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Research Article

# The Introduction of Exclusive Pyrrolo[3,2-c]coumarins as Anti-breast Cancer Agents

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## Abstract

The condensation of various 4-hydroxy coumarin with various Nitroethenes, (E)-3-(4-(2-nitrovinyl)-1-phenyl-1H-pyrazol-3-yl)-pyridine and (E)-4-(4-(2-nitrovinyl)-1-phenyl-1H-pyrazol-3-yl)-pyridine in presence of acetic acid and ammonium acetate gives pyrrolo[3,2-c]coumarins in good yields. All the synthesized compounds were determined by spectroscopy and screened for anti-cancer activity study.

**Keywords:** Nitroethene; 4-Hydroxy Coumarin; Pyrrolo[3,2-c]coumarins and Anticancer Activity

## Introduction

A large number of valuable species used commonly as medicinal plants, aromatic plants, and edible plants for human and animal feeding belongs to coumarin-rich plant families. Among them are species with well-documented biological activity, in which coumarins are part of the active principles. Coumarin is the natural product and it is obtained from the tonka bean. The first occurrence of coumarin was reported by Vogel [1]. One member of this family Suksdorfin is a dihydroseselin type angular pyranocoumarin. A furanocoumarin, Imperatorin obtained from methanolic extracts of dried roots of Ferula sumbul showed an HIV inhibitory activity [2]. Novobiocin is a natural product isolated from soil samples containing Streptomyces spheroids [3] and has clinical use for the treatment of bacterial infection [4,5] and more recently some forms of cancer [6]. Now in continuation of our interest in synthesizing newer pyrrolo[3,2-c]coumarin derivatives, it was thought worthwhile to incorporate pyrazolyl-pyridine moiety in pyrrolo[3,2-c]coumarins. Therefore in the present work various pyrrolo[3,2-c]coumarins (6a-c) and (7a-c) have been synthesized by reacting 4-hydroxy coumarins (5a-c) with newer nitro ethenes (3) and (4) by using refluxing acetic acid in presence of ammonium acid condition.

## Materials and Methods

### Synthesis and Characterisation

All chemicals were purchased from Sigma-Aldrich, Germany. Melting points were determined by the open capillary method and were uncorrected. FTIR spectra of the synthesized compounds were recorded on a Shimadzu-8400S, using KBr pellets in 10-4 resolution and 30 scans. $^{1}$H NMR spectra were recorded on a Varian spectrometer, USA at 400 MHz at room temperature. Samples were prepared in $CDCl_3$ containing TMS as an internal standard. Splitting patterns were designated as follows: s, singlet; d, doublet; t, triplet; m, multiplet. Chemical shift values were given in parts per million (ppm). $^{13}$C NMR were recorded on Varian 400 spectrometer, operating at 400 MHz. The Liquid Chromatography Mass Spectra

(LC-MS) were recorded on a Varian Inc, USA, 410 Prostar Binary LC with 500 MS IT PDA detectors.

## Cell lines

MCF-7 (breast cancer) cell were cultured in DMEM medium and supplemented with 10% of fetal bovine serum (FBS) then the culture flasks were incubated for 3-4 days at 37˚C in 5% $CO_2$ incubator.

## Analysis of cell viability by MTT assay

Cell viability was measured quantitatively by using MTT, showed the activity of living cells [Plumb., *et al*. 1989]. MCF-7 was seeded into 24 well plates and treated with 100µl/ml, 150µl/ml, 200µl/ml, 250µl/ml and 300µl/ml of various pyrrolo[3,2-c]coumarins mixture dissolved in $CHCl_3$ and dried extracts were used as triplicate. The DMSO was used as control in each experiment. The treated mixture was then incubated at 37ºC with 5% $CO_2$ for 24 hours. After incubation, 2µl/ml of the labeled reagent was added to each well followed by incubation for 3 hours at 37ºC with 5% $CO_2$ and then the medium was discarded and the crystals were dissolved in 1.0 ml of 0.04N HCl. The absorbance of cells was measured at 570 nm with an ELISA reader. MTT assay was performed in the Department of Microbiology, SSR College of Arts, Commerce and Science, Silvassa.

## Statistical analysis

Each data point was obtained by making at least 3 independent measurements. All data are expressed as mean + S.D. Data were analyzed by an analysis of variance ($p<0.05$) and the means separated by one way ANOVA

## Experimental

## Preparation of various pyrrolo[3,2-c]coumarins.

The synthesis of various pyrrolo[3,2-c] coumarins (6a-c) and (7a-c) has been carried out by the reaction of 4-hydroxy coumarins (5a-c) with appropriate (E)-3-(4-(2-nitrovinyl)-1-phenyl-1H-pyrazol-3-yl)-pyridine (3) and (E)-4-(4-(2-nitrovinyl)-1-phenyl-1H-pyrazol-3-yl)-pyridine (4) in the presence of catalytic amount of piperidine in refluxing methanol (Scheme 1).

The required (E)-3-(4-(2-nitrovinyl)-1-phenyl-1H-pyrazol-3-yl)-pyridine (3) and (E)-4-(4-(2-nitrovinyl)-1-phenyl-1H-pyrazol-3-yl)-pyridine (4) were prepared by the reaction of 1-phenyl-3-(pyridin-3-yl)-1H-pyrazole-4-carbaldehyde (1) and 1-phenyl-3-(pyridin-4-yl)-1H-pyrazole-4-carbaldehyde (2) with nitromethane in the presence of ammonium acetate in refluxing acetic acid.

The condensation of various 4-hydroxy coumarins (5a-c) with (E)-3-(4-(2-nitrovinyl)-1-phenyl-1H-pyrazol-3-yl)-pyridine (3) and (E)-4-(4-(2-nitrovinyl)-1-phenyl-1H-pyrazol-3-yl)-pyridine (4) proceeded smoothly and gave the expected products (6a-c) and (7a-c) in 65-75% Yield.

The formation of furan nucleus in (6a-c) and (7a-c) follows Nef reaction mechanism (Scheme: 2) and (Scheme: 3).

The structures of all the compounds (6a-c) and (7a-c) were confirmed by analytical and spectral data.

## Note

In $^1$H NMR Spectroscopic characterization, the N-H proton of pyrrole moiety was separated out from other aromatic proton signals and gave two singlets, which were $D_2O$ exchangeable also. The appearance of pyrrole proton as two singlets rather than one singlet may be because of its possible enol form with coumarin carbonyl.

6a ($R_1 = R_2 = H$)

Yield 90%, mp 197°C, IR: $\nu_{max}$ 1724 (C=O stretching of δ-lactone of coumarin), 1598 and 1480 (aromatic C=C and C=N stretchings), 3424 (N-H stretching vibration), 3057 (aromatic C-H stretching), 755 and 692 (C-H bending vibrations of mono substituted benzene ring), 1103 (C-O-C stretching of furan ring). $^1$H-NMR: (δ, ppm) ($CDCl_3$) 7.26-8.95 (12H, multiplet, aromatic protons except proton at $C_5'$, $C_2''$ and $C_6''$), 8.35 (1H, singlet, proton at $C_5'$). 8.66 (1H, doublet of the doublet, proton at $C_6''$, J= 4.6 Hz and 1.6 Hz), 8.95 (1H, meta coupled doublet, proton at $C_2''$, J= 2.0 Hz), 10.24 and 12.09 (1H each, two singlets, N-H proton of pyrrole). $^{13}$C NMR: (δ, ppm) ($CDCl_3$) 102.35(C), 119.91(CH), 121.19(C), 121.97(C), 123.25(CH), 124.08(CH), 125.42(C), 125.91(CH), 126.02(CH), 126.26(CH), 128.74(C), 129.14(CH), 129.32(CH), 130.57(CH), 133.03(C), 134.02(CH), 141.93(CH), 143.61(C), 147.53(CH), 147.99(CH), 151.16(C), 157.66(C), 159.98 (CO). Calcd. for $C_{25}H_{16}N_4O_2$: C, 74.25; H, 3.99; N, 13.85; O, 7.91%. Found: C, 74.13; H, 2.79; N, 13.77; O, 7.88%.

6b ($R_1 = CH_3$, $R_2 = H$)

Yield 90%, mp 197°C, IR: $\nu_{max}$ 1719 (C=O stretching of δ-lactone of coumarin), 1591 and 1477 (aromatic C=C and C=N stretchings), 3420 (N-H stretching vibration), 3052 (aromatic C-H stretching), 755 and 695 (C-H bending vibrations of mono substituted benzene ring), 2937 (aliphatic C-H stretching), 1107 (C-O-C stretching of furan ring). ). $^1$H-NMR: (δ, ppm) ($CDCl_3$) 2.38 (3H, singlet, $CH_3$), 7.26-8.91 (11H, multiplet, aromatic protons except proton at $C_5'$, $C_2''$ and $C_6''$), 8.35 (1H, singlet, proton at $C_5'$). 8.66 (1H, doublet of the doublet, proton at $C_6''$, J= 4.6 Hz and 1.6 Hz), 8.91 (1H, meta coupled doublet, proton at $C_2''$, J= 2.0 Hz), 10.14 and 12.15 (1H each, two singlets, N-H proton of pyrrole). $^{13}$C NMR: (δ, ppm) ($CDCl_3$) 15.14($CH_3$), 102.35(C), 119.91(CH), 121.19(C), 121.97(C), 123.25(CH), 124.08(CH), 125.42(C), 125.91(CH), 126.02(CH), 126.26(CH), 128.74(C), 129.32(CH), 130.57(CH), 133.03(C), 134.02(CH), 141.93(CH), 143.61(C), 147.53(CH), 147.99(CH), 151.16(C), 157.73(C), 159.98 (CO). Anal.Calcd.for $C_{26}H_{18}N_4O_2$: C, 74.63; H, 4.34; N, 13.39; O, 7.65%. Found: C, 74.53; H, 4.22; N, 13.08; O, 7.55%.

**Scheme 1**

6c ($R_1$ = H, $R_2$ = $CH_3$)

Yield 90%, mp 197°C, IR: $\nu_{max}$ 1727 (C=O stretching of δ-lactone of coumarin), 1598 and 1483 (aromatic C=C and C=N stretchings), 3427 (N-H stretching vibration), 3054 (aromatic C-H stretching), 755 and 692 (C-H bending vibrations of mono substituted benzene ring), 2939 (aliphatic C-H stretching), 1102 (C-O-C stretching of furan ring). $^1$H-NMR: (δ, ppm) ($CDCl_3$) 2.32 (3H, singlet, $CH_3$), 7.26-8.93 (11H, multiplet, aromatic protons except proton at $C_5'$, $C_2''$ and $C_6''$), 8.35 (1H, singlet, proton at $C_5'$). 8.66 (1H, doublet of the doublet, proton at $C_6''$, J= 4.6 Hz and 1.6 Hz), 8.93 (1H, meta coupled doublet, proton at $C_2''$, J= 2.0 Hz), 10.17 and 12.21 (1H each, two singlets, N-H proton of pyrrole). $^{13}$C NMR: (δ, ppm) ($CDCl_3$) 15.09($CH_3$), 102.35(C), 119.91(CH), 121.19(C), 121.97(C), 123.25(CH), 124.08(CH), 125.42(C), 125.91(CH), 126.26(CH), 128.74(C), 129.14(CH), 129.32(CH), 130.57(CH), 133.03(C), 134.02(CH), 141.93(CH), 143.61(C), 147.53(CH), 147.99(CH), 151.16(C), 157.73(C), 159.98 (CO). Anal.Calcd.for $C_{26}H_{18}N_4O_2$: C, 74.63; H, 4.34; N, 13.39; O, 7.65%. Found: C, 74.48; H, 4.17; N, 13.08; O, 7.60%.

**Scheme 2**

7a ($R_1$ = $R_2$ = H)

Yield 90%, mp 197°C, IR: $\nu_{max}$ 1718 (C=O stretching of δ-lactone of coumarin), 1597 and 1487 (aromatic C=C and C=N stretchings), 3419 (N-H stretching vibration), 3054 (aromatic C-H stretching), 755 and 692 (C-H bending vibrations of mono substituted benzene ring), 1103 (C-O-C stretching of furan ring). $^1$H-NMR: (δ, ppm) ($CDCl_3$) 7.32-8.73 (12H, multiplet, aromatic protons except proton at $C_5'$, $C_2''$ and $C_6''$), 8.21 (1H, singlet, proton at $C_5'$). 8.73 (2H, ortho coupled doublet, protons at $C_2''$ and $C_6''$, J= 4.4 Hz), 10.13 and 12.18 (1H each, two singlets, N-H proton of pyrrole). $^{13}$C NMR: (δ, ppm) ($CDCl_3$) 102.37(C), 119.98(CH), 121.16(C), 121.32(CH), 121.94(C), 123.26(CH), 125.45(C), 125.92(CH), 126.11(CH), 126.24(CH), 128.76(C), 129.15(CH), 129.33(CH), 130.51(CH), 140.35(C), 141.97(CH), 143.61(C), 149.84(CH), 151.13(C), 157.72(C), 159.91(CO). Anal.Calcd.for $C_{25}H_{16}N_4O_2$: C, 74.25; H, 3.99; N, 13.85; O, 7.91%. Found: C, 74.11; H, 3.91; N, 13.67; O, 7.81%.

7b ($R_1$ = $CH_3$, $R_2$ = H)

Yield 90%, mp 197°C, IR: $\nu_{max}$ 1722 (C=O stretching of δ-lactone of coumarin), 1598 and 1483 (aromatic C=C and C=N stretchings), 3427 (N-H stretching vibration), 3057 (aromatic C-H stretching), 755 and 692 (C-H bending vibrations of mono substituted benzene ring), 2934 (aliphatic C-H stretching), 1103 (C-O-C stretching of furan ring). $^1$H-NMR: (δ, ppm) ($CDCl_3$) 2.17 (3H, singlet, $CH_3$), 7.32-8.77 (11H, multiplet, aromatic protons except proton at $C_5'$, $C_2''$ and $C_6''$), 8.16 (1H, singlet, proton at $C_5'$). 8.77 (2H, ortho coupled doublet, protons at $C_2''$ and $C_6''$, J= 4.4 Hz), 10.09 and 12.13 (1H each, two singlets, N-H proton of pyrrole). $^{13}$C NMR: (δ, ppm) ($CDCl_3$) 15.17($CH_3$), 102.37(C), 119.98(CH), 121.16(C), 121.32(CH), 121.94(C), 123.26(CH), 125.45(C), 125.92(CH), 126.24(CH), 128.76(C), 129.15(CH), 129.33(CH), 130.51(CH), 140.35(C), 141.97(CH), 143.61(C), 149.84(CH), 151.13(C), 157.72(C), 159.91(CO). Anal.Calcd.for $C_{26}H_{18}N_4O_2$: C, 74.63; H, 4.34; N, 13.39; O, 7.65%. Found: C, 74.60; H, 4.18; N, 12.92; O, 7.51%.

**Scheme 3**

7c ($R_1$ = H, $R_2$ = $CH_3$)

Yield 90%, mp 197°C, IR: $\nu_{max}$ 1724 (C=O stretching of δ-lactone of coumarin), 1598 and 1480 (aromatic C=C and C=N stretchings), 3419 (N-H stretching vibration), 3057 (aromatic C-H stretching), 755 and 692 (C-H bending vibrations of mono substituted benzene ring), 2937 (aliphatic C-H stretching), 1103 (C-O-C stretching of furan ring). $^1$H-NMR: (δ, ppm) ($CDCl_3$) 2.20 (3H, singlet, $CH_3$), 7.32-8.69 (11H, multiplet, aromatic protons except proton at $C_5'$, $C_2''$ and $C_6''$), 8.25 (1H, singlet, proton at $C_5'$). 8.69 (2H, ortho coupled doublet, protons at $C_2''$ and $C_6''$, J= 4.4 Hz), 10.17 and 11.97 (1H each, two singlets, N-H proton of pyrrole). $^{13}$C NMR: (δ, ppm) ($CDCl_3$) 15.29($CH_3$), 102.37(C), 119.98(CH), 121.16(C), 121.32(CH), 121.94(C), 123.26(CH), 125.45(C), 125.92(CH), 126.11(CH), 126.24(CH), 128.76(C), 129.33(CH), 130.51(CH), 140.35(C), 141.97(CH), 143.61(C), 149.84(CH), 151.13(C), 157.72(C), 159.91(CO). Anal.Calcd.for $C_{26}H_{18}N_4O_2$: C, 74.63; H, 4.34; N, 13.39; O, 7.65%. Found: C, 74.46; H, 4.17; N, 12.97; O, 7.58%.

Preparation of 4-hydroxy coumarin (5a), 6-methyl-4-hydroxy coumarin (5b) and 8-methyl-4-hydroxy coumarin (5c)

**Scheme 4**

The following general procedure was used.

In a 500 mL round bottom flask attached with a reflux condenser and gas absorption trap, a mixture of an appropriate phenol (0.2 mole), malonic acid (0.1 mole), anhydrous zinc chloride (0.6 mole) and phosphorous oxychloride (0.4 mole) were heated with stirring at 60-65 °C for 35 hours. The yellow coloured mixture was cooled and decomposed with water and left overnight. The resulting crude 4-hydroxy coumarin was filtered out, washed with water and dried. This crude product was purified by dissolving it in 10% sodium bicarbonate solution, filtering and reprecipitating by adding dilute HCl solution. The solid product was separated out which was filtered out, washed with water, dried and recrystallized from ethanol.

- 4-Hydroxy coumarin (5a): $R_1$ = $R_2$= H; Yield: 60%, mp 202-204°C (lit.[7] mp 206°C).
- 6-Methyl-4-hydroxy coumarin (5b): $R_1$ = $CH_3$, $R_2$ = H; Yield: 43%, mp 236-238°C (lit.[7] mp 240°C).
- 8-Methyl-4-hydroxy coumarin (5c): $R_1$= H, $R_2$ = $CH_3$; Yield: 53%, mp 222°C(lit.[7] mp 223°C).

Preparation of (E)-3-(4-(2-nitrovinyl)-1-phenyl-1H-pyrazol-3-yl)-pyridine (3) and (E)-4-(4-(2-nitrovinyl)-1-phenyl-1H-pyrazol-3-yl)-pyridine (4)

**Scheme 5**

The following general procedure was used.

The 1-phenyl-3-(pyridin-3-yl)-1H-pyrazole-4-carbaldehyde[8] (1) or 1-phenyl-3-(pyridin-4-yl)-1H-pyrazole-4-carbaldehyde[8] (2) (0.16 mol), nitro methane (0.1 mol), ammonium acetate (0.16 mol) and glacial acetic acid (100 mL) were mixed in a 250 mL round bottom flask fitted with a reflux condenser. The reaction mixture was refluxed for 4 to 5 hours in an oil bath. It was then poured into crushed ice. Fine yellow crystals irritating to the skin obtained were filtered out and were recrystallized from rectified spirit.

### (E)-3-(4-(2-nitrovinyl)-1-phenyl-1H-pyrazol-3-yl)-pyridine (3)

Yield 94%, mp 184-186°C, IR: $\nu_{max}$ 1647 and 1540 (aromatic C=C and C=N stretchings), 3133 (aromatic C-H stretching), 1540 ($NO_2$ stretching). $^1$H-NMR: *(δ, ppm) (CDCl$_3$)* 7.26-8.17 (12H, multiplet, ten aromatic protons + 2 olefinic proton). Anal.Calcd.for $C_{16}H_{12}N_4O_2$: C, 65.75; H, 4.14; N, 19.17; O, 10.95%. Found: C, 65.70; H, 4.11; N, 19.12; O, 10.92%.

### (E)-4-(4-(2-nitrovinyl)-1-phenyl-1H-pyrazol-3-yl)pyridine (4)

Yield 94%, mp 184-186°C, IR: $\nu_{max}$ 1636 and 1545 (aromatic C=C and C=N stretchings), 3129 (aromatic C-H stretching), 1540 ($NO_2$ stretching). $^1$H-NMR: (δ, ppm) ($CDCl_3$) 7.26-8.20 (12H, multiplet, ten aromatic protons + 2 olefinic proton). Anal.Calcd.for $C_{16}H_{12}N_4O_2$: C, 65.75; H, 4.14; N, 19.17; O, 10.95%. Found: C, 65.64; H, 4.11; N, 19.14; O, 10.89%.

## Results and Discussion

Various pyrrolo[3,2-c] coumarins (6a-c) and (7a-c) were screened at concentration of 100 µl/ml, 150 µl/ml, 200 µl/ml, 250 µl/ml and 300 µl/ml. The most of compounds significantly reduced the growth of MCF-7 cell line. The evaluation of reduction for MCF-7 cell line treated with pyrrolo[3,2-c]coumarins mixture at 570nm using ELISA reader data are shown in Chart: 1. The assay shows all the compounds show a reduction of around 65%.

| Concentration | Cell viability (%) | | | | |
|---|---|---|---|---|---|
| | 100 µl/ml | 150 µl/ml | 200 µl/ml | 250 µl/ml | 300 µl/ml |
| Control | 100 | 100 | 100 | 100 | 100 |
| 6a | 69.73 ± 1.42 | 59.03 ± 1.15 | 49.7 ± 0.79 | 34.97 ± 0.65 | 31.13 ± 0.91 |
| 6b | 67.37 ± 1.1 | 60.86 ± 1.5 | 46.57 ± 0.45 | 28.87 ± 1.11 | 27.2 ± 1.61 |
| 6c | 75.47 ± 1.44 | 57.63 ± 0.81 | 45.93 ± 0.8 | 35.23 ± 0.32 | 32.3 ± 0.44 |
| 7a | 67.73 ± 0.46 | 55.83 ± 0.86 | 49.47 ± 0.9 | 34.87 ± 0.42 | 31.53 ± 0.9 |
| 7b | 66.27 ± 0.93 | 56.6 ± 1.15 | 47.83 ± 0.57 | 32.47 ± 1.08 | 30.6 ± 0.61 |
| 7c | 68.27 ± 1.27 | 54.51 ± 1.15 | 45.27 ± 1.22 | 36.8 ± 0.82 | 32.7 ± 0.7 |

**Table 1**

**Chart 1**

## Conclusion

Thus, to gain a better understanding of the beneficial biological activities of pyrrolo[3,2-c]coumarins upon cancer prevention, a greater knowledge of the metabolism of pyrrolo[3,2-c]coumarins is needed. More research is clearly needed to identify and characterize additional pyrrolo[3,2-c]coumarins metabolites and their biological activities, which will potentially provide invaluable insights into the mechanisms underlying the beneficial effects of pyrrolo[3,2-c]coumarins to humans, especially in terms of cancer prevention. The synthesized compounds can also be screened with non-cancerous cell lines such as CHO or HEK293 cell lines in future. If such studies succeed in identifying an active pyrrolo[3,2-c]coumarins derivative, it could be used as a parent compound for the development of potent anticancer drugs.

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## Declarations

- The synthesis and characterizations has been carried out by author.
- The syntheses of all compounds were carried out in Chemistry Laboratory-2 of SSR College of Arts. Commerce and Science.
- The anti-cancer cell viability study has been conducted in Department of Microbiology, SSR College of Arts. Commerce and Science.

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- The expanses of spectroscopic analysis were paid by author only.
- The cell were collected and analyzed by Department of Microbiology, SSR College of Arts. Commerce and Science with funding of SSR Memorial Trust.

## Conflicts of Interest

Academic Progress only.

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