Synthesis of biogenetically possible 3-substituted pyrano-[2,3-*a*]carbazoles

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3-Substituted pyrano[2,3-*a*]carbazol-2(11*H*)-ones have been synthesised by the reaction of 1-hydroxy-carbazole-2-carbaldehyde with malononitrile, ethyl cyanoacetate, Meldrum's acid, (carbethoxymethylene)triphenylphosphorane, ethyl benzoylacetate and phenylacetonitrile.

Keywords: carbazoles, fused carbazoles, pyrans, Wittig reactions, Meldrum's acid

Carbazole alkaloids isolated from taxonomically related higher plants of the genus *Murraya*, *Glycosmis* and *Clausena* which belong to the *Rutaceae* family[1-4] have been reported to show antitumor, antibiotic, antimalarial and antifungal properties.[5] Many of these compounds have oxygenated functionality in the 1- or 2-position and possess cytotoxic activity.[5,6]

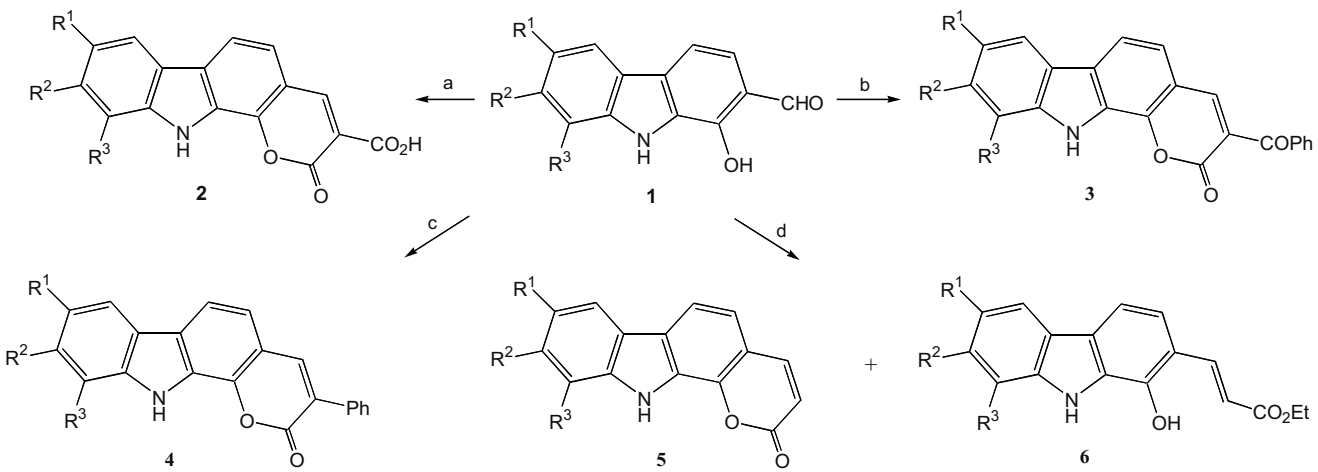
Girinimbine was the first isolated pyrano[3,2-*a*]carbazole alkaloid.[7,8] Later, several other pyranocarbazoles were isolated and synthesised due to their important biological activities.[1,9-11] As indicated in an earlier report, it has been observed that carbazole having an α-pyrone as part of their structure with [2,3-*a*] fusion are biogenetically possible as evident from the naturally available mupamine.[12] The naturally occurring carbazole alkaloids, clauszoline-A[13], clauszoline-B[13] and clauszoline-H[14] have also the same basic carbazole skeleton of [2,3-*a*] fusion with α-pyran ring. Clauszoline-A and clauszoline-B were the first examples of naturally occurring 1-oxygenated (equivalent C_8) carbazole alkaloids having a dimethylpyran ring fused with the carbazole nucleus. Some pyranocarbazol-2-ones have been prepared and used as intermediates in the synthesis of pyridocarbazole[15] and also to prepare 2,2-dimethyl-2*H*-pyranocarbazole by use of a Grignard reagent.[16] Based on the interesting features of these 1-oxygenated carbazole compounds, a simple synthetic method was felt desirable, with a view to the future isolation of these biogenetically possible compounds from natural sources.

Recently we have reported the synthesis of some substituted pyranocarbazoles.[15,17-20] In continuation of this work, we report here some new 3-substituted pyrano[2,3-*a*]carbazol-2(11*H*)-ones prepared by a simple synthetic pathway.

Results and discussion

To obtain the pyrano[2,3-*a*]carbazoles, we utilised 1-hydroxy-carbazole-2-carbaldehyde (**1**), obtained[15] from the easily accessible 2,3,4,9-tetrahydro-1*H*-carbazol-1-one through the intermediate 1-hydroxycarbazole, in different ways, to effect the synthesis of 3-substituted pyrano[2,3-*a*]carbazol-2(11*H*)-ones.

Then, 1-hydroxycarbazole-2-carbaldehyde (**1d**) was reacted with malononitrile under mildly basic conditions (NH_4OAc/ethanol) to yield a single product (Scheme 1). Its IR spectrum showed bands at 3500–2600 cm^{-1} and 1718 cm^{-1} due to (CO)OH and α-pyrone carbonyl groups respectively. Further, signals at 165.5 ppm and 158.1 ppm in the ^{13}C NMR were consistent with the presence of lactone and acid carbonyl carbons. The mass spectrum showed the molecular ion peak at *m/z* 279 (M^+) as the base peak. All the spectral and analytical details attest the obtained compound to be 2-oxo-2*H*-pyrano[2,3-*a*]carbazole-3-carboxylic acid (**2d**). The yield of the product was only 20%. In order to improve the yield, alternative reagents were adopted, in which 1-hydroxycarbazole-2-carbaldehyde (**1**) was reacted with ethyl cyanoacetate and Meldrum's acid under the same



1-6 **a**: $R^1 = CH_3$, R^2, $R^3 = H$
b: $R^2 = CH_3$, R^1, $R^3 = H$
c: $R^3 = CH_3$, R^1, $R^2 = H$
d: R^1, R^2, $R^3 = H$

Reagents and conditions: a: malononitrile, ethyl cyanoacetate, or Meldrum's acid, NH_4OAc, EtOH; b: ethyl benzoylacetate, pyridine, piperidine, reflux; c: phenylacetonitrile, pyridine, piperidine, reflux; d: $Ph_3P{=}CHCO_2Et$, toluene, 120°

Scheme 1

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conditions to get the product **2**, in moderate (40%) and good (80%) yields, respectively.

Our next objective was 3-benzoylpyrano[2,3-*a*]carbazol-2(11*H*)-one. 1-Hydroxycarbazole-2-carbaldehyde (**1**) reacted with ethyl benzoylacetate in pyridine and piperidine at reflux temperature to afford a single product. The presences of an α-pyrone carbonyl peak at 1724 cm^{-1} and C=O peak at 1643 cm^{-1} in its IR spectrum and 13 aromatic protons in its ^1H NMR spectrum clearly indicate that the product was 3-benzoylpyrano[2,3-*a*]carbazol-2(11*H*)-one **3d** (Scheme 1).

3-Phenylpyrano[2,3-*a*]carbazol-2(11*H*)-one was synthesised by the reaction of 1-hydroxycarbazole-2-carbaldehyde (**1**) with phenylacetonitrile in pyridine and piperidine, which yielded a single product. Its IR spectrum showed absorption at 1699 cm^{-1} due to the presence of α-pyrone carbonyl group and its proton NMR spectrum showed the presence of 13 aromatic protons. Its mass spectrum showed the molecular ion peak at *m/z* 311 (M^+) as the base peak. All the spectral and analytical details confirm the obtained compound to be 3-phenylpyrano[2,3-*a*]carbazol-2(11*H*)-one (**4d**) (Scheme 1).

Much interest centres around the simple pyrano[2,3-*a*]carbazol-2(11*H*)-one structure, because these are suitable stable intermediates for the synthesis of the biogenetically possible 2,2-dimethyl-2*H*-pyrano[2,3-*a*]carbazoles by Grignard reaction and pyrido[2,3-*a*]carbazoles by treatment with ammonium acetate. The synthesis of unsubstituted pyrano[2,3-*a*]carbazol-2(11*H*)-one was achieved utilising Wittig reaction conditions in which 1-hydroxycarbazole-2-carbaldehyde (**1**) reacted with (carbethoxymethylene)triphenylphosphorane to afford two products, which were separated by column chromatography on silica gel, eluting with petroleum ether/ethyl acetate (98 : 2 and 95 : 5) (Scheme 1). The product obtained from the first fraction was found to be similar to the known[15] compound pyrano[2,3-*a*]carbazol-2(11*H*)-one (**5d**), with superimposible IR spectra. The IR spectrum of the second product showed absorption at 1653 cm^{-1} and its proton NMR spectrum exhibited two doublets with J = 15.84 Hz corresponding to olefinic *trans* protons. A two proton quartet at δ 3.34 ppm and a three proton triplet at δ 1.39 ppm with J = 7.12 Hz indicate the presence of an ethyl ester group. Its molecular ion peak appeared at *m/z* 281. All the spectral and analytical details revealed that the product obtained was ethyl (*E*)-β-(1-hydroxy-9*H*-carbazol-2-yl)acrylate (**6d**). Mechanistically, it can be supposed that the reaction of 1-hydroxycarbazole-2-carbaldehyde (**1**) with (carbethoxymethylene)triphenylphosphorane yielded both *E*- and *Z*-isomers, the more reactive *Z* isomer *in situ* affording the pyrano-[2,3-*a*]carbazol-2(11*H*)-one (**5**) on intramolecular cyclisation.

In conclusion, some 3-substituted pyrano[2,3-*a*]carbazol-2(11*H*)-ones have been synthesised using a simple pathway. These heterocyclic analogues are suitable stable intermediates to the synthesis of biogenetically possible 2,2-dimethyl-2*H*-pyrano[2,3-*a*]carbazoles and pyrido[2,3-*a*]carbazoles and may possess important applications in the preparation of biologically active natural products as well as in pharmaceuticals.

Experimental

Melting points were determined on a Mettler FP 51apparatus (Mettler Instruments, Switzerland). IR spectra were recorded on a Shimadzu FTIR-8201PC spectrophotometer (Shimadzu, Japan) using KBr discs. ^1H NMR and ^{13}C NMR spectra were recorded on a Bruker AMX 400 spectrometer, and also a Bruker AMX 500 spectrometer; the chemical shifts are expressed in parts per million (ppm) from tetramethylsilane (TMS) as internal reference. Mass spectra (MS) were recorded on AutoSpec EI and Shimadzu QP 2010 PLUS GC-MS mass spectrometers. Microanalyses were performed on a Vario EL III model CHNS analyser (Vario, Germany) at the Department of Chemistry, Bharathiar University. The purity of the products was tested by TLC with plates coated with silica gel-G with petroleum ether, ethyl acetate and methanol as developing solvents.

2-Oxo-2H-pyrano[2,3-a]carbazole-3-carboxylic acids (**2**)**:** *general (optimal) procedure*

A mixture of the respective 1-hydroxycarbazole-2-carbaldehyde (**1**) (0.5 mmol), Meldrum's acid (86 mg, 0.6 mmol) and ammonium acetate (154 mg, 2 mmol) in dry ethanol (15 mL) was refluxed on a steam bath for 2 h. The reaction was monitored by TLC. After the completion of the reaction the obtained precipitate was filtered, washed with ethanol and then water to give the respective 2-oxo-2*H*-pyrano[2,3-*a*]carbazole-3-carboxylic acid (**2**) which was then recrystallised from a large volume of methanol.

8-Methyl-2-oxo-2H-pyrano[2,3-a]carbazole-3-carboxylic acid (**2a**): Orange solid (124 mg, 85%), m.p. >300 °C. IR: ν_{max} 3500–2600, 3400, 3046, 1736, 1611 cm^{-1}. NMR (DMSO-d_6): δ_H 2.48 (s, 3H, C8-CH_3), 7.31 (d, 1H, C6-H, J = 8.32 Hz), 7.43–7.48 (m, 2H, C9-, C10-H), 7.99–8.01 (m, 2H, C5-, C7-H), 8.33 (s, 1H, C4-H), 12.00 (b s, 1H, N11-H); δ_C 21.05 (C8-CH_3), 111.4 (C5), 112.0 (C10), 114. 6 (C6a), 117.4 (C3), 118.2 (C6), 120.9 (C9), 122.2 (C7), 122.3 (C4), 122.9 (C4a), 126.3 (C11a), 127.1 (C6b), 128.4 (C8), 139.1 (C11b), 140.5 (C10a), 158.0 (C2), 165.4 (COOH). MS: *m/z* (%) 293(M^+, 58), 276 (100), 248 (8), 220 (15), 195 (22), 179 (65), 155 (15), 90 (5), 60 (12), 43 (58). Anal. Calcd for $C_{17}H_{11}NO_4$: C, 69.62; H, 3.78; N, 4.78. Found: C, 69.48; H, 3.82; N, 4.22%.

9-Methyl-2-oxo-2H-pyrano[2,3-a]carbazole-3-carboxylic acid (**2b**): Yellow solid (117 mg, 80%), m.p. >300 °C. IR: ν_{max} 3500–2600, 3402, 3022, 1739, 1607 cm^{-1}. NMR (DMSO-d_6): δ_H 2.50 (s. 3H, C9-CH_3), 7.08 (d, 1H, C8-H, J = 8.08 Hz), 7.35 (s, 1H, C10-H), 7.56 (d, 1H, C6-H, J = 8.20 Hz), 8.05 (d, 1H, C5-H, J = 8.20 Hz), 8.08 (d, 1H, C7-H, J = 8.08 Hz), 8.88 (s, 1H, C4-H), 12.15 (b s, 1H, N11-H); δ_C 21.45 (C9-CH_3), 111.7 (C10), 112.1 (C5), 114. 5 (C6a), 117.25 (C3), 118.5 (C6), 120.8 (C7), 121.1 (C6b), 122.0 (C8), 122.2 (C4), 122.9 (C4a), 126.2 (C11a), 129.3 (C9), 139.4 (C11b), 140.5 (C10a), 158.9 (C2), 165.0 (COOH). MS: *m/z* (%) 293(M^+, 70), 276 (100), 247 (16), 220 (8), 194 (12), 167 (38), 98 (14), 60 (18), 43 (46). Anal. Calcd for $C_{17}H_{11}NO_4$: C, 69.62; H, 3.78; N, 4.78. Found: C, 69.65; H, 3.67; N, 4.35%.

10-Methyl-2-oxo-2H-pyrano[2,3-a]carbazole-3-carboxylic acid (**2c**): Orange solid (130 mg, 89%), m.p. >300 °C. IR: ν_{max} 3500–2600, 3270, 3016, 1735, 1629 cm^{-1}. NMR (DMSO-d_6): δ_H 2.49 (s, 3H, C10-CH_3), 7.17 (t, 1H, C8-H, J = 7.50 Hz), 7.31 (d, 1H, C9-H, J = 7.45), 7.61 (d, 1H, C6-H, J = 8.2 Hz), 8.05 (d, 1H, C7-H, J = 7.45 Hz), 8.11 (d, 1H, C5-H, J = 8.16 Hz), 8.92 (s, 1H, C4-H), 12.14 (b s, 1H, N11-H), 13.11 (s, 1H, C3-COOH, D_2O exchangeable); δ_C 16.8 (C10-CH_3), 111.7 (C5), 115.1 (C6a), 117.6 (C3), 118.3 (C6), 118.5 (C7), 120.6 (C9), 120.9 (C8), 121.95 (C4), 122.0 (C10), 123.0 (C4a), 126.5 (C11a), 127.0 (C10a), 127.8 (C6b), 140.6 (C11b), 158.5 (C2), 165.0 (COOH). MS: *m/z* (%) 293(M^+, 65), 276 (100), 248 (30), 235 (6), 220 (13), 192 (16), 165 (7), 123 (6), 96 (9), 60 (23), 43 (93). Anal. Calcd for $C_{17}H_{11}NO_4$: C, 69.62; H, 3.78; N, 4.78. Found: C, 69.53; H, 3.62; N, 4.84%.

2-Oxo-2H-pyrano[2,3-a]carbazole-3-carboxylic acid (**2d**): Yellow solid (124 mg, 88%), m.p. >300 °C. IR: ν_{max} 3500–2700, 3400, 1718, 1639, 1609 cm^{-1}. NMR (DMSO-d_6): δ_H 7.21 (t, 1H, C9-H, J = 7.44 Hz), 7.42–7.47 (m, 2H, C8-, C10-H), 7.53 (d, 1H, C6-H, J = 8.15 Hz), 8.02 (d, 1H, C5-H, J = 8.10 Hz), 8.17 (d, 1H, C7-H, J = 7.84 Hz), 8.24 (s, 1H, C4-H), 12.12 (b s, 1H, N11-H); δ_C 111.7 (C5), 115.4 (C6a), 116. 1 (C10), 117.2 (C3), 118.4 (C6), 119.4 (C8), 120.7 (C7), 122.1 (C4), 122.8 (C4a), 125.6 (C6b), 126.2 (C11a), 126.6 (C9), 140.7 (C11b), 142.4 (C10a), 158.1 (C2), 165.5 (COOH). MS: *m/z* (%) 279(M^+, 90), 262 (100), 235 (57), 207 (60), 178 (76), 152 (53), 139 (19), 125 (15), 103 (23), 89 (38), 76 (52), 63 (25), 45 (49). Anal. Calcd for $C_{16}H_9NO_4$: C, 68.82; H, 3.25; N, 5.02. Found: C, 68.66; H, 3.28; N, 4.96%.

3-Benzoylpyrano[2,3-a]carbazol-2(11H)-ones (**3**): *general procedure*

To a hot solution of the 1-hydroxycarbazole-2-carbaldehyde (**1**) (0.5 mmol) and ethyl benzoylacetate (0.192 g, 1 mmol) in pyridine (5 mL) was added 4 drops of piperidine. Then the temperature was raised to reflux and maintained for 6 h. The reaction was monitored by TLC. After completion of reaction the excess solvent was removed and the reaction mixture was poured into ice-water and neutralised with 5N HCl. The solid was filtered, dried and purified by column chromatography over silica gel using chloroform/methanol (95:5) as eluant to get the respective 3-benzoylpyrano[2,3-*a*]carbazol-2(11*H*)-ones (**3**). The compound thus obtained was recrystallised from ethanol.

3-Benzoyl-8-methyl-pyrano[2,3-a]carbazol-2(11H)-one (**3a**): Yellow solid (113 mg, 64%), m.p. 303 °C. IR: ν_{max} 3312, 2935, 1717, 1654, 1631 cm^{-1}. NMR (DMSO-d_6): δ_H 2.51 (s, 3H, C8-CH_3), 7.34 (d, 1H, C9-H, J = 7.8 Hz), 7.48 (d, 1H, C6-H, J = 8.32 Hz), 7.53–7.56 (m, 3H, C10-, C3'-, C5'-H), 7.69 (t, 1H, C4'-H, J = 7.4 Hz), 7.93–7.95 (m, 2H, C2'-, C6'-H), 8.02 (s, 1H, C7-H), 8.10 (d, 1H, C5-H, J = 8.12 Hz), 8.58 (s, 1H, C4-H), 12.17 (b s, 1H, N11-H); δ_C 21.0 (C8-CH_3), 109.4 (C6a), 111.7 (C10), 114.4 (C5), 116.8 (C6), 119.05 (C4a), 120.6 (C9), 122.1 (C7), 123.65 (C3), 126.4 (C6b), 127.2 (C11a), 128.6 (C2', C6'), 129.0 (C8), 129.4 (C3', C5'), 133.5 (C11b), 136.5 (C4'), 139.5 (C1'), 141.6 (C10a), 147.5 (C4), 158.05 (C2), 192.0 (C=O). MS: *m/z* (%) 353 (M^+, 70), 339 (12), 325 (12), 276 (15), 248 (6), 192 (32), 191 (7), 190 (8), 178 (9), 163 (5), 105 (100), 77 (94), 51 (17). Anal. Calcd for $C_{23}H_{15}NO_3$: C, 78.17; H, 4.28; N, 3.96. Found: C, 78.07; H, 4.32; N, 3.96%.

3-Benzoyl-9-methylpyrano[2,3-a]carbazol-2(11H)-one (**3b**): Yellow solid (102 mg, 58%), m.p. 273 °C. IR: ν_{max} 3302, 2949, 1718, 1639. NMR (DMSO-d_6): δ_H 2.51 (s, 3H, C9-CH_3), 7.06 (d, 1H, C8-H, J = 7.5 Hz), 7.39 (s, 1H, C10-H), 7.54–7.61 (m, 3H, C6-, C3'-, C5'-H), 7.70 (t, 1H, C4'-H, J = 7.5 Hz), 7.95–7.98 (m, 2H, C2'-, C6'-H), 8.10 (d, 1H, C5-H, J = 8.16 Hz), 8.15 (d, 1H, C7-H, J = 8.0 Hz), 8.62 (s, 1H, C4-H), 12.37 (b s, 1H, N11-H); δ_C 21.2 (C9-CH_3), 109.4 (C6a), 111.1 (C10), 113.4 (C5), 116.7 (C6), 119.3 (C4a), 120.1 (C6b), 120.6 (C7), 121.5 (C8), 123.45 (C3), 127.4 (C11a), 128.6 (C2', C6'), 129.5 (C3', C5'), 130.7 (C9), 132.6 (C11b), 136.4 (C4'), 139.1 (C1'), 140.2 (C10a), 148.0 (C4), 157.9 (C2), 191.9 (C=O). MS: *m/z* (%) 353 (M^+, 55), 339 (8), 338 (5), 325 (17), 276 (9), 248 (4), 192 (43), 190 (6), 163 (7), 105 (100), 77 (61). Anal. Calcd for $C_{23}H_{15}NO_3$: C, 78.17; H, 4.28; N, 3.96. Found: C, 78.21; H, 4.30; N, 4.05%.

3-Benzoyl-10-methylpyrano[2,3-a]carbazol-2(11H)-one (**3c**): Yellow solid (120 mg, 68%), m.p. 248 °C. IR: ν_{max} 3253, 2931, 1689, 1626, 1602 cm^{-1}. NMR (DMSO-d_6): δ_H 2.65 (s, 3H, C10-CH_3), 7.19 (t, 1H, C8-H, J = 8.0 Hz), 7.33 (d, 1H, C6-H, J = 7.7 Hz), 7.55–7.60 (m, 3H, C9-, C3'-, C5'-H), 7.71 (t, 1H, C4'-H, J = 7.5 Hz), 7.95–7.98 (m, 2H, C2'-, C6'-H), 8.07 (d, 1H, C5-H, J = 7.5 Hz), 8.15 (d, 1H, C7-H, J = 8.5 Hz), 8.61 (s, 1H, C4-H), 12.17 (b s, 1H, N11-H); δ_C 16.6 (C10-CH_3), 109.3 (C6a), 114.1 (C5), 116.5 (C6), 118.4 (C7), 119.8 (C4a), 120.6 (C9), 120.9 (C8), 122.2 (C10), 123.6 (C3), 127.0 (C11a), 127.7 (C10a), 127.9 (C6b), 128.75 (C2', C6'), 129.4 (C3', C5'), 133.8 (C11b), 136.6 (C4'), 139.4 (C1'), 147.5 (C4), 158.0 (C2), 191.9 (C=O). MS: *m/z* (%) 353 (M^+, 60), 339 (12), 338 (8), 324 (15), 276 (11), 248 (5), 192 (38), 190 (4), 163 (18), 105 (100), 77 (74). Anal. Calcd for $C_{23}H_{15}NO_3$: C, 78.17; H, 4.28; N, 3.96. Found: C, 78.28; H, 4.37; N, 3.95%.

3-Benzoylpyrano[2,3-a]carbazol-2(11H)-one (**3d**): Yellow solid (113 mg, 67%), m.p. 296 °C. IR: ν_{max} 3302, 1724, 1643, 1591 cm^{-1}. NMR (DMSO-d_6): δ_H 7.27 (t, 1H, C8-H, J = 8.0 Hz), 7.50-7.61 (m, 5H, C6-, C9-, C10-, C3'-, C5'-H), 7.70 (t, 1H, C4'-H, J = 7.5 Hz), 7.95-7.97 (m, 2H, C2'-, C6'-H), 8.16 (d, 1H, C5-H, J = 8.0 Hz), 8.25 (d, 1H, C7-H, J = 8.0 Hz), 8.60 (s, 1H, C4-H), 12.43 (b s, 1H, N11-H); δ_C 108.8 (C6a), 114.5 (C5), 116.1 (C10), 116.7 (C6), 119.4 (C8), 119.65 (C4a), 120.85 (C7), 123.4 (C3), 125.6 (C6b), 126.7 (C9), 127.0 (C11a), 129.0 (C2', C6'), 129.5 (C3', C5'), 133.8 (C11b), 136.6 (C4'), 138.8 (C1'), 141.3 (C10a), 148.3 (C4), 158.6 (C2), 191.0 (C=O). MS: *m/z* (%) 339 (M^+, 64), 313 (24), 287 (8), 262 (6), 248 (11), 234 (8), 206 (11), 171 (38), 143 (4), 115 (13), 94 (100), 77 (21). Anal. Calcd for $C_{22}H_{13}NO_3$: C, 77.87; H, 3.86; N, 4.13. Found: C, 77.89; H, 3.91; N, 4.09%.

3-Phenylpyrano[2,3-a]carbazol-2(11H)-ones (**4**), *general procedure*

To a hot solution of 1-hydroxycarbazole-2-carbaldehyde (**1**, 0.5 mmol) and phenylacetonitrile (0.117 g, 1 mmol) in pyridine (5 mL) was added piperidine (4 drops). Then the temperature was raised to reflux and maintained for 6 h. The reaction was monitored by TLC. After completion of the reaction the excess solvent was removed and the residue was poured into ice water and neutralised with 5N HCl. The solid was filtered off, dried, and purified by column chromatography over silica gel using petroleum ether/ethyl acetate (98 : 2) as eluant to isolate the respective 3-phenylpyrano[2,3-*a*] carbazol-2(11*H*)-one (**4**). The compound thus obtained was recrystallised from ethanol.

8-Methyl-3-phenylpyrano[2,3-a]carbazol-2(11H)-one (**4a**): Yellow solid (83 mg, 51%), m.p. 316 °C. IR: ν_{max} 3315, 2917, 1700, 1635, 1603 cm^{-1}. NMR ($CDCl_3$): δ_H 2.55 (s, 3H, C8-CH_3), 7.33 (d, 1H, C6-H, J = 8.12 Hz), 7.34 (d, 1H, C9-H, J = 8.28 Hz), 7.40–7.49 (m, 4H, C10-, C3'-, C4'-, C5'-H), 7.74–7.77 (m, 2H, C2'-, C6'-H), 7.90 (s, 1H, C7-H), 7.92 (d, 1H, C5-H, J = 8.08 Hz), 8.01 (s, 1H, C4-H), 8.69 (b s, 1H, N11-H); δ_C 21.0 (C8-CH_3), 108.6 (C6a), 112.1 (C10), 112.5 (C5), 117.4 (C6), 118.6 (C4a), 120.7 (C9), 122.7 (C7), 124.1 (C3), 127.2 (C6b), 128.0 (C4'), 128.5 (C8), 128.6 (C3', C5'), 128.8 (C2', C6'), 130.3 (C11a) 132.9 (C11b), 134.5 (C1'), 140.6 (C10a), 141.1 (C4), 160.4 (C2). MS: *m/z* (%) 325 (M^+, 100), 298 (12), 297 (72), 296 (40), 267 (26), 254 (13), 239 (5), 163 (8), 149 (29), 134 (32), 120 (10), 77 (8). Anal. Calcd for $C_{22}H_{15}NO_2$: C, 81.21; H, 4.65; N, 4.30. Found: C, 81.28; H, 4.67; N, 4.40%.

9-Methyl-3-phenylpyrano[2,3-a]carbazol-2(11H)-one (**4b**): Yellow solid (76 mg, 47%), m.p. 280 °C. IR: ν_{max} 3323, 2923, 1696, 1624, 1599 cm^{-1}. NMR ($CDCl_3$): δ_H 2.51 (s, 3H, C9-CH_3), 7.05 (d, 1H, C8-H, J = 8.0 Hz), 7.33 (d, 1H, C6-H, J = 8.3 Hz), 7.40 (s, 1H, C10-H), 7.47–7.50 (m, 3H, C3'-, C4'-, C5'-H), 7.76–7.78 (m, 2H, C2'-, C6'-H), 7.95 (d, 1H, C5-H, J = 8.3 Hz), 8.00 (d, 1H, C7-H, J = 8.00 Hz), 8.03 (s, 1H, C4-H), 8.72 (b s, 1H, N11-H); δ_C 21.5 (C9-CH_3), 110.3 (C6a), 112.2 (C5), 112.9 (C10), 117.1 (C6), 118.6 (C4a), 120.3 (C6b), 120.7 (C7), 121.7 (C8), 124.6 (C3), 127.8 (C4'), 128.6 (C3', C5'), 128.9 (C2', C6'), 130.7 (C11a) 132.0 (C9), 133.7 (C11b), 134.9 (C1'), 141.0 (C4), 142.1 (C10a), 160.3 (C2). MS: *m/z* (%) 325 (M^+, 100), 297 (46), 296 (38), 267 (17), 248 (13), 239 (8), 163 (21), 134 (27), 120 (7), 77 (5). Anal. Calcd for $C_{22}H_{15}NO_2$: C, 81.21; H, 4.65; N, 4.30. Found: C, 81.14; H, 4.69; N, 4.37%.

10-Methyl-3-phenylpyrano[2,3-a]carbazol-2(11H)-one (**4c**): Yellow solid (82 mg, 51%), m.p. 271 °C. IR: ν_{max} 3350, 3045, 1689, 1610 cm^{-1}. NMR ($CDCl_3$): δ_H 2.63 (s, 3H, C10-CH_3), 7.25 (t, 1H, C8-H, J = 8.0 Hz), 7.34 (d, 1H, C6-H, J = 8.0 Hz), 7.36 (d, 1H, C9-H, J = 7.92 Hz), 7.44 (t, 1H, C4'-H, J = 7.40 Hz), 7.48–7.51 (m, 2H, C3'-, C5'-H), 7.77–7.80 (m, 2H, C2'-, C6'-H), 7.96 (d, 1H, C5-H, J = 8.0 Hz), 7.97 (d, 1H, C7-H, J = 8.00 Hz), 8.03 (s, 1H, C4-H), 8.75 (b s, 1H, N11-H); δ_C 16.8 (C10-CH_3), 110.3 (C6a), 112.3 (C6), 112.4 (C5), 118.4 (C7), 118.7 (C4a), 120.7 (C9), 120.9 (C8), 122.3 (C10), 124.8 (C3), 127.7 (C10), 127.8 (C4'), 128.0 (C6b), 128.6 (C3', C5'), 128.9 (C2', C6'), 130.7 (C11a) 133.2 (C11b), 134.9 (C1'), 141.2 (C4), 160.5 (C2). MS: *m/z* (%) 325 (M^+, 100), 297 (41), 296 (62), 267 (11), 254 (8), 248 (21), 220 (8), 163 (21), 153 (27), 129 (9), 77 (9). Anal. Calcd for $C_{22}H_{15}NO_2$: C, 81.21; H, 4.65; N, 4.30. Found: C, 81.41; H, 4.72; N, 4.32%.

3-Phenylpyrano[2,3-a]carbazol-2(11H)-one (**4d**): Yellow solid (82 mg, 53%), m.p. 289 °C. IR: ν_{max} 3307, 1699, 1633, 1607 cm^{-1}. NMR ($CDCl_3$): δ_H 7.33 (t, 1H, C8-H, J = 7.5 Hz), 7.38 (d, 1H, C6-H, J = 8.0 Hz), 7.44 (t, 1H, C4'-H, J = 7.40 Hz), 7.48–7.55 (m, 3H, C9-, C3'-, C5'-H), 7.58 (d, 1H, C10-H, J = 8.0 Hz), 7.77–7.79 (m, 2H, C2'-, C6'-H), 7.98 (d, 1H, C5-H, J = 8.0 Hz), 8.04 (s, 1H, C4-H), 8.13 (d, 1H, C7-H, J = 8.0 Hz), 8.88 (b s, 1H, N11-H); δ_C 110.4 (C6a), 112.4 (C5), 116.1 (C10), 116.4 (C6), 118.5 (C4a), 119.8 (C9), 120.7 (C7), 124.7 (C3),125.6 (C6b), 126.0 (C8), 127.9 (C4'), 128.7 (C3', C5'), 128.9 (C2', C6'), 130.6 (C11a) 132.5 (C11b), 134.4 (C1'), 141.2 (C4), 142.3 (C10a), 160.75 (C2). MS: *m/z* (%) 311 (M^+, 100), 285 (54), 261 (17), 235 (38), 234 (15), 220 (12), 206 (8), 165 (6), 143 (8), 115 (9), 77 (16). Anal. Calcd for $C_{21}H_{13}NO_2$: C, 81.01; H, 4.21; N, 4.50. Found: C, 81.10; H, 4.18; N, 4.38%.

Pyrano[2,3-a]carbazol-2(11H)-ones (**5**) *and ethyl (E)-*β*-(1-hydroxy-9H-carbazol-2-yl)acrylates* (**6**), *general procedure*

To a solution of the 1-hydroxycarbazole-2-carbaldehyde (**1**, 0.5 mmol) in toluene (10 mL) was added (carbethoxymethylene)triphenylphosphorane (174 mg, 0.5 mmol). The reaction mixture was heated at 120 °C for 6 h. After completion of the reaction the solvent was removed and the residue was poured into ice-water and extracted with ethyl acetate. The organic phase was dried ($MgSO_4$), evaporated and purified by column chromatography over silica gel using petroleum ether/ethyl acetate (98:2 and 95:5) as eluant to give the products pyrano[2,3-*a*]carbazol-2(11*H*)-one (**5**) and ethyl (*E*)-β-(1-hydroxy-9*H*-carbazol-2-yl)acrylate (**6**) successively.

8-Methylpyrano[2,3-a]carbazol-2(11H)-one (**5a**): Yellow solid (47 mg, 38%), m.p. 206 °C (lit.[15] m.p. 205 °C).

*Ethyl (E)-*β*-(1-hydroxy-6-methyl-9H-carbazol-2-yl)acrylate* (**6a**): Yellow solid: (68 mg, 46%), m.p. 222 °C. IR: ν_{max} 3406, 3230, 1664, 1610 cm^{-1}. NMR ($CDCl_3$): δ_H 1.37 (t, 3H, $OCH_2\underline{CH_3}$, J = 7.12 Hz), 2.52 (s, 3H, C6-CH_3), 4.31 (q, 2H, OCH_2, J = 7.12 Hz), 6.07 (s, 1H, C1-OH), 6.55 (d, 1H, C2'-H, J = 15.8 Hz), 7.29 (d, 1H, C7-H, J = 7.28 Hz), 7.34 (d, 1H, C3-H, J = 8.28 Hz), 7.36 (d, 1H, C8-H, J = 7.42 Hz), 7.62 (d, 1H, C4-H, J = 8.24 Hz), 7.82 (s, 1H, C5-H), 8.14 (d, 1H, C1'-H, J = 15.8 Hz), 8.33 (b s, 1H, N9-H); δ_C 14.1 ($OCH_2\underline{CH_3}$), 21.2 (C6-CH_3), 61.65 (OCH_2), 111.0 (C8), 111.7 (C4a), 114.2 (C4), 115.4 (C2), 116.0 (C3), 117.0 (C2'), 120.5 (C7), 123.8 (C5), 127.7 (C9a), 128.4 (C4b), 128.7 (C6), 136.4 (C1), 138.2 (C8a), 145.1 (C1'), 160.7 (C3'). MS: *m/z* (%) 295(M^+, 35), 250 (29), 249 (100), 221 (81), 220 (51), 207 (8), 194 (22), 192 (14), 165 (9), 125 (5), 97 (27). Anal. Calcd for $C_{18}H_{17}NO_3$: C, 73.20; H, 5.80; N, 4.78. Found: C, 73.08; H, 5.69; N, 4.91%.

9-Methylpyrano[2,3-a]carbazol-2(11H)-one (**5b**): Yellow solid (44 mg, 35%), m.p. 165 °C (lit.[15] m.p. 162 °C).

(E)-Ethyl β-*(1-hydroxy-7-methyl-9H-carbazol-2-yl)acrylate* (**6b**): Yellow solid (60 mg, 41%), m.p. 276 °C. IR: ν_{max} 3402, 3233, 2939, 1665, 1611 cm^{-1}. NMR ($CDCl_3$): δ_H 1.39 (t, 3H, $OCH_2C\underline{H}_3$, J = 7.12 Hz), 2.51 (s, 3H, C7-CH_3), 4.33 (q, 2H, OCH_2, J = 7.12 Hz), 6.18 (s, 1H, C1-OH), 6.59 (d, 1H, C2'-H, J = 15.86 Hz), 7.04 (d, 1H, C6-H, J = 8.18 Hz), 7.34 (d, 1H, C3-H, J = 8.2 Hz), 7.37 (s, 1H, C8-H), 7.62 (d, 1H, C4-H, J = 8.2 Hz), 8.06 (d, 1H, C5-H, J = 8.12 Hz), 8.28 (d, 1H, C1'-H, J = 15.86 Hz), 8.58 (b s, 1H, N9-H); δ_C 14.5 ($OCH_2\underline{C}H_3$), 21.2 (C7-CH_3), 61.5 (OCH_2), 111.3 (C8), 114.1 (C4), 115.2 (C2), 116.4 (C3), 116.6 (C4a), 116.8 (C2'), 120.2 (C4b), 120.6 (C5), 121.8 (C6), 127.5 (C9a), 131.6 (C7), 136.9 (C1), 140.9 (C8a), 145.3 (C1'), 160.9 (C3'). MS: *m/z* (%) 295(M^+, 22), 249 (100), 221 (62), 220 (34), 207 (6), 194 (18), 165 (15), 164 (6), 97 (33). Anal. Calcd for $C_{18}H_{17}NO_3$: C, 73.20; H, 5.80; N, 4.78. Found: C, 73.15; H, 5.68; N, 4.86%.

10-Methylpyrano[2,3-a]carbazol-2(11H)-one (**5c**): Yellow solid (50 mg, 40%), m.p. 196 °C (lit.[15] m.p. 197 °C).

Ethyl (E)-β-*(1-hydroxy-8-methyl-9H-carbazol-2-yl)acrylate* (**6c**): Yellow solid (69 mg, 47%), m.p. 208 °C. IR: ν_{max} 3401, 3235, 2966, 1660, 1609 cm^{-1}. NMR ($CDCl_3$): δ_H 1.39 (t, 3H, $OCH_2C\underline{H}_3$, J = 7.12 Hz), 2.60 (s, 3H, C8-CH_3), 4.35 (q, 2H, OCH_2, J = 7.12 Hz), 6.66 (d, 1H, C2'-H, J = 15.92 Hz), 7.18 (t, 1H, C6-H, J = 7.6 Hz), 7.26 (d, 1H, C7-H, J = 7.6 Hz), 7.36 (d, 1H, C3-H, J = 8.24 Hz), 7.48 (s, 1H, C1-OH), 7.63 (d, 1H, C4-H, J = 8.2 Hz), 7.89 (d, 1H, C5-H, J = 7.84 Hz), 8.31 (d, 1H, C1'-H, J = 15.92 Hz), 8.72 (b s, 1H, N9-H); δ_C 14.4 ($OCH_2\underline{C}H_3$), 16.85 (C8-CH_3), 61.8 (OCH_2), 111.6 (C4a), 114.2 (C4), 115.3 (C2), 116.6 (C3), 116.7 (C2'), 118.45 (C5), 120.6 (C7), 120.9 (C6), 122.2 (C8), 127.4 (C9a), 127.9 (C8a), 127.95 (C4b), 136.8 (C1), 145.2(C1'), 160.9 (C3'). MS: *m/z* (%) 295(M^+, 46), 250 (24), 249 (100), 221 (54), 220 (18), 194 (8), 164 (16), 97 (51). Anal. Calcd for $C_{18}H_{17}NO_3$: C, 73.20; H, 5.80; N, 4.78. Found: C, 73.31; H, 5.76; N, 4.72%.

Pyrano[2,3-a]carbazol-2(11H)-one (**5d**): Yellow solid (46 mg, 39%), m.p. 169 °C (lit.[15] m.p. 169 °C).

Ethyl (E)-β-*(1-hydroxy-9H-carbazol-2-yl)acrylate* (**6d**): Yellow solid (61 mg, 44%), m.p. 213 °C. IR: ν_{max} 3375, 3275, 1663, 1617 cm^{-1}. NMR ($CDCl_3$): δ_H 1.39 (t, 3H, $OCH_2C\underline{H}_3$, J = 7.12 Hz), 4.34 (q, 2H, OCH_2, J = 7.12 Hz), 6.23 (s, 1H, C1-OH), 6.61 (d, 1H, C2'-H, J = 15.84 Hz), 7.24 (t, 1H, C6-H, J = 7.9 Hz), 7.35 (d, 1H, C3-H, J = 8.2 Hz), 7.44-7.48 (m, 2H, C8-, C9-H), 7.66 (d, 1H, C4-H, J = 8.2 Hz), 8.04 (d, 1H, C5-H, J = 7.92 Hz), 8.22 (d, 1H, C1'-H, J = 15.84 Hz), 8.54 (b s, 1H, N9-H); δ_C 14.16 ($OCH_2\underline{C}H_3$), 61.58 (OCH_2), 114.68 (C4), 115.17 (C2), 116.08 (C8), 116.28 (C3), 166.44 (C4a), 116.61 (C2'), 119.39 (C6), 120.91 (C5), 125.62 (C4b), 126.00 (C7), 127.58 (C9a), 135. 92 (C1), 141.83 (C10a), 145.09(C1'), 160.54 (C3'). MS: *m/z* (%) 281(M^+, 63), 236 (16), 235 (100), 208 (42), 182 (10), 181 (6), 165 (16), 77 (21). Anal. Calcd for $C_{17}H_{15}NO_3$: C, 72.58; H, 5.37; N, 4.98. Found: C, 72.35; H, 5.42; N, 4.96%.

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