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Solvent-Free Microwave Assisted Synthesis of (*E*)-1-{3-[2-(9-Ethyl-9*H*-carbazol-3-yl)vinyl]benzofuran-2-yl}-2,2-dimethylpropan-1-ones and Their Antimicrobial Activity[1]

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Abstract—We report the solvent–free synthesis of (*E*)-1-{3-[2-(9-Ethyl-9*H*-carbazol-3-yl)vinyl]benzofuran-2-yl}-2,2-dimethylpropan-1-ones starting with 9-Ethyl-9*H*-carbazole-3-carbaldehyde under conventional and microwave irradiation methods. All products were characterised by IR, ^{1}H NMR, ^{13}C NMR, mass spectrometry, and elemental analysis. The compounds were tested in vitro for their antimicrobial activity.

Keywords: microwave assisted synthesis, carbazole-3-carbaldehyde, carbazolylaryl prop-2-enones, carbazolyl-vinylbenzofurans, antimicrobial activity

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INTRODUCTION

Carbazole derivatives have attracted attention due to broad spectrum of biological activities and their natural occurrence. The carbazole moiety (Fig. 1a) is present in numerous drugs such as Olivacine, Ondansetron, Rimcazole, Staurosporine, Carvedilol, Carprofen, Cacothelin, Rebaccamycin, and Ellipticine. Benzofuran derivatives exhibit antibacterial [1], antimicrobial [2], antitumor [3], and antiproliferative [4] activities. Pharmaceuticals such as Amiodarone, Befunolol and Bergapten (Fig. 1b) contain benzofuron moiety in their core structures. Chalcones are versatile molecular natural scaffolds that exhibit numerous beneficial biological activities such as anticancer [5], anti-inflammatory [6], antimicrobial and antioxidant [7], antileishmanial [8], antituberculosis [9], anti-malarial [10], antibacterial [11], and antiangiogenic [12].

Microwave assisted organic synthesis [13, 14] has emerged as a simple and efficient environmentally friendly method. In continuation of our effort to synthesize novel carbazole derivatives by an eco-sustainable method, we have performed the synthesis of (*E*)-1-{3-[2-(9-Ethyl-9*H*-carbazol-3-yl)vinyl]benzofuran-2-yl}-2,2-dimethylpropan-1-ones under solvent-free microwave irradiation and tested their anti-microbial activity in vitro.

The precursor chalcones (*E*)-3-(9-Ethyl-9*H*-carbazol-3-yl)-1-(2-hydroxyphenyl)prop-2-en-1-ones **IIIa–IIIi** were synthesized according to the Claisen-Schmidt condensation of substituted 2-hydroxy acetophenones with 9-ethyl-9*H*-carbazol-3-carbaldehyde in the presence of KOH. Subsequent cyclisation of chalcones **IIIa–IIIi** using 1-bromo-3,3-dimethylbutanone and K_2CO_3 under microwave irradiation and conventional heating gave (*E*)-1-{3-[2-(9-ethyl-9*H*-carbazol-3-yl)-vinyl]benzofuran-2-yl}-2,2-dimethhylpropan-1-ones **IVa–IVi** in high yields. The microwave irradiation method resulted in higher reaction rate and yields (Table 1).

Antibacterial activity. The products **IIIa–IIIi** and **IVa–IVi** were screened in vitro for antibacterial activity [16] against gram +ve bacterial strains [*Staphylococcus aureus* (ATCC 6538), *Bacillus subtilis* (ATCC 6633)] and gram –ve bacterial strains [*Escherichia coli* (ATCC 25922), *Klebsiella pneumoniae* (ATCC 13883)] at 20 and 40 μg/mL concentrations. The inhibition zone (mm) was referred to the standard drug Ciprofloxacin (Table 2).

All products exhibited higher activity against gram +ve bacterial strains than gram –ve bacterial strains.

[1] The text was submitted by the authors in English.

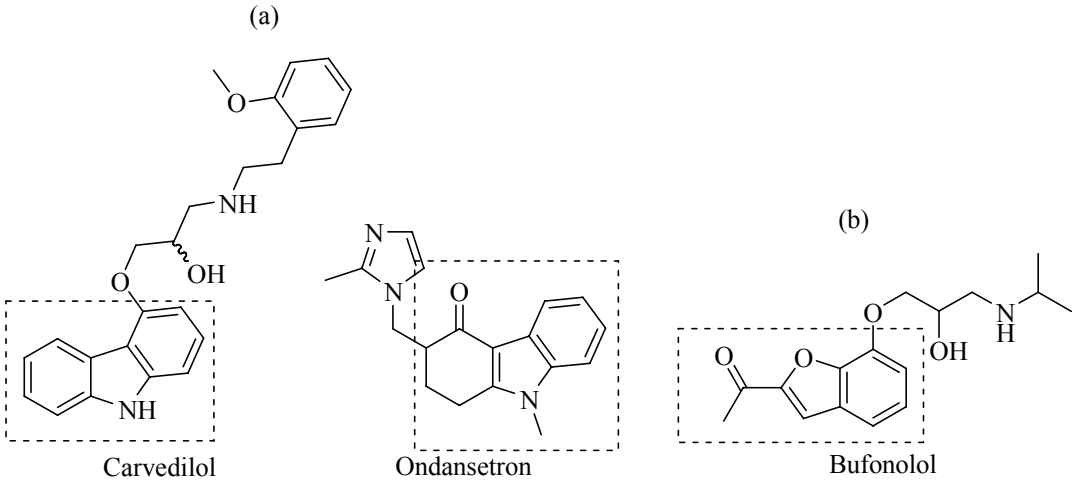


Fig. 1. (a) Carbazol based drugs and (b) benzofuran based drug.

Compounds **IIIa**, **IIIh, IIIi, IVa, IVh** and **IVi** were of high potential against gram +ve bacterial strains. Compounds **IVh** and **IVi** had maximum zone of inhibition and the other compounds were moderately active against gram –ve bacterial strains.

Antifungal activity. The antifungal activity [17] of compounds **IIIa–IIIi and IVa–IVi** was tested against three pathogenic fungi, *Fusarium oxysporum, Aspergillus nigerzeae,* and *Aspergillus flavus*. The zone of inhibition (in mm) was compared with that of

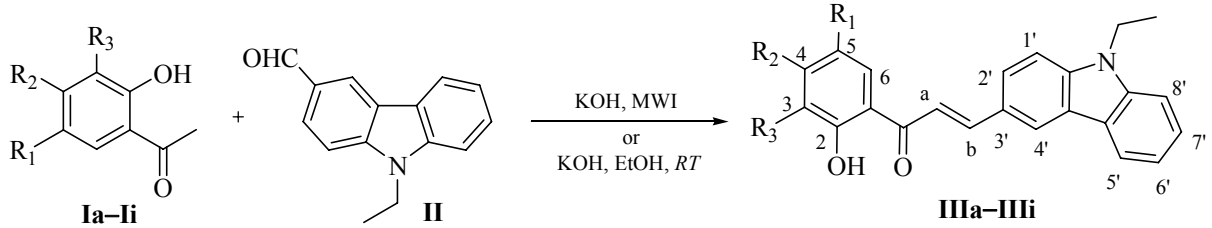
Table 1. Preparation conditions for (*E*)-3-(9-Ethyl-9H-carbazol-3-yl)-1-(2-hydroxyphenyl)prop-2-en-1-ones (**IIIa–IIIi**) and (*E*)-1-{3-[2-(9-Ethyl-9H-carbazol-3-yl)vinyl]benzofuran-2-yl}-2,2-dimethylpropan-1-ones (**IVa–IVi**) and melting points

Comp. no.	R_1	R_2	R_3	mp, °C	Conventional method		Microwave irradiation method	
					time, h	yield[a], %	time, min	yield[a], %
IIIa[b]	H	H	H	141–143	10	64	8	88
IIIb	F	H	H	198–200	11	68	6	84
IIIc	Cl	H	H	148–150	12	72	8	92
IIId	Br	H	H	131–133	12	64	7	88
IIIe	CH_3	H	H	174–176	9	76	6	92
IIIf	Cl	CH_3	H	188–190	10	62	7	94
IIIh	Cl	H	H	168–170	9	68	5	86
IIIh	H	OCH_3	Cl	158–160	11	62	6	82
IIIi	H	OC_2H_5	H	138–140	12	66	8	78
IVa	H	H	H	134–136	6	56	2	78
IVb	F	H	H	128–130	7	52	3	72
IVc	Cl	H	H	146–149	5	68	2	76
IVd	Br	H	H	136–138	8	56	2	86
IVe	CH_3	H	H	143–146	5	68	3	82
IVf	Cl	CH_3	H	224–226	6	64	3	78
IVg	Cl	H	Cl	238–240	6	62	2	72
IVh	H	OCH_3	H	152–154	7	68	3	78
IVi	H	OCH_3	H	176–178	8	62	3	76

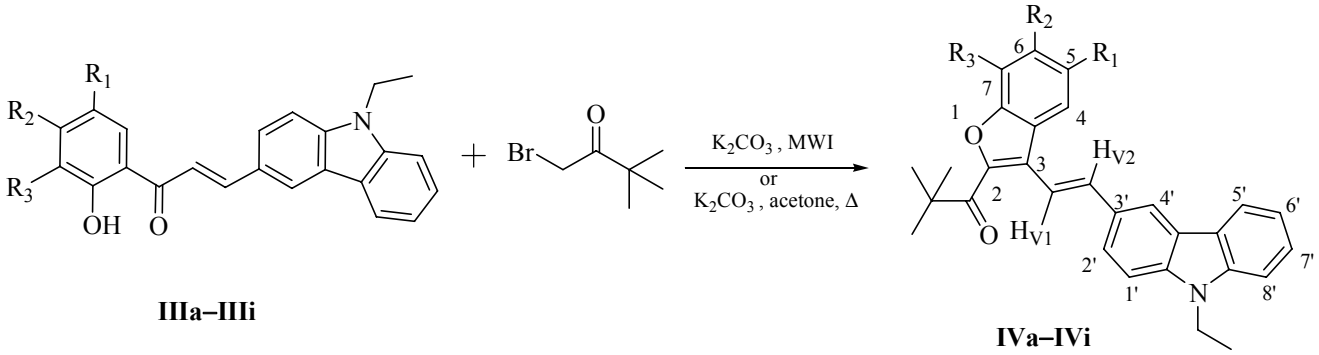
[a] Isolated yields. [b] Reported in literature [15].

Scheme 1.

Step 1



Step 2



the standard drug Amphotericin-B. All compounds were of moderate to good activity against the tested fungal strains. Compounds **IVb** and **IVi** demonstrated the highest activity against *A. nigerzeae.* The compound **IVi** was active against *A. flavus* and compounds **IVh, IVi** exhibited promising activity against *F. oxysporum* (Scheme 1).

EXPERIMENTAL

Melting points were determined in open glass capillary tube on a Gallen-Kamp MFB-595 apparatus. The IR spectra were recorded by a Perkin-Elmer FT-IR-8400s spectrophotomete in KBr disks. Microwave supported synthesis was carried out in the milestone multi SYNTH microwave system. The ^{1}H NMR (400 MHz) and ^{13}C NMR (100 MHz) spectra were recorded by Bruker Avance II 400 spectrometer in $CDCl_3$ solvent with TMS internal standard. Mass spectra were recorded by GCMS-QP 1000 EX and SHIMADZU LCMS 2020 mass spectrometers. The progress of reactions was monitored by TLC (Silica gel, 60 F_{254}, Merck). Elemental analysis was performed by a Perkin Elmer CHN-2400 analyzer.

Synthesis of (*E*)-3-(9-Ethyl-9*H*-carbazol-3-yl)-1-(2-hydroxyphenyl)prop-2-en-1-ones (IIIa–IIIi). *Conventional method.* To a stirred solution of substituted 2-hydroxy acetophenones **Ia–Ii** (10 mmol) and KOH (30 mmol) in ethanol (30 mL) was added 9-Ethyl-9*H*-carbazol-3-carbaldehyde **II** (10 mmol) and the mixture was stirred at room temperature for 9–12 h. Upon completion of the reaction (as indicated by TLC), the reaction mixture was poured into ice cold water and neutralized with dil. HCl. The yellow solid was filtered off and recrystallized from ethanol.

Microwave irradiation method . A quartz tube was charged with a mixture of substituted 2-hydroxy acetophenones **Ia–Ii** (10 mmol), 9-ethyl-9*H*-carbazol-3-carbaldehyde **II** (10 mmol) and KOH (30 mmol) and inserted into a Teflon via. The reaction mixture was subjected to microwave irradiation at 180 watts for 5–8 min. Upon completion of the process the reaction mixture was poured into ice cold water and neutralized with dil. HCl. The yellow solid was filtered off and recrystallized from ethanol.

Compound IIIa. IR spectrum, ν, cm^{-1}: 3442 (C–OH), 1630 (C=O). ^{1}H NMR spectrum, δ, ppm: 3.13 s (1H, OH), 8.40 d (1H, J = 1.6 Hz, Ar$H^{4'}$), 8.19–8.14 m (2H, Ar$H^{1'}$, H_β), 8.03–8.02 d.d (1H, J = 7.6, 1.2 Hz, Ar$H^{2'}$), 7.72 d (1H, J = 15.6 Hz, H_α), 7.82–6.95 m (8H, ArH), 4.40 q (2H, N–CH_2), 1.47 t (3H, CH_3). ^{13}C NMR spectrum, δ_C, ppm: 193.6, 163.6, 147.0, 141.7, 140.6, 135.7, 129.5, 126.6, 126.5, 126.4, 125.8, 123.7, 122.9,

Table 2. Antimicrobial activity of synthesized compounds

Comp. no.	Inhibition zone, mm										
	gram-positive bacteria				gram-negative bacteria				fungi		
	concentration, μg		concentration, μg		concentration, μg		concentration, μg		concentration, μg		
	S. aeures		*B. subtilis*		*K. pneumoniae*		*E. coli*		*A. nigerzeae*	*A. flavus*	*F. oxysporum*
	20	40	20	40	20	40	20	40	100	100	100
IIIa'	12	23	12	25	12	23	11	20	7.5	4.8	7.1
IIIb	10	22	7	16	8	16	10	21	6.3	9.6	8.2
IIIc	12	23	11	20	9	16	9	17	3.8	5.4	4.4
IIId	11	22	9	15	9	19	6	13	8.6	6.1	4.2
IIIe	11	20	9	13	8	15	6	12	2.7	5.2	8.0
IIIf	12	19	–	15	7	15	8	17	8.7	6.4	3.7
IIIh	8	15	9	15	4	8	2	7	2.6	7.4	7.9
IIIh	13	17	13	25	7	15	5	10	8.7	6.1	3.7
IIIi	14	20	12	25	9	17	9	16	2.6	7.8	3.9
IVa	16	28	14	26	13	26	14	30	13.4	10.5	12.3
IVb	11	22	6	14	7	15	5	12	15.9	5.0	17.4
IVc	12	24	9	18	8	15	8	17	4.6	6.1	5.4
IVd	11	20	9	17	9	19	10	17	2.5	6.2	4.4
IVe	10	22	7	16	5	10	7	7	8.7	9.2	7.6
IVf	11	21	9	18	7	15	9	10	8.4	11.4	4.3
IVg	13	23	10	21	9	19	7	15	10.2	7.8	11.6
IVh	16	29	16	29	24	35	17	32	13.6	12.7	15.7
IVi	18	30	17	30	25	36	19	33	14.9	15.2	18.7
[a]	15	28	16	30	23	35	18	35	–	–	–
[b]	–	–	–	–	–	–	–	–	14.0	12.5	15.2

[a] Ciprofloxacin. [b] Amphotericin-B.

121.8, 120.6, 120.4, 119.8, 118.5, 117.0, 108.9, 37.7, 13.7. Found, %: C 81.05; H 5.68; N 4.15. $C_{23}H_{19}NO_2$. Calculated, %: C 80.92; H 5.61; N 4.10. GC-MS: 341 $[M]^+$.

Compound IIIb. IR spectrum, ν, cm^{-1}: 3445 (C–OH), 1634 (C=O). ^1H NMR spectrum, δ, ppm: 12.81 s (1H, OH), 8.40 d (1H, J = 1.2 Hz, $ArH^{4'}$), 8.20–8.15 m (2H, $ArH^{1'}$, H_β), 7.82–7.79 d.d (1H, J = 1.6, 6.8 Hz, $ArH^{2'}$), 7.58 d (1H, J = 15.2 Hz, H_α), 7.68–6.98 m (7H, ArH), 4.39 q (2H, N–CH_2), 1.47 t (3H, CH_3). ^{13}C NMR spectrum, δ_C, ppm: 192.6, 159.7, 156.0, 153.6, 148.1, 141.8, 140.5, 126.7, 126.5, 125.3, 123.6, 123.2, 122.8, 122.2, 120.6, 120.7, 119.9, 119.6, 116.0, 114.4, 114.3, 37.8, 13.8. Found, %: C 76.95; H 5.13; N 3.95. $C_{23}H_{18}FNO_2$. Calculated, %: C 76.86; H 5.05; N 3.90. GC-MS: 359 $[M]^+$.

Compound IIIc. IR spectrum, ν, cm^{-1}: 3424 (C–OH), 1632 (C=O). ^1H NMR spectrum, δ, ppm: 13.04 s (1H, OH), 8.43 d (1H, J = 1.2 Hz, $ArH^{4'}$), 8.21–8.17 m (2H, $ArH^{1'}$, H_β), 7.96 d (1H, J = 2.4 Hz, ArH), 7.83–7.81 d.d (1H, J = 1.6, 7.2 Hz, $ArH^{2'}$), 7.76–7.30 m (6H, ArH), 6.99 d (1H, J = 9.2 Hz, ArH), 4.40 q (2H,

N–CH_2), 1.47 t (3H, –CH_2–C$\underline{H}_3$). ^{13}C NMR spectrum, δ_C, ppm: 192.6, 162.0, 148.3, 141.9, 140.5, 135.7, 128.7, 126.8, 126.5, 125.3, 123.6, 123.3, 122.8, 121.9, 120.9, 120.7, 119.9, 115.9, 109.0, 37.8, 13.8. Found, %: C 73.61; H 4.88; N 3.77. $C_{23}H_{18}ClNO_2$. Calculated, %: C 73.50; H 4.83; N 3.73. GC-MS: 375 $[M]^+$.

Compound IIId. IR spectrum, ν, cm^{-1}: 3442 (C–OH), 1627 (C=O). ^{1}H NMR spectrum, δ, ppm: 13.06 s (1H, OH), 8.43 d (1H, J = 2.0 Hz, $ArH^{4'}$), 8.22–8.18 m (2H, $ArH^{1'}$, H_β), 8.10 d (1H, J = 2.8 Hz, $ArH^{2'}$), 7.83 d.d (1H, J = 2.0, 9.0 Hz, ArH), 7.61 d (1H, J = 14.8 Hz, H_α), 7.58–7.30 m (5H, ArH), 6.94 d (1H, J = 8.8 Hz, ArH), 4.40 q (2H, N–CH_2), 1.46 t (3H, –CH_2–C$\underline{H}_3$); ^{13}C NMR spectrum, δ_C, ppm: 192.5, 162.3, 148.3, 141.9, 140.5, 138.4, 131.7, 126.9, 126.9, 126.5, 125.3, 123.6, 122.8, 122.3, 121.5, 120.8, 120.5, 115.9, 110.3, 109.0, 37.8, 13.8. Found, %: C 65.78; H 4.38; N 3.36. $C_{23}H_{18}BrNO_2$. Calculated, %: C 65.73; H 4.32; N 3.33. GC-MS: 419 $[M]^+$.

Compound IIIe. IR spectrum, ν, cm^{-1}: 3430 (C–OH), 1636 (C=O). ^{1}H NMR spectrum, δ, ppm: 12.90 s (1H, OH), 8.42 d (1H, J = 1.6 Hz, $ArH^{4'}$), 8.18–8.14 m (2H, $ArH^{1'}$, H_β), 7.84–7.81 d.d (1H, J = 1.6, 7.2 Hz, $ArH^{2'}$), 7.78 s (1H, ArH), 7.71 d (1H, J = 15.6 Hz, H_α), 7.54–7.28 m (5H, ArH), 6.94 d (1H, J = 8.4 Hz, ArH_4), 4.40 q (2H, N–CH_2), 2.39 s (3H, Ar-CH_3), 1.47 t (3H, –CH_2–C$\underline{H}_3$); ^{13}C NMR spectrum, δ_C, ppm: 191.9, 161.5, 147.0, 140.5, 137.0, 131.1, 129.2, 127.7, 126.7, 126.5, 126.4, 125.7, 122.8, 121.9, 119.8, 118.3, 116.8, 107.5, 101.0, 37.8, 20.7, 13.8. Found, %: C 81.17; H 6.02; N 3.96. $C_{24}H_{21}NO_2$. Calculated, %: C 81.10; H 5.96; N 3.94. GC-MS: 355 $[M]^+$.

Compound IIIf. IR spectrum, ν, cm^{-1}: 3436 (C–OH), 1624 (C=O). ^{1}H NMR spectrum, δ, ppm: 13.00 s (1H, OH), 8.42 d (1H, J = 2.0 Hz, $ArH^{4'}$), 8.19–8.15 m (2H, $ArH^{1'}$, H_β), 7.93 s (1H, ArH_4), 7.82 d.d (1H, J = 1.6, 6.8 Hz, $ArH^{2'}$), 7.59 d (1H, J = 15.6 Hz, H_α), 7.54–7.29 m (4H, ArH), 6.91 s (1H, ArH_7), 4.41 q (2H, N–CH_2), 2.40 s (3H, Ar-CH_3), 1.47 t (3H, –CH_2–C$\underline{H}_3$); ^{13}C NMR spectrum, δ_C, ppm: 192.2, 162.0, 147.7, 145.0, 141.8, 140.5, 129.1, 126.8, 126.5, 124.0, 123.6, 122.8, 122.1, 120.7, 120.5, 120.3, 119.9, 119.2, 116.1, 109.0, 37.8, 20.8, 13.8. Found, %: C, 74.04; H, 5.19; N, 3.65. $C_{24}H_{20}ClNO_2$. Calculated, %: C 73.94; H 5.17; N 3.59. GC-MS: 389 $[M]^+$.

Compound IIIg. IR spectrum, ν, cm^{-1}: 3443 (C–OH), 1629 (C=O). ^{1}H NMR spectrum, δ, ppm: 13.84 br. s (1H, OH), 8.44 d (1H, J = 1.6 Hz, $ArH^{4'}$), 8.25 d (1H, J = 15.2 Hz, H_β), 8.18 d (1H, J = 8.0 Hz, $ArH^{1'}$), 7.90 d (1H, J = 2.8 Hz, ArH), 7.83 d.d (1H, J = 2.0, 7.6 Hz, $ArH^{2'}$), 7.59 d (1H, J = 15.2 Hz, H_α), 7.64–7.32 m (5H, ArH), 4.41 q (2H, N–CH_2), 1.48 t (3H, –CH_2–C$\underline{H}_3$); ^{13}C NMR spectrum, δ_C, ppm: 192.2, 149.4, 142.1, 140.5, 135.2, 129.6, 128.4, 127.3, 127.0, 126.6, 125.1, 123.7, 123.0, 122.8, 122.5, 121.3, 120.7, 120.1, 115.2, 109.1, 109.0, 37.9, 13.8. Found, %: C 67.41; H 4.21; N 3.46. $C_{23}H_{17}Cl_2NO_2$. Calculated, %: C 67.33; H 4.18; N 3.41. GC-MS: 409 $[M]^+$.

Compound IIIh. IR spectrum, ν, cm^{-1}: 3436 (C–OH), 1648 (C=O). ^{1}H NMR spectrum, δ, ppm: 13.72 s (1H, OH), 8.39 d (1H, J = 1.6 Hz, $ArH^{4'}$), 8.17–8.14 m (2H, $ArH^{1'}$, H_β), 7.93 d (1H, J = 8.8 Hz, ArH), 7.81-7.78 d.d (1H, J = 2.0, 6.8 Hz, $ArH^{2'}$), 7.63 d (1H, J = 15.6 Hz, H_α), 7.54–7.28 m (4H, ArH), 6.49-6.53 m (2H, ArH), 4.39 q (2H, N–CH_2), 3.87 s (3H,–OCH_3), 1.46 t (3H, –CH_2–C$\underline{H}_3$); ^{13}C NMR spectrum, δ_C, ppm: 191.9, 166.6, 165.9, 146.1, 141.5, 140.5, 131.1, 126.5, 126.4, 125.8, 123.5, 122.8, 121.7, 120.6, 119.7, 116.9, 114.3, 108.9, 108.8, 107.5, 101.0, 55.5, 37.8, 13.8. Found, %: C 77.65; H 5.75; N 3.76. $C_{24}H_{21}NO_3$. Calculated, %: C 77.61; H 5.70; N 3.77. GC-MS: 371 $[M]^+$.

Compound IIIi. IR spectrum, ν, cm^{-1}: 3441 (C–OH), 1629 (C=O). ^{1}H NMR spectrum, δ, ppm: 13.7 s (1H, OH), 8.39 d (1H, J = 2.0 Hz, $ArH^{4'}$), 8.16–8.10 m (2H, $ArH^{1'}$, H_β), 7.91 d.d (1H, J = 2.4, 7.2 Hz, $ArH^{2'}$), 7.63 d (1H, J = 15.6 Hz, H_α), 7.53–7.27 m (5H, ArH), 6.51–6.47 m (2H, ArH), 4.39 q (2H, N–CH_2), 4.10 q (2H, O–CH_2), 1.43–1.48 m (6H, N–CH_2–C$\underline{H}_3$, O–CH_2–C$\underline{H}_3$); ^{13}C NMR spectrum, δ_C, ppm: 191.8, 166.6, 165.3, 146.0, 141.5, 140.5, 131.1, 126.5, 126.4, 125.8, 123.5, 122.8, 121.7, 120.6, 119.7, 116.9, 114.1, 108.9, 108.8, 107.9, 101.4, 63.9, 37.8, 14.6, 13.8. Found, %: C 77.93; H 6.04; N 3.66. $C_{25}H_{23}NO_3$. Calculated, %: C 77.90; H 6.01; N 3.65. GC-MS: 385 $[M]^+$.

Synthesis of (*E*)-1-{3-[2-(9-ethyl-9*H*-carbazol-3-yl)vinyl]benzofuran-2-yl}-2,2-dimethylpropan-1-ones (IVa–IVi). *Conventional method.* A solution of (*E*)-3-(9-Ethyl-9*H*-carbazol-3-yl)-1-(2-hydroxyphenyl)-prop-2-en-1-ones **IIIa–IIIi** (10 mmol) and K_2CO_3 (30 mmol) in dry acetone (30 mL) was refluxed for 30 min. Upon cooling down to room temperature 1-bromo-3,3-dimethylbutanone (10 mmol) was added drop wise. The reaction mixture was refluxed for 3–4 h. Upon completion (as indicated by TLC) the reaction mixture was poured into ice cold water and then extracted with dichloromethane (2 × 30 mL). The combined organic extracts were washed with water, dried over anhydrous sodium sulphate and con-

centrated in vacuum to give the crude product which was recrystallized from ethanol.

Microwave irradiation method. A mixture of **IIIa–IIIi** (10 mmol) and 1-bromo-3,3-dimethylbutanone (10 mmol) was dissolved in minimum quantity of ethanol and adsorbed by K_2CO_3 (30 mmol). This was delivered into a quartz tube and inserted into a Teflon vial and subjected to microwave irradiation at 180 Wt for 2–3 min. Upon completion of the process (TLC), the reaction mixture was poured into ice cold water and extracted by CH_2Cl_2 (2 × 30 mL) and dried over Na_2SO_4. The crude product was recrystallized from ethanol.

Compound IVa. IR spectrum, ν, cm^{-1}: 1651 (C=O), 1524 (C=C). ^1H NMR spectrum, δ, ppm: δ 8.35 d (1H, *J* = 1.2 Hz, $ArH^{4'}$), 8.19–8.14 m (2H, $ArH^{1'}$, $ArH^{2'}$), 8.10 d (1H, *J* = 16.8 Hz, vinylic H^2), 7.81 d.d (1H, *J* = 2.0, 8.6 Hz, ArH), 7.61 d (1H, *J* = 16.8 Hz, vinylic H^1), 7.52–7.27 m (7H, ArH), 4.39 q (2H, N–CH_2), 1.46–1.45 m [12H, 3(–CH_3), –CH_2–C$\underline{H}_3$]. ^{13}C NMR spectrum, δ_C, ppm: 198.8, 154.0, 147.1, 140.4, 140.1, 136.2, 128.4, 127.9, 127.0, 125.9, 125.8, 124.8, 123.6, 123.3, 123.0, 120.6, 119.4, 119.1, 119.0, 117.7, 112.3, 108.6, 44.4, 37.7, 26.6, 26.5, 26.4, 13.8. Found, %: C 82.65; H 6.49; N 3.35. $C_{29}H_{27}NO_2$. Calculated, %: C 82.63; H 6.46; N 3.32. ESI-MS: 422 $[M + H]^+$.

Compound IVb. IR spectrum, ν, cm^{-1}: 1649 (C=O), 1521 (C=C). ^1H NMR spectrum, δ, ppm: 8.33 s (1H, $ArH^{4'}$), 8.16 d (1H, *J* = 7.6 Hz, $ArH^{1'}$), 8.11 d (1H, *J* = 16.8 Hz, vinylic H^2), 7.84–7.78 m (2H, $ArH^{2'}$, ArH), 7.58 d (1H, *J* = 16.8 Hz, vinylic H^1), 7.52-7.39 m (4H, ArH), 7.28–7.23 m (2H, ArH), 4.37 q (2H, N–CH_2), 1.47–1.46 m [12H, 3(–CH_3), –CH_2–C$\underline{H}_3$]. ^{13}C NMR spectrum, δ_C, ppm: 198.6, 160.7, 158.3, 150.2, 148.3, 140.4, 140.2, 136.1, 134.5, 128.2, 126.9, 125.9, 124.8, 123.3, 123.0, 120.6, 119.4, 119.2, 117.2, 116.2, 116.0, 113.2, 108.7, 108.6, 44.4, 37.7, 26.5, 13.8. Found, %: C 79.29; H 6.01; N 3.24. $C_{29}H_{26}FNO_2$. Calculated, %: C 79.25; H 5.96; N 3.19. ESI-MS: 440 $[M + H]^+$.

Compound IVc. IR spectrum, ν, cm^{-1}: 1653 (C=O), 1528 (C=C). ^1H NMR spectrum, δ, ppm: 8.35 d (1H, *J* = 1.2 Hz, $ArH^{4'}$), 8.18–8.14 m (2H, $ArH^{1'}$, $ArH^{2'}$), 8.09 d (1H, *J* = 16.8 Hz, vinylic H^2), 7.81 d.d (1H, *J* = 2.0, 8.6 Hz, ArH), 7.61 d (1H, *J* = 16.8 Hz, vinylic H^1), 7.52-7.27 m (6H, ArH), 4.39 q (2H, N–CH_2), 1.46–1.44 m [12H, 3(–CH_3), –CH_2–C$\underline{H}_3$]. ^{13}C NMR spectrum, δ_C, ppm: 198.1, 152.6, 147.8, 141.1, 140.3, 137.4, 129.6, 126.6, 125.5, 124.8, 123.2, 123.0, 120.8, 119.4, 119.1, 117.2, 116.8, 116.0, 113.8, 108.7, 108.2, 44.6, 37.8, 26.6, 13.7. Found, %: C 76.42; H 5.78; N 3.11. $C_{29}H_{26}ClNO_2$. Calculated, %: C 76.39; H 5.75; N 3.07. ESI-MS: 456 $[M + H]^+$.

Compound IVd. IR spectrum, ν, cm^{-1}: 1658 (C=O), 1526 (C=C). ^1H NMR spectrum, δ, ppm: 8.35 d (1H, *J* = 1.2 Hz, $ArH^{4'}$), 8.18–8.14 m (2H, $ArH^{1'}$, $ArH^{2'}$), 8.09 d (1H, *J* = 16.8 Hz, vinylic H^2), 7.81 d.d (1H, *J* = 2.0, 8.6 Hz, ArH), 7.61 d (1H, *J* = 16.8 Hz, vinylic H^1), 7.52–7.27 m (6H, ArH), 4.39 q (2H, N–CH_2), 1.46–1.44 m [12H, 3(–CH_3, –CH_2–C$\underline{H}_3$)]. ^{13}C NMR spectrum, δ_C, ppm: 198.5, 152.2, 147.1, 142.6, 140.8, 139.2, 129.6, 126.3, 125.6, 124.8, 123.2, 123.0, 120.6, 119.6, 119.1, 117.6, 116.8, 116.1, 113.8, 108.9, 108.2, 44.7, 37.7, 26.6, 13.8. Found, %: C 69.64; H 5.28; N 2.85. $C_{29}H_{26}BrNO_2$. Calculated, %: C 69.60; H 5.24; N 2.80. ESI-MS: 500 $[M + H]^+$.

Compound IVe. IR spectrum, ν, cm^{-1}: 1656 (C=O), 1522 (C=C). ^1H NMR spectrum, δ, ppm: 8.34 s (1H, $ArH^{4'}$), 8.18–8.13 m (2H, $ArH^{1'}$, vinylic H^2), 7.95 s (1H, ArH_4), 7.83 d.d (1H, *J* = 1.6, 8.8 Hz, ArH), 7.68 d (1H, *J* = 16.4 Hz, vinylic H^1), 7.48–7.24 m (6H, ArH), 4.38 q (2H, N–CH_2), 2.55 s (3H, Ar-CH_3), 1.47–1.44 m [12H, 3(–CH_3), –CH_2–C$\underline{H}_3$]. ^{13}C NMR spectrum, δ_C, ppm: 198.8, 152.5, 147.3, 140.4, 140.1, 135.9, 133.2, 129.4, 128.5, 126.8, 125.9, 124.8, 123.3, 123.0, 122.8, 120.6, 119.4, 119.1, 117.9, 111.8, 108.6, 44.4, 37.7, 26.6, 26.4, 21.6, 13.8. Found, %: C 82.76; H 6.74; N 3.26. $C_{30}H_{29}NO_2$. Calculated, %: C 82.73; H 6.71; N 3.22. ESI-MS: 436 $[M + H]^+$.

Compound IVf. IR spectrum, ν, cm^{-1}: 1649 (C=O), 1521 (C=C). ^1H NMR spectrum, δ, ppm: 8.35 d (1H, *J* = 1.2 Hz, $ArH^{4'}$), 8.17 d (1H, *J* = 7.6 Hz, $ArH^{1'}$), 8.15 s (1H, ArH_4), 8.11 d (1H, *J* = 9.6 Hz, vinylic H^2), 7.81 d.d (1H, *J* = 1.6, 8.8 Hz, $ArH^{2'}$), 7.62 d (1H, *J* = 16.8 Hz, vinylic H^1), 7.51–7.40 m (4H, ArH), 7.28 d (1H, *J* = 7.2 Hz ArH), 4.39 q (2H, N–CH_2), 2.54 s (3H, Ar-CH_3), 1.46–1.45 m [12H, 3(–CH_3), –CH_2–C$\underline{H}_3$]. ^{13}C NMR spectrum, δ_C, ppm: 198.6, 152.7, 147.4, 140.4, 140.2, 136.4, 136.3, 130.2, 128.2, 126.5, 125.9, 125.0, 124.8, 123.5, 123.0, 122.9, 120.7, 119.5, 119.2, 117.3, 113.8, 108.7, 44.4, 37.7, 26.5, 26.3, 21.1, 13.8. Found, %: C 76.69; H 6.02; N 3.02. $C_{30}H_{28}ClNO_2$. Calculated, %: C 76.66; H 6.00; N 2.98. ESI-MS: 470 $[M + H]^+$.

Compound IVg. IR spectrum, ν, cm^{-1}: 1650 (C=O), 1528 (C=C). ^1H NMR spectrum, δ, ppm: 8.34 d (1H, *J* = 1.2 Hz, $ArH^{4'}$), 8.17 d (1H, *J* = 7.6 Hz,

$ArH^{1'}$), 8.08–8.04 m (2H, vinylic H^2, $ArH^{2'}$), 7.81 d.d (1H, J = 1.6, 8.8 Hz, ArH), 7.59 d (1H, J = 16.8 Hz, vinylic H^1), 7.54–7.28 m (5H, ArH), 4.39 q (2H, N–CH_2), 1.48–1.46 m [12H, 3(–CH_3), –CH_2–$C\underline{H}_3$]. ^{13}C NMR spectrum, δ_C, ppm: 198.9, 153.2, 147.5, 140.8, 140.3, 136.4, 135.6, 131.2, 129.2, 126.9, 126.0, 125.5, 124.8, 124.5, 123.0, 122.8, 121.5, 119.8, 119.2, 115.3, 113.8, 109.7, 44.6, 37.6, 26.8, 13.8. Found, %: C 71.06; H 5.19; N 2.91. $C_{29}H_{25}Cl_2NO_2$. Calculated, %: C 71.02; H 5.14; N 2.86. ESI-MS: 490 $[M + H]^+$.

Compound IVh. IR spectrum, ν, cm^{-1}: 1655 (C=O), 1523 (C=C). ^1H NMR spectrum, δ, ppm: 8.33 s (1H, $ArH^{4'}$), 8.18–8.14 m (2H, $ArH^{1'}$, vinylic H^2), 8.05 d (1H, J = 7.6 Hz, $ArH^{2'}$), 7.81 d.d (1H, J = 1.6, 8.6 Hz, ArH), 7.67 d (1H, J = 16.8 Hz, vinylic H^1), 7.50–7.39 m (3H, ArH), 7.28–7.24 m (1H, ArH), 7.05–7.01 m (2H, ArH), 4.39 q (2H, N–CH_2), 3.93 s (3H, O–CH_3), 1.46–1.45 m [12H, 3(–CH_3), –CH_2–$C\underline{H}_3$]. ^{13}C NMR spectrum, δ_C, ppm: 197.8, 159.8, 155.3, 148.1, 142.2, 140.3, 136.2, 134.3, 131.5, 131.2, 128.8, 128.2, 127.2, 125.1, 124.8, 124.5, 123.0, 122.4, 120.6, 118.9, 117.2, 108.7, 55.5, 45.2, 37.7, 26.5, 26.4, 13.7. Found, %: C 79.83; H 6.50; N 3.14. $C_{30}H_{29}NO_3$. Calculated, %: C 79.80; H 6.47; N 3.10. ESI-MS: 452 $[M + H]^+$.

Compound IVi. IR spectrum, ν, cm^{-1}: 1649 (C=O), 1510 (C=C). ^1H NMR spectrum, δ, ppm: 8.33 s (1H, $ArH^{4'}$), 8.18–8.14 m (2H, $ArH^{1'}$, vinylic H^2), 8.03 d (1H, J = 9.6 Hz, $ArH^{2'}$), 7.80 d.d (1H, J = 1.6, 8.4 Hz, ArH), 7.67 d (1H, J = 16.8 Hz, vinylic H^1), 7.50–7.38 m (3H, ArH), 7.28–7.24 m (1H, ArH), 7.02–7.00 m (2H, ArH), 4.38 q (2H, N–CH_2), 4.14 q (2H, O–CH_2), 1.48–1.44 m [15H, 3(–CH_3), N–CH_2–$C\underline{H}_3$, O–CH_2–$C\underline{H}_3$]. ^{13}C NMR spectrum, δ_C, ppm: 198.2, 160.0, 155.5, 146.9, 140.3, 136.1, 134.1, 128.5, 128.2, 127.6, 125.8, 124.8, 123.6, 123.0, 121.4, 120.6, 119.4, 118.9, 114.4, 108.6, 107.9, 96.0, 64.0, 44.2, 37.7, 26.6, 26.5, 14.7, 13.8. Found, %: C 79.99; H 6.75; N 3.03. $C_{31}H_{31}NO_3$. Calculated, %: C 79.97; H 6.71; N 3.01. ESI-MS: 466 $[M + H]^+$.

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