SYNTHESIS AND CHARACTERIZATION OF 2-PHENYL-4-BENZOYL-6,7-DIHYDRO-5*H*-CYCLOPENTA[*b*]PYRIDINE AND ITS DERIVATIVES

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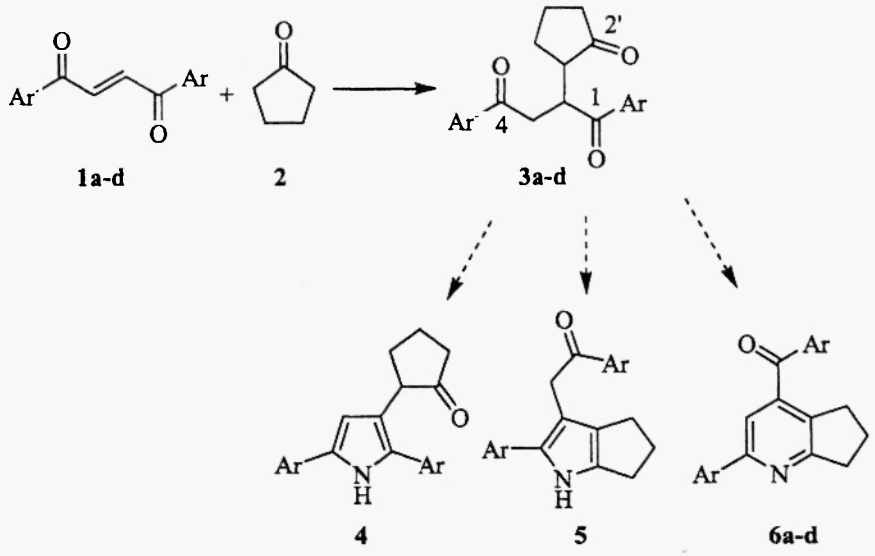
Abstract: Amination-cyclization of triketones derived from variously substituted dibenzoyl ethylene and cyclopentanone furnished 2-phenyl-4-benzoyl-6,7-dihydro-5*H*-cyclopenta[*b*]pyridine and its derivatives.

Keywords: Amination-cyclization, 1,4-Diphenylbut-2-ene-1,4-dione (dibenzoyl ethylene), Cyclopenta[*b*]pyridine

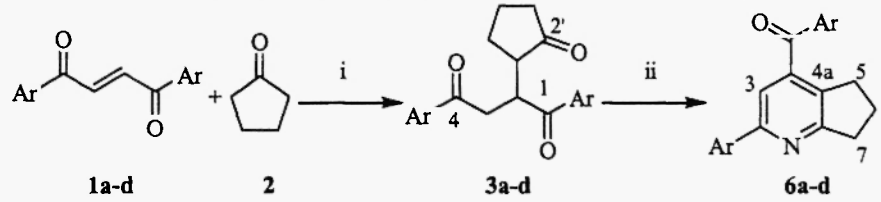
Introduction

Synthesis and characterization of variously substituted cyclopenta annulated heterocycles is of continuing interest since they show impressive biological properties. For example, the drug Ramipril® (1) which shows antihypertensive properties has cyclopenta[*b*]pyrrolidine carboxylic acid core structure. On the other hand, the drug Nordialex® (2) having cyclopenta[*c*]pyrrolidine nucleus shows anti-diabetic properties. Similarly, Lenacil® (3) having cyclopentapyrimidine structure is used as herbicide. Furthermore, cyclopenta annulated heterocycles form structural motifs on a number of alkaloids. Cyclopenta[*b*]pyridine moiety which is of particular interest to the present study forms a part structure on several annonaceae and menispermaceae alkaloids (4). Furthermore, Cefpirome® (5), an injectable cephalosporin antibacterial agent used for treatment for severe urinary and respiratory tract infections is a salt of cyclopenta[*b*]pyridine. Literature survey also revealed that some 3-dimethylcarbomoyloxyphenyl substituted cyclopenta[*b*]pyridine derivatives were developed as acetylcholinestrase inhibitors (6).



Scheme 1

As a part of ongoing program on the studies on the amination-cyclization reactions from diketones, we became interested to study the reaction of triketones of the type **3** derived from the reaction of 1,4-diarylbut-2-ene-1,4-dione (dibenzoyl ethylene derivatives) **1** with cyclopentanone **2**. Molecular stitching involving of 1,4-carbonyl groups in the amination-cyclization step generates 2,3,5-trisubstituted pyrrole derivatives **4** (Scheme 1). On the other hand amination-cyclization on 1,2'-carbonyl groups lead to 2,3-disubstituted 1,4,5,6-tetrahydrocyclopenta[*b*]pyrrole derivative **5**. Finally, amination-cyclization connecting 4,2'-carbonyl groups in **3** furnishes 2,4-disubstituted 6,7-dihydro-5*H*-cyclopenta[*b*]pyridine derivative **6**. To test above possibilities we conducted the amination-cyclization reaction on triketones **3** with ammonium acetate in methanol and the results are presented here. Literature search revealed that 4-aroyl cyclopenta[*b*]pyridine derivatives of the type **6** are not known.



1b, 3a, 6a: Ar = C_6H_5; 1b, 3b, 6b: Ar = 4-Cl-C_6H_4; 1c, 3c, 6c: Ar = 4-CH_3-C_6H_4; 1d, 3d, 6d: Ar = 4-OCH_3-C_6H_4.

Reagents and conditions: i. $Ba(OH)_2$, EtOH, rt, 12h, 42-53%; ii. NH_4OAc, MeOH, rt, 18h, 25-35%.

Scheme 2

Results and Discussion

Initially the amination-cyclization reaction was conducted on triketone **3a** derived from 1,4-diphenylbut-2-ene-1,4-dione (dibenzoyl ethylene, DBE) **1a**. Conjugate addition (Michael Reaction) of the anion generated from cyclopentanone to DBE **1a** in the presence of barium hydroxide (7) in ethanol medium furnished diasteromeric mixture of triketones **3a** in 53% yield in 3:1 ratio (Scheme 2). Previously Kaupp and coworkers reported the isolation of

triketone **3a** as a byproduct in their study on the synthesis of cage compounds from DBE (8). While performing the column purification of the conjugate addition product the major isomer crystallized out of the fractions. The IR spectrum of the major isomer showed the cyclopentanone carbonyl absorption at 1730 cm^{-1} and aromatic ketone absorption at 1670 cm^{-1}. The ^1H NMR spectrum revealed a multiplet for C_2-H at 4.6 ppm. The ^{13}C NMR spectrum revealed six signals in the aliphatic region, three for carbonyl groups and the rest for aromatic carbons. Previously, we have isolated carbocyclic products along with expected 1,5-diketones from barium hydroxide mediated reaction of some α,β-unsaturated ketones, *viz.* chalcone or phenyl vinyl ketone with cyclopentanone (9). However, in the present reaction of the α,β-unsaturated ketone, DBE **1a** with cyclopentanone we did not detect the formation of any carbocylic products. Similarly, we found only the triketone **3a** when the reaction was conducted in the presence of different bases such as sodium ethoxide, potassium hydroxide and sodium hydroxide in ethanol medium. Reaction of 4,4'-dichlorodibenzoyl ethylene **1b**, 4,4'-dimethyldibenzoyl ethylene **1c** and 4,4'-dimethoxydibenzoyl ethylene **1d** with cyclopentanone in the presence of barium hydroxide resulted in the corresponding diastereomeric triketones **3b-d** in good yields.

The triketone **3a** was then treated with ammonium acetate in dry methanol for 18 h under the conditions of Hantzsch synthesis of pyridine derivatives (10). This reaction furnished cyclopenta[*b*]pyridine derivative **6a** as a single product in moderate yield (28%). The IR spectrum of **6a** showed carbonyl group absorption at 1650 cm^{-1}. The ^1H NMR spectrum showed two triplets and a multiplet for six hydrogens in the aliphatic region accounting for cyclopentane ring hydrogens. The C_3-H aromatic hydrogen appeared as singlet at 7.41 ppm. The ^{13}C NMR spectrum showed expected seventeen signals out of which three were in the aliphatic region. The carbonyl carbon was observed at 195.7 ppm. Presence of aromatic keto group (IR) couple with three methylenes (^1H NMR and DEPT) in **6a** ruled out the formation of pyrrole derivatives of the type 4 or **5** in the amination-cyclization step. We attempted to increase the yield in the reaction by using ammonium acetate in glacial acetic acid, or ammonium bromide in methanol/glacial acetic acid, ammonium carbonate in methanol and finally, ammonia in methanol. But, there was no improvement in the yield of **6a**. The cyclopenta[*b*]pyridine derivative **6a** was found to decompose on standing at room temperature (35 °C) or even at 0 °C. Having established the structure of **6a**, next, we studied the scope of the amination-cyclization reaction by conducting the oxidative amination-cyclization on triketones **3b-d** having electron withdrawing (Cl, **3b**) and electron donating (Me **3c** or OMe **3d**) groups located on the *para* position of the aryl rings. The three triketones **3b-d** were smoothly transformed into only cyclopenta[*b*]pyridine derivatives **6b-d** in moderate yield. No other product was detected in the reaction mixture. The spectral data for **6b-d** matched well with the ketone **6a**.

Conclusions

Thus, in this study we demonstrated that triketones of the type **3** on one-pot molecular stitching through oxidative amination-cyclization sequence furnish cyclopenta[*b*]pyridine derivatives of the type **6** exclusively.

Experimental Section

General

Progress of all the reactions was monitored by TLC (TLC silica gel: Qualigens or TLC alumina: SRL, India) using hexane/ethyl acetate as eluent. Column chromatography was accomplished on silica gel (100-200 mesh, Acme synthetic chemicals) using hexane/ethyl acetate as eluent. Melting points were determined using a Gallenkamp melting point apparatus. IR spectra were recorded neat, KBr pellets or Nujol mulls using ABB Bomem MB-104, JASCO FT IR or Perkin-Elmer spectrophotometer. ^{1}H NMR and ^{13}C NMR spectra were recorded in $CDCl_3$ with JEOL 400 MHz, Varian 300 MHz and Bruker 200 MHz spectrophotometers. Mass spectra were recorded on Finnigan MAT 8230 Mass spectrometer. The elemental analysis was carried out on a Elementar vario EL (Germany) apparatus. DBE and derivatives **1a-d** were prepared according to literature procedure (11).

General procedure for the preparation of 1,4-diarylbut-2-ene-1,4-dions (dibenzoyl ethylenes). Synthesis of 1,4-diphenylbut-2-ene-1,4-dione **1a**: Fumaric acid (11.6 g, 0.1 mol) and PCl_5 (22. 9 g, 0.11 mol) was taken in a 100 mL round bottomed flask fitted with a condenser and $CaCl_2$ guard tube. On heating (120 °C) the reaction mixture was converted to light yellow liquid and the heating was continued for 30 minutes. After completion of the reaction the flask was connected to a distillation setup and heated in a mantle. The first fraction, which distilled at about 105 °C was discarded and the second fraction, fumaryl chloride, which distilled at 160 °C was collected (12.2 g, 80%). The acid chloride was immediately used for the preparation of dibenzoyl ethylene following the literature method (11). To a mixture of aluminum chloride (21.2 g, 0.1 mol) and benzene (120 mL) fumaryl chloride (12.2 g, 0.08 mol) was added drop-wise over a period of 30 minutes with constant stirring. The reaction mixture was stirred for 1 h at room temperature and then it was poured onto crushed ice (1 kg) having Conc. HCl (10 mL). The organic layer was separated, washed with saturated sodium bicarbonate (2 x 100 mL), brine (2 x 100 mL), dried (anhydrous Na_2SO_4) and concentrated to give 15.06 g (80%) of DBE.

1,4-Diphenyl-2-buten-1,4-dione (DBE) **1a**: mp 106 °C; IR (KBr) ν 1649, 1602, 1448, 1334, 1199, 1025, 970, 708 cm^{-1}; ^{1}H NMR (300 MHz, $CDCl_3/CCl_4$) δ 8.01 (d, J = 7.2 Hz, 2H), 7.96 (s, 1H), 7.44-7.59 (m, 3H); ^{13}C NMR (75 MHz, $CDCl_3/CCl_4$) δ 189.2, 136.9, 134.5, 133.9, 128.9 (2C).

1,4-Di(4-chlorophenyl)-2-buten-1,4-dione **1b**: Following the general procedure described as above, the reaction of chlorobenzene (12.5 g, 11.5 mmole) and fumaryl chloride (5.1 g, 33 mmol) in the presence of aluminum chloride (12.5 g, 94 mmol) in carbon disulfide (30 mL) resulted in 4.56 g (45%) of 1,4-di(4-chlorophenyl)-2-buten-1,4-dione **1b**; mp 170 °C; IR (KBr) ν 1643, 1596, 1571, 1253, 1176, 850 cm^{-1}; ^{1}H NMR (300 MHz, $CDCl_3/CCl_4$) δ 7.99 (dd, J = 7.0, 2.0 Hz, 2H), 7.97 (s, 1H), 7.51 (dd, J = 7.0, 2.0 Hz, 2H); ^{13}C NMR (75 MHz, $CDCl_3/CCl_4$) δ 188.3, 140.6, 135.0, 134.8, 130.2, 129.2.

1,4-Di(4-methylphenyl)-2-buten-1,4-dione **1c**: Following the general procedure described as above, the reaction of toluene (14.5 g) and fumaryl chloride (3.3 g, 22 mmol) in the presence of aluminum chloride (3.0 g, 23 mmol) resulted in 4.04 g (71%) of 1,4-di(4-methylphenyl)-2-buten-1,4-dione **1c**; mp 150 °C; IR (KBr) ν 1643, 1596, 1571, 1253, 1176, 850 cm^{-1}; ^{1}H NMR (300 MHz, $CDCl_3/CCl_4$) δ 7.93 (d, J = 8.5 Hz, 2H), 7.90 (s, 1H), 7.25 (d, J = 8.5 Hz,

2H), 2.4(s, 3H); ^{13}C NMR (75 MHz, $CDCl_3/CCl_4$) δ 189.0, 144.7, 138.1, 134.9, 129.6, 129.1, 21.8.

1,4-Di(4-methoxylphenyl)-2-buten-1,4-dione **1d**: Following the general procedure described as above, the reaction of anisole (4.5 g, 4.2 mmole) and fumaryl chloride (3.1 g, 20 mmol) in the presence of aluminum chloride (7.0 g, 52 mmol) in nitrobenzene (40 mL) resulted in 2.4 g (40%) of 1,4-di(4-methoxyphenyl)-2-buten-1,4-dione **1d**; mp 158 °C; IR (KBr) ν 1643, 1596, 1571, 1253, 1176, 850 cm^{-1}; ^{1}H NMR (300 MHz, $CDCl_3/CCl_4$) δ 8.06 (d, *J* = 8.7 Hz, 2H), 8.00 (s, 1H), 6.97 (d, *J* = 8.7 Hz, 2H), 3.90 (s, 3H); ^{13}C NMR (75 MHz, $CDCl_3/CCl_4$) δ 187.7, 164.1, 134.5, 131.3, 130.2, 114.1, 55.4.

Reaction of dibenzoyl ethylene with cyclopentanone under basic conditions, general procedure: To a stirred suspension of freshly activated $Ba(OH)_2$ (heated to 100 °C for 2h and cooled in a desiccator, 0.171 g, 1 mmol) in 5 mL of absolute alcohol, cyclopentanone (0.462 g, 5.5 mmol) was added drop-wise at room temperature and stirred for 10 min. dibenzoyl ethylene (1.18 g, 5 mmol) was added to the reaction mixture in three portions during 30 minutes and stirred for 12 h at room temperature for completion of the reaction (TLC). The reaction mixture was diluted with dichloromethane (25 mL), washed with ice water (2 x 20 mL), brine (2 x 10 mL), dried (Na_2SO_4) and concentrated. The crude product was purified through column chromatography using silica gel (100-200 mesh) and eluting with hexanes/ethyl acetate solutions (99:1 to 90:10) to give **3a**. The ^{1}H NMR spectrum of **3a** revealed the product was a diasteromeric mixture of two products formed in the ratio of 3:1. The major diasteromer crystallized out of the column fractions on standing and the spectral data of this isomer is given in the following.

1,4-Di(phenyl)-2-(2-oxocyclopentyl)-1,4-butanedione **3a**: Yield = 0.848 g (53%); R_f = 0.4 (80:20 hexane/ethyl acetate); mp 66 °C; IR (KBr) ν 3020, 2397, 1730, 1680, 1597, 1450, 1402, 1217, 1157, 1001, 833, 742, 690 cm^{-1}; ^{1}H NMR (200 MHz, $CDCl_3$) δ 8.05 (d, *J* = 8.3 Hz, 2H), 7.92 (d, *J* = 9.0 Hz, 2H), 7.43-7.48 (m, 3H), 7.38 (dd, *J* = 10.0, 5.0 Hz, 3H), 4.62-4.65 (m, 1H), 3.61 (dd, *J* = 12.0, 8.0 Hz, 1H), 3.17 (dd, *J* = 12.0, 8.3 Hz, 1H), 2.30-2.50 (m, 1H), 1.90-2.10 (m, 2H), 1.50-1.80 (m, 4H); ^{13}C NMR (50 MHz, $CDCl_3$) δ 219.9, 197.8, 196.9, 144.2, 143.9, 129.9, 129.3, 128.6, 127.4, 127.2, 126.9, 49.7, 42.3, 41.1, 39.3, 26.2, 20.9; elemental analysis calcd. for $C_{21}H_{20}O_3$: C, 78.73; H, 6.29. Found: C, 78.79; H, 6.24.

1,4-Di(4-chlorophenyl)-2-(2-oxocyclopentyl)-1,4-butanedione **3b**: Following the general procedure described as above, the reaction of 1,4-di(4-chlorophenyl)-2-buten-1,4-dione (3.65 g, 12 mmole) and cyclopentanone (1.11 g, 13.2 mmol) in the presence of activated barium hydroxide (0.408 g, 2.4 mmol) in absolute ethanol (10 mL) resulted in 1.96 g (42%) of 1,4-di(4-chlorophenyl)-2-(2-oxocyclopentyl)-1,4-butanedione **3b**; R_f = 0.42 (80:20 hexane/ethyl acetate); mp 67 °C; IR (KBr) ν 3020, 2397, 1730, 1680, 1597, 1450, 1402, 1217, 1157, 1001, 833, 742, 690 cm^{-1}; ^{1}H NMR (400 MHz, $CDCl_3$) δ 8.0 (dd, *J* = 8.3, 8.8 Hz, 2H), 7.87 (dd, *J* = 8.3, 8.8 Hz, 2H), 7.46 (dd, *J* = 8.3, 8.8 Hz, 2H), 7.41 (dd, *J* = 8.8, 8.3 Hz, 2H), 4.54-4.59 (m, 1H), 3.59 (dd, *J* = 4.4, 5.4 Hz, 1H), 3.09 (dd, *J* = 3.9, 4.4 Hz, 1H), 2.40-2.60 (m, 1H), 2.00-2.30 (m, 2H), 1.50-1.90 (m, 4H); ^{13}C NMR (100 MHz, $CDCl_3$) δ 218.9, 196.9, 196.2, 139.9, 139.6, 135.6, 134.6, 130.1, 129.4, 129.2, 128.6, 50.1, 41.2, 40.7, 38.1, 25.9, 20.5; elemental analysis calcd. for $C_{21}H_{18}Cl_2O_3$: C, 64.79; H, 4.66. Found: C, 64.77; H, 4.69.

1,4-Di(4-methylphenyl)-2-(2-oxocyclopentyl)-1,4-butanedione **3c**: Following the general procedure described as above, the reaction of 1,4-di(4-methylphenyl)-2-buten-1,4-dione (2.11 g, 4 mmole) and cyclopentanone (0.37 g, 4.4 mmol) in the presence of activated barium hydroxide (0.137 g, 0.8 mmol) in absolute ethanol (5 mL) resulted in 1.31 g (47%) of 1,4-di(4-methylphenyl)-2-(2-oxocyclopentyl)-1,4-butanedione **3c**; R_f = 0.38 (80:20 hexane/ethyl acetate); viscous oil; IR (neat) ν 3019, 2401, 1729, 1689, 1608, 1447, 1407, 1219, 1004, 930, 762, 675 cm^{-1}; ^1H NMR (200 MHz, $CDCl_3$) δ 8.04 (dd, *J* = 5.0, 1.0 Hz, 2H), 7.94 (dd, *J* = 5.0, 2.5 Hz, 2H), 7.46-7.50 (m, 2H), 7.24 (dd, *J* = 10.0, 5.0 Hz, 2H), 4.63-4.68 (m, 1H), 3.59 (dd, *J* = 11.0, 9.0 Hz, 1H), 3.18 (dd, *J* = 11.0, 3.0 Hz, 1H), 2.40-2.60 (m, 1H), 2.39 (s, 3H), 2.37 (s, 3H), 2.00-2.20 (m, 2H), 1.60-1.90 (m, 4H); ^{13}C NMR (50 MHz, $CDCl_3$) δ 218.0, 197.9, 197.7, 144.1, 144.0, 137.3, 136.5, 129.4, 129.2, 128.5, 128.0, 49.8, 41.1, 40.9, 38.3, 26.1, 21.6, 20.6, 20.5; HRMS (M^+) m/z calcd. for $C_{23}H_{24}O_3$ 348.1725 obsd. 348.1727.

1,4-Di(4-methoxyphenyl)-2-(2-oxocyclopentyl)-1,4-butanedione **3d**: Following the general procedure described as above, the reaction of 1,4-di(4-methoxyphenyl)-2-buten-1,4-dione (1.301 g, 4.4 mmole) and cyclopentanone (0.407 g, 4.8 mmol) in the presence of activated barium hydroxide (0.151 g, 0.88 mmol) in absolute ethanol (5 mL) resulted in 0.752 g (45%) of 1,4-di(4-methoxyphenyl)-2-(2-oxocyclopentyl)-1,4-butanedione **3d**; R_f = 0.34 (80:20 hexane/ethyl acetate); viscous oil; IR (neat) ν 2960, 2936, 1735, 1671, 1600, 1511, 1449, 1404, 1257, 1170, 1113, 1026, 837 cm^{-1}; ^1H NMR (300 MHz, $CDCl_3/CCl_4$) δ 7.96 (dd, *J* = 8.7, 8.7 Hz, 2H), 7.86 (dd, *J* = 6.9, 6.6 Hz, 2H), 6.88 (d, *J* = 8.7 Hz, 2H), 6.83 (d, *J* = 9.0 Hz, 2H), 4.0 (m, 1H), 3.81 (s, 3H), 3.79 (s, 3H), 3.38 (dd, *J* = 7.5, 7.5 Hz, 1H), 3.22 (dd, *J* = 5.7, 5.7 Hz, 1H), 2.15 (m, 1H), 1.91 (m, 2H), 1.52 (m, 4H); ^{13}C NMR (75 MHz, $CDCl_3/CCl_4$) δ 218.1, 199.2, 195.8, 163.5 (2C), 131.1, 130.9, 130.4, 129.8, 113.9, 113.6, 55.3, 55.2, 49.3, 40.5, 38.3, 36.6, 26.4, 20.7; HRMS (M^+) m/z calcd. for $C_{23}H_{24}O_5$ 380.1624 obsd. 380.1630.

General procedure for the formation of cyclopenta[b]pyridine derivatives from triketones
The triketone **3a** (0.225 g, 0.7 mmol), dissolved in dry methanol (5 mL), ammonium acetate (0.539 g, 7 mmol) was added to it and allowed to stir at rt for 18 h. The reaction mixture was concentrated *in vacuo*, diluted with dichloromethane (10mL), washed with water (2 x 15 mL), brine (2 x 10 mL), dried (anhyd. Na_2SO_4) and concentrated *in vacuo*. The crude product was purified by column chromatography with silica gel (100-200 mesh) using hexane/ethyl acetate 98:2 as eluent.

(Phenyl)[2-phenyl-6,7-dihydro-5H-cyclopenta[b]pyridin-4-yl]methanone **6a** Yield = 59 mg (28%); R_f = 0.35 (90:10 hexane/ethyl acetate); mp = 134 °C; IR (nujol) ν 2920, 1650, 1580, 1440, 1370, 1340, 1240, 1190, 1060, 1020, 880, 840, 790, 710, 680 cm^{-1}; ^1H NMR (300 MHz, $CDCl_3/CCl_4$) δ 7.93 (d, *J* = 7.8 Hz, 2H), 7.82 (d, *J* = 8.4 Hz, 2H), 7.42-7.62 (m, 3H), 7.41 (s, 1H), 7.32-7.38 (m, 3H), 3.14 (t, *J* = 15.6 Hz, 2H), 2.95 (t, *J* = 15.0 Hz, 2H), 2.15 (m, 2H); ^{13}C NMR (75 MHz, $CDCl_3/CCl_4$) δ 195.7, 167.7, 156.2, 141.9, 139.1, 136.5, 133.7, 133.4, 129.6, 129.9, 128.8, 128.6, 126.9, 116.7, 34.3, 30.0, 23.1; LRMS: 299 (M^+, 100), 284 (32), 222 (16), 194 (24), 165 (8), 153 (11), 105 (52), 77 (54); HRMS m/z (M^+) for $C_{21}H_{17}NO$ calcd. 299.1310 obsd. 299.1320.

(4-Chlorophenyl)[2-(4-chlorophenyl)-6,7-dihydro-5H-cyclopenta[b]pyridin-4-yl]methanone **6b**: Following the general procedure described as above, the reaction of 1,4-di(4-chlorophenyl)-2-(2-oxocyclopentyl)-1,4-butanedione (0.201 g, 0.55 mmole) and ammonium acetate (0.424 g, 5.5 mmol) in dry methanol (4 mL) resulted in 64 mg (35%) of (4-

chlorophenyl)[2-(4-chlorophenyl)-6,7-dihydro-5*H*-cyclopenta[*b*]pyridin-4-yl]methanone **6b**; viscous oil; R_f = 0.30 (90:10 hexane/ethyl acetate); IR (nujol) ν 2920, 2840, 1655, 1580, 1455, 1370, 1240, 1080, 1000, 850 cm^{-1}; ^1H NMR (300 MHz, $CDCl_3/CCl_4$) δ 8.02 (d, *J* = 8.7 Hz, 2H), 7.87 (d, *J* = 9.0 Hz, 2H), 7.58 (d, *J* = 8.7 Hz, 2H), 7.49 (d, *J* = 8.7 Hz, 2H), 7.35 (s, 1H), 3.24 (t, *J* = 15.6 Hz, 2H), 3.06 (t, *J* = 15.0 Hz, 2H), 2.29 (m, 2H); ^{13}C NMR (75 MHz, $CDCl_3/CCl_4$) δ 196.3, 168.2, 155.2, 144.0, 141.3, 135.1, 133.8, 133.2, 131.4, 129.2, 129.0, 128.2, 116.2, 34.4, 30.2, 23.3; LRMS: 367 (M^+, 100), 369 (65), 371 (9), 256 (15), 228 (30), 139 (47), 111 (56); HRMS (M^+) m/z calcd. for $C_{21}H_{15}Cl_2NO$ 367.0531 obsd. 367. 0526.

(4-Methylphenyl)[2-(4-methylphenyl)-6,7-dihydro-5H-cyclopenta[b]pyridin-4-yl]methanone **6c**: Following the general procedure described as above, the reaction of 1,4-di(4-methylphenyl)-2-(2-oxocyclopentyl)-1,4-butanedione (0.381 g, 1.1 mmole) and ammonium acetate (0.847 g, 11 mmol) in dry methanol (5 mL) resulted in 104 mg (29%) of (4-methylphenyl)[2-(4-methylphenyl)-6,7-dihydro-5*H*-cyclopenta[*b*]pyridin-4-yl]methanone **6c**; viscous oil; R_f = 0.32 (90:10 hexane/ethyl acetate); IR (nujol) ν 2910, 2840, 1650, 1590, 1430, 1395, 1365, 1335, 1245, 1170, 1080, 1010, 960, 810, 755 cm^{-1}; ^1H NMR (300 MHz, $CDCl_3/CCl_4$) δ 7.76 (d, *J* = 7.5 Hz, 2H), 7.68 (d, *J* = 9.6 Hz, 2H), 7.39 (s, 1H), 7.18 (d, *J* = 8.1 Hz, 2H), 7.13 (d, *J* = 7.5 Hz, 2H), 3.05 (t, *J* = 15.3 Hz, 2H), 2.86 (t, *J* = 15.0 Hz, 2H), 2.08 (m, 2H), 2.36 (s, 3H), 2.31 (s, 3H); ^{13}C NMR (75 MHz, $CDCl_3/CCl_4$) δ 195.5, 167.5, 156.2, 144.3, 142.2, 138.5, 136.4, 134.0, 133.2, 130.2, 129.4, 129.2, 126.9, 116.4, 31.5, 24.3, 23.2, 21.8, 21.3; LRMS: 327 (M^+, 100), 236 (18), 207 (32), 118 (67), 90 (43); HRMS (M^+) m/z calcd. for $C_{23}H_{21}NO$ 327.1617 obsd. 327.1623.

(4-Methoxyphenyl)[2-(4-methoxyphenyl)-6,7-dihydro-5H-cyclopenta[b]pyridin-4-yl]methanone **6d**: Following the general procedure described as above, the reaction of 1,4-di(4-methoxyphenyl)-2-(2-oxocyclopentyl)-1,4-butanedione (0.411 g, 1.14 mmole) and ammonium acetate (0.878 g, 11.4 mmol) in dry methanol (5 mL) resulted in 93 mg (25%) of (4-methoxyphenyl)[2-(4-methoxyphenyl)-6,7-dihydro-5*H*-cyclopenta [*b*]pyridin-4-yl]methanone **6d**; viscous oil; R_f = 0.32 (90:10 hexane/ethyl acetate); IR (KBr) ν 2925, 2855, 1679, 1587, 1461, 1399, 1248, 1184, 1089, 1010, 968, 829 cm^{-1}; ^1H NMR (200 MHz, $CDCl_3$) δ 7.91 (d, *J* = 8.7 Hz, 2H), 7.84 (d, *J* = 8.7 Hz, 2H), 7.46 (s, 1H), 6.97 (d, *J* = 8.8 Hz, 4H), 3.89 (s, 3H), 3.85 (s, 3H), 3.13 (t, *J* = 15.3 Hz, 2H), 2.92 (t, *J* = 14.9 Hz, 2H), 2.17 (m, 2H); LRMS: 359 (M^+, 100), 252 (21), 135 (56), 106 (49); HRMS (M^+) m/z calcd. for $C_{23}H_{21}NO_3$ 359.1521 obsd. 359.1516.

Acknowledgement: KJ and SPSK thank CSIR, India for fellowship. HSPR thanks UGC and AICTE for financial support. We thank Professor A. Srikrishna, IISc, Bangalore and RSIC, IITM, Chennai for spectral data.

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Received on September 25, 2002.