Microwave assisted synthesis of quinolinyl-pyrazolyl substituted coumarins

The work incorporated in this chapter is on microwave assisted synthesis of various quinolinyl-pyrazolyl substituted coumarins. The synthesis of compounds has been carried out by reacting various 3-(3-(2-hydroxy/aryloxyquinolin-3-yl)acryloyl)coumarins (coumarin chalcones) with hydrazine hydrate in acetic acid or propionic acid and phenyl hydrazine derivatives in acetic acid respectively under MWI. The structures of all the compounds synthesized have been supported by analytical and spectral data.

5.1 Introduction

Microwave assisted organic synthesis has revolutionized organic syntheses. Compounds can be synthesized within a very short time, a fraction of a time required by classical thermal methods. As a result, this technique has rapidly gained acceptance as a valuable tool for accelerating drug discovery and development processes.

During the last decade, microwave heating has become a convenient and widely used tool in organic synthesis. In the past few decades, especially when heating was necessary, oil baths and heating jackets were the main equipments used. These traditional heating techniques are slow and time-consuming, and sometimes can lead to overheating and decomposition of the substrates and products. To end this, microwave irradiation (MWI) has not only dramatically accelerated organic reactions and reduced reaction time from days or hours to minutes, but also improved yields and selectivity\textsuperscript{1-3}. Microwave technologies have found extensive application especially in medicinal chemistry and pharmaceuticals in the field of drug discovery. The demand for new chemical compounds is continuously growing in medicinal chemistry, thereby promoting the development of new technologies, which are designed for fast synthesis of large
number of compounds. Acceleration of chemical reactions by microwave irradiation enables both the intensification of already existing methods and the development of new processes in medicinal chemistry.

Synthesis of heterocycles is one of the most widely used areas in the microwave chemistry. Furthermore, heterocycles are among the most frequently encountered scaffolds in drugs and pharmaceutically relevant substances. Because of the drug like character and considerable range of structural diversity, large collections or libraries of diverse heterocycles are routinely employed in high thorough put screening at early stages of drug discovery programs. Due to potential automatization, microwave technology has become one of the most suitable methods for synthesis of large heterocycle libraries. Moreover, microwave heating has emerged as a powerful technique to promote a variety of chemical reactions\textsuperscript{4-6}. Microwave reactions under solvent-free conditions are attractive in offering reduced pollution with simplicity in processing and handling\textsuperscript{7-8}. The recent introduction of single-mode technology\textsuperscript{9} assures safe and reproducible experimental procedures and microwave synthesis has gained acceptance and popularity among the synthetic chemist community. The growing number of publications in microwave-assisted syntheses includes virtually all types of chemical reactions such as additions, substitutions, eliminations, hydrolysis, hydrogenation, cyclization, aromatization, fragmentations, etc\textsuperscript{10-15}. 

5.1.1 Pyrazoline substituted coumarins

Pyrazolines are important nitrogen containing five membered heterocyclic compounds. Several pyrazoline derivatives showed considerable biological activities, e.g. antimicrobial\textsuperscript{16}, central nervous system\textsuperscript{17}, immuno-suppressive\textsuperscript{18}, antifungal\textsuperscript{19}, antitubercular\textsuperscript{19,20}, anti-inflammatory\textsuperscript{21-23}, anticancer\textsuperscript{24}, antidepressant and anticonvulsant activities\textsuperscript{25} and as potent selective androgen receptor modulators\textsuperscript{26}. Considering the bioactivities of both the coumarins and the pyrazolines, researchers have synthesized certain pyrazoline substituted coumarins. The work on pyrazoline substituted coumarins reported in literature is summarized in the following paragraphs.
Albert Levai et al.\textsuperscript{27} had synthesized various 1-acetyl/propiionyl-5-aryl-3-(3-coumarinyl)-2-pyrazolines and 5-aryl-3-(3-coumarinyl)-1-phenyl-2-pyrazolines by reacting 1-[2(\textit{H})-1-benzopyran-2-one-3-yl]-3-aryl-prop-2-en-1-ones (coumarin chalcones) with hydrazine hydrate in refluxing acetic acid or propionic acid and phenyl hydrazine in refluxing pyridine respectively.

Suresh Khode et al.\textsuperscript{28} have also synthesized some 5-aryl-3-(3-coumarinyl)-1-phenyl-2-pyrazolines by reacting 3-aryl-1-(3-coumarinyl)propan-1-ones with phenyl hydrazine in refluxing pyridine and studied their bioactivity. The compounds were found to possess anti-inflammatory, analgesic and antipyretic activity.

A H Mandour et al.\textsuperscript{29} had synthesized 5-aryl-3-(3-coumarinyl)-1\textit{H}-pyrazolines and 5-aryl-3-(3-coumarinyl)-1-phenyl-2-pyrazolines by reacting 3-cinnamoyl coumarin derivatives with hydrazine hydrate and phenyl hydrazine in refluxing ethanol respectively.
M Bhalla et al\textsuperscript{30} had synthesized 1-acetyl-5-aryl-3-\{(7-hydroxy-4-methyl-2(\textit{H})-1-benzopyran-2-one-8-yl\}-2-pyrazolines by reacting 8-cinnamoyl coumarin derivatives with hydrazine hydrate/acetic acid in refluxing ethanol. The compounds were screened for anti-inflammatory activity against the carrageenin-induced rat’s paw oedema in albino rats.

Considering the importance of pyrazoline substituted coumarins, some pyrazoline substituted coumarins were synthesized from our laboratory\textsuperscript{31} using microwave irradiation. In continuation of our work in synthesizing newer pyrazoline substituted coumarins, in the present work various quinolinyl-pyrazolyl substituted coumarins have been synthesized using microwave irradiation.

### 5.2 Present work

As discussed in introduction, various 3-\{(1-acetyl/propionyl-5-(2-hydroxy/aryloxyquinolin-3-yl)-4,5-dihydro-1\textit{H}-pyrazol-3-yl)coumarins (3) and 1-aryl-3-\{(5-(2-hydroxy/aryloxyquinolin-3-yl)-4,5-dihydro-1\textit{H}-pyrazol-3-yl)coumarins (5) have been synthesized using microwave
irradiation. The synthesis of these compounds is outlined in scheme 1.

Scheme 1

5.2.1 Synthesis of 3-(1-acetyl/propionyl-5-(2-hydroxy/aryloxy quinolin-3-yl)-4,5-dihydro-1H-pyrazol-3-yl)coumarins (3a-h)

The synthesis of 3-(1-acetyl/propionyl-5-(2-hydroxy/aryloxy quinolin-3-yl)-4,5-dihydro-1H-pyrazol-3-yl)coumarins (3a-h) have been carried out by reacting various 3-(3-(2-hydroxy/aryloxyquinolin-3-yl)acryloyl)coumarins (2a-d) with hydrazine hydrate in acetic/propionic acid under MWI for 4 minutes (Scheme 2).
The formation of (3a-h) was observed very fast (4 minutes) and with good yields (77-86%). The structures of all the compounds (3a-h) were confirmed by analytical and spectral data.

Thus, the microwave irradiation of 3-(3-(2-hydroxyquinolin-3-yl)acryloyl)coumarin (coumarin chalcone) (2a) with hydrazine hydrate in the presence of acetic acid proceeded smoothly and gave the expected product (3a) as a light yellow colored solid in 77% yield.

The IR spectrum of 3a (Fig 1) showed strong bands at 1736 and 1661 cm\(^{-1}\) which are due to carbonyl stretching of \(\delta\)-lactone ring present in coumarin nucleus and carbonyl of \(-N-CO-CH_3\) group respectively. The bands observed at 1609 and 1461 cm\(^{-1}\) are due to aromatic C=C and C=N stretching vibrations respectively. The compound showed bands at 2946 and 3063 cm\(^{-1}\), which are due to aliphatic C-H stretching of pyrazoline ring and aromatic C-H stretching vibrations respectively.
The $^1$H NMR spectrum of compound 3a (in DMSO-$d_6$) (Fig 2 and 3) showed a signal at 2.40 $\delta$ integrating for three protons. This is due to methyl group (-N-CO-CH$_3$). A doublet of doublet centered at 3.20 $\delta$ ($J = 18.4$ and $4.8$ Hz) integrating for one proton, is due to C$_{4'}$-H$_{\text{trans}}$. A doublet of doublet centered at 3.83 $\delta$ ($J = 18.4$ and $12.0$ Hz) integrating for one proton, is due to C$_{4'}$-H$_{\text{cis}}$. A doublet of doublet centered at 5.52 $\delta$ ($J = 12.0$ and $4.8$ Hz) integrating for one proton, is due to proton attached at C$_5'$. Nine aromatic protons were observed between 7.15-7.86 $\delta$ as a multiplet. The proton at C$_4$ of coumarin ring appeared as a singlet at 8.56 $\delta$ (1H). A singlet appeared at 11.96 $\delta$ (1H) is due to –OH proton, which was confirmed by recording D$_2$O exchanged spectrum (spectrum not shown).

The $^{13}$C NMR spectrum of compound 3a (in DMSO-$d_6$) (Fig 4) showed signals at 22.22, 42.29, 56.21, 115.34, 116.50, 119.14, 119.26, 119.52, 122.38, 125.35, 128.42, 129.82, 130.49, 131.89, 133.44, 134.15, 138.48, 142.39, 151.98, 153.91, 158.20, 161.16 and 168.35 $\delta$ corresponding to twenty three different type of carbon atoms present in the compound. The signal appeared at 22.22 $\delta$ is due to carbon of methyl group (-N-CO-CH$_3$). The signals appeared at 42.29 and 56.21 $\delta$ are due to C$_{4'}$ and C$_{5'}$ respectively. The signal appeared at 161.16 $\delta$ can be assigned to the carbonyl carbon of the $\delta$-lactone ring of coumarin. The most downfield signal appeared at 168.35 $\delta$ can be assigned to the carbonyl carbon of -N-CO-CH$_3$ group present in pyrazoline nucleus. The DEPT-135 spectrum of compound 3a (in DMSO-$d_6$) (Fig 5) showed inverted signal at 42.28 $\delta$, which further confirms that this signal is for C$_{4'}$ carbon. The upward signals at 22.23 and 56.21 $\delta$ confirm that these signals are due to carbon of methyl group (-N-CO-CH$_3$) and C$_{5'}$ respectively. The signals appeared at 115.23, 116.51, 122.39, 125.35, 128.43, 129.83, 130.53, 133.47, 134.15 and 142.43 $\delta$ correspond to ten non equivalent tertiary carbon atoms present in the compound.

The mass spectrum of compound 3a (Fig 6) showed M$^+$ peak at 399(5%) (m/z %) alongwith some other fragments peaks at 384 (2%), 356(100%), 328(3%), 270(3%), 254(3%), 213(13%), 187(5%), 170(15%),
The appearance of molecular ion peak at 399 mass unit supports the structure of compound 3a.

The IR and NMR data for other compounds (3b-h) are given below.

**Compound 3b**

**IR (cm⁻¹)**

$\nu_{\text{max}}$ 1750 and 1663 (C=O stretching of $\delta$-lactone of coumarin and carbonyl of $-N-CO-CH_3$ group present in pyrazoline nucleus respectively), 1609 and 1490 (aromatic C=C and C=N stretchings), 688 and 761 (C-H out of plane bending vibrations of mono substituted benzene ring), 1253 (aromatic C-O-C stretching), 2946 (aliphatic C-H stretching), 3065 (aromatic C-H stretching)

$^1\text{H NMR} (\delta, \text{ ppm}) (\text{CDCl}_3)$ (Fig 7)

2.52 (3H, singlet, $-N-CO-CH_3$), 3.59 (1H, doublet of a doublet, $J = 18.8$ and $4.8 \text{ Hz}$, $C_4'$-H$_{\text{trans}}$), 4.13 (1H, doublet of a doublet, $J = 18.8$ and $12.0 \text{ Hz}$, $C_4'$-H$_{\text{cis}}$), 6.00 (1H, doublet of a doublet, $J = 12.0$ and $4.8 \text{ Hz}$, proton at $C_5'$), 7.22-7.90 (14H, multiplet, aromatic protons), 8.38 (1H, singlet, proton at $C_4$)

$^{13}\text{C NMR} (\delta, \text{ ppm}) (\text{CDCl}_3)$ (Fig 8)

22.02(=N-CO-CH$_3$), 42.98(CH$_3$), 57.21(CH), 116.69(CH), 118.78(C), 119.69(C), 121.55(CH), 124.46(C), 124.68(CH), 124.94(CH), 125.05(CH), 125.75(C), 127.44(CH), 127.50(CH), 128.76(CH), 129.37(CH), 129.58(CH), 132.87(CH), 136.01(CH), 141.15(CH), 145.70(C), 151.64(C), 153.56(C), 154.16(C), 158.51(C), 159.12(CO of coumarin), 169.15(-N-CO-CH$_3$)

**Compound 3c**

**IR (cm⁻¹)**

$\nu_{\text{max}}$ 1750 and 1667 (C=O stretching of $\delta$-lactone of coumarin and carbonyl of $-N-CO-CH_3$ group present in pyrazoline nucleus respectively), 1609 and 1497 (aromatic C=C and C=N stretchings), 865 (C-H bending vibrations of p-disubstituted benzene ring), 1254 (aromatic C-O-C stretching), 2934 (aliphatic C-H stretching), 3036 (aromatic C-H stretching)
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1H NMR (δ, ppm) (CDCl₃) (Fig 9)

2.39 (3H, singlet, CH₃), 2.52 (3H, singlet, -N-CO-CH₃), 3.58 (1H, doublet of a doublet, J = 19.2 and 5.2 Hz, C₄'-Htrans), 4.12 (1H, doublet of a doublet, J = 19.2 and 12.0 Hz, C₄'-Hcis), 5.99 (1H, doublet of a doublet, J = 12.0 and 5.2 Hz, proton at C₅'), 7.13-7.88 (13H, multiplet, aromatic protons), 8.38 (1H, singlet, proton at C₄)

13C NMR (δ, ppm) (CDCl₃) (Fig 10)

20.90(CH₃), 22.03(-N-CO-CH₃), 42.96(CH₂), 57.22(CH), 116.68(CH), 118.79(C), 119.71(C), 121.33(CH), 121.61(C), 124.37(C), 124.92(CH), 125.67(C), 127.41(CH), 127.48(CH), 128.75(CH), 129.49(CH), 129.88(CH), 132.85(CH), 134.18(C), 135.83(CH), 141.12(CH), 145.73(C), 151.21(C), 151.66(C), 154.15(C), 158.68(C), 159.10(CO of coumarin), 169.15(-N-CO-CH₃)

**Compound 3d**

**IR (cm⁻¹)**

ν_max 1754 and 1656 (C=O stretching of δ-lactone of coumarin and carbonyl of -N-CO-CH₃ group present in pyrazoline nucleus respectively), 1609 and 1486 (aromatic C=C and C=N stretchings), 869 (C-H bending vibrations of p-disubstituted benzene ring), 1250 (aromatic C-O-C stretching), 2946 (aliphatic C-H stretching), 3055 (aromatic C-H stretching)

1H NMR (δ, ppm) (CDCl₃) (Fig 11)

2.52 (3H, singlet, -N-CO-CH₃), 3.58 (1H, doublet of a doublet, J = 19.2 and 5.2 Hz, C₄'-Htrans), 4.11 (1H, doublet of a doublet, J = 19.2 and 12.4 Hz, C₄'-Hcis), 5.99 (1H, doublet of a doublet, J = 12.4 and 5.2 Hz, proton at C₅'), 7.21-7.90 (13H, multiplet, aromatic protons), 8.41 (1H, singlet, proton at C₄)

13C NMR (δ, ppm) (CDCl₃) (Fig 12)

22.02(-N-CO-CH₃), 43.01(CH₂), 57.01(CH), 116.71(CH), 118.75(C), 119.58(C), 123.02(CH), 124.34(C), 125.01(CH), 125.24(CH), 125.82(C), 127.43(CH), 127.47(CH), 128.79(CH), 129.40(CH), 129.75(CH), 129.91(C), 132.96(CH), 136.11(CH), 141.15(CH), 145.54(C), 151.57(C), 151.99(C), 154.16(C), 158.20(C), 159.15(CO of coumarin), 169.16(-N-CO-CH₃)
**Compound 3e**

**IR (cm\(^{-1}\))**

\( \nu_{\text{max}} \) 1732 and 1659 (C=O stretching of \( \delta \)-lactone of coumarin and carbonyl of -N-CO-CH\(_3\) group present in pyrazoline nucleus respectively), 1606 and 1461 (aromatic C=C and C=N stretchings), 2941 (aliphatic C-H stretching), 3047 (aromatic C-H stretching)

**\(^1\)H NMR (\( \delta, \text{ppm} \)) (DMSO-d\(_6\))** (Fig 13)

1.13 (3H, triplet, \( J = 7.6 \) Hz, -CH\(_2\)CH\(_3\)), 2.84 (2H, multiplet, -CH\(_2\)CH\(_3\)), 3.20 (1H, doublet of a doublet, \( J = 18.4 \) and 4.8 Hz, C\(_4\)'-H\(_{\text{trans}}\)), 3.82 (1H, doublet of a doublet, \( J = 18.4 \) and 12.4 Hz, C\(_4\)'-H\(_{\text{cis}}\)), 5.52 (1H, doublet of a doublet, \( J = 12.4 \) and 4.8 Hz, proton at C\(_5\)'), 7.11-7.88 (9H, multiplet, aromatic protons), 8.57 (1H, singlet, proton at C\(_4\)), 11.95 (1H, singlet, OH proton, D\(_2\)O exchangeable)

**\(^{13}\)C NMR (\( \delta, \text{ppm} \)) (DMSO-d\(_6\))** (Fig 14)

9.60(-CH\(_2\)CH\(_3\)), 27.25(-CH\(_2\)CH\(_3\)), 42.03(CH\(_2\)), 56.29(CH), 115.37(CH), 116.53(CH), 119.17(C), 119.27(C), 119.60(C), 122.40(CH), 125.37(CH), 128.43(CH), 129.81(CH), 130.48(CH), 131.89(C), 133.41(CH), 134.16(CH), 138.50(C), 142.37(CH), 151.82(C), 153.89(C), 158.21(C), 161.16(CO of coumarin), 171.67(-N-CO-CH\(_2\)CH\(_3\))

**Compound 3f**

**IR (cm\(^{-1}\))**

\( \nu_{\text{max}} \) 1730 and 1665 (C=O stretching of \( \delta \)-lactone of coumarin and carbonyl of -N-CO-CH\(_3\) group present in pyrazoline nucleus respectively), 1610 and 1489 (aromatic C=C and C=N stretchings), 688 and 758 (C-H out of plane bending vibrations of mono substituted benzene ring), 1249 (aromatic C-O-C stretching), 2927 (aliphatic C-H stretching), 3057 (aromatic C-H stretching)

**\(^1\)H NMR (\( \delta, \text{ppm} \)) (CDCl\(_3\))** (Fig 15)

1.26 (3H, triplet, \( J = 7.6 \) Hz, -CH\(_2\)CH\(_3\)), 2.89 (2H, multiplet, -CH\(_2\)CH\(_3\)), 3.58 (1H, doublet of a doublet, \( J = 19.2 \) and 5.2 Hz, C\(_4\)'-H\(_{\text{trans}}\)), 4.10 (1H, doublet of a doublet, \( J = 19.2 \) and 12.0 Hz, C\(_4\)'-H\(_{\text{cis}}\)), 5.98 (1H, doublet of a doublet, \( J = 12.0 \) and 5.2 Hz, proton at C\(_5\)'), 7.21-7.92 (14H, multiplet, aromatic protons), 8.36 (1H, singlet,
proton at C₄)

**¹³C NMR (δ, ppm) (CDCl₃) (Fig 16)**

9.08(-CH₂CH₃), 27.65(-CH₂CH₃), 42.65(CH₂), 57.46(CH), 116.68(CH), 118.82(C), 119.82(C), 121.48(CH), 122.17(C), 124.62(CH), 124.92(CH), 125.03(CH), 125.80(C), 127.44(CH), 127.50(CH), 128.73(CH), 129.36(CH), 129.56(CH), 132.83(CH), 136.35(CH), 141.00(CH), 145.73(C), 151.33(C), 153.57(C), 154.15(C), 158.55(C), 159.17(CO of coumarin), 172.63(-N-CO-CH₂CH₃)

**Compound 3g**

**IR (cm⁻¹)**

νmax 1752 and 1657 (C=O stretching of δ-lactone of coumarin and carbonyl of -N-CO-CH₃ group present in pyrazoline nucleus respectively), 1608 and 1503 (aromatic C=C and C=N stretchings), 861 (C-H bending vibrations of p-disubstituted benzene ring), 1253 (aromatic C-O-C stretching), 2942 (aliphatic C-H stretching), 3047 (aromatic C-H stretching)

**¹H NMR (δ, ppm) (CDCl₃) (Fig 17)**

1.27 (3H, multiplet, -CH₂CH₃), 2.39 (3H, singlet, CH₃), 2.91 (2H, multiplet, -CH₂CH₃), 3.57 (1H, doublet of a doublet, J = 18.8 and 5.2 Hz, C₄'-Htrans), 4.09 (1H, doublet of a doublet, J = 18.8 and 12.0 Hz, C₄'-Hcis), 5.98 (1H, doublet of a doublet, J = 12.0 and 5.2 Hz, proton at C₅'), 7.12-7.89 (13H, multiplet, aromatic protons), 8.37 (1H, singlet, proton at C₄)

**¹³C NMR (δ, ppm) (CDCl₃) (Fig 18)**

9.09(-CH₂CH₃), 20.90(CH₃), 27.64(-CH₂CH₃), 42.63(CH₂), 57.44(CH), 116.67(CH), 118.82(C), 119.83(C), 121.28(CH), 124.55(C), 124.91(CH), 125.72(C), 127.43(CH), 127.47(CH), 128.73(CH), 129.49(CH), 129.87(CH), 132.79(CH), 134.14(C), 136.14(CH), 141.00(CH), 145.74(C), 151.25(C), 151.38(C), 154.13(C), 158.73(C), 159.14(CO of coumarin), 172.63(-N-CO-CH₂CH₃)

**Compound 3h**

**IR (cm⁻¹)**

νmax 1734 and 1665 (C=O stretching of δ-lactone of coumarin and carbonyl of -N-CO-CH₃ group present in pyrazoline nucleus
respectively), 1609 and 1486 (aromatic C=C and C=N stretchings), 865 (C-H bending vibrations of p-disubstituted benzene ring), 1247 (aromatic C-O-C stretching), 2934 (aliphatic C-H stretching), 3065 (aromatic C-H stretching)

$^1$H NMR ($\delta$, ppm) (CDCl$_3$) (Fig 19)
1.26 (3H, triplet, $J = 7.6$ Hz, $-\text{CH}_2\text{CH}_3$), 2.90 (2H, multiplet, $-\text{CH}_2\text{CH}_3$), 3.58 (1H, doublet of a doublet, $J = 18.8$ and 5.2 Hz, $\text{C}_4'$-H$_{\text{trans}}$), 4.08 (1H, doublet of a doublet, $J = 18.8$ and 12.0 Hz, $\text{C}_4'$-H$_{\text{cis}}$), 5.97 (1H, doublet of a doublet, $J = 12.0$ and 5.2 Hz, proton at $\text{C}_5'$), 7.19-7.91 (13H, multiplet, aromatic protons), 8.40 (1H, singlet, proton at $\text{C}_4$

$^{13}$C NMR ($\delta$, ppm) (CDCl$_3$) (Fig 20)
9.07($-\text{CH}_2\text{CH}_3$), 27.64($-\text{CH}_2\text{CH}_3$), 42.68(CH$_2$), 57.25(CH), 116.70(CH), 118.78(C), 119.71(C), 122.96(CH), 124.52(C), 124.99(CH), 125.23(CH), 125.88(C), 127.43(CH), 127.48(CH), 128.76(CH), 129.39(CH), 129.74(CH), 129.86(C), 132.90(CH), 136.40(CH), 141.02(CH), 145.55(C), 151.28(C), 152.03(C), 154.15(C), 158.24(C), 159.18(CO of coumarin), 172.63(-N-CO-CH$_2$CH$_3$)

In case of the compound 3g, the $^{13}$C NMR spectrum showed twenty eight non equivalent carbon signals. The compound is having twenty nine different types of non equivalent carbon atoms and hence expected number of signals is twenty nine. Experimentally, the number of signals observed is twenty eight. The lack of one signal may be due to overlapping of two carbon signals, which may have identical chemical shifts.

It is interesting to note over here that in the $^1$H NMR spectra of compounds 3e-h, the multiplicity of the CH$_3$-CH$_2$- protons of the propionyl group attached at N-1 did not show an expected triplet-quartet pattern. In compound 3g, CH$_3$ and CH$_2$ protons appear as two multiplets. In compounds 3e, 3f and 3h, the CH$_3$ protons appear as expected triplet however, the CH$_2$ protons do not appear as a quartet but appear as multiplet. This unusual multiplicity of the CH$_3$ and CH$_2$ proton signals may be probably due to the possible formation of hydrogen bonding between phenolic/phenoxy oxygen of quinoline and
one of the protons of CH₃ group (as shown below). Such type of hydrogen bonding can convert the CH₃ protons from one set to two sets and consequently this can change the expected multiplicity.
Fig 1  IR spectrum of compound 3a

Fig 2  $^1$H NMR spectrum of compound 3a
Fig 3  Expanded $^1$H NMR (2.9-5.9 δ) of compound 3a

Fig 4  $^{13}$C NMR spectrum of compound 3a
Fig 5  DEPT-135 spectrum of compound 3a

Fig 6  Mass spectrum of compound 3a
Fig 7  $^1$H NMR spectrum of compound 3b

Fig 8  $^{13}$C NMR spectrum of compound 3b
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Fig 9  $^1$H NMR spectrum of compound 3c

Fig 10  $^{13}$C NMR spectrum of compound 3c
Fig 11  $^1$H NMR spectrum of compound 3d

Fig 12  $^{13}$C NMR spectrum of compound 3d
Fig 13 $^1$H NMR spectrum of compound 3e

Fig 14 $^{13}$C NMR spectrum of compound 3e
Fig 15  $^1$H NMR spectrum of compound 3f

Fig 16  $^{13}$C NMR spectrum of compound 3f
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*Quinolinyl-pyrazolyl substituted coumarins (MW)*

**Fig 17** $^1$H NMR spectrum of compound 3g

**Fig 18** $^{13}$C NMR spectrum of compound 3g
**Fig 19**  $^1$H NMR spectrum of compound 3h

**Fig 20**  $^{13}$C NMR spectrum of compound 3h
5.2.2 Synthesis of 1-aryl-3-(5-(2-hydroxy/aryloxyquinolin-3-yl)-4,5-dihydro-1H-pyrazol-3-yl)coumarins (5a-l)

The synthesis of 1-aryl-3-(5-(2-hydroxy/aryloxyquinolin-3-yl)-4,5-dihydro-1H-pyrazol-3-yl)coumarins (5a-l) have been carried out by reacting various 3-(3-(2-hydroxy/aryloxyquinolin-3-yl)acryloyl)coumarins (2a-d) with appropriate phenyl hydrazine (4a-c) in the presence of acetic acid under MWI for 6 minutes (Scheme 3).

The formation of (5a-l) was observed very fast (6 minutes) and with good yields (72-87%). The structures of all the compounds (5a-l) were confirmed by analytical and spectral data.

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Scheme 3

The formation of (5a-l) was observed very fast (6 minutes) and with good yields (72-87%). The structures of all the compounds (5a-l) were confirmed by analytical and spectral data.
Thus, the microwave irradiation of 3-(3-(2-hydroxyquinolin-3-yl)acryloyl)coumarins (coumarin chalcone) (2a) with phenyl hydrazine (4a) in the presence acetic acid proceeded smoothly and gave the expected product (5a) as a yellow colored solid in 73% yield.

The IR spectrum of 5a (Fig 21) showed strong band at 1718 which is due to carbonyl stretching of δ-lactone ring present in coumarin nucleus. The bands observed at 1598 and 1498 cm\(^{-1}\) are due to aromatic C=C and C=N stretching vibrations respectively. The sharp and intense bands observed at 688 and 752 cm\(^{-1}\) are due to C-H out of plane bending vibrations for mono substituted benzene ring. The bands observed at 2957 and 3028 cm\(^{-1}\) are due to aliphatic C-H stretching of pyrazoline ring and aromatic C-H stretching vibrations respectively.

The \(^1\)H NMR spectrum of compound 5a (in DMSO-d\(_6\)) (Fig 22 and 23) showed a doublet of doublet centered at 3.29 δ (J = 18.0 and 6.0 Hz) integrating for one proton, is due to C\(_4\)′-H\(_{\text{trans}}\). A doublet of doublet centered at 3.98 δ (J = 18.0 and 12.8 Hz) integrating for one proton, is due to C\(_4\)′-H\(_{\text{cis}}\). A doublet of doublet centered at 5.53 δ (J = 12.8 and 6.0 Hz) integrating for one proton, is due to proton attached at C\(_5\)′. Fourteen aromatic protons were observed between 6.78-7.93 δ as a multiplet. The proton at C\(_4\) of coumarin ring appeared as a singlet at 8.49 δ (1H). A singlet appeared at 12.07 δ (1H) is due to –OH proton, which was confirmed by recording D\(_2\)O exchanged spectrum (spectrum not shown).

The \(^{13}\)C NMR spectrum of compound 5a (in DMSO-d\(_6\)) (Fig 24) showed signals at 43.06, 58.74, 113.51, 115.44, 115.88, 116.35, 119.82, 122.43, 123.11, 125.22, 128.44, 129.26, 129.59, 130.67, 131.37, 132.40, 134.13, 138.55, 139.15, 141.63, 142.88, 143.95, 144.76, 153.41 and 161.41 δ corresponding to twenty five different type of carbon atoms present in the compound. The signals appeared at 43.06 and 58.74 δ are due to C\(_4\)′ and C\(_5\)′ respectively. The most downfield signal appeared at 161.41 δ can be assigned to the carbonyl carbon of the δ-lactone ring of coumarin. The DEPT-135 spectrum of compound 5a (in DMSO-d\(_6\)) (Fig 25) showed inverted signal at 43.11 δ, which further confirms that this signal is for C\(_4\)′ carbon. The upward signal at 58.72 δ confirms that this signal is due to carbon of C\(_5\)′.
signals appeared at 113.50, 115.44, 115.89, 116.38, 119.81, 122.45, 123.13, 125.25, 128.47, 129.62, 130.69, 134.15 and 139.18 δ correspond to thirteen non equivalent tertiary carbon atoms present in the compound.

The mass spectrum of compound 5a (Fig 26) showed M⁺ peak at 433(1%) (m/z %) alongwith some other fragments peaks at 344(1%), 314(1%), 219(5%), 122(3%), 104(2%), 76(9%), 70(34%), 69(30%), 57(17%), 55(79%), 43(20%), 41(100%), etc. The appearance of molecular ion peak at 433 mass unit supports the structure of compound 5a.

The IR and NMR data for other compounds (5b-l) are given below.

**Compound 5b**

**IR (cm⁻¹)**

\( \nu_{max} \) 1754 (C=O stretching of δ-lactone of coumarin), 1598 and 1505 (aromatic C=C and C=N stretchings), 688 and 739 (C-H bending vibrations of mono substituted benzene ring), 1255 (aromatic C-O-C stretching), 2927 (aliphatic C-H stretching), 3050 (aromatic C-H stretching)

\(^1H\) NMR (δ, ppm) (CDCl₃) (Fig 27)

3.56 (1H, doublet of a doublet, \( J = 18.4 \) and 6.4 Hz, \( C_4'\)-H\text{trans} ), 4.29 (1H, doublet of a doublet, \( J = 18.4 \) and 12.8 Hz, \( C_4'\)-H\text{cis} ), 5.87 (1H, doublet of a doublet, \( J = 12.8 \) and 6.4 Hz, proton at \( C_5'\) ), 6.90-7.90 (19H, multiplet, aromatic protons), 8.44 (1H, singlet, proton at \( C_4\) )

\(^{13}C\) NMR (δ, ppm) (CDCl₃) (Fig 28)

43.81(CH₂), 59.61(CH), 113.57(CH), 116.49(CH), 119.46(C), 120.13(CH), 120.77(C), 121.15(C), 121.76(CH), 124.74(CH), 124.89(CH), 125.03(CH), 125.86(C), 127.52(CH), 128.24(CH), 129.24(CH), 129.47(CH), 129.61(CH), 131.67(CH), 135.86(CH), 138.03(CH), 143.80(C), 143.94(C), 145.64(C), 153.53(C), 153.64(C), 158.68(C), 159.57(CO of coumarin)

**Compound 5c**

**IR (cm⁻¹)**

\( \nu_{max} \) 1731 (C=O stretching of δ-lactone of coumarin), 1598 and 1499 (aromatic C=C and C=N stretchings), 694 and 757 (C-H bending
vibrations of mono substituted benzene ring), 869 (C-H bending vibrations of p-disubstituted benzene ring), 1248 (aromatic C-O-C stretching), 2934 (aliphatic C-H stretching), 3053 (aromatic C-H stretching)

\(^1\)H NMR (\(\delta\), ppm) (CDCl\(_3\)) (Fig 29)
2.44 (3H, singlet, CH\(_3\)), 3.55 (1H, doublet of a doublet, \(J = 18.4\) and 6.4 Hz, C\(_4^{'-}\)H\(_{\text{trans}}\)), 4.28 (1H, doublet of a doublet, \(J = 18.4\) and 12.8 Hz, C\(_4^{'-}\)H\(_{\text{cis}}\)), 5.86 (1H, doublet of a doublet, \(J = 12.8\) and 6.4 Hz, proton at C\(_5^{'}\)), 6.87-7.88 (18H, multiplet, aromatic protons), 8.44 (1H, singlet, proton at C\(_4\))

\(^{13}\)C NMR (\(\delta\), ppm) (CDCl\(_3\)) (Fig 30)
21.04(CH\(_3\)), 43.83(CH\(_2\)), 59.66(CH), 113.56(CH), 116.49(CH), 119.46(C), 120.07(CH), 120.79(C), 121.11(C), 121.50(CH), 124.72(CH), 124.93(CH), 125.04(C), 125.78(CH), 127.52(CH), 128.25(CH), 129.25(CH), 129.56(CH), 129.97(CH), 131.64(CH), 135.72(CH), 138.02(CH), 143.80(C), 143.97(C), 145.67(C), 151.20(C), 153.63(C), 158.84(C), 159.56(CO of coumarin)

**Compound 5d**

**IR (cm\(^{-1}\))**
\(v_{\text{max}}\) 1730 (C=O stretching of \(\delta\)-lactone of coumarin), 1607 and 1486 (aromatic C=C and C=N stretchings), 694 and 753 (C-H bending vibrations of mono substituted benzene ring), 871 (C-H bending vibrations of p-disubstituted benzene ring), 1252 (aromatic C-O-C stretching), 2927 (aliphatic C-H stretching), 3063 (aromatic C-H stretching)

\(^1\)H NMR (\(\delta\), ppm) (CDCl\(_3\)) (Fig 31)
3.54 (1H, doublet of a doublet, \(J = 18.4\) and 6.4 Hz, C\(_4^{'-}\)H\(_{\text{trans}}\)), 4.28 (1H, doublet of a doublet, \(J = 18.4\) and 12.8 Hz, C\(_4^{'-}\)H\(_{\text{cis}}\)), 5.84 (1H, doublet of a doublet, \(J = 12.8\) and 6.4 Hz, proton at C\(_5^{'}\)), 6.88-7.90 (18H, multiplet, aromatic protons), 8.45 (1H, singlet, proton at C\(_4\))

\(^{13}\)C NMR (\(\delta\), ppm) (CDCl\(_3\)) (Fig 32)
43.81(CH\(_2\)), 59.61(CH), 113.57(CH), 116.52(CH), 118.75(C), 119.43(C), 120.16(CH), 120.71(CH), 123.25(CH), 124.77(CH), 125.23(CH), 125.94(C), 127.46(CH), 127.58(CH), 128.25(CH), 129.24(CH), 129.49(CH), 129.77(CH), 130.13(C), 131.72(CH), 137.32(CH), 138.02(CH), 143.80(C), 143.97(C), 145.67(C), 151.20(C), 153.63(C), 158.84(C), 159.56(CO of coumarin)
136.00(C), 136.09(CH), 138.07(CH), 143.78(C), 143.94(C), 149.33(C), 153.66(C), 159.64(C), 160.86(CO of coumarin)

**Compound 5e**

**IR (cm⁻¹)**

ν_max 1728 (C=O stretching of δ-lactone of coumarin), 1612 and 1504 (aromatic C=C and C=N stretchings), 833 (C-H bending vibrations of p-disubstituted benzene ring), 2947 (aliphatic C-H stretching), 3063 (aromatic C-H stretching)

**¹H NMR (δ, ppm) (DMSO-d₆) (Fig 33)**

3.26 (1H, doublet of a doublet, J = 18.0 and 6.0 Hz, C₄′-Htrans), 3.98 (1H, doublet of a doublet, J = 18.0 and 12.4 Hz, C₄′-Hcis), 5.52 (1H, doublet of a doublet, J = 12.4 and 6.0 Hz, proton at C₅′), 6.76-7.83 (13H, multiplet, aromatic protons), 8.50 (1H, singlet, proton at C₄), 12.07 (1H, singlet, OH proton, D₂O exchangeable)

**¹³C NMR (δ, ppm) (DMSO-d₆) (Fig 34, 34a and 34b)**

43.24(CH₂), 58.95(CH), doublet centered at 114.63(C₂‴ and C₆‴, ³JC-F = 7.0 Hz), doublet centered at 115.82(C₃‴ and C₅‴, ²JC-F = 22.0 Hz), 116.49(CH), 119.38(C), 120.64(C), 121.72(CH), 124.75(CH), 124.87(C), 124.91(CH), 125.14(CH), 125.82(C), 128.27(CH), 129.50(CH), 129.75(C), 131.76(CH), 135.93(CH), 138.11(CH), 140.45(C), 144.04(C), 145.65(C), 153.46(C), doublet centered at 157.32(C₄‴, ¹JC-F = 237.0 Hz), 162.23(CO of coumarin)

**Compound 5f**

**IR (cm⁻¹)**

ν_max 1753 (C=O stretching of δ-lactone of coumarin), 1613 and 1509 (aromatic C=C and C=N stretchings), 695 and 752 (C-H bending vibrations of mono substituted benzene ring), 822 (C-H bending vibrations of p-disubstituted benzene ring), 1256 (aromatic C-O-C stretching), 2917 (aliphatic C-H stretching), 3050 (aromatic C-H stretching)

**¹H NMR (δ, ppm) (CDCl₃) (Fig 35)**

3.55 (1H, doublet of a doublet, J = 18.0 and 6.8 Hz, C₄′-Htrans), 4.30 (1H, doublet of a doublet, J = 18.0 and 12.8 Hz, C₄′-Hcis), 5.81 (1H, doublet of a doublet, J = 12.8 and 6.8 Hz, proton at C₅′), 6.95-7.90
(18H, multiplet, aromatic protons), 8.40 (1H, singlet, proton at C4)

$^{13}$C NMR ($\delta$, ppm) (CDCl$_3$) (Fig 36)

43.95(CH$_2$), 60.07(CH), doublet centered at 114.65(C$_2''$ and C$_6''$, $^3J_{C-F} = 8.0$ Hz), doublet centered at 115.83(C$_3''$ and C$_5''$, $^2J_{C-F} = 22.0$ Hz), 116.51(CH), 119.41(C), 120.67(C), 121.75(CH), 124.78(CH), 124.85(C), 124.95(CH), 125.13(CH), 125.83(C), 127.50(CH), 127.55(CH), 128.24(CH), 129.51(CH), 129.73(CH), 131.75(CH), 135.96(CH), 138.09(CH), 140.44(C), 144.06(C), 145.67(C), 153.49(C), 153.64(C), doublet centered at 157.37(C$_4''$, $^1J_{C-F} = 237.0$ Hz), 158.66(C), 159.50(CO of coumarin)

**Compound 5g**

IR (cm$^{-1}$)

$\nu_{max}$ 1729 (C=O stretching of $\delta$-lactone of coumarin), 1605 and 1505 (aromatic C=C and C=N stretchings), 818 (C-H bending vibrations of p-disubstituted benzene ring), 1253 (aromatic C-O-C stretching), 2920 (aliphatic C-H stretching), 3062 (aromatic C-H stretching)

$^1$H NMR ($\delta$, ppm) (CDCl$_3$) (Fig 37)

2.44 (3H, singlet, CH$_3$), 3.53 (1H, doublet of a doublet, $J = 18.4$ and 6.8 Hz, C$_4'$-H$_{trans}$), 4.29 (1H, doublet of a doublet, $J = 18.4$ and 12.8 Hz, C$_4'$-H$_{cis}$), 5.81 (1H, doublet of a doublet, $J = 12.8$ and 6.8 Hz, proton at C$_5'$), 6.95-7.87 (17H, multiplet, aromatic protons), 8.40 (1H, singlet, proton at C4)

$^{13}$C NMR ($\delta$, ppm) (CDCl$_3$) (Fig 38)

20.95(CH$_3$), 43.92(CH$_2$), 60.07(CH), doublet centered at 114.63(C$_2''$ and C$_6''$, $^3J_{C-F} = 8.0$ Hz), doublet centered at 115.80(C$_3''$ and C$_5''$, $^2J_{C-F} = 23.0$ Hz), 116.50(CH), 119.39(C), 120.69(C), 121.47(CH), 124.75(CH), 124.82(C), 125.00(CH), 125.75(C), 127.46(CH), 127.53(CH), 128.22(CH), 129.64(CH), 129.99(CH), 131.72(CH), 134.46(C), 135.80(CH), 138.05(CH), 140.42(C), 144.05(C), 145.70(C), 151.15(C), 153.63(C), doublet centered at 157.36(C$_4''$, $^1J_{C-F} = 238.0$ Hz), 158.82(C), 159.49(CO of coumarin)

**Compound 5h**

IR (cm$^{-1}$)

$\nu_{max}$ 1712 (C=O stretching of $\delta$-lactone of coumarin), 1607 and 1506
(aromatic C=C and C=N stretchings), 823 (C-H bending vibrations of p-disubstituted benzene ring), 1253 (aromatic C-O-C stretching), 2936 (aliphatic C-H stretching), 3072 (aromatic C-H stretching)

$^1$H NMR ($\delta$, ppm) (CDCl$_3$) (Fig 39)

3.53 (1H, doublet of a doublet, $J = 18.4$ and 6.8 Hz, C$_4$'-H$_{trans}$), 4.29 (1H, doublet of a doublet, $J = 18.4$ and 12.8 Hz, C$_4$'-H$_{cis}$), 5.79 (1H, doublet of a doublet, $J = 12.8$ and 6.8 Hz, proton at C$_5'$), 6.94-7.90 (17H, multiplet, aromatic protons), 8.42 (1H, singlet, proton at C$_4$)

$^{13}$C NMR ($\delta$, ppm) (CDCl$_3$) (Fig 40)

43.93(CH$_2$), 60.08(CH), doublet centered at 114.63(C$_2''$ and C$_6''$, $^3$J$_{C-F}$ = 7.0 Hz), doublet centered at 115.83(C$_3''$ and C$_5''$, $^2$J$_{C-F}$ = 23.0 Hz), 116.52(CH), 119.37(C), 120.59(C), 123.21(CH), 124.63(C), 124.80(CH), 125.31(CH), 125.87(C), 127.47(CH), 127.52(CH), 128.25(CH), 129.50(CH), 129.88(CH), 130.18(C), 131.79(CH), 136.14(CH), 138.13(CH), 140.39(C), 144.03(C), 145.50(C), 151.86(C), 153.64(C), doublet centered at 157.38(C$_4''$, $^1$J$_{C-F}$ = 237.0 Hz), 158.34(C), 159.56(CO of coumarin)

**Compound 5i**

$\nu$$_{max}$ 1749 (C=O stretching of $\delta$-lactone of coumarin), 1595 and 1497 (aromatic C=C and C=N stretchings), 814 (C-H bending vibrations of p-disubstituted benzene ring), 2934 (aliphatic C-H stretching), 3057 (aromatic C-H stretching)

$^1$H NMR ($\delta$, ppm) (DMSO-d$_6$) (Fig 41)

3.27 (1H, doublet of a doublet, $J = 18.0$ and 6.0 Hz, C$_4$'-H$_{trans}$), 3.99 (1H, doublet of a doublet, $J = 18.0$ and 12.4 Hz, C$_4$'-H$_{cis}$), 5.53 (1H, doublet of a doublet, $J = 12.4$ and 6.0 Hz, proton at C$_5'$), 6.77-7.84 (13H, multiplet, aromatic protons), 8.50 (1H, singlet, proton at C$_4$), 12.07 (1H, singlet, OH proton, D$_2$O exchangeable)

$^{13}$C NMR ($\delta$, ppm) (DMSO-d$_6$) (Fig 42)

43.20(CH$_2$), 58.89(CH), 114.27(C), 114.95(CH), 115.43(CH), 115.89(CH), 116.37(CH), 119.61(CH), 122.67(CH), 123.43(C), 125.27(CH), 125.48(CH), 128.51(CH), 129.39(CH), 129.46(C), 130.75(CH), 131.52(C), 132.55(CH), 138.59(C), 139.68(CH), 142.80(C), 145.62(C), 148.24(C), 153.49(C), 163.71(CO of coumarin)
**Compound 5j**

**IR (cm⁻¹)**

\( \nu_{\text{max}} \) 1721 (C=O stretching of \( \delta \)-lactone of coumarin), 1610 and 1492 (aromatic C=C and C=N stretchings), 693 and 755 (C-H bending vibrations of mono substituted benzene ring), 818 (C-H bending vibrations of p-disubstituted benzene ring), 1255 (aromatic C-O-C stretching), 2946 (aliphatic C-H stretching), 3061 (aromatic C-H stretching)

**\(^1H\text{ NMR} (\delta, \text{ ppm}) (\text{CDCl}_3) (\text{Fig 43})**

3.57 (1H, doublet of a doublet, \( J = 18.8 \) and 6.4 Hz, C₄′-H\text{trans} ), 4.29 (1H, doublet of a doublet, \( J = 18.8 \) and 12.4 Hz, C₄′-H\text{cis} ), 5.83 (1H, doublet of a doublet, \( J = 12.4 \) and 6.4 Hz, proton at C₅′ ), 7.04-7.85 (18H, multiplet, aromatic protons), 8.42 (1H, singlet, proton at C₄)

**\(^{13}C\text{ NMR} (\delta, \text{ ppm}) (\text{CDCl}_3) (\text{Fig 44})**

43.93(CH₂), 59.59(CH), 114.68(CH), 116.52(CH), 119.34(C), 120.51(C), 121.73(CH), 124.50(C), 124.80(CH), 124.92(C), 124.97(CH), 125.16(CH), 125.76(C), 127.50(CH), 127.54(CH), 128.30(CH), 129.16(CH), 129.50(CH), 129.78(CH), 131.86(CH), 135.84(CH), 138.37(CH), 142.33(C), 144.58(C), 145.68(C), 153.44(C), 153.68(C), 158.59(C), 159.46(CO of coumarin)

**Compound 5k**

**IR (cm⁻¹)**

\( \nu_{\text{max}} \) 1735 (C=O stretching of \( \delta \)-lactone of coumarin), 1601 and 1496 (aromatic C=C and C=N stretchings), 820 (C-H bending vibrations of p-disubstituted benzene ring), 1237 (aromatic C-O-C stretching), 2957 (aliphatic C-H stretching), 3046 (aromatic C-H stretching)

**\(^1H\text{ NMR} (\delta, \text{ ppm}) (\text{CDCl}_3) (\text{Fig 45})**

2.44 (3H, singlet, CH₃), 3.56 (1H, doublet of a doublet, \( J = 18.4 \) and 6.4 Hz, C₄′-H\text{trans} ), 4.28 (1H, doublet of a doublet, \( J = 18.4 \) and 12.8 Hz, C₄′-H\text{cis} ), 5.82 (1H, doublet of a doublet, \( J = 12.8 \) and 6.4 Hz, proton at C₅′ ), 7.09-7.83 (17H, multiplet, aromatic protons), 8.41 (1H, singlet, proton at C₄)

**\(^{13}C\text{ NMR} (\delta, \text{ ppm}) (\text{CDCl}_3) (\text{Fig 46})**

20.95(CH₃), 43.91(CH₂), 59.58(CH), 114.68(CH), 116.52(CH),
119.34(C), 120.52(C), 121.48(CH), 124.48(C), 124.79(CH), 124.90(C), 125.05(CH), 125.69(C), 127.49(CH), 128.29(CH), 129.15(CH), 129.72(CH), 130.02(CH), 131.85(CH), 134.52(C), 135.73(CH), 138.36(CH), 142.33(C), 144.58(C), 145.70(C), 151.12(C), 153.66(C), 158.78(C), 159.47(CO of coumarin)

**Compound 5l**

**IR (cm$^{-1}$)**

$\nu_{\text{max}}$ 1734 (C=O stretching of $\delta$-lactone of coumarin), 1601 and 1495 (aromatic C=C and C=N stretchings), 818 (C-H bending vibrations of p-disubstituted benzene ring), 1252 (aromatic C-O-C stretching), 2925 (aliphatic C-H stretching), 3043 (aromatic C-H stretching)

**$^1$H NMR ($\delta$, ppm) (CDCl$_3$) (Fig 47)**

3.56 (1H, doublet of a doublet, $J = 18.4$ and 6.4 Hz, C$_4$'-H$_{\text{trans}}$), 4.28 (1H, doublet of a doublet, $J = 18.4$ and 12.8 Hz, C$_4$'-H$_{\text{cis}}$), 5.80 (1H, doublet of a doublet, $J = 12.8$ and 6.4 Hz, proton at C$_5$'), 7.08-7.85 (17H, multiplet, aromatic protons), 8.43 (1H, singlet, proton at C$_4$)

**$^{13}$C NMR ($\delta$, ppm) (CDCl$_3$) (Fig 48)**

43.93(CH$_2$), 59.60(CH), 114.66(CH), 116.54(CH), 119.31(C), 120.44(C), 123.21(CH), 124.29(C), 124.83(CH), 124.99(C), 125.34(CH), 125.81(C), 127.46(CH), 127.53(CH), 128.31(CH), 129.17(CH), 129.52(CH), 129.94(CH), 130.21(C), 131.92(CH), 136.05(CH), 138.43(CH), 142.30(C), 144.55(C), 145.51(C), 151.81(C), 153.68(C), 158.28(C), 159.53(CO of coumarin)

In case of the compounds 5b, 5c and 5k, the number of non equivalent carbon signals in $^{13}$C NMR spectra is one less than expected. This may be due to identical chemical shifts of certain carbons which may appear at same position.

In $^{13}$C NMR spectrum of compounds 5e-h, the three sets of carbon i.e., C$_2''$/C$_6''$, C$_3''$/C$_5''$ and C$_4''$ appear as doublets due to the $^3$J$_{C-F}$, $^2$J$_{C-F}$, $^1$J$_{C-F}$ couplings respectively. In figure 34a and 34b, the expanded $^{13}$C spectra of these doublets are shown for compound 5e.
**Fig 21**  IR spectrum of compound 5a

**Fig 22**  $^1$H NMR spectrum of compound 5a
**Fig 23** Expanded $^1$H NMR (3.0-5.7 $\delta$) of compound 5a

**Fig 24** $^{13}$C NMR spectrum of compound 5a
Fig 25  DEPT-135 spectrum of compound 5a

Fig 26  Mass spectrum of compound 5a
Fig 27  $^1$H NMR spectrum of compound 5b

Fig 28  $^{13}$C NMR spectrum of compound 5b
Fig 29 $^1$H NMR spectrum of compound 5c

Fig 30 $^{13}$C NMR spectrum of compound 5c
Fig 31  $^1$H NMR spectrum of compound 5d

Fig 32  $^{13}$C NMR spectrum of compound 5d
**Fig 33** $^1$H NMR spectrum of compound 5e

**Fig 34** $^{13}$C NMR spectrum of compound 5e
**Fig 34a** Expanded $^{13}$C NMR (114.2-116.4 δ) of compound 5e

**Fig 34b** Expanded $^{13}$C NMR (153.0-160.0 δ) of compound 5e
**Fig 35** $^1$H NMR spectrum of compound 5f

**Fig 36** $^{13}$C NMR spectrum of compound 5f
Fig 37  $^1$H NMR spectrum of compound 5g

Fig 38  $^{13}$C NMR spectrum of compound 5g
**Fig 39** $^1$H NMR spectrum of compound 5h

**Fig 40** $^{13}$C NMR spectrum of compound 5h
Fig 41 $^1$H NMR spectrum of compound 5i

Fig 42 $^{13}$C NMR spectrum of compound 5i
**Fig 43** $^1$H NMR spectrum of compound 5j

**Fig 44** $^{13}$C NMR spectrum of compound 5j
**Fig 45** $^1$H NMR spectrum of compound 5k

**Fig 46** $^{13}$C NMR spectrum of compound 5k
**Fig 47** $^1$H NMR spectrum of compound 5l

**Fig 48** $^{13}$C NMR spectrum of compound 5l
5.3 Experimental

The starting material 3-acetyl coumarin is prepared as described in the chapter 2.

The microwave reactions were carried out on Raga’s electromagnetic system.

5.3.1 Preparation of 2-chloro-3-formyl quinoline

\[
\text{CH}_2\text{N} - \text{CHO} \xrightarrow{\text{DMF, POCl}_3} \text{CHO}
\]

In a 250 mL three necked round bottom flask fitted with addition funnel and guard tube, anhydrous dimethyl formamide (DMF) (0.6 mole) was taken and cooled to 0°C with stirring. To it phosphorous oxychloride (POCl\(_3\)) (0.18 mole) was added dropwise with stirring at 0-10°C. In this well stirred reaction mixture, an acetanilide (0.25 mole) was added and the reaction mixture was heated at 75°C for six hours. The reaction mixture was then cooled to room temperature and poured into crushed ice (200 g) during which a solid product was separated out which was filtered off, washed with 5% sodium carbonate (3 x 30 mL) and water. It was then dried and recrystallized from ethyl acetate.

Yield: 84%, mp 149°C (lit.\(^{32}\) mp 149°C)

5.3.2 Preparation of 2-hydroxy-3-formyl quinoline (1a)

\[
\text{CHO} \xrightarrow{\text{AcOH}} \text{CHO}
\]

In a 50 mL round bottom flask fitted with reflux condenser, 2-chloro-3-formylquinoline (0.025 mole) was taken in 25 ml glacial acetic acid. The reaction mixture was then refluxed for 2 hours. On cooling, a yellow solid product was obtained, which was filtered out and washed with 5% sodium carbonate (3 x 30 mL) and water. It was then dried and recrystallized from DMF.

**Compound 1a:** Yield: 91%, mp 302-303°C (lit.\(^{32}\) mp 303-304°C)
5.3.3 Preparation of 2-aryloxy quinoline-3-carbaldehydes (1b-d)

In a 50 mL round bottomed flask fitted with reflux condenser, a mixture of 2-chloro-3-formylquinoline (0.01 mole), appropriate phenol (0.015 mole), anhydrous potassium carbonate (0.02 mole) in dimethylformamide (20 mL) was taken. The reaction mixture was heated at 100°C for 3 hours with stirring and the reaction completion was monitored by TLC. After the completion of reaction, the reaction mixture was cooled to room temperature and then poured into chilled water (50 mL) with continuous stirring followed by neutralization with dil. HCl (1:1). The solid mass separated was filtered, washed with water, dried and crystallized from ethyl acetate.

**Compound 1b**: R = H; Yield: 87%, mp 144°C

<table>
<thead>
<tr>
<th>Analysis</th>
<th>% C</th>
<th>% H</th>
<th>%N</th>
</tr>
</thead>
<tbody>
<tr>
<td>Found</td>
<td>76.86</td>
<td>4.37</td>
<td>5.51</td>
</tr>
<tr>
<td>Calculated</td>
<td>77.10</td>
<td>4.45</td>
<td>5.62</td>
</tr>
</tbody>
</table>

*IR (cm⁻¹)*

ν<sub>max</sub> 1690 (C=O stretching of -CHO), 1590 and 1490 (aromatic C=C and C=N stretching), 1250 (C-O-C stretching), 690 and 760 (C-H bending vibrations of mono substituted benzene ring), 3060 (aromatic C-H stretching)

*¹H NMR (δ, ppm) (CDCl₃)*

7.31-7.93 (9H, multiplet, aromatic protons except proton at C₄ of quinoline ring), 8.77 (1H, singlet, proton at C₄ of quinoline ring), 10.68 (1H, singlet, aldehyde proton)

**Compound 1c**: R = CH₃; Yield: 82%, mp 131°C

<table>
<thead>
<tr>
<th>Analysis</th>
<th>% C</th>
<th>% H</th>
<th>%N</th>
</tr>
</thead>
<tbody>
<tr>
<td>Found</td>
<td>77.25</td>
<td>4.90</td>
<td>5.41</td>
</tr>
<tr>
<td>Calculated</td>
<td>77.55</td>
<td>4.98</td>
<td>5.32</td>
</tr>
</tbody>
</table>

*IR (cm⁻¹)*

ν<sub>max</sub> 1690 (C=O stretching of -CHO), 1589 and 1497 (aromatic C=C and C=N stretching), 1242 (C-O-C stretching), 818 (C-H bending
vibrations of p-disubstituted benzene ring), 3063 (aromatic C-H stretching)

$^1$H NMR ($\delta$, ppm) (CDCl$_3$)

2.44 (3H, singlet, CH$_3$ protons), 7.20-7.92 (8H, multiplet, aromatic protons except proton at C$_4$ of quinoline ring), 8.75 (1H, singlet, proton at C$_4$ of quinoline ring), 10.67 (1H, singlet, aldehyde proton)

**Compound 1d**: R = Cl; Yield: 84%, mp 139°C

<table>
<thead>
<tr>
<th>Analysis</th>
<th>% C</th>
<th>% H</th>
<th>%N</th>
</tr>
</thead>
<tbody>
<tr>
<td>Found</td>
<td>67.42</td>
<td>3.44</td>
<td>4.81</td>
</tr>
<tr>
<td>Calculated</td>
<td>67.74</td>
<td>3.55</td>
<td>4.94</td>
</tr>
</tbody>
</table>

$^\nu$max 1690 (C=O stretching of -CHO), 1582 and 1489 (aromatic C=C and C=N stretching), 1242 (C-O-C stretching), 818 (C-H bending vibrations of p-disubstituted benzene ring), 3063 (aromatic C-H stretching)

$^1$H NMR ($\delta$, ppm) (CDCl$_3$)

7.26-7.94 (8H, multiplet, aromatic protons except proton at C$_4$ of quinoline ring), 8.77 (1H, singlet, proton at C$_4$ of quinoline ring), 10.65 (1H, singlet, aldehyde proton)

**5.3.4 Preparation of 3-(3-(2-hydroxy/aryloxyquinolin-3-yl)acryloyl) coumarins (2a-d)**

In a 100 mL round bottom flask, 3-acetyl coumarin (0.01 mole) and an appropriate 2-hydroxy/aryloxyquinoline-3-carbaldehydes (0.01 mole) (1a-d) 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 mixture was then refluxed on waterbath for 4 hours. It was 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 2a**: R = H; Yield: 64%, mp 295-300°C (dec.)

<table>
<thead>
<tr>
<th>Analysis</th>
<th>% C</th>
<th>% H</th>
<th>%N</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Found (C$_{21}$H$_{13}$NO$_{4}$) 73.11 3.73 3.97
Calculated 73.46 3.82 4.08

IR (cm$^{-1}$)
$\nu_{\text{max}}$ 1727 and 1674 (C=O stretching of $\delta$-lactone of coumarin and $\alpha$, $\beta$-unsaturated carbonyl group), 1620 and 1489 (aromatic C=C and C=N stretchings), 3056 (aromatic C-H stretchings)
(As the compound was insoluble in common NMR solvents, NMR spectra were not recorded.)

**Compound 2b:** R = Ph; Yield: 71%, mp 198°C

<table>
<thead>
<tr>
<th>Analysis</th>
<th>% C</th>
<th>% H</th>
<th>%N</th>
</tr>
</thead>
<tbody>
<tr>
<td>Found (C$<em>{27}$H$</em>{17}$NO$_{4}$)</td>
<td>77.06</td>
<td>4.02</td>
<td>3.43</td>
</tr>
<tr>
<td>Calculated</td>
<td>77.32</td>
<td>4.09</td>
<td>3.34</td>
</tr>
</tbody>
</table>

IR (cm$^{-1}$)
$\nu_{\text{max}}$ 1732 and 1656 (C=O stretching of $\delta$-lactone of coumarin and $\alpha$, $\beta$-unsaturated carbonyl group), 1609 and 1490 (aromatic C=C and C=N stretchings), 3043 (aromatic C-H stretchings), 1251 (aromatic C-O-C stretching)

$^1$H NMR ($\delta$, ppm) (CDCl$_3$)
7.33-7.86 (13H, multiplet, aromatic protons except proton at C$_4$ of quinoline), 8.29 (1H, doublet, $J = 15.2$ Hz, $\alpha$-proton of $\alpha$, $\beta$-unsaturated carbonyl system), 8.35 (1H, doublet, $J = 16.0$ Hz, $\beta$-proton of $\alpha$, $\beta$-unsaturated carbonyl system), 8.55 (1H, singlet, proton at C$_4$ of quinoline), 8.65 (1H, singlet, proton at C$_4$ of coumarin)

$^{13}$C NMR ($\delta$, ppm) (CDCl$_3$)
116.76(CH), 118.59(C), 120.39(C), 121.86(CH), 124.84(CH), 125.05(CH), 125.22(C), 125.37(CH), 125.74(C), 126.93(CH), 127.66(CH), 128.09(CH), 129.38(CH), 130.13(CH), 130.97(CH), 134.37(CH), 138.56(CH), 138.83(CH), 146.82(C), 148.36(CH), 153.44(C), 155.33(C), 159.42(C), 159.48(CO of coumarin), 186.46(CO of $\alpha$, $\beta$-unsaturated carbonyl system)

**Compound 2c:** R = 4-CH$_3$Ph; Yield: 76%, mp 223°C

<table>
<thead>
<tr>
<th>Analysis</th>
<th>% C</th>
<th>% H</th>
<th>%N</th>
</tr>
</thead>
<tbody>
<tr>
<td>Found (C$<em>{28}$H$</em>{19}$NO$_{4}$)</td>
<td>77.26</td>
<td>4.50</td>
<td>3.12</td>
</tr>
<tr>
<td>Calculated</td>
<td>77.59</td>
<td>4.42</td>
<td>3.23</td>
</tr>
</tbody>
</table>
**IR (cm\(^{-1}\))**

\(\nu_{\text{max}} \) 1732 and 1653 (C=O stretching of \(\delta\)-lactone of coumarin and \(\alpha,\beta\)-unsaturated carbonyl group), 1609 and 1490 (aromatic C=C and C=N stretchings), 3050 (aromatic C-H stretchings), 1252 (aromatic C-O-C stretching)

\(^1\)H NMR (\(\delta\), ppm) (CDCl\(_3\))

2.42 (3H, singlet, CH\(_3\) protons), 7.20-7.85 (12H, multiplet, aromatic protons except proton at C\(_4\) of quinoline), 8.28 (1H, doublet, \(J = 16.0\) Hz, \(\alpha\)-proton of \(\alpha,\beta\)-unsaturated carbonyl system), 8.35 (1H, doublet, \(J = 15.6\) Hz, \(\beta\)-proton of \(\alpha,\beta\)-unsaturated carbonyl system), 8.53 (1H, singlet, proton at C\(_4\) of quinoline), 8.65 (1H, singlet, proton at C\(_4\) of coumarin)

\(^{13}\)C NMR (\(\delta\), ppm) (CDCl\(_3\))

20.95(CH\(_3\)), 116.76(CH), 118.59(C), 120.39(C), 121.57(CH), 125.03(CH), 125.25(CH), 125.27(CH), 125.68(C), 126.87(CH), 127.67(CH), 128.08(CH), 129.89(CH), 130.11(CH), 130.55(C), 130.90(CH), 134.30(C), 134.35(CH), 138.68(CH), 138.76(C), 146.90(C), 148.31(CH), 151.12(C), 155.34(C), 159.40(CO of coumarin), 186.49(CO of \(\alpha,\beta\)-unsaturated carbonyl system)

**Compound 2d**: R = 4-ClPh; Yield: 74%, mp 260°C

<table>
<thead>
<tr>
<th>Analysis</th>
<th>% C</th>
<th>% H</th>
<th>%N</th>
</tr>
</thead>
<tbody>
<tr>
<td>Found (C(<em>{27})H(</em>{16})ClNO(_4))</td>
<td>71.22</td>
<td>3.49</td>
<td>3.01</td>
</tr>
<tr>
<td>Calculated</td>
<td>71.45</td>
<td>3.55</td>
<td>3.09</td>
</tr>
</tbody>
</table>

**IR (cm\(^{-1}\))**

\(\nu_{\text{max}} \) 1733 and 1660 (C=O stretching of \(\delta\)-lactone of coumarin and \(\alpha,\beta\)-unsaturated carbonyl group), 1609 and 1490 (aromatic C=C and C=N stretchings), 3055 (aromatic C-H stretchings), 1252 (aromatic C-O-C stretching)

\(^1\)H NMR (\(\delta\), ppm) (CDCl\(_3\))

7.29-7.87 (12H, multiplet, aromatic protons except proton at C\(_4\) of quinoline), 8.31 (2H, multiplet, \(\alpha\) and \(\beta\) protons of \(\alpha,\beta\)-unsaturated carbonyl system), 8.55 (1H, singlet, proton at C\(_4\) of quinoline), 8.66 (1H, singlet, proton at C\(_4\) of coumarin)
\[ ^{13} \text{C NMR (δ, ppm) (CDCl}_3 \]\]

116.77(CH), 118.58(C), 120.23(C), 123.02(C), 123.31(CH), 125.07(CH), 125.11(C), 125.56(CH), 125.81(C), 127.12(CH), 127.64(CH), 128.16(CH), 129.43(CH), 130.08(C), 130.17(CH), 131.17(CH), 134.47(CH), 138.27(CH), 139.02(CH), 145.65(C), 148.50(CH), 151.87(C), 155.33(C), 159.14(CO of coumarin), 186.38(CO of \( \alpha, \beta \)-unsaturated carbonyl system)

5.3.5 Preparation of 3-(1-acetyl/propionyl-5-(2-hydroxy/aryloxy quinolin-3-yl)-4,5-dihydro-1\( H \)-pyrazol-3-yl)coumarins (3a-h)

![Chemical Structure](image)

The following general procedure was used.

A mixture of appropriate 3-(3-(2-hydroxy/aryloxyquinolin-3-yl) acryloyl)coumarins (coumarin chalcone) (2a-d) (0.003 mol), hydrazine hydrate (0.009 mol) in an acetic acid or propionic acid (12 mL) were stirred at room temperature for 15 minutes and then irradiated for 4 minutes in microwave at 240 W (35%) power. The reaction mixture was then poured into water (100 mL), whereby a solid product was separated out, which was filtered out, washed with water and recrystallized from methanol to afford 3-(1-acetyl/propionyl-5-(2-hydroxy/aryloxyquinolin-3-yl)-4,5-dihydro-1\( H \)-pyrazol-3-yl)coumarins (3a-h).

**Compound 3a:**  \( R = \text{CH}_3 \), \( R_1 = \text{H} \);

Yield = 77%  
mp 315-320°C  
Molecular Formula: C\(_{23}\)H\(_{17}\)N\(_3\)O\(_4\)

Analysis  
% C  
% H  
% N  

Found  
68.88  
4.22  
10.43  

Calculated  
69.17  
4.29  
10.52

**Compound 3b:**  \( R = \text{CH}_3 \), \( R_1 = \text{Ph} \);

Yield = 83%  
mp 239-241°C  
Molecular Formula: C\(_{29}\)H\(_{21}\)N\(_3\)O\(_4\)

Analysis  
% C  
% H  
% N  

Found  
68.22  
4.22  
10.43  

Calculated  
67.91  
4.29  
10.49
Found 73.04 4.40 8.78  
Calculated 73.25 4.45 8.84  

**Compound 3c**:  R = CH$_3$, R$_1$ = 4-CH$_3$Ph;  
Yield = 80%  
mp 236-238°C  
Molecular Formula: C$_{30}$H$_{23}$N$_3$O$_4$  
Analysis % C % H % N  
Found 73.34 4.79 8.50  
Calculated 73.61 4.74 8.58  

**Compound 3d**:  R = CH$_3$, R$_1$ = 4-ClPh;  
Yield = 82%  
mp 257-258°C  
Molecular Formula: C$_{29}$H$_{20}$ClN$_3$O$_4$  
Analysis % C % H % N  
Found 68.51 3.99 8.30  
Calculated 68.30 3.95 8.24  

**Compound 3e**:  R = CH$_2$CH$_3$, R$_1$ = H;  
Yield = 78%  
mp 320-325°C  
Molecular Formula: C$_{24}$H$_{19}$N$_3$O$_4$  
Analysis % C % H % N  
Found 69.48 4.57 10.09  
Calculated 69.72 4.63 10.16  

**Compound 3f**:  R = CH$_2$CH$_3$, R$_1$ = Ph;  
Yield = 81%  
mp 126-128°C  
Molecular Formula: C$_{30}$H$_{23}$N$_3$O$_4$  
Analysis % C % H % N  
Found 73.39 4.68 8.51  
Calculated 73.61 4.74 8.58  

**Compound 3g**:  R = CH$_2$CH$_3$, R$_1$ = 4-CH$_3$Ph;  
Yield = 82%  
mp 168-170°C  
Molecular Formula: C$_{31}$H$_{25}$N$_3$O$_4$  
Analysis % C % H % N  
Found 74.19 4.96 8.39  
Calculated 73.94 5.00 8.34  

**Compound 3h**:  R = CH$_2$CH$_3$, R$_1$ = 4-ClPh;  
Yield = 86%  
mp 178-180°C  
Molecular Formula: C$_{30}$H$_{22}$ClN$_3$O$_4$  
Analysis % C % H % N  
Found 68.52 4.18 7.95  
Calculated 68.77 4.23 8.02
5.3.6 Preparation of 1-aryl-3-(5-(2-hydroxy/aryloxyquinolin-3-yl)-4,5-dihydro-1H-pyrazol-3-yl)coumarins (5a-l)

The following general procedure was used.

A mixture of appropriate 3-(3-(2-hydroxy/aryloxyquinolin-3-yl)acryloyl)coumarins (coumarin chalcone) (2a-d) (0.003 mol) and appropriate phenyl hydrazine (0.009 mol) in acetic acid (12 mL) were stirred at room temperature for 15 minutes and then irradiated for 6 minutes in microwave at 240 W (35%) power. The reaction mixture was then poured in to water (100 mL), whereby a solid product was separated out, which was filtered out, washed with water and recrystallized from methanol to afford 1-aryl-3-(5-(2-hydroxy/aryloxyquinolin-3-yl)-4,5-dihydro-1H-pyrazol-3-yl)coumarins (5a-l).

**Compound 5a:** $R_1 = H, R_2 = H$;
Yield = 73% \[\text{mp } 255-260^\circ C\] Molecular Formula: $C_{27}H_{19}N_3O_3$

<table>
<thead>
<tr>
<th>Analysis</th>
<th>% C</th>
<th>% H</th>
<th>% N</th>
</tr>
</thead>
<tbody>
<tr>
<td>Found</td>
<td>74.59</td>
<td>4.37</td>
<td>9.61</td>
</tr>
<tr>
<td>Calculated</td>
<td>74.81</td>
<td>4.42</td>
<td>9.69</td>
</tr>
</tbody>
</table>

**Compound 5b:** $R_1 = \text{Ph}, R_2 = H$;
Yield = 83% \[\text{mp } 180-181^\circ C\] Molecular Formula: $C_{33}H_{23}N_3O_3$

<table>
<thead>
<tr>
<th>Analysis</th>
<th>% C</th>
<th>% H</th>
<th>% N</th>
</tr>
</thead>
<tbody>
<tr>
<td>Found</td>
<td>77.57</td>
<td>4.50</td>
<td>8.17</td>
</tr>
<tr>
<td>Calculated</td>
<td>77.78</td>
<td>4.55</td>
<td>8.25</td>
</tr>
</tbody>
</table>

**Compound 5c:** $R_1 = 4-\text{CH}_3\text{Ph}, R_2 = H$;
Yield = 79% \[\text{mp } 218-220^\circ C\] Molecular Formula: $C_{34}H_{25}N_3O_3$

<table>
<thead>
<tr>
<th>Analysis</th>
<th>% C</th>
<th>% H</th>
<th>% N</th>
</tr>
</thead>
<tbody>
<tr>
<td>Found</td>
<td>78.21</td>
<td>4.74</td>
<td>8.10</td>
</tr>
<tr>
<td>Calculated</td>
<td>77.99</td>
<td>4.81</td>
<td>8.03</td>
</tr>
</tbody>
</table>
**Compound 5d**: \( R_1 = 4\text{-ClPh}, R_2 = H; \)
Yield = 85%  
mp 206-208°C  
Molecular Formula: C\(_{33}H_{22}ClN_3O_3\)
Analysis
% C  % H  % N
Found  72.63  4.00  7.65
Calculated  72.86  4.08  7.72

**Compound 5e**: \( R_1 = H, R_2 = F; \)
Yield = 72%  
mp 260-262°C  
Molecular Formula: C\(_{27}H_{18}F_3N_3O_3\)
Analysis
% C  % H  % N
Found  71.63  3.98  9.26
Calculated  71.83  4.02  9.31

**Compound 5f**: \( R_1 = \text{Ph}, R_2 = F; \)
Yield = 81%  
mp 182-184°C  
Molecular Formula: C\(_{33}H_{22}F_3N_3O_3\)
Analysis
% C  % H  % N
Found  75.34  4.14  8.03
Calculated  75.13  4.20  7.97

**Compound 5g**: \( R_1 = 4\text{-CH}_3\text{Ph}, R_2 = F; \)
Yield = 84%  
mp 159-160°C  
Molecular Formula: C\(_{34}H_{24}F_3N_3O_3\)
Analysis
% C  % H  % N
Found  75.13  4.40  7.70
Calculated  75.40  4.47  7.76

**Compound 5h**: \( R_1 = 4\text{-ClPh}, R_2 = F; \)
Yield = 82%  
mp 188-190°C  
Molecular Formula: C\(_{33}H_{21}ClF_3N_3O_3\)
Analysis
% C  % H  % N
Found  70.74  3.71  7.56
Calculated  70.53  3.77  7.48

**Compound 5i**: \( R_1 = H, R_2 = Cl; \)
Yield = 77%  
mp 252-253°C  
Molecular Formula: C\(_{27}H_{18}ClN_3O_3\)
Analysis
% C  % H  % N
Found  69.06  3.82  8.91
Calculated  69.31  3.88  8.98

**Compound 5j**: \( R_1 = \text{Ph}, R_2 = Cl; \)
Yield = 83%  
mp 222-223°C  
Molecular Formula: C\(_{33}H_{22}ClN_3O_3\)
Analysis
% C  % H  % N
Found  72.67  4.04  7.67
Chapter 5  
Quinolinyl-pyrazolyl substituted coumarins (MW)

Calculated  72.86  4.08  7.72

**Compound 5k:** \( R_1 = 4-\text{CH}_3\text{Ph}, R_2 = \text{Cl}; \)

Yield = 87%  \( \text{mp } 140-141^\circ\text{C} \)  Molecular Formula: \( \text{C}_{34}\text{H}_{24}\text{ClN}_3\text{O}_3 \)

Analysis % C  % H  % N

Found  73.39  4.41  7.62
Calculated  73.18  4.34  7.53

**Compound 5l:** \( R_1 = 4-\text{ClPh}, R_2 = \text{Cl}; \)

Yield = 85%  \( \text{mp } 247-249^\circ\text{C} \)  Molecular Formula: \( \text{C}_{33}\text{H}_{21}\text{Cl}_2\text{N}_3\text{O}_3 \)

Analysis % C  % H  % N

Found  68.24  3.62  7.20
Calculated  68.52  3.66  7.26
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