Regioselective Oxidative C-H Acylation of Carbazoles Using Aldehydes as the Acyl Source