WORLD JOURNAL OF PHARMACEUTICAL RESEARCH
SJIF Impact Factor 7.523
Volume 6, Issue 4, 1130-1142. Research Article ISSN 2277– 7105

STUDY ON NEWLY SYNTHESIZED OF METAL HETEROCHELATES BASED ON NORFLOXACIN AND DICUMAROL DERIVATIVE: BIOLOGICAL ASSESSMENT

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Article Received on
29 January 2017,

Revised on 16 February 2017,
Accepted on 08 March 2017

DOI: 10.20959/wjpr20174-8149

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ABSTRACT

Some newly heterochelates synthesized by reflux of different coumarin derivative, Norfloxacin and transition metal as Cu(II). The structures of the ligands and their copper complexes were investigated and confirmed by the elemental analysis, FT-IR, ^{1}H-NMR, ^{13}C-NMR, and mass spectral data. Thermal behavior of newly synthesized mixed ligand Cu(II) complexes were investigated by means of thermogravimetry, electronic spectra and magnetic measurements. The compounds were screened for their antimicrobial and antioxidant viewing using serial broth dilution method and Minimum Inhibitory Concentration (MIC) is determined.

KEYWORDS: Norfloxacin, biological study, octahedral Complexes.

1. INTRODUCTION

Coumarin and its derivatives represent one of the most active classes of compounds possessing a wide spectrum of biological activity.[1-4] Many of these compounds have proved to be active as antitumor,[5] antibacterial,[6] antifungal,[7] anticoagulant.[8] and anti-inflammatory.[9] In addition, these compounds are used as additives to food and cosmetics.[10] dispersed Fluorescent and laser.[11] Various analogues of 3- Substituted coumarins such as 3-amino coumarins exhibit antimicrobial activity.[12-13] From the above line of reasoning we directed this paper towards synthesis of various coumarin derivatives of biological interest using 3-amino coumarin a key starting material. Coumarin in itself possess much of broad range of biological activities namely anticoagulation, antibiotic, antifungal, antipsoriasis, cytotoxic, anti-HIV, anti-inflammatory. Especially 7- hydroxycoumarin has antioxidant

properties and cytostatic, antibacterial, antiviral, xanthine oxidase inhibitor, antihyperglycemic,[16] casein kinase 2 inhibitor.[17] activities,vasorelaxant.[18] antitubercular.[19] Recently, coumarin derivatives have been evaluated in the treatment of human immunodeficiency virus, due to their ability to inhibit human immunodeficiency virus integrase.

Norfloxacin is a synthetic chemotherapeutic antibacterial agent.[20] occasionally used to treat common as well as complicated urinary tract infections. It is sold under various brand names with the most common being Noroxin. In form of ophthalmic solutions it is known as Chibroxin (Apiflox eye drops in Jordan. Norfloxacin is a first generation synthetic fluoroquinolone(quinolone) developed by Kyorin Seiyaku K.K. (Kyorin).[21-22] Norfloxacin is approved for the treatment of urinary tract infections, prostatitis, and sexually transmitted diseases. but is no longer used for the latter due to the development of bacterial resistance.[23] Chibroxin (ophthalmic) is approved for use in children older than one year of age. The first members of the quinolone antibacterial class were relatively low potency drugs such as nalidixic acid, used mainly in the treatment of urinary tract infections owing to their renal excretion and propensity to be concentrated in urine.[24]

The aim of this study was to prepare the mixed ligand complexes of Cu(II) using norfloxacin with coumarin derivatives and to determine their properties. In our previous reports, we have mentioned a series of fused coumarin derivatives and its transition metal complexes.[25] In continuation of our preceding work, we describe here synthesis, characterization and spectroscopic features of new mixed ligand Cu(II) complexes along with antimicrobial and anti-oxidant activities.

2. EXPERIMENTAL

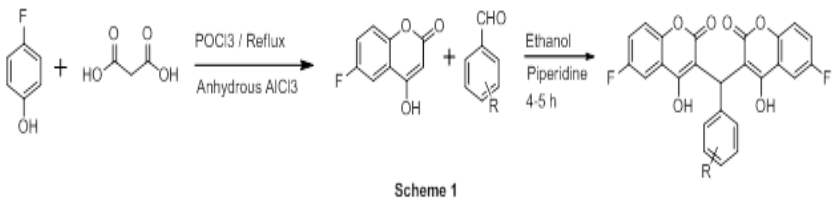
2.1 Materials

All reagents were of analytical reagent (AR) grade purchased commercially from Spectro chem. Ltd., Mumbai-India and used without further purification. Solvents employed were distilled, purified and dried by standard procedures prior to use.[26] Clioquinol was purchased from Agro Chemical Division, Atul Ltd., Valsad-India. The metal nitrates used were in hydrated form.

2.2 Physical measurements

All reactions were monitored by thin-layer chromatography (TLC on alluminium plates coated with silica gel 60 F254, 0.25 mm thickness, E. Merck, Mumbai-India) and detection of the components were measured under UV light or explore in Iodine chamber. Carbon, hydrogen and nitrogen were estimated by elemental analyzer PerkinElmer, USA 2400-II CHN analyzer. Metal ion analyses was carry out by the dissolution of solid complex in hot concentrated nitric acid, further diluting with distilled water and filtered to remove the precipitated organic ligands. Remaining solution was neutralized with ammonia solution and the metal ions were titrated against EDTA. ^{1}H and ^{13}C NMR measurements were carried out on Advance-II 400 Bruker NMR spectrometer, SAIF, Chandigarh. The chemical shifts were measured with respect to TMS which used as internal standard and DMSO-d_6 used as solvent. Infrared spectra of solids were recorded in the region 4000-400 cm^{-1} on a Nicolet Impact 400D Fourier-Transform Infrared Spectrophotometer using KBr pellets. Melting point of the ligands and metal complexes were measured by open capillary tube method. Solid state magnetic susceptibility measurements were carried out at room temperature using a Gouy's magnetic susceptibility balance with mercury tetrathiocyanato cobaltate(II) being used as a reference standard (g = 16.44×10^{-6} c.g.s. units). Molar susceptibility was corrected using Pascal's constant. The electronic spectra were collected using LAMBDA 19 UV/Vis/NIR spectrophotometer in the region 200-1200 nm.

2.3 General procedure for the preparation of Coumarine chalcone (L)



Scheme 1

Where R = *H* (L^1); *m*-Cl (L^2); *m*-OH (L^3); *m*-NO_2 (L^4); *p*-OH-*m*-OCH_3 (L^5);

2.3.1 3,3'-(phenylmethylene)bis(6-flouro-4-hydroxy-2H-chromen-2-one): (L1)

Yield: 67 %, m.p. 225 °C. FT-IR (KBr, cm^{-1}): *ν*(-OH/H_2O) 3183, 3053, *ν*(C=O) 1660,1653, *ν*(C=C) 1646, 1564, *ν*(C-O) 1177, 1122, 1086, 822, 794, 749. ^{1}H NMR (DMSO-d^6 400 MHz) δ: 6.53 (^{1}H, Aliphatic), 7.11-7.94 (13H, m, Aromatic proton), 10.36 (-OH phenolic); ^{13}C NMR (DMSO-d^6 100 MHz): δ: 36.6 (C-9), 103.5 (C-3, 18), 116.3, 117.4, 123.5 125.4, 125.3, 127.73, 128.2, 128.3, 143.5(9C, Ar-C), 152.5(C-8a, 23a), 164.6(C-2, 17), 167.4(C-4, 19); ESI-MS (*m/z*): 455.02$(M+H)^+$. Elemental analysis found (%): C, 62.28; H, 2.81; Calculated for $C_{25}H_{14}F_2O_6$ (454.28): C, 62.39; H, 2.93.

2.3.2 **3,3'-((3-chlorophenyl)methylene)bis(6-flouro-4-hydroxy-2H-chromen-2-one): (L2)**

Yield: 70%, m.p.: 260 °C. FT-IR (KBr, cm^{-1}): *v*(-OH/H^2O) 3192, 3055, *v*(C=O) 1664,1656, *v*(C=C) 1648, 1557, *v*(C-O) 1205, 1125, 1083, 817, 784, 744. 1H NMR (DMSO-d^6 400 MHz) δ: 6.44 (^{1}H, Aliphatic), 7.19-8.78 (12H, m, Aromatic proton), 10.43 (-OH phenolic); ^{13}C NMR (DMSO-d^6 100 MHz): δ: 36.3 (C-9), 102.2 (C-3, 18), 116.4, 116.8, 123.5, 125.6, 125.7, 125.8, 128.4, 128.7, 131.3, 134.6, 144.7 (11C, Ar-C), 151.7(C-8a, 23a), 163.5(C-2, 17), 165.4(C-4, 19); ESI-MS (*m/z*): 489.98$(M+H)^+$. Elemental analysis found (%): C, 67.20; H, 3.38; Calculated for $C_{25}H_{15}F_2O_6$ (488.73): C, 58.22; H, 2.54.

2.3.3 **3,3'-((3-hydroxyphenyl)methylene)bis(6-flouro-4-hydroxy-2H-chromen-2-one): (L3)**

Yield: 70%, m.p.: 217 °C. FT-IR (KBr, cm^{-1}): *v*(-OH/H_2O) 3137, 3055, *v*(C=O) 1664,1657 *v*(C=C) 1625, 1576, *v*(C-O) 1153, 1126, 1092, 815, 797, 774. ^{1}H NMR (DMSO-*d6* 400 MHz) δ: 6.35 (1H, Aliphatic), 6.97-7.74 (12H, m, Aromatic proton), 9.37, 10.34 (-OH phenolic); ^{13}C NMR (DMSO-d^6 100 MHz): δ: 36.5 (C-9), 101.4 (C-3, 18), 113.7, 114.5, 116.3, 116.8, 120.3, 123.4 125.6, 128.8, 130.4, 142.2 (10C, Ar-C), 152.3(C-8a, 23a), 157.3(C-12, carbon attach to phenolic OH) 161.4(C-2, 17), 164.5(C-4, 19); ESI-MS (*m/z*): 471.01$(M+H)^+$. Elemental analysis found (%): C, 60.09; H, 2.76; Calculated for $C_{25}H_{16}F_2O_7$ (470.28): C, 60.38; H, 2.84.

2.3.4 **3,3'-((3-nitrophenyl)methylene)bis(6-flouro-4-hydroxy-2H-chromen-2-one): (L4)**

Yield: 69%, m.p.: 287 °C, FT-IR (KBr, cm^{-1}): *v*(m,-OH/H_2O) 3159, 3034, *v*(C=O) 1666,1653 *v*(C=C) 1625, 1574, *v*(C-O) 1161, 1125, 1078, 813, 781, 748. ^{1}H NMR (DMSO-d^6 400 MHz) δ: 6.41 (1H, Aliphatic), 7.19-8.25 (12H, m, Aromatic proton), 10.84 (-OH phenolic). ^{13}C NMR (DMSO-d^6 100 MHz): δ: 35.2 (C-9), 100.7 (C-3, 18), 115.9, 116.6, 119.6, 120.24, 121. 6 122.5 124.52, 127.4, 133.3, 144.7, 148.2 (11C, Ar-C), 151.4(C-8a, 23a), 162.6(C-2, 17), 165.6(C-4, 19); ESI-MS (*m/z*): 500.00. Elemental analysis found (%): C, 57.65; H, 23.31; N, 2.06; Calculated for $C_{25}H_{13}F_2NO_8$ (499.28): C, 57.05; H, 2.49; N, 2.66.

2.3.5**3,3'-((4-hydroxy-3-methoxyphenyl)methylene)bis(6-Flouro-4-hydroxy-2H-chromen-2- one): (L5)**

Yield: 68 %, m.p.: 289 °C. FT-IR (KBr, cm^{-1}): *v*(OH/H_2O) 3444, 3027, *v*(C=O) 1662,1659, *v*(C=C) 1622, 1574, *v*(C-O)1152, 1123, 1084, 813, 784, 731, (C-O-C, asymmetric) 1241, (C-O-C, symmetric) 1,036, (aromatic C=C & C-H Stretching) 1602, 3027. ^{1}H NMR (DMSO-d^6 400 MHz) δ: 3.82 (3H, s, -OCH_3), 6.34 (1H, Aliphatic), 7.15-8.08 (11H, m, Aromatic

proton), 9.53, 10.46 (-OH phenolic). ^{13}C NMR (DMSO-d^6 100 MHz): δ: 36.7 (C-9), 56.9 (-OCH3), 101.7 (C-3, 18), 113.5, 114.5, 116.1 116.8, 120.7, 122.8 126.2, 127.9, 134.2 (9C, Ar-C), 144.2(C-13, carbon attach to phenolic OH), 147.3(C-12, carbon attach to –OCH_3), 153.75(C-8a, 23a), 163.2(C-2, 17), 164.7(C-4, 19); ESI-MS (*m/z*): 401.02(M +H)$^+$. Elemental analysis found (%): C, 59.12; H, 2.96; Calculated for $C_{26}H_{16}F_2O_8$ (400.31): C, 59.22; H, 3.06.

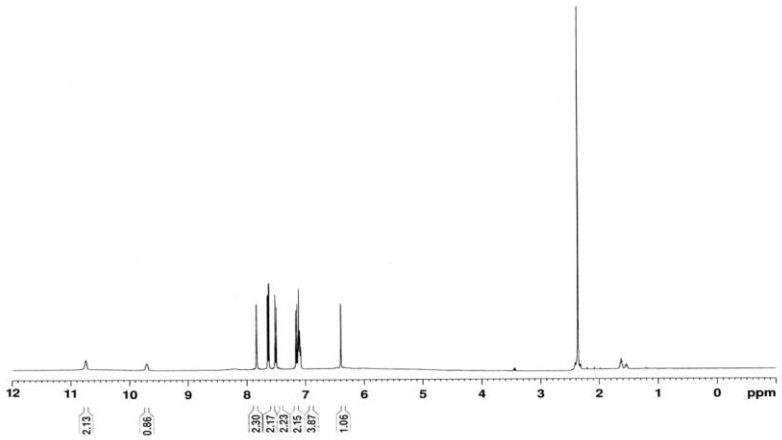


Figure 1. ^{1}H NMR Spectra of L3

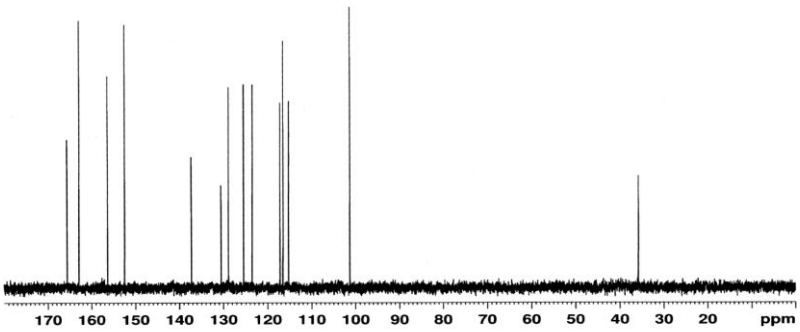


Figure 2. ^{13}C NMR Spectra of L3

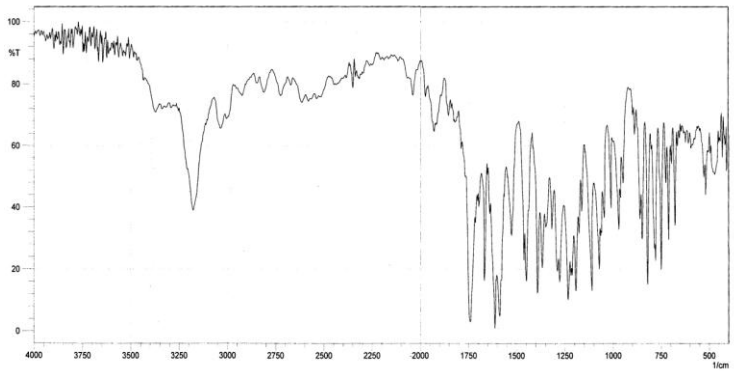


Figure 3. IR Spectra of L3

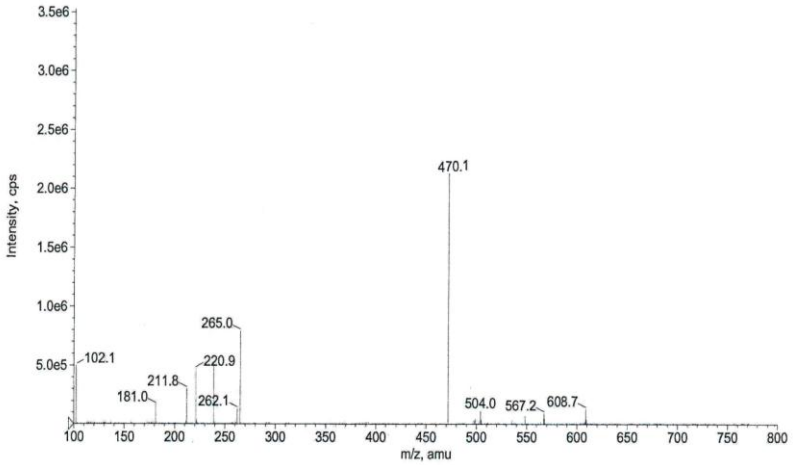
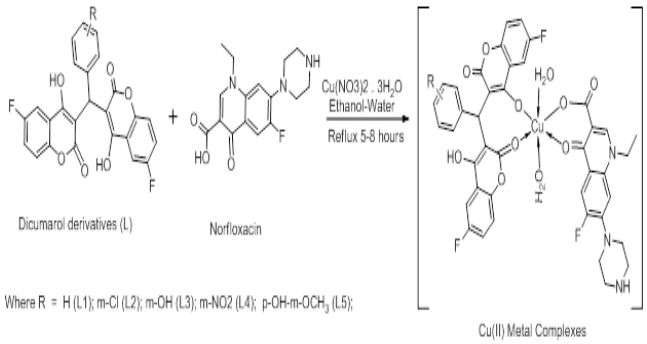


Figure 4. Mass Spectra of L3

2.4 Synthesis of metal complexes: [M(L)(NF)(H$_2$O)$_2$](C)

An aqueous solution of $Cu(NO_3)_2$•$3H_2O$ salt (10 mmol) was added into ethanolic solution of ligand (L) (10 mmol) and subsequently an ethanolic solution of Norfloxacine (10 mmol) was added with continuous stirring. Then the pH was adjusted in between 4.5-6.0 by addition of diluted NH_4OH solution. The resulting solution was refluxed for 5 h and then heated over a steam bath to evaporate up to half of the volume. The reaction mixture was kept overnight at room temperature. A fine coloured crystalline product was obtained. The obtained product was washed with ether and dried over vacuum desiccators.

Complexes C_2-C_4 was prepared according to same method and their physicochemical parameters are summarized in Table 1. The synthetic protocol of complexes is shown in Scheme 2, while FT-IR spectrum of C_1 is given in the figure 5.



Scheme 2 General Scheme for Complexes

2.5 Antimicrobial activity

All the ATCC culture was collected from institute of microbial technology, Bangalore. 2% Luria broth solution was prepared in distilled water while, pH of the solution was adjusted to

7.4±0.2 at room temperature and sterilized by autoclaving at 15 lb pressure for 25 min. The tested bacterial and fungal strains were prepared in the luria broth and incubated at 37 °C and 200 rpm in an orbital incubator for overnight. Sample solutions were prepared in DMSO for concentration 200, 150, 100, 50, 25, 12 and 6µg/mL. The standard drug solution of Streptomycin (antibacterial drug) and Nystatin (antifungal drug) were prepared in DMSO. Serial broth micro dilution was adopted as a reference method. 10 µl solution of test compound was inoculated in 5 mL luria broth for each concentration respectively and additionally one test tubes was kept as control. Each of the test tubes was inoculated with a suspension of standard microorganism to be tested and incubated at 35 °C for 24 h. At the end of the incubation period, the tubes were examined for the turbidity. Turbidity in the test tubes indicated that microorganism growth has not inhibited by the antibiotic contained in the medium at the test concentration. The antimicrobial activity tests were run in triplicate.

2.6 Antioxidant studies

Ferric reducing antioxidant power (FRAP) was determine using an adapted method.[27] The antioxidant potentials of the compounds were examine by their reducing power of the TPTZ-Fe(III) complex to TPTZ-Fe(II) complex for the total antioxidant capacity of tested samples, This method was employed because of its simple, fast and also results can be obtain was reproducible. Initially following solutions were prepared, A) acetate buffer, 300 mM pH 3.6 (3.1g sodium acetate trihydrate and 16 ml conc. acetic acid per L of buffer solution), B) 10 mM 2,4,6-tripyridyl-s-triazine in 40 mM HCl, C) 20 mM $FeCl_3 \cdot 6H_2O$ in distilled water, D) 1mM of ascorbic acid dissolved in 100 mL distilled water. FRAP working solution was prepared by mixing the above (A), (B) and (C) solutions in the ratio of 10:1:1 respectively. A mixture of 40.0 µL, 0.5 mM sample solution and 1.2 mL FRAP reagent was incubated at 37 ℃ for 15 min. The working solution was necessary to use as freshly prepared. The ascorbic acid was used as a standard antioxidant compound and results were expressed with compared to ascorbic acid.

3. RESULT AND DISCUSSION

The synthesized Cu(II) complexes were characterized by elemental analysis, FTIR spectra, The metal ion in their complexes were determined after mineralization. The metal content in chemical analysis was estimated by complexometrically,[28] while geometry of the complexes was confirmed from electronic spectra and magnetic moment.

3.1 Elemental analysis

The analytical and physiochemical data of the complexes are summarized in Table 1. The experimental data were in very good agreement with the calculated ones. The complexes were colored, insoluble in water and commonly organic solvents while soluble in DMSO as well as stable in air. The structure of the complexes is assumed according to the chemical reaction as shown below;

Table 1 Analytical and physical parameters of complexes

Comps.	Elemental analyses, % found (required)				M.P. (^{o}C)	Yield (%)	Molecular weight	μeff/B. M.
	C	H	N	Cu(II)				
C1	62.83(62.92)	4.45(4.59)	4.38(4.31)	10.55(10.71)	>300	71	865.26	1.83
C2	55.87(55.96)	4.26(4.39)	4.30(4.46)	9.71(9.93)	>350	72	899.71	1.85
C3	57.46(57.63)	3.86(4.20)	4.65(4.81)	9.98(10.09)	>350	66	881.26	1.84
C4	58.55(58.66)	4.32(4.45)	6.41(6.55)	9.25(9.39)	>350	71	910.26	1.89
C5	54.57(54.64)	4.34(4.49)	6.44(6.52)	9.23(9.37)	>350	69	911.29	1.82

3.2 FT-IR spectra

The analysis of the FT-IR spectra of both ligands and complex provided information on the coordination mode between the ligands and the metal ion *IR* Spectra. The IR spectral data are summarized in Table 2. The infrared spectra of fluoroquinolones are quite complex due to the presence of the numerous functional groups in the molecules, therefore their interpretation is based on the most typical vibrations being the most important region in the IR spectra of fluoroquinolones between ~1815 and ~1325 cm^{-1}.[28] Spectra of the mixed-ligand Cu(II) complexes reveals that a broad band in the region ~3435-3455 cm^{-1} due to stretching vibration of OH group. The ν(C=O) stretching vibration band appears at ~1706 cm–1 in the spectra of ciprofloxacin, and the complexes show this band at ~1625 cm^{-1}; this band shifted towards lower energy, suggesting that coordination occurs through the pyridone oxygen atom.[29] The strong absorption bands obtained at ~1625 and ~1390 cm^{-1} in ciprofloxacin are observed at ~1580-1590 and ~1360-1390 cm^{-1} for ν(COO)a and ν(COO)s in the complexes, respectively; in the present case the separation frequency Δν > 210 cm^{-1} (Δν = νCOO a - νCOO s), suggesting unidentate binding of the carboxylato group.[30] The IR spectra of the coumarin derivatives shows ~1615 and ~1755 cm^{-1} bands corresponding to *α, β*-unsaturated ketone and lactone carbonyl ketone respectively, on complexation these peaks shifted to a lower frequency ~1610 and ~1745 cm^{-1} due to complex formation. In all the complexes, a new band is seen in the ~ 535-545 cm^{-1} region, which is probably due to the formation of the weak band observed in the ~ 440-465 cm^{-1} range can be attributed to ν(M-O).[30] (Fig.5)

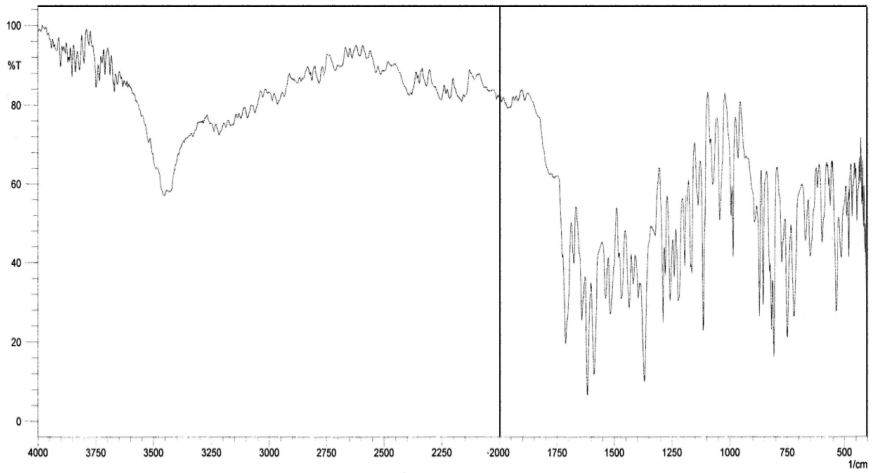


Figure5. FT IR Spectrum of C_2

Table 2 FT-IR data of synthesized compounds

Complexes	ν(OH/H_2O) br cm^{-1}	ν(C=N) w cm^{-1}	α, β-unsaturated ν(C=O) s cm^{-1}	lactone carbonyl ν(C=O) s cm^{-1}	ν(Cu-O)w cm^{-1}	ν(Cu-N)w cm^{-1}
C1	3420	1552	1603	1714	467	562
C2	3430	1545	1604	1713	475	577
C3	3435	1544	1607	1703	465	564
C4	3426	1545	1612	1709	468	570
C5	3425	1547	1604	1725	465	555

3.3 Electronic spectra and magnetic measurement

The Cu(II), Ni(II), Co(II), and Mn(II) complexes show magnetic moments of 1.82. 3.15, 3.86 and 5.90 B.M. respectively which is characteristic of mononuclear, Cu(II) (d9, 1 unpaired electron) octahedral, Ni(II) (d8, 2 unpaired electrons), Co(II) (d7, 3 unpaired electrons), and Mn(II) (d5, 5 unpaired electrons) complexes.[31]

The electronic spectral data of the complexes in DMF are shown in Table 3. The Cu(II) complexes display three prominent bands. Low intensity broad band in the region 16,920-17,930 cm−1 was assigned as 10 Dq band corresponding to 2Eg→2T2g transition.[32] In addition, there was a high intensity band in the region 22,900-27,100 cm−1. This band is due to symmetry forbidden ligand → metal charge transfer transition.[33] The band above 27,100 cm^{-1} was assigned as ligand band. Therefore distorted octahedral geometry around Cu(II) ion was suggested on the basis of electronic spectra.[34] (Fig. 6).

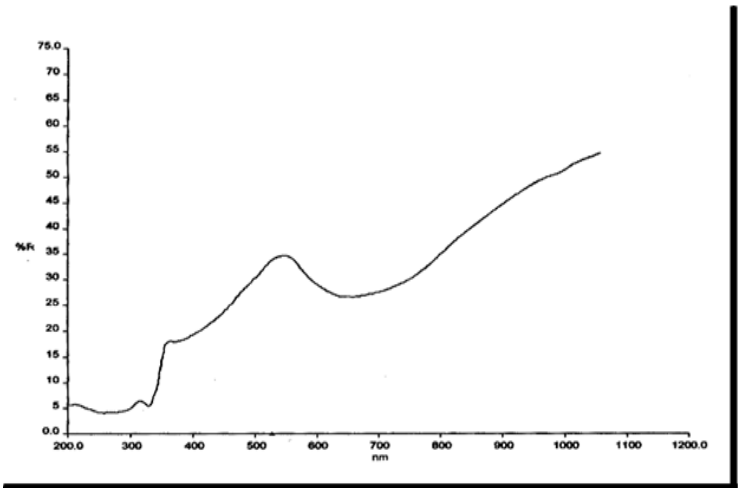


Fig.6. Electronics Spectrum of complex Cu(II)

Table 3. Electronic spectral data of the complexes

Compounds	Transition band observed (cm-1)			μ_{eff} B.M.	Geometry
C1	9572	12075	15748	1.83	Octahedral
C2	9365	13394	16145	1.85	Octahedral
C3	9579	12075	16385	1.84	Octahedral
C4	9463	13978	16702	1.89	Octahedral
C5	9317	12582	15907	1.82	Octahedral

3.4 Antimicrobial bioassay

The ligand and its metal complexes were screened for their antibacterial and antifungal activities according to the respective literature protocol.[35] and the results obtained are presented in Table 4. The results were compared with those of the standard drug. All the metal complexes were more potent bactericides and fungicides than the ligand. C_1 and C_2 complexes were much less bacterial activity than the C_4 and C_5 complex while C_3 complex shows superior antifungal activity compare to other complexes. From Table 4,

3.5 Antioxidant studies

A capacity to transfer a single electron i.e. the antioxidant power of all compounds was determined by a FRAP assay. The FRAP value was expressed as an equivalent of standard antioxidant ascorbic acid (mmol/100 g of dried compound). FRAP values indicate that all the compounds have a ferric reducing antioxidant power. The compounds C_1 and C_2 showed relatively high antioxidant activity while compound C_3, C_5 and C_4 shows poor antioxidant power (Table 4).

Table 4 Antimicrobial, Anti-tubercular and antioxidant results of compounds

Antimicrobial Activity (Minimal Inhibition Concentration, in µg/mL)							Antioxidant Activity
Compounds	**Gram negative bacteria**		**Gram positive bacteria**		**Fungus**		**FRAP value (mmol/100 g)**
	E. coli	*P. aeruginosa*	*S. pyogenes*	*B. subtilis*	*C. albicans*	*A. niger*	
L1	100	200	100	200	200	200	NT
L2	200	200	400	400	200	400	NT
L3	400	200	200	600	200	200	NT
L4	400	400	400	>600	400	200	NT
L5	100	100	100	200	200	200	NT
C1	100	100	100	200	100	100	54.05
C2	70	100	100	100	100	100	63.92
C3	40	70	40	40	100	100	82.44
C4	100	100	100	100	200	100	75.76
C5	70	100	70	100	100	100	86.32
Norfloxacin	10	10	10	10	NT	NT	NT
Flucanazole	NT	NT	NT	NT	10	10	NT
Nystatin	NT	NT	NT	NT	100	100	NT
***E. Coli*= ATCC25922; *P. aeruginosa*= ATCC25619; *S. pyogenes*= ATCC12384 ; *B. subtilis*= ATCC11774 ; *C.albicans*= ATCC 66027; *A.niger*= ATCC 64958 NT= Not tested**							

4. CONCLUSIONS

Here elucidate the synthesis of biological active coumarin derivatives and their Cu(II) complexes (C_1-C_5). Octahedral geometry were allocate for Cu(II) complexes on the basis of electronic spectra and magnetic moment. Complexes shows momentous effective antioxidant activities compared to their ligand employed for complexation. In vitro antimicrobial activity of all synthesized compounds show good results with an enhancement of activity on complexation with metal ions. This enhancement in the activity may be attributed to increased lipophilicity of the complexes. The structures of the ligands were investigated and confirmed by the elemental analysis, FT-IR, ^{1}H-NMR, ^{13}C-NMR and mass spectral studies.

ACKNOWLEDGEMENTS

We are grateful to The Principal, and management of Shree P M Patel Institute of P G Studies and research, Sardar Patel University, Anand 388001 for providing infrastructures and obligatory facilities for research. Authors are also grateful to The Director, SAIF-RSIC, Punjab University, Chandigarh for NMR analysis. We are articulate our appreciation to IIT-Bombay for ESR Studies.

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