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## RESEARCH ARTICLE

# *Synthesis, Characterization and Antimicrobial Screening of Some New Benzofuranyl Pyridinyl and Benzofuranyl Styryl Pyridinyl Substituted Coumarins*

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## ABSTRACT

The synthesis of various benzofuranyl pyridinyl and benzofuranyl styryl pyridinyl substituted coumarins has been carried out by reacting 3-cinnamoyl coumarins and 3-(5-arylpenta-2,4-dienoyl)coumarins (coumarin chalcones) with substituted benzofuranoyl methyl pyridinium iodide salts in the presence of ammonium acetate and acetic acid under Krohnke's reaction condition. The structures of all the synthesized compounds were established on the basis of analytical and spectral data like IR, $^{1}$H-NMR, $^{13}$C-NMR and mass. The compounds were subjected to *in vitro* antimicrobial screening against a representative panel of bacteria (*Bacillus subtilis, Staphylococcus aureus, Escherichia coli, Salmonella typhi*) and fungi (*Aspergillus niger, Candida albicans*).

## KEYWORDS

Coumarins, benzofuranyl pyridine, styryl pyridine, Pyridylcoumarins Kröhnke's reaction, Antimicrobial activity

## INTRODUCTION

Coumarins occupy an important place in the realm of natural and synthetic organic chemistry. Coumarin and its derivatives possess high activity profile due to their wide range of biological activities such as anti-inflammatory[1], antipyretic and analgesic[2], antitumor[3], antibacterial[4], antimalarial[5] etc. The incorporation of pyridine moiety in coumarins especially in lactone part converts them into important derivatives. Many such 3- or 4-pyridine substituted coumarins are reported to have important biological activities like antifungal[6], fish toxicity and bactericidal[7]. The incorporation of styryl group in pyridines converts them in to styryl pyridines. Certain styryl pyridines are known for variety of physiological activity like choline acetyl transferase (CNS depressant)[8], herbicidal[9], anesthetics to fish[10], antimicrobia[11] etc.

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On the other hand, benzofuran compounds are also known for their biological properties such as antimicrobial[12a], anti-inflammatory[12b], anti-tumour[12c], anti-alzheimer[12d] etc. The most recognized benzofurans are *Ailanthoidol*, *Bufuralol* and *Amiodarone*[13]. *Ailanthoidol*, is a neolignan derivative, which has been reported to have antiviral, antioxidant and antifungal activities[14]. Encouraged by the interesting biological properties of pyridyl coumarins, styryl pyridines and benzofurans, it was thought worthwhile to synthesize hybrid coumarin derivatives incorporating benzofuran and styryl pyridine moeities in a single scaffold and therefore in the present work synthesis of some benzofuranyl pyridinyl and benzofuranyl styryl pyridinyl substituted coumarins has been carried out.

## MATERIALS AND METHOD

**Chemistry:** All the melting points were determined in open capillaries and are

uncorrected. All solvents and reagents were obtained from commercial sources and used without any additional purification. All the IR spectra (KBr disc) were recorded on Shimadzu FT-IR 8400-S spectrometer. $^{1}$H-NMR and $^{13}$C-NMR spectra were recorded on a Bruker Avance 400 spectrometer operating at 400 MHz for $^{1}$H-NMR and 100 MHz for $^{13}$C-NMR. The chemical shift (δ) is reported in ppm using chloroform-d as a solvent and calibrated standard solvent signal. Mass spectra were recorded on Shimadzu QP 2010 spectrometer. The compounds were purified by column chromatography using silica gel (60-120 mesh). Thin layer chromatography was performed on precoated silica gel on aluminum sheets (Kieselgel 60, F254, Merck) and spots were visualized with UV light (254 nm) and/or in an iodine chamber.

Starting precursors 3-acetyl coumarins (**1a-b)** [15] and benzofuranoyl methyl pyridinium iodide salts **6a-c** [16] were prepared according to reported procedures.

***General procedure for the synthesis of 3-cinnamoyl coumarins (4a-d) and 3-(5-arylpenta-2,4-dienoyl)coumarins (5a-d)***

In a 100 mL round bottom flask, an appropriate 3-acetyl coumarin (0.01 mol) and appropriate benzaldehydes (0.01 mol) or an appropriate cinnamaldehyde (0.01 mol) were taken in 50 mL of ethanol. Catalytic amount of piperidine (1.0 mL) was added and the reaction mixture was stirred for 10 minutes at room temperature. The reaction mixture was then refluxed on water bath for 4 hours. It was then allowed to cool to room temperature. A solid product separated out was filtered off, washed with cold ethanol and dried. It was recrystallized from ethanol.

Compound 4a: R = $R_1$ =H; Yield: 65%, mp 157-159˚C (lit. [17] mp 159-160˚C)

Compound 4b: R = $OCH_3$, $R_1$= H; Yield: 59%, mp 146-147˚C (lit. [18] mp 148-149˚C)

Compound 4c: R =H, $R_1$ = $OCH_3$; Yield: 68%, mp 79-80˚C (lit. [17] mp 79˚C)

Compound 4d: R = $R_1$= $OCH_3$; Yield: 65%, mp 150-151˚C (lit. [18] mp 151-152˚C)

Compound 5a: R=$R_1$=H, Yield: 80%; mp: 182-184°C (lit. [19] mp 184˚C)

Compound 5b: R = $OCH_3$, $R_1$ = H, Yield = 82%; mp 208-210°C (lit. [20] mp 209-210˚C)

Compound 5c: R =H, $R_1$ = $OCH_3$; 82%; mp 198-201°C (lit. [20] mp 199-201˚C)

Compound 5d: R = $R_1$= $OCH_3$; 86%; mp 217-219°C (lit. [20] mp 220˚C)

***General procedure for the synthesis of 3-[6-(benzofuran-2-yl)-4-arylpyridin-2-yl]coumarins (7a-l) and 3-[6-(benzofuran-2-yl)-4-styrylpyridin-2-yl]coumarins (8a-l)***

In a 100 mL round bottom flask equipped with a condenser, guard tube and magnetic needle, an appropriate benzofuranoyl methyl pyridinium iodide salt **6a or 6b or 6c** (0.003 mole) in glacial acetic acid (10mL) was taken. To this, ammonium acetate (0.03 mole) was added with stirring at room temperature. Then a solution of an appropriate 3-cinnamoyl coumarins (**4a-d)** or 3-(5- arylpenta-2,4-dienoyl)coumarins (**5a-d)** (0.003 mole) in glacial acetic acid (15 mL) was added with stirring at room temperature. The reaction was further stirred for 1 hour at room temperature and then refluxed for 8 hours at 140°C. It was then allowed to come to room temperature and was poured into ice-cold water (75 mL). A crude solid obtained was extracted with chloroform (3 x 30 mL). The organic layer was washed with 5% sodium bicarbonate solution (3 x 20 mL), water (2 x 20 mL) and dried over anhydrous sodium sulfate. The removal of chloroform under reduced pressure gave crude material which was subjected to column chromatography using silica gel and chloroform-petroleum ether (60-80) (1:4) as an eluent to give an appropriate compound (**7a-l)** or **(8a-l)** which was recrystallized from chloroform-hexane.

The reaction proceeded smoothly and gave the expected products (**7a-l) and (8a-l)** in moderate yield (45-67%). The structures of the compounds (**7a-l)** and (**8a-l)** were established on the basis of IR, $^{1}$H-NMR, $^{13}$C-NMR spectral data and elemental analysis and representative data are given below.

***3-[6-(Benzofuran-2-yl)-4-phenylpyridin-2-yl] coumarin (7a)***

White solid; yield = 57%; mp 250˚C, Anal. Calcd. for $C_{28}H_{17}NO_3$ :C, 80.95; H, 4.12; N, 3.37%. Found: C, 80.91; H, 4.16; N, 3.35%. IR (KBr, $v_{max}$, $cm^{-1}$):1730 (C=O stretching of δ-lactone of coumarin), 1612 and 1452 (aromatic C=C and C=N stretchings), 750 and 698 (C-H bending vibrations of mono substituted benzene ring), 3052 (aromatic C-H stretching), $^1$H-NMR (400MHz, $CDCl_3$,δ): 7.29-8.68 (16 H, multiplet, aromatic protons), 8.98 (1H, singlet, $C_4$-H of coumarin ring), $^{13}$C-NMR (100MHz, $CDCl_3$, δ ): 105.17(CH), 111.59(CH), 116.44(CH), 117.37(CH), 119.57(C), 121.30(CH), 121.72(CH), 123.29(CH), 124.65(CH), 125.09(C), 125.30(CH), 127.33(CH), 128.86(C), 129.00(CH), 129.13(CH), 129.32(CH), 132.29(CH), 138.08(C), 143.03(CH), 149.26(C), 150.03(C), 151.83(CH), 154.02(C), 155.29(C), 155.37(C), 160.34δ (CO of the coumarin). The mass spectrum of compound showed $M^+$ peak at 415(49%) (m/z%) alongwith some other fragments peaks at 386(20%), 324(50%), 272(100%) etc. The appearance of molecular ion peak at 415 mass unit supports the structure of compound **7a**.

***8-Methoxy-3-[6-(7-methoxybenzofuran-2-yl)-4-phenylpyridin-2-yl]coumarin (7b)***

White solid; yield = 64%; mp 234-236 ˚C, Anal. Calcd. for $C_{30}H_{21}NO_5$ : C, 75.78; H, 4.45; N, 2.95%, Found: C, 75.80; H, 4.49; N, 2.92%. IR (KBr, $v_{max}$, $cm^{-1}$): 1741 (C=O stretching of δ-lactone of coumarin), 1611 and 1472 (aromatic C=C and C=N stretchings), 771 and 701 (C-H bending vibrations of mono substituted benzene ring), 2918 (aliphatic C-H stretching), 3040 (aromatic C-H stretching), $^1$H-NMR (400MHz, $CDCl_3$,δ): 4.04 and 4.10 (6H, two singlets, 2 x $OCH_3$), 6.89-8.69 (14H, multiplet, aromatic protons), 8.97 (1H, singlet, $C_4$-H of coumarin ring), $^{13}$C-NMR (100MHz,$CDCl_3$,δ): 56.26($OCH_3$), 56.43($OCH_3$), 107.46(CH), 113.25(CH), 116.27(C), 116.40(CH), 117.46(CH), 119.06(C), 119.57(C), 121.56(C), 124.26(CH), 124.52(CH), 124.86(CH), 127.22(C), 128.16(CH), 129.01(CH), 129.15(CH), 129.40(CH), 130.79(C), 132.35(CH), 137.82(C), 143.01(CH), 148.65(C), 150.00(C), 151.85(C), 154.15 (C), 156.02(C), 160.26(CO of coumarin).

***3-[6-(5-Bromobenzofuran-2-yl)-4-(4-methoxy phenyl)pyridin-2-yl)]coumarin (7c)***

White solid; yield = 65%; mp 215-216˚C, Anal. Calcd. for $C_{29}H_{18}BrNO_4$ : C, 66.43; H, 3.46; N, 2.67%, Found: C, 66.49; H, 3.41; N, 2.62%. IR (KBr, $v_{max}$, $cm^{-1}$): 1712 (C=O stretching of δ-lactone of coumarin), 1605 and 1470 (aromatic C=C and C=N stretchings), 828 (C-H bending vibrations of p-disubstituted benzene ring), 2924 (aliphatic C-H stretching), 3056(aromatic C-H stretching),$^1$H-NMR (400MHz, $CDCl_3$,δ): 4.04 (3H, singlet, $OCH_3$), 7.37-8.70 (14H, multiplet, aromatic protons), 8.96 (1H, singlet, $C_4$-H of coumarin ring), $^{13}$C-NMR (100MHz,$CDCl_3$,δ): 56.35($OCH_3$), 104.43(CH), 113.06(CH), 116.00(CH), 116.37(C), 117.42(CH), 117.86(C), 119.46(C), 121.56(C), 124.25(CH), 124.62(CH), 124.82(CH), 127.26(C), 128.12(CH), 129.05(CH), 129.14(CH), 129.40(CH), 130.79(C), 132.31(CH), 137.84(C), 143.01(CH), 148.64(C), 150.02(C), 151.85(C), 154.02(C), 156.42(C), 160.48 (CO of coumarin).

***3-[6-(Benzofuran-2-yl)-4-(4-methoxyphenyl) pyridin-2-yl)]8-methoxycoumarin (7d)***

White solid; yield = 53%; mp 194-195˚C, Anal. Calcd. for $C_{30}H_{21}NO_5$ : C, 75.78; H, 4.45; N, 2.95%, Found: C, 75.73; H, 4.42; N, 2.98%. IR (KBr, $v_{max}$, $cm^{-1}$): 1736 (C=O stretching of δ-lactone of coumarin), 1610 and 1463 (aromatic C=C and C=N stretchings), 824 (C-H bending vibrations of p-disubstituted benzene ring), 2925 (aliphatic C-H stretching),3052(aromatic C-H stretching), $^1$H-NMR (400MHz, $CDCl_3$,δ): 3.98 and 4.04 (6H, two singlets, 2 x $OCH_3$), 7.15-8.52 (14H, multiplet, aromatic protons), 8.94 (1H, singlet, $C_4$-H of coumarin ring)., $^{13}$C-NMR (100MHz,$CDCl_3$,δ): 55.12($OCH_3$), 56.39($OCH_3$), 106.12(CH), 111.89(CH), 116.44(CH), 119.34(C), 119.62(CH), 121.10(C), 121.87(C), 123.06(CH), 123.65(CH), 124.89(C), 125.22(CH), 125.37(CH), 127.70(C), 128.53(CH), 130.02(CH), 130.11(CH), 133.21(CH), 139.36(C), 141.19(C), 143.68(CH),

149.12(C), 151.65(C), 153.93(C), 154.70(C), 159.83(CO of coumarin).

***3-[6-(7-Methoxybenzofuran-2-yl)-4-phenyl-pyridin-2-yl]coumarin (7e)***

White solid; yield = 59%; mp 223-225˚C, Anal. Calcd. for $C_{29}H_{19}NO_4$ :C, 78.19; H, 4.30; N, 3.14%, Found: C, 78.24; H, 4.46; N, 3.10%. IR (KBr, $v_{max}$, $cm^{-1}$): 1729 (C=O stretching of δ-lactone of coumarin), 1610 and 1454 (aromatic C=C and C=N stretchings), 760 and 710 (C-H bending vibrations of mono substituted benzene ring), 2924 (aliphatic C-H stretching), 3060 (aromatic C-H stretching).,$^1$H-NMR (400MHz, $CDCl_3$,δ): 4.10 (3H, singlet, $OCH_3$), 6.89-8.67 (15H, multiplet, aromatic protons), 8.92 (1H, singlet, $C_4$-H of coumarin ring)., $^{13}$C-NMR (100MHz, $CDCl_3$, δ ): 55.73($OCH_3$), 113.17(CH), 114.00(CH), 116.45(CH), 117.40(CH), 119.61(CH) 120.62(C) 121.40(CH) 123.98(CH), 124.66(CH), 125.11(C), 127.43(CH), 124.66(CH), 125.11(C), 127.43(CH), 129.00(CH), 129.11(CH), 129.32(CH), 130.50(C), 132.19(CH), 138.03(C), 143.03(CH), 145.27(C), 149.23(C), 150.22(C), 151.77(C), 153.39(C), 154.02(C), 155.50 (C), 160.29(CO of coumarin).

***3-([6-(5-Bromobenzofuran-2-yl)-4-phenyl-pyridin-2-yl]8-methoxycoumarin (7f)***

White solid; yield = 64%; mp 220˚C, Anal. Calcd. for $C_{29}H_{18}BrNO_4$ : C, 71.44; H, 3.89; N, 2.67%, Found: C, 71.37; H, 3.92; N, 2.63%. IR (KBr, $v_{max}$, $cm^{-1}$): 1734 (C=O stretching of δ-lactone of coumarin), 1602 and 1460 (aromatic C=C and C=N stretchings), 745 and 697 (C-H bending vibrations of mono substituted benzene ring), 2922 (aliphatic C-H stretching), 3058 (aromatic C-H stretching), $^1$H-NMR (400MHz, $CDCl_3$,δ): 4.03 (3H, singlet, $OCH_3$), 7.15-8.13 (14H, multiplet, aromatic protons), 8.71 (1H, singlet, $C_4$-H of coumarin ring), $^{13}$C-NMR (100MHz,$CDCl_3$,δ): 56.26($OCH_3$), 104.40(CH), 113.07(CH), 114.00(CH), 116.28(CH), 117.54(C), 119.69(C), 120.16(CH), 120.42(CH), 123.83CH), 124.22(CH), 124.53(C), 125.13(CH), 126.99(C), 127.33(C), 128.13(CH), 129.09(CH), 129.37(CH), 130.83(C), 137.87C), 143.13(CH), 149.23(C), 150.27(C), 152.06(C), 154.16(C), 156.47(C), 160.29(CO of coumarin).

***3-[6-(Benzofuran-2-yl)-4-(4-methoxyphenyl) pyridin-2-yl]coumarin (7g)***

White solid; yield = 66%; mp 224-225˚C, Anal. Calcd. for $C_{29}H_{19}NO_4$ : C, 78.19; H, 4.30; N, 3.14%, Found: C, 78.23; H, 4.34; N, 3.19%. IR (KBr, $v_{max}$, $cm^{-1}$): 1735 (C=O stretching of δ-lactone of coumarin), 1608 and 1460 (aromatic C=C and C=N stretchings), 830 (C-H bending vibrations of p-disubstituted benzene ring), 2929 (aliphatic C-H stretching), 3052(aromatic C-H stretching, $^1$H-NMR (400MHz, $CDCl_3$,δ): 4.04 (3H, singlet, $OCH_3$), 6.89-8.69 (15H, multiplet, aromatic protons), 8.97 (1H, singlet, $C_4$-H of coumarin ring), $^{13}$C-NMR(100MHz,$CDCl_3$,δ): 55.79($OCH_3$), 105.19(CH), 111.54(CH), 116.37(CH), 117.30(CH), 119.57(C), 121.29(CH), 121.72(CH), 123.20(C), 124.65(CH), 125.03(C), 125.39(CH), 127.33(CH), 128.86(C), 129.03(CH), 129.13(CH), 129.32(CH), 132.23(CH), 138.26(C), 143.03(CH), 149.26(C), 150.87(C), 151.83(C), 154.7(C), 155.02(C), 155.37(C), 160.33(CO of coumarin).

***8-Methoxy-3-[6-(7-methoxybenzofuran-2-yl)-4-(4-methoxyphenyl)pyridin-2-yl)]coumarin (7h)***

White solid; yield = 58%; mp 215-216 ˚C Anal. Calcd. for $C_{31}H_{23}NO_6$: C, 73.65; H, 4.59; N, 2.77%, Found: C, 73.61; H, 4.53; N, 2.81%. IR (KBr, $v_{max}$, $cm^{-1}$): 1719 (C=O stretching of δ-lactone of coumarin), 1599 and 1464 (aromatic C=C and C=N stretchings), 821 (C-H bending vibrations of p-disubstituted benzene ring), 2920 (aliphatic C-H stretching),3068(aromatic C-H stretching), $^1$H-NMR (400MHz, CDCl3,δ): 3.91 and 4.10 (9H, two singlets, 3 x $OCH_3$), 6.89-8.64 (13H, multiplet, aromatic protons), 8.98 (1H, singlet, $C_4$-H of coumarin ring),$^{13}$C-NMR (100MHz,$CDCl_3$,δ): 55.82($OCH_3$), 56.26($OCH_3$), 56.43($OCH_3$), 104.46(CH), 113.01(CH), 116.27(C), 116.40(CH), 117.46(C), 119.07(C), 119.87(C), 121.56(C), 124.26(CH), 124.52(CH), 124.82(CH), 127.26(C), 128.12(CH), 129.01(CH), 129.15(CH), 129.40(CH), 130.79(C), 132.35(CH), 137.82(C), 143.01(CH),

148.65(C), 150.02(C), 151.86(C), 154.26(C), 156.02(C), 159.85(CO of coumarin).

***3-[6-(5-Bromobenzofuran-2-yl)-4-phenylpyridin-2-yl]coumarin (7i)***

White solid; yield = 61%; mp 273-275˚C, Anal. Calcd. for $C_{28}H_{16}BrNO_4$ : C, 68.03; H, 3.26; N, 2.83%, Found: C, 68.01; H, 3.21; N, 2.86%. IR (KBr, $\nu_{max}$, $cm^{-1}$): 1735 (C=O stretching of δ-lactone of coumarin), 1613 and 1460 (aromatic C=C and C=N stretchings), 758 and 715 (C-H bending vibrations of mono substituted benzene ring), 3032 (aromatic C-H stretching).,$^1$H-NMR (400MHz, $CDCl_3$,δ): 7.34-8.67 (15H, multiplet, aromatic protons), 8.92 (1H, singlet, $C_4$-H of coumarin ring)., $^{13}$C-NMR (100MHz, $CDCl_3$, δ ): 104.37(CH), 113.01(CH), 116.35(C), 116.43(CH), 117.40(CH), 119.47(C), 121.56(CH), 124.21(CH), 124.66(CH), 124.82(C), 127.26(CH), 128.12(CH), 129.01(CH), 129.14(CH), 129.40(CH), 130.79(C), 132.35(CH), 137.84(C), 143.01(CH), 148.64(C), 150.02(C), 151.87(C), 154.01(C), 156.48(C), 160.26(CO of coumarin).

***3-[6-(Benzofuran-2-yl)-4-phenylpyridin-2-yl]-8-methoxycoumarin (7j)***

White solid; yield = 57%; mp 233-235˚C, Anal. Calcd. for $C_{29}H_{19}NO_4$ : C, 78.19; H, 4.30; N, 3.14%, Found: C, 78.21; H, 4.34; N, 3.10%. IR (KBr, $\nu_{max}$, $cm^{-1}$): 1737 (C=O stretching of δ-lactone of coumarin), 1615 and 1456 (aromatic C=C and C=N stretchings), 768 and 692 (C-H bending vibrations of mono substituted benzene ring), 2922 (aliphatic C-H stretching), 3062 (aromatic C-H stretching), $^1$H-NMR (400MHz, $CDCl_3$,δ): 4.15 (3H, singlet, $OCH_3$), 7.37-8.63 (15H, multiplet, aromatic protons), 9.34 (1H, singlet, $C_4$-H of coumarin ring),$^{13}$C-NMR (100MHz,$CDCl_3$,δ): 56.64($OCH_3$), 112.34(CH), 112.61(C), 112.93(CH), 115.74(C), 118.42(CH), 118.75(CH), 118.96(CH), 121.84(CH), 123.29(CH), 125.28(CH), 127.12(CH), 127.40(C), 127.76(CH), 129.58(CH), 130.14(CH), 133.01(CH), 134.00(C), 140.81(C), 144.23(C), 145.95(C), 147.15(C), 148.95(CH), 156.44(C), 159.04(C), 160.90(C), 161.03(CO of coumarin).

***3-[6-(7-Methoxybenzofuran-2-yl)-4-(4-methoxy phenyl)pyridin-2-yl)]coumarin (7k)***

White solid; yield = 65%; mp 197˚C, Anal. Calcd. for $C_{30}H_{21}NO_5$ : C, 75.78; H, 4.45; N, 2.95%, Found: C, 75.72; H, 4.49; N, 2.92%. IR (KBr, $\nu_{max}$, $cm^{-1}$): 1732 (C=O stretching of δ-lactone of coumarin), 1620 and 1459 (aromatic C=C and C=N stretchings), 831 (C-H bending vibrations of p-disubstituted benzene ring), 2932 (aliphatic C-H stretching), 3065(aromatic C-H stretching).,$^1$H-NMR (400MHz, $CDCl_3$,δ): 3.91 and 4.10 (6H, two singlets, 2 x $OCH_3$), 6.89-8.64 (14H, multiplet, aromatic protons), 8.98 (1H, singlet, $C_4$-H of coumarin ring), $^{13}$C-NMR (100MHz,$CDCl_3$,δ): 55.43($OCH_3$), 56.09($OCH_3$), 105.41(CH), 107.25(CH), 113.98(CH), 114.47(CH), 116.43(CH), 116.74(CH), 119.62(C), 120.79(CH), 123.91(CH), 124.60(CH), 125.24(C), 128.63(CH), 128.96(CH), 130.33(C), 130.60(C), 132.18(CH), 142.89(CH), 145.52(C), 149.11(C), 149.55(C), 151.66(C), 154.03(C), 155.69(C), 160.35(C), 60.73(CO of coumarin).

***3-[6-(5-Bromobenzofuran-2-yl)-4-(4-methoxy phenyl)pyridin-2-yl)]8-methoxycoumarin (7l)***

White solid; yield = 58%; mp 220˚C Anal. Calcd. for $C_{30}H_{20}BrNO_5$ : C, 64.99; H, 3.64; N, 2.53%, Found: C, 64.95; H, 3.68; N, 2.58%. IR (KBr, $\nu_{max}$, $cm^{-1}$): 1715 (C=O stretching of δ-lactone of coumarin), 1600 and 1474 (aromatic C=C and C=N stretchings), 829 (C-H bending vibrations of p-disubstituted benzene ring), 2930 (aliphatic C-H stretching),3045(aromatic C-H stretching), $^1$H-NMR (400MHz, $CDCl_3$,δ): 3.91 and 4.04 (6H, two singlets, 2 x $OCH_3$), 7.51-8.62 (13H, multiplet, aromatic protons), 8.94 (1H, singlet, $C_4$-H of coumarin ring), $^{13}$C-NMR (100MHz,$CDCl_3$,δ): 55.53($OCH_3$), 56.39($OCH_3$), 105.47(CH), 107.25(CH), 113.79(CH), 114.47(CH), 116.43(CH), 116.74(CH), 117.30(C), 119.62(C), 120.79(C), 123.71(CH), 124.60(CH), 125.24(C), 128.63(CH), 128.91(CH), 130.33(C), 130.61(C), 132.18(CH), 142.81(CH), 145.52(C), 149.11(C), 149.60(C), 151.65(C), 154.13(C), 155.63(C), 160.35(C), 160.75(CO of coumarin).

***3-[6-(Benzofuran-2-yl)-4-styrylpyridin-2-yl] coumarin (8a)***

White solid; yield = 67%; mp 233-235˚C Anal. Calcd. for $C_{30}H_{19}NO_3$ :C, 81.62; H, 4.32; N, 3.17%, Found: C, 81.60; H, 4.38; N, 3.19%. IR (KBr, $\nu_{max}$, $cm^{-1}$):1726 (C=O stretching of δ-lactone of coumarin), 1606 and 1453 (aromatic C=C and C=N stretchings), 748 and 688 (C-H bending vibrations of mono substituted benzene ring), 3060 (aromatic C-H stretching), $^1$H-NMR (400MHz, $CDCl_3$,δ): 7.16-8.52 δ (18H, multiplet, sixteen aromatic protons + two olefinic protons), 8.98 (1H, singlet, $C_4$-H of coumarin ring). $^{13}$C-NMR (100MHz, $CDCl_3$, δ ): 105.17(CH), 111.54(CH), 116.30(CH), 116.40(CH), 119.58(C), 120.71(CH), 121.68(CH), 123.26(CH), 124.60(C), 124.97(CH), 125.24(CH), 126.14(CH), 127.20(C), 128.80(CH), 128.86(CH), 128.98(CH), 132.22(CH), 133.79(CH), 136.24(C), 142.90(CH), 146.15(C), 149.15(C), 151.67(C), 154.01(C), 155.36(C), 160.33δ.δ.(COof coumarin). The mass spectrum of compound showed $M^+$ peak at 441(6%) (m/z%) alongwith some other fragments peaks at 44(100%), 412(25%), 382(16%), etc. The appearance of molecular ion peak at 441 mass unit supports the structure of compound **8a**.

***8-Methoxy-3-[6-(7-methoxybenzofuran-2-yl)-4-styrylpyridin-2-yl]coumarin (8b)***

White solid; yield = 54%; mp 234-235˚C, Anal. Calcd. for $C_{32}H_{23}NO_5$ :C, 76.63; H, 4.62 N, 2.79%, Found: C, 76.67; H, 4.68; N, 2.72%, IR (KBr, $\nu_{max}$,$cm^{-1}$): 1725 (C=O stretching of δ-lactone of coumarin), 1618 and 1454 (aromatic C=C and C=N stretchings), 745 and 681 (C-H bending vibrations of mono substituted benzene ring), 2918 (aliphatic C-H stretching), 3025 (aromatic C-H stretching),$^1$H-NMR (400MHz, $CDCl_3$,δ). 3.95 and 4.03 (6H, two singlets, 2 x $OCH_3$), 6.96-8.52 (16H, multiplet, fourteen aromatic protons + two olefinic protons), 8.08 (1H, singlet, $C_4$-H of coumarin ring), $^{13}$C-NMR (100MHz, $CDCl_3$, δ): 55.50($OCH_3$), 56.89($OCH_3$), 110.09(CH), 111.07(CH), 116.37(CH), 116.45(C), 119.64(C), 120.47(C), 121.07(CH), 121.64CH), 122.07(CH), 123.27(CH), 124.63(CH), 125.10(CH), 125.28(C), 126.68(CH), 127.48(CH), 128.90(CH), 129.08(C), 129.95(CH), 132.19(CH), 143.03(CH), 147.16(C), 149.14(CH), 151.51(C), 153.94 (C), 155.13(C), 155.46C), 157.14(C), 160.57(CO of coumarin).

***3-[6-(5-Bromobenzofuran-2-yl)-4-(2-methoxy styryl)pyridin-2-yl]coumarin (8c)***

White solid; yield = 65%; mp 219-220 ˚C, Anal. Calcd. for $C_{31}H_{20}BrNO_4$ :C, 67.65; H, 3.66 N, 2.54%, Found: C, 67.61; H, 3.61; N, 2.52%, IR (KBr, $\nu_{max}$,$cm^{-1}$): 1730 (C=O stretching of δ-lactone of coumarin), 1625 and 1468 (aromatic C=C and C=N stretchings), 2919 (aliphatic C-H stretching), 3055(aromatic C-H stretching), $^1$H-NMR (400MHz, $CDCl_3$,δ).98 (3H, singlet, $OCH_3$), 6.96-8.51 (16H, multiplet, fourteen aromatic protons + two olefinic protons), 8.96 (1H, singlet, $C_4$-H of coumarin ring), $^{13}$C-NMR (100MHz, $CDCl_3$, δ ): 55.57($OCH_3$), 100.08(CH), 104.98(CH), 111.08(CH), 111.56(CH), 116.32(C), 116.41(C), 119.84(CH), 120.85(C), 121.02(CH), 121.65(CH), 123.23(CH), 124.60(CH), 125.18(CH), 125.33(CH), 126.71(C), 127.45(CH), 128.92(CH), 128.96(CH), 129.02(C), 129.93(CH), 132.17(CH), 142.87(CH), 147.13(C), 149.10(C), 151.70(C), 154.02(C), 155.37(C), 157.49(C), 160.40(CO of coumarin).

***3-[(6-(Benzofuran-2-yl)-4-(2-methoxy styryl) pyridin -2-yl]8-methoxycoumarin (8d)***

White solid; yield = 53%; mp 198˚C, Anal. Calcd. for $C_{32}H_{23}NO_5$ : C, 76.63; H, 4.62 N, 2.79%, Found: C, 76.68; H, 4.68; N, 2.75%, IR (KBr, $\nu_{max}$,$cm^{-1}$): $\nu_{max}$ 1704 (C=O stretching of δ-lactone of coumarin), 1609 and 1452 (aromatic C=C and C=N stretchings), 2918(aliphatic C-H stretching), 3061 (aromatic C-H stretching),$^1$H-NMR (400MHz, $CDCl_3$,δ): 3.98 and 4.04 (6H, two singlets, 2 x $OCH_3$), 6.96-8.52 (16H, multiplet, fourteen aromatic protons + two olefinic protons), 8.94 (1H, singlet, $C_4$-H of coumarin ring), $^{13}$C-NMR (100MHz, $CDCl_3$, δ): 55.57($OCH_3$), 56.33($OCH_3$), 100.08(CH), 104.96(CH), 111.08(CH), 111.56(CH), 116.32(CH), 116.41(CH), 119.64(C), 120.85(C), 121.02(CH), 121.65(C), 123.23(CH),

124.60(CH), 125.18(CH), 125.33(CH), 126.71(CH), 127.45(C), 128.92(CH), 128.96(CH), 129.02(CH), 129.93(C), 132.17(CH), 142.87(CH), 147.13(C), 149.10(C), 151.70(C), 154.02(C), 155.37(C), 157.49(C), 159.47(C), 160.40(CO of coumarin).

***3-[6-(7-Methoxybenzofuran-2-yl)-4-styryl pyridin-2-yl]coumarin (8e)***

White solid; yield = 55%; mp 245-246˚C Anal. Calcd. for $C_{31}H_{21}NO_4$ :C, 78.97; H, 4.49; N, 2.97%, Found: C, 78.94; H, 4.46; N, 3.01%. IR (KBr, $\nu_{max}$, $cm^{-1}$): 1730 (C=O stretching of δ-lactone of coumarin), 1625 and 1460 (aromatic C=C and C=N stretchings), 745 and 690 (C-H bending vibrations of mono substituted benzene ring), 2935 (aliphatic C-H stretching), 3055 (aromatic C-H stretching),$^1$H-NMR (400MHz, $CDCl_3$,δ): 4.04 (3H, singlet, $OCH_3$), 7.09-8.55 (17H, multiplet, fifteen aromatic protons + two olefinic protons), 8.86 (1H, singlet, $C_4$-H of coumarin ring), $^{13}$C-NMR (100MHz, $CDCl_3$, δ ): 55.59($OCH_3$), 104.09(CH), 111.00(C), 116.37(CH), 116.45(C), 119.64(CH), 120.47(C), 121.07(CH), 121.64(CH), 122.07(CH), 123.24(CH), 124.63(CH), 125.20(CH), 125.28(C), 126.68(CH), 127.48(CH), 128.90(CH), 129.08(C), 129.91(CH), 132.19(CH), 143.03(CH), 147.16(C), 149.14(C), 151.66(C), 153.99(C), 155.16(C), 155.49(C), 157.46(C), 160.43 (CO of coumarin).

***3-[6-(5-Bromobenzofuran-2-yl)-4-styrylpyridin-2-yl]8-methoxycoumarin (8f)***

White solid; yield = 61%; mp 223 ˚C, Anal. Calcd. for $C_{31}H_{20}BrNO4$ :C, 67.65; H, 3.66 N, 2.54%, Found: C, 67.61; H, 3.70; N, 2.51%, IR (KBr, $\nu_{max}$,$cm^{-1}$): $\nu_{max}$ 1728 (C=O stretching of δ-lactone of coumarin), 735 and 689 (C-H bending vibrations of mono substituted benzene ring), 1600 and 1456 (aromatic C=C and C=N stretchings), 2928 (aliphatic C-H stretching), 3070 (aromatic C-H stretching),$^1$H-NMR (400MHz, CDCl3,δ3. 4.09 (3H, singlet, $OCH_3$), 7.15-8.56 (16H, multiplet, fourteen aromatic protons + two olefinic protons), 8.95 (1H, singlet, $C_4$-H of coumarin ring), $^{13}$C-NMR (100MHz, $CDCl_3$, δ):56.84($OCH_3$), 105.03(CH), 111.54(CH), 116.38(CH), 116.40(C), 117.23(CH), 119.58(CH), 120.71(C), 121.68(CH), 123.26(CH), 124.60(C), 124.97(CH), 125.34(C), 126.14(CH), 127.03(C), 127.98(C), 128.30(CH), 128.82(CH), 128.96(CH), 132.29(CH), 133.49(CH), 136.24(C), 142.64(CH), 146.37(C), 149.15(C), 151.77(C), 154.06(C), 155.36(C), 160.98(CO of coumarin).

***3-[6-(Benzofuran-2-yl)-4-(2-methoxy styryl) pyridin-2-yl]coumarin (8g)***

White solid; yield = 62%; mp 210˚C, Anal. Calcd. for $C_{31}H_{21}NO_4$ :C, 78.97; H, 4.49; N, 2.97%, Found: C, 78.93; H, 4.47; N, 2.93%. IR (KBr, $\nu_{max}$,$cm^{-1}$): 1725 (C=O stretching of δ-lactone of coumarin), 1610 and 1460 (aromatic C=C and C=N stretchings), 2929 (aliphatic C-H stretching), 3058(aromatic C-H stretching), $^1$H-NMR (400MHz, $CDCl_3$,δ): 3.98 (3H, singlet, $OCH_3$), 6.97-8.51 (17H, multiplet, fifteen aromatic protons + two olefinic protons), 8.96 (1H, singlet, $C_4$-H of coumarin ring), $^{13}$C-NMR (100MHz, $CDCl_3$, δ ): 55.58($OCH_3$), 100.01(CH), 104.99(CH), 111.06(CH), 111.60(CH), 116.31(CH), 116.45(C), 119.64(CH), 120.87(C), 121.07(CH), 121.68(CH), 122.00(CH), 123.24(CH), 124.63(CH), 125.20(CH), 125.28(C), 126.68(CH), 127.42(CH), 128.90(CH), 129.08(C), 129.91(CH), 132.19(CH), 143.03(CH), 147.16(C), 149.14(C), 151.66(C), 153.99(C), 155.13(C), 155.49(C), 157.47(C), 160.40 (CO of coumarin).

***8-Methoxy-3-[6-(7-methoxybenzofuran-2-yl)-4-(2-methoxystyryl)pyridin-2-yl]coumarin (8h)***

White solid; yield = 60%; mp 225˚C, Anal. Calcd. for $C_{33}H_{25}NO_6$ : C, 74.56; H, 4.74 N, 2.64%, Found: C, 74.60; H, 4.71; N, 2.61%. IR (KBr, $\nu_{max}$,$cm^{-1}$): $\nu_{max}$ 1711 (C=O stretching of δ-lactone of coumarin), 1660 and 1450 (aromatic C=C and C=N stretchings), 2915 (aliphatic C-H stretching), 3069(aromatic C-H stretching),$^1$H-NMR (400MHz, $CDCl_3$,δ). 4.04 (3H, singlet, $OCH_3$), 3.97 and 4.11 (6H, two singlets, 2 x $OCH_3$), 6.76-8.78 (15H, multiplet, thirteen aromatic protons + two olefinic protons), 9.17 (1H, singlet, $C_4$-H of coumarin ring), $^{13}$C-NMR (100MHz, $CDCl_3$, δ): 55.58($OCH_3$),

55.85($OCH_3$), 56.49($OCH_3$), 100.00(CH), 105.06(CH), 111.08(CH), 111.56(CH), 116.32(C), 116.46(C), 119.64(C), 120.85(C), 121.05(CH), 121.65(CH), 123.23(CH), 124.60(CH), 125.18(CH), 125.33(C), 126.77(CH), 127.48(CH), 128.92(CH), 128.96(CH), 129.02(C), 129.93(CH), 132.17(CH), 142.87(CH), 147.13(C), 149.10(C), 151.77(C), 154.00(C), 155.33(C), 157.02(C), 159.37(C) , 160.47(CO of coumarin).

***3-[6-(5-Bromobenzofuran-2-yl)-4-styrylpyridin-2-yl]coumarin (8i)***

White solid; yield = 65%; mp 243-245˚C, Anal. Calcd. for $C_{30}H_{18}BrNO_3$ :C, 69.24; H, 3.49; N, 2.69%, Found: C, 69.29; H, 3.43; N, 2.66%. IR (KBr, $\nu_{max}$,$cm^{-1}$): 1729 (C=O stretching of δ-lactone of coumarin), 1625 and 1458 (aromatic C=C and C=N stretchings), 765 and 690 (C-H bending vibrations of mono substituted benzene ring), 3059(aromatic C-H stretching, $^1$H-NMR (400MHz, $CDCl_3$,δ):, 6.97-8.51 (17H, multiplet, fifteen aromatic protons + two olefinic protons), 8.96 (1H, singlet, $C_4$-H of coumarin ring)., $^{13}$C-NMR (100MHz, $CDCl_3$, δ ): 106.24(CH), 111.85(CH), 116.44(CH), 119.30(CH), 119.67(C), 120.53(C), 120.88(CH), 121.26(CH), 123.32(CH), 123.78(CH), 124.85(C), 125.28(CH), 125.50(CH), 127.83(CH), 128.52(C), 130.14(CH), 130.23(CH), 133.26(CH), 139.37(C), 141.29(C), 142.05(CH), 145.74(C), 148.05(C), 150.85(C), 153.96(C), 154.16(C), 159.84 (CO of coumarin).

***3-[6-(Benzofuran-2-yl)-4-styrylpyridin-2-yl]-8-methoxy coumarin (8j)***

White solid; yield = 67%; mp 219-222 ˚C, Anal. Calcd. for $C_{31}H_{21}NO_4$ :C, 78.97; H, 4.49 N, 2.97%, Found: C, 78.92; H, 4.44; N, 2.97%, IR (KBr, $\nu_{max}$,$cm^{-1}$): 1710 (C=O stretching of δ-lactone of coumarin), 1622 and 1469 (aromatic C=C and C=N stretchings), 750 and 689 (C-H bending vibrations of mono substituted benzene ring), 2915 (aliphatic C-H stretching), 3070 (aromatic C-H stretching), $^1$H-NMR (400MHz, $CDCl_3$,). 4.04 (3H, singlet, $OCH_3$), 7.14-8.55 (17H, multiplet, fifteen aromatic protons + two olefinic protons), 8.86 (1H, singlet, $C_4$-H of coumarin ring), $^{13}$C-NMR (100MHz, $CDCl_3$, δ ): 55.35($OCH_3$), 105.04(CH), 111.59(CH), 116.37(CH), 116.60(C), 119.58(C), 120.71(CH), 121.08(C), 121.68(CH), 123.26(CH), 124.60(CH), 124.99(CH), 125.21(CH), 126.14(CH), 127.26(C), 127.86(C), 128.86(CH), 128.89(CH), 128.98(CH), 132.26(CH), 133.79(CH), 136.24(C), 142.90(CH), 146.37(C), 149.15(C), 151.67(C), 154.05(C), 155.37(C), 160.13(CO of coumarin).

***3-[6-(7-Methoxybenzofuran-2-yl)-4-(2-methoxy styryl)pyridin-2-yl]coumarin (8k)***

White solid; yield = 62%; mp 214-215˚C, Anal. Calcd. for $C_{32}H_{23}NO_5$ :C, 76.63; H, 4.62; N, 2.79% , Found: C, 76.64; H, 4.65; N, 2.75%, IR (KBr, $\nu_{max}$,$cm^{-1}$): 1728 (C=O stretching of δ-lactone of coumarin), 1620 and 1471 (aromatic C=C and C=N stretchings), 2925 (aliphatic C-H stretching), 3065(aromatic C-H stretching), $^1$H-NMR (400MHz, $CDCl_3$,δ): 3.90 and 4.03 (6H, two singlets, 2 x $OCH_3$), 7.03-8.68 (16H, multiplet, fourteen aromatic protons + two olefinic protons), 8.99 (1H, singlet, $C_4$-H of coumarin ring), $^{13}$C-NMR (100MHz, $CDCl_3$, δ ): 55.58($OCH_3$), 56.49($OCH_3$), 100.00(CH), 105.06(CH), 111.08(CH), 111.56(CH), 116.32(C), 116.46(C), 119.64(CH), 120.85(C), 121.05(CH), 121.65(CH), 123.23(CH), 124.60(CH), 125.18(CH), 125.33(CH), 126.77(C), 127.48(CH), 128.92(CH), 128.96(C), 129.02(CH), 129.93(CH), 132.17(CH), 142.87(CH), 147.13(C), 149.10(C), 151.77(C), 154.00(C), 155.33(C), 157.02(C), 159.37(C), 160.47 (CO of coumarin).

***3-[6-(5-Bromobenzofuran-2-yl)-4-(2-methoxy styryl)pyridin-2-yl]8-methoxycoumarin (8l)***

White solid; yield = 58%; mp 198˚C, Anal. Calcd. for $C_{32}H_{22}BrNO_5$ : C, 66.22; H, 3.82 N, 2.41%, Found: C, 66.28; H, 3.85; N, 2.39%, IR (KBr, $\nu_{max}$,$cm^{-1}$): $\nu_{max}$ 1730 (C=O stretching of δ-lactone of coumarin), 1605 and 1458 (aromatic C=C and C=N stretchings), ,2918 (aliphatic C-H stretching), 3015(aromatic C-H stretching), $^1$H-NMR (400MHz, $CDCl_3$,δ), 3.91 and 4.14 (6H, two singlets, 2 x $OCH_3$), 6.91-8.34 (15H, multiplet, thirteen aromatic protons + two olefinic protons), 8.98 (1H, singlet, $C_4$-H of

coumarin ring), $^{13}$C-NMR (100MHz, $CDCl_3$, δ): 55.58($OCH_3$), 55.85($OCH_3$), 56.49($OCH_3$), 100.00(CH), 105.06(CH), 111.08(CH), 111.56(CH), 116.32(C), 116.46(C), 119.64(C), 120.85(C), 121.05(CH), 121.65(CH), 123.23(CH), 124.60(CH), 125.18(CH), 125.33(C), 126.77(CH), 127.48(CH), 128.92(CH), 128.96(CH), 129.02(C), 129.93(CH), 132.17(CH), 142.87(CH), 147.13(C), 149.10(C), 151.77(C), 154.00(C), 155.33(C), 157.02(C), 159.37(C) and 160.47(CO of coumarin).

In case of compounds **7c, 7e, 7j** and **8c**, the number of non-equivalent carbon signals observed is one less and for compound **8a**, the number of non-equivalent carbon signals observed is two less than expected. This may be due to identical chemical shift of carbons which may appear at the same position.

## RESULTS AND DISCUSSION

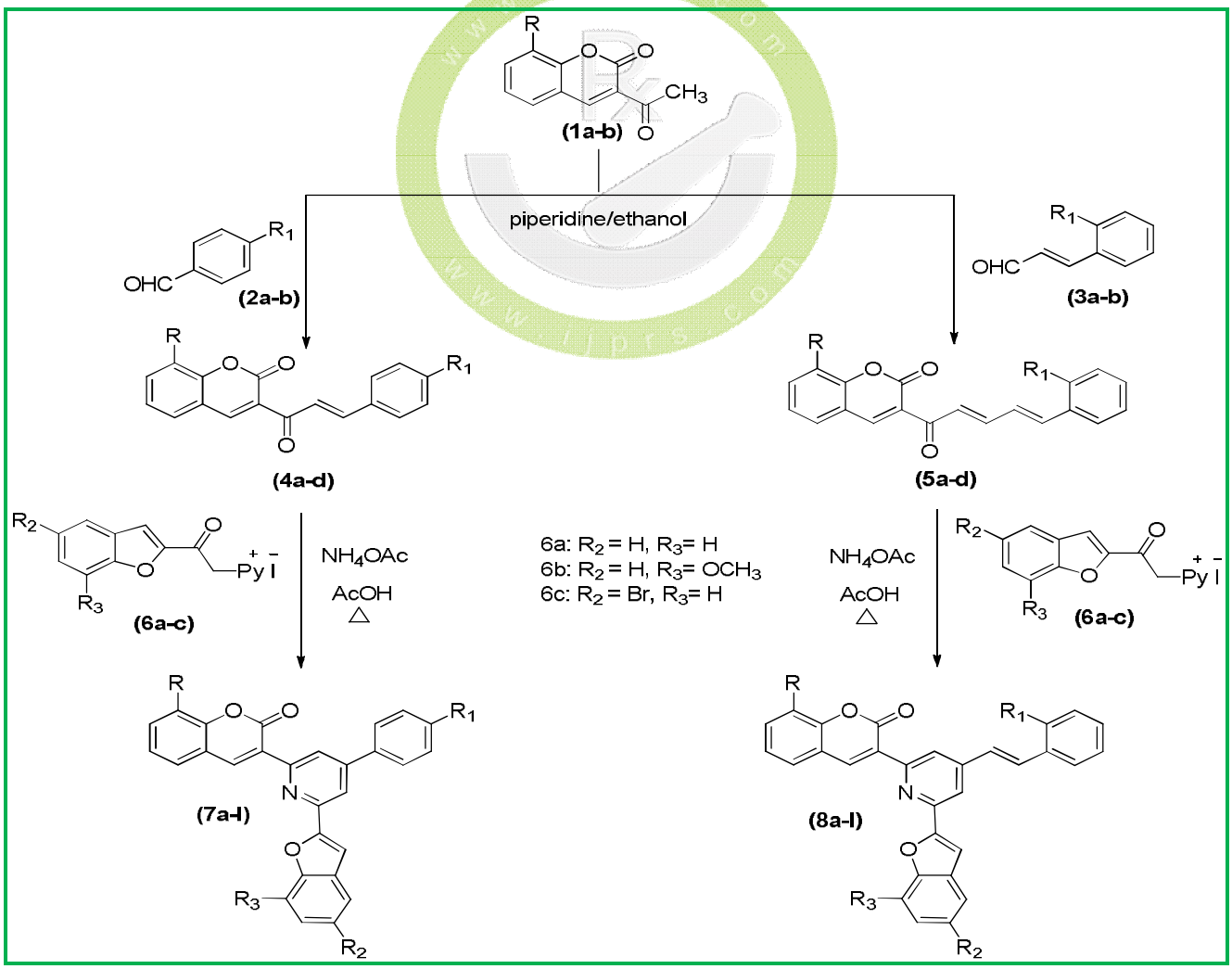
### Chemistry

Reaction of various various 3-cinnamoyl coumarins **(4a-d)** and 3-(-5-arylpenta-2,4-dienoyl)coumarins (**5a-d)** with benzofuranoyl methyl pyridinium iodide salts (**6a-c)** in the presence of ammonium acetate in refluxing acetic acid gave target compounds (**7a-l)** and (**8a-l)** respectively in 45-67% yield (**Scheme 1**). The formation of pyridine nucleus follows Krohnke's reaction mechanism[21].

The structures of all the synthesized compounds (**7a-l)** and (**8a-l)** were established by IR, $^1$H-NMR, $^{13}$C-NMR and selected mass spectral data.

### Evaluation of Antimicrobial Activity

All the compounds **7a–l** and **8a-l** were assayed for their *in vitro* antimicrobial activity against




Scheme 1: Synthetic scheme for the preparation of compounds 7a-l and 8a-l

| Compounds | | R | R1 | R2 | R3 |
|---|---|---|---|---|---|
| 7a | 8a | H | H | H | H |
| 7b | 8b | $OCH_3$ | H | H | $OCH_3$ |
| 7c | 8c | H | $OCH_3$ | Br | H |
| 7d | 8d | $OCH_3$ | $OCH_3$ | H | H |
| 7e | 8e | H | H | H | $OCH_3$ |
| 7f | 8f | $OCH_3$ | H | Br | H |
| 7g | 8g | H | $OCH_3$ | H | H |
| 7h | 8h | $OCH_3$ | $OCH_3$ | H | $OCH_3$ |
| 7i | 8i | H | H | Br | H |
| 7j | 8j | $OCH_3$ | H | H | H |
| 7k | 8k | H | $OCH_3$ | H | $OCH_3$ |
| 7l | 8l | $OCH_3$ | $OCH_3$ | Br | H |

Table 1: Antimicrobial activity of compounds 7a-l and 8a-l

| Compound | Minimum Inhibitory Concentration (MIC,μgmL$^{-1}$) | | | | | |
|---|---|---|---|---|---|---|
| | Gram +ve Bacteria | | Gram -ve Bacteria | | Fungi | |
| | ***B.s.*** | ***S.a.*** | ***E.c.*** | ***S.t.*** | ***A.n.*** | ***C.a.*** |
| **7a** | 200 | 125 | 100 | 100 | >1000 | 1000 |
| **7b** | 100 | 100 | 100 | 100 | 1000 | 500 |
| **7c** | 100 | 200 | 125 | 125 | 500 | 250 |
| **7d** | 125 | 200 | 200 | 100 | 250 | 1000 |
| **7e** | 62.5 | 200 | 125 | 125 | 1000 | 500 |
| **7f** | 200 | 250 | 250 | 250 | 250 | >1000 |
| **7g** | 250 | 250 | 250 | 250 | 500 | >1000 |
| **7h** | 62.5 | 100 | 100 | 200 | 1000 | 250 |
| **7i** | 100 | 100 | 125 | 250 | >1000 | 500 |
| **7j** | 250 | 200 | 250 | 200 | 250 | 1000 |
| **7k** | 200 | 200 | 250 | 125 | 500 | >1000 |
| **7l** | 125 | 250 | 250 | 125 | >1000 | >1000 |
| **8a** | 100 | 200 | 250 | 250 | >1000 | >1000 |
| **8b** | 250 | 250 | 100 | 125 | 1000 | 250 |
| **8c** | 250 | 250 | 100 | 100 | 1000 | 500 |
| **8d** | 100 | 200 | 62.5 | 100 | 1000 | 500 |
| **8e** | 62.5 | 125 | 250 | 250 | >1000 | 1000 |
| **8f** | 100 | 250 | 250 | 500 | >1000 | >1000 |
| **8g** | 200 | 100 | 250 | 100 | >1000 | 500 |
| **8h** | 250 | 250 | 250 | 250 | 1000 | >1000 |
| **8i** | 200 | 125 | 100 | 200 | 250 | 500 |
| **8j** | 100 | 200 | 125 | 125 | 500 | 1000 |
| **8k** | 100 | 100 | 100 | 100 | 1000 | 250 |
| **8l** | 125 | 125 | 200 | 100 | 500 | 500 |
| Ampicillin | 250 | 250 | 100 | 100 | - | - |
| Chloramphenicol | 50 | 50 | 50 | 50 | - | - |
| Ciprofloxacin | 50 | 50 | 25 | 25 | - | - |
| Norfloxacin | 100 | 10 | 10 | 10 | - | - |
| Griseofulvin | - | - | - | - | 100 | 500 |
| Nystatin | - | - | - | - | 100 | 100 |

**B.s**.: *Bacillus subtilis*, **S.a**.: *Staphylococcus aureus*, **E.c**.: *Escherichia coli*, **S.t**.: *Salmonella typhi*, **A.n**.: *Aspergillus niger*, **C.a**.: *Candida albicans*

Gram-positive bacteria viz. *Bacillus subtilis* (MTCC 441), *Staphylococcus aureus* (MTCC 96), Gram-negative bacteria viz. *Escherichia coli* (MTCC 443), *Salmonella typhi* (MTCC 98) and antifungal activity against *Aspergillus niger* (MTCC 282) and *Candida albicans* (MTCC 227) by Broth dilution method[22].

Upon evaluating the antimicrobial activity data, it was observed that compounds **7e, 7h, and 8e** (MIC = 62.5$\mu g$/mL) exhibited excellent activity against gram positive bacteria *B. subtilis* compared to Ampicillin (MIC = 250$\mu g$/mL) and Norfloxacin (MIC = 100$\mu g$/mL). Compounds **7b, 7c, 7i, 8a, 8d, 8f, 8j** and **8k** (MIC = 100$\mu g$/mL) were found to be more potent compared to Ampicillin (MIC = 250$\mu g$/mL) and equipotent to Norfloxacin (MIC = 100$\mu g$/mL) against gram positive bacteria *B. subtilis.* The compounds **7d, 7l** and **8l** (MIC = 125$\mu g$/mL) exerted good activity against gram positive bacteria *B. subtilis* compared to Ampicillin (MIC = 250$\mu g$/mL). Compounds 7a, 7f, 7k, 8g and 8i (MIC = 200$\mu g$/mL) exhibited moderate activity compared to Ampicillin (MIC = 250$\mu g$/mL) against gram positive bacteria bacteria *B. subtilis.*

Compounds **7b, 7h, 7i, 8g and 8k** (MIC = 100$\mu g$/mL) and compounds **7a, 8e, 8i and 8l** (MIC = 125$\mu g$/mL) exhibited better activity compared to Ampicillin (MIC = 250$\mu g$/mL) against gram positive bacteria *S. aureus.* Compounds **7c, 7d, 7e, 7j, 7k, 8a, 8d and 8j** (MIC = 200$\mu g$/mL) showed moderate activity compared to Ampicillin (MIC = 250$\mu g$/mL) against gram positive bacteria *S. aureus* .

Compound **8d** (MIC = 62.5$\mu g$/mL) exhibited outstanding activity compared to Ampicillin (MIC = 100$\mu g$/mL) against gram negative bacteria *E. coli*. The compounds **7a, 7b, 7h, 8b, 8c, 8i,** and **8k** (MIC = 100$\mu g$/mL) and compounds **7a, 7b, 7d, 8c, 8d, 8g, 8k** and **8l** (MIC = 100$\mu g$/mL) were found equipotent compared to Ampicillin (MIC = 100$\mu g$/mL) against *E. coli and S. typhi* respectively.

Antifungal activity data of target compounds revealed that compounds **7c, 7h, 8b** and **8k** (MIC = 250$\mu g$/mL) were found to be more active against *C. albicans* compared to Griseofulvin (MIC = 500$\mu g$/mL). Compounds **7b, 7e, 7i, 8c, 8d, 8g, 8i** and **8l** (MIC = 500$\mu g$/mL) were found equipotent to Griseofulvin (MIC = 500$\mu g$/mL) against *C. albicans.* No compound showed good activity against fungis *A. Niger*.

It is perceived from the antimicrobial data that almost all the tested derivatives **7a-l** and **8a-l** were found to be potent against the gram positive bacterial strains. Among all the tested compounds, the compounds **7b, 7e, 7h, 8e** and **8k** were found to be more efficient members of the series.

## CONCLUSION

The present study reports expedient synthesis of various benzofuranyl pyridinyl and benzofuranyl styryl pyridinyl substituted coumarins. The synthesized compounds were subjected to antibacterial and antifungal studies. The screening results revealed that all the compounds exhibited moderate to excellent activities against the pathogenic strains. The antimicrobial data revealed that compounds **7a-l** and **8a-l** were found to be potent against the gram positive bacterial strains. Among all the tested compounds, the compounds **7b, 7e, 7h, 8e** and **8k** were found to be more efficient members of the series, hence the compounds are ideal for further modifications to obtain more efficacious antimicrobial agents.

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