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BIOLOGICAL ASSESS OF METAL HETEROCHELATES BASED ON ENROFLOXACIN AND DICUMAROL DERIVATIVE

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ABSTRACT:
Some newly heterochelates synthesized by reflux of different coumarin derivative, Enrofloxacin 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.

KEY WORDS: Enrofloxacine, biological study, octahedral complexe.

1. INTRODUCTION

Coumarin and its derivatives represent one of the most active classes of compounds possessing a wide spectrum of biological activity [I-IV]. Many of these compounds have proved to be active as antitumor [V], antibacterial [VI], antifungal[VII], anticoagulant[VIII] and antiinflammatory[IV]. In addition, these compounds are used as additives to food and cosmetics[X].dispersed Fluorescent and laser[XI]. Various analogues of 3- Substituted coumarins suchas 3-amino coumarins exhibit antimicrobial activity[XII-XV]. From the above line of reasoning we directed this paper toward 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, [XVI] casein kinase 2 inhibitor[XVII] activities,vasorelaxant[XVIII], antitubercular [XIX]. Recently, coumarin derivatives have been evaluated in the treatment of human immunodeficiency virus, due to their ability to inhibit human immunodeficiency virus integrase.

Enrofloxacen is awell-known bidentate chelating ligand.[XX] Transition metal complexes of Enrofloxacen and its derivatives are of increasing interest because of their versatile roles inmanyfields such as coordinationchemistry, analytical chemistry and biological chemistry.[XXI] Likewise, study of enrofloxacin derivatives has been prompted by current interest in their catalytic, redox, physicochemical, biological properties and novel supramolecular chemistry. [XXII–XIII] In recent years, the study of copper-Enrofloxacine complexes has become progressivelymore important owing to their antimicrobial properties.[XXIV] Furthermore, copper complexes of enrofloxacen are capable of cleaving DNA. Copper complexes of nitrogen-donor heterocyclic ligands have been used widely to improve nuclease activity.

The aim of this study was to prepare the mixed ligand complexes of Cu(II) using enrofloxacen 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.[XXV] 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

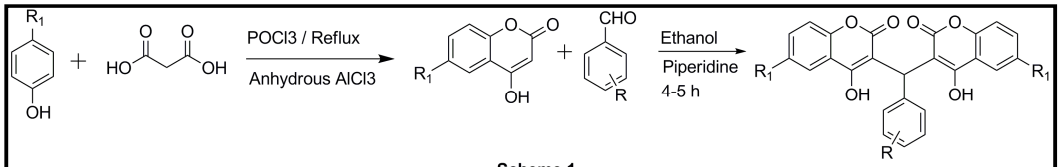
2.1 Materials

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 [XXVI]. 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 ($g = 16.44\times10^{-6}$ 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_1 = Br
Where R = H (L^1);*m*-Cl (L^2); *m*-OH (L^3); *m*-NO_2 (L^4); and *p*-OH-*m*-OCH_3 (L^5)

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

Yield: 67 %, m.p. 225 °C. FT-IR (KBr, cm^{-1}): *v*(-OH/H_2O) 3183, 3053, *v*(C=O) 1660,1653, *v*(C=C) 1646, 1564, *v*(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*): 497.02(M+H)$^+$, 499.02(M+H)$^{+2}$. Elemental analysis found (%): C, 62.28; H, 2.81; Calculated for $C_{25}H_{14}Br_2O_6$ (499.28): C, 62.39; H, 2.93.

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

Yield: 70%, m.p.: 260 °C. FT-IR (KBr, cm^{-1}): *v*(-OH/H^{2}O) 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*): 531.98(M +H)$^+$, 533.98(M +H)$^{+2}$. Elemental analysis found (%): C, 67.20; H, 3.38; Calculated for $C_{25}H_{15}Br_2O_6$ (533.73): C, 58.22; H, 2.54.

2.3.3 3,3'-((3-hydroxyphenyl)methylene)bis(6-bromo-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*): 514.01(M +H)$^+$, 516.01(M +H)$^{+2}$. Elemental analysis found (%): C, 60.09; H, 2.76; Calculated for $C_{25}H_{16}Br_2O_7$ (515.28): C, 60.38; H, 2.84.

2.3.4 3,3'-((3-nitrophenyl)methylene)bis(6-bromo-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*): 543.00(M +H)$^+$, 545.00(M +H)$^{+2}$. Elemental analysis found (%): C, 57.65; H, 23.31; N, 2.06; Calculated for $C_{25}H_{13}Br_2NO_8$ (544.28): C, 57.05; H, 2.49; N, 2.66.

2.3.5 **3,3'-((4-hydroxy-3-methoxyphenyl)methylene)bis(6-bromo-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*): 544.02(M +H)$^+$, 546.02(M +H)$^{+2}$. Elemental analysis found (%): C, 59.12; H, 2.96; Calculated for $C_{26}H_{16}Br_2O_8$ (545.31): C, 59.22; H, 3.06.

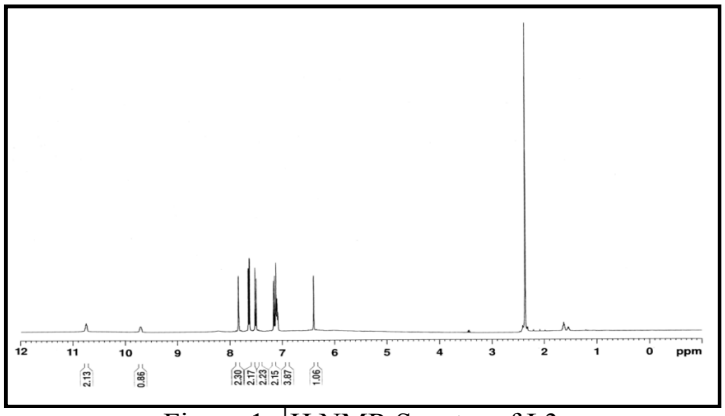


Figure 1. ^{1}H NMR Spectra of L3

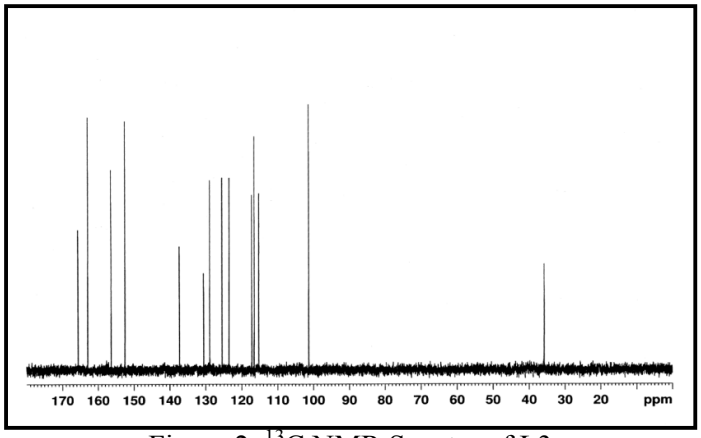


Figure 2. ^{13}C NMR Spectra of L3

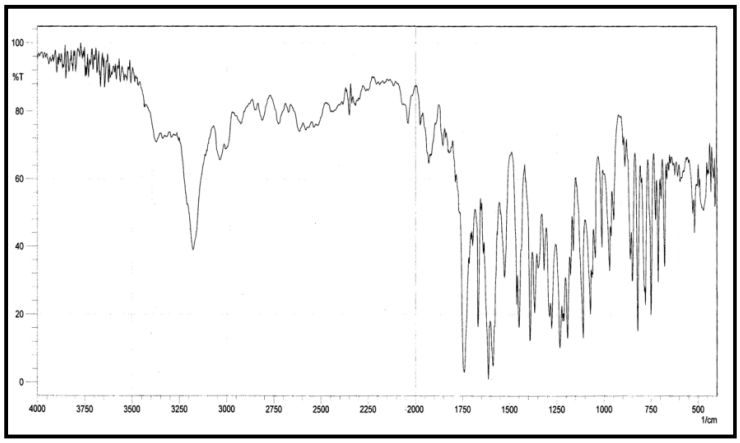


Figure 3. IR Spectra of L3

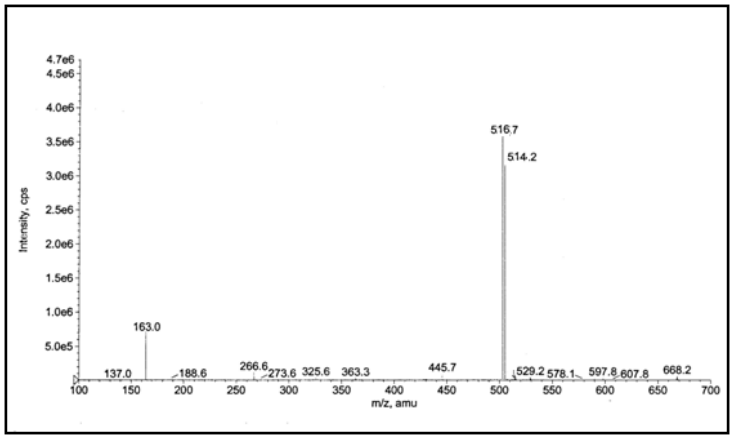
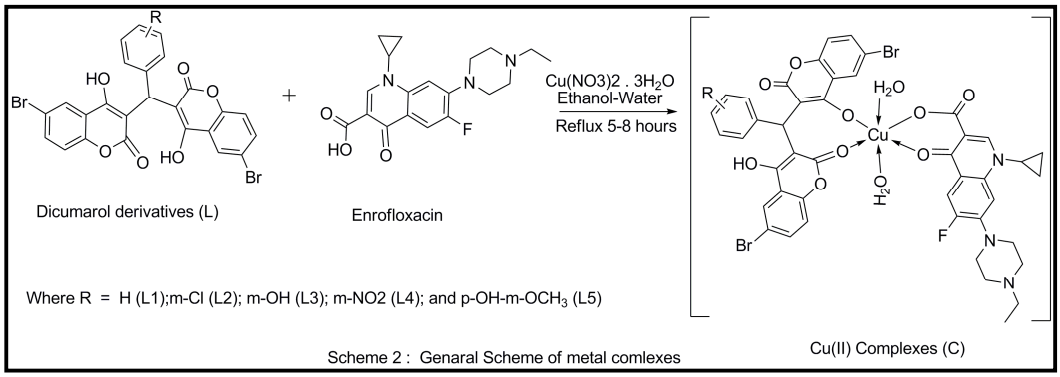


Figure 4. Mass Spectra of L3

2.4 Synthesis of metal complexes: [M(L)(PH)(H_2O)$_2$](C)

An aqueous solution of $Cu(NO_3)_2$•$6H_2O$ salt (10 mmol) was added into ethanolic solution of ligand (L) (10 mmol) and subsequently an ethanolic solution of Enrofloxacine (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 : Genaral Scheme of metal comlexes

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 [XXVII]. 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 FeCl3•6H2O 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[XXVIII], 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. (^oC)	Yield (%)	Molecular weight	μ_{eff}/B.M.
	C	H	N	Cu(II)				
C1	61.84(61.93)	4.35(4.49)	4.65(4.81)	10.55(10.71)	>350	74	619.09	1.84
C2	56.88(56.99)	4.16(4.29)	4.28(4.41)	9.71(9.93)	>350	71	671.55	1.82
C3	58.49(58.64)	3.96(4.10)	4.40(4.56)	9.98(10.09)	>300	71	651.54	1.83
C4	59.58(59.69)	4.22(4.35)	6.51(6.65)	9.25(9.39)	>350	72	662.12	1.85
C5	59.55(59.66)	4.24(4.39)	6.54(6.62)	9.23(9.37)	>350	66	662.12	1.89

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 ~1810 and ~1320 cm^{-1} [XXVIII]. Spectra of the mixed-ligand Cu(II) complexes reveals that a broad band in the region ~3430-3450 cm^{-1} due to stretching vibration of OH group. The ν(C=O) stretching vibration band appears at ~1704 cm–1 in the spectra of ciprofloxacin, and the complexes show this band at ~1628 cm^{-1}; this band shifted towards lower energy, suggesting that coordination occurs through the pyridone oxygen atom [XXIX]. The strong absorption bands obtained at ~1620 and ~1385 cm^{-1} in ciprofloxacin are observed at ~1580-1590 and ~1355-1385 cm^{-1} for ν(COO)a and ν(COO)s in the complexes, respectively; in the present case the separation frequency $\Delta\nu > 210$ cm^{-1} ($\Delta\nu$ = νCOO a - νCOO s), suggesting unidentate binding of the carboxylato group [XXX]. 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)

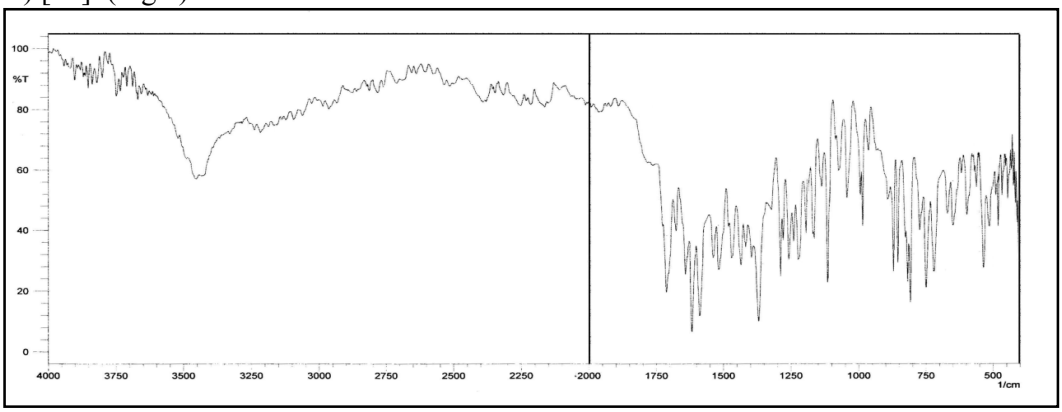


Figure 5. FT IR Spectrum of C_2

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	3437	1540	1605	1700	468	562
C2	3420	1547	1612	1708	466	572
C3	3424	1545	1602	1721	461	558
C4	3415	1550	1601	1715	469	561
C5	3435	1548	1606	1710	471	579

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).

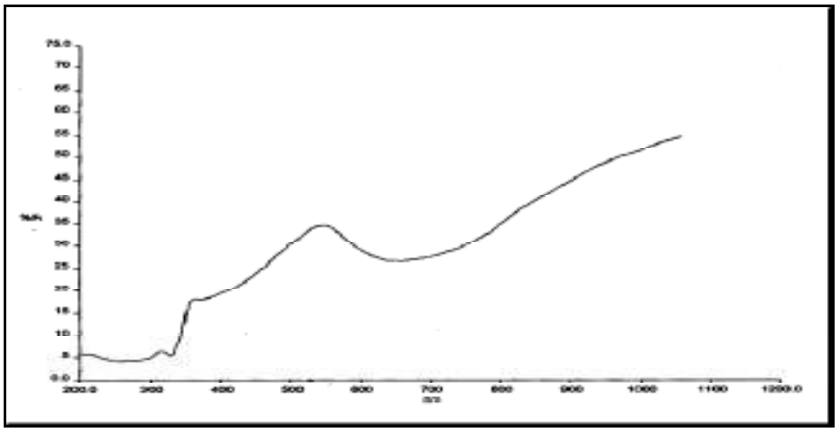


Fig.6. Electronics Spectrum of complex Cu(II)

Table 3. Electronic spectral data of the complexes

Compounds	Transition band observed (cm-1)			μ_{eff} B.M.	Geometry
C1	9365	13394	16145	2.87	Octahedral
C2	9463	13978	16702	2.79	Octahedral
C3	9579	12075	16385	2.84	Octahedral
C4	9572	12075	15748	2.83	Octahedral
C5	9317	12582	15907	2.80	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	400	400	400	>600	400	200	NT
L2	100	100	100	200	200	200	NT
L3	100	200	100	200	200	200	NT
L4	400	200	200	600	200	200	NT
L5	200	200	400	400	200	400	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
Ciprofloxacin	20	10	20	05	NT	NT	NT
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**							

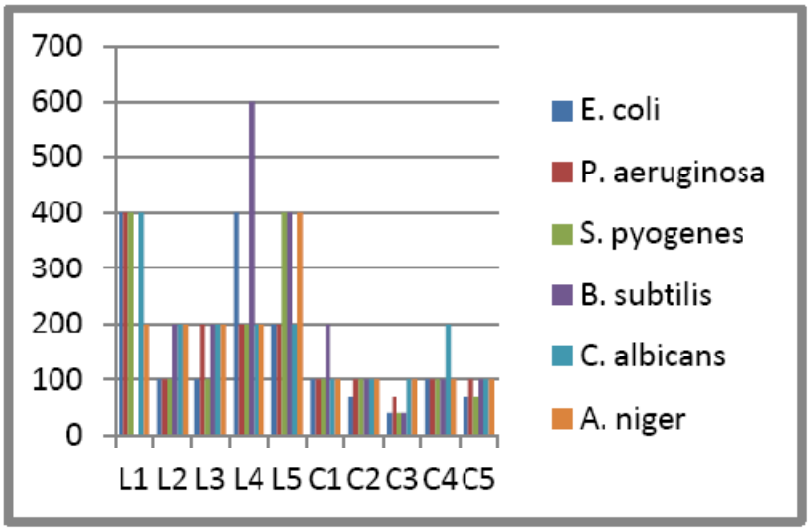


Fig. 7. Statistical representation for biological activity of ligand and its complexes.

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.

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REFERENCES

[I] S. Sardari, Y. Mori, K. Horita, R.G. Micetich, S. Nishibe, M. Daneshtalab, Bioorg. Med. Chem. 7 (1999) 1933-1940.

[II] B.S. Creaven, D.A. Egan, K. Kavanagh, M. McCann, A. Noble, B. Thati, M. Walsh, Inorg. Chim. Acta. 359 (2009) 3976–3984.

[III] G.J. Finn, E. Kenealy, B.S. Creaven, D.A. Egan, Cancer Lett. 183 (2000) 61-68.

[IV] D.A. Egan, P. James, D. Cooke, R.O. Kennedy, Cancer Lett. 118 (1997) 201-211.

[V] I. Kostova, I. Nikolova, Am. J. Pharmaco. Toxico. 1 (2006) 30-35.

[VI] A.D. Marques, C-T Lin, J. Photochem. Photobio. B. 74 (2004) 63–71.

[VI] A. Bencinia, V. Lippolisb, Coord. Chem. Rev. 254 (2010) 2096-2180.

[VII] J. Reedijk, G. Wilkinson, R.D. Gillard, J.A. McCleaverty, Comprehensive Coordination Chemistry, Eds. Vol. 2., Oxford, Pergamon, U.K., 1987.
[VIII] M. Barcelo-Oliver, Á. García-Raso, Á. Terron, E. Molins, M.J. Prieto, V. Moreno, J. Martínez-Serra, V. Lladó, I. López, A. Gutiérrez, V. Pablo, Inorg. Chem. Acta. 362(2009) 4744-4753.
[IX] Escribáe S. Sakaki, G .Koga, K. Ohkubo, Inorg. Chem. 25 (1986) 2330-2333.
[X] P.G. Sammes, G. Yahioglu, Chem. Soc. Rev. 23 (1994) 327-334.
[XI] L. Jia, P. Jiang, J. Xu, Z.V. Hao, X.M. Xu, L.H. Chen, J.C. Wu, N. Tang, Q. Wang, J. Jagadese. Vittal, Inorg. Chim. Acta. 363 (2010) 855-865.
[XII] R. Olar, M. Badea, O. Carp, D. Marinescu, L.V. Veronica, C. Balotescu, A. Dumbrava, J. Therm. Anal. Calorim. 92 (2008) 245–251.
[XIII] J. Al-Enferm, Enferm Infecc. Microbiol. Clin. 21(2003) 261–267.
[XIV] M.M. Meijler, O. Zelenko, D.S. Sigman, J. Am. Chem. Soc. 119 (1997) 1135-1136.
[XV] G. Psomas, C.P. Raptopoulou, L. Iordanidis, C. Dendrinou-Samara, V. Tangoulis, D.P.Kessissoglou, Inorg. Chem. 39 (2000) 3042–3048.
[XVI] B.K. Santra, P.A.N. Reddy, G. Neelakanta, S. Mahadevan, M. Nethaji, A.R. Chakravarty, J.Inorg. Biochem. 89 (2005) 191–196.
[XVII] A.I. Vogel, Textbook of Practical Organic Chemistry, fifth ed., Longman, London, 1989.
[XVIII] A. Weiss, H. Witte, MagnetoChemie Verlag Chemie, Weinheim, 1973, pp. 345.
[XIX] G. Wanare, R. Aher, N. Kawathekar, R. Ranjan, N.K. Kaushik, D. Sahal, Bio. Org. Med.Chem. lett. 20 (2010) 4675-4678.
[XX] O.M. Abdelhafez, K.M. Amin, R.Z. Batran, T.J. Maher, S.A. Nada, S. Sethumadhvan, Bio.Org. Med. Chem. 18 (2010) 3371-3378.
[XXI] P.K. Panchal, M.N. Patel, Synth. React. Inorg. Met-Org. chem. 34 (2004) 1277–1289.
[XXII] F. Karipcin, E. Kabalcilar, Acta. Chim. Slov. 54 (2007) 242–247.
[XXIII] H. Olmez, F. Arslan, H. Icbud, J. Therm. Anal. Calorim. 76 (2004) 793–800.
[XXIV] A.A. Ahmed, S.A. BenGuzzi, A.A. Hadi, J. Sci. Appl. 1 (2007) 79-90.
[XXV] E. Tas, M. Aslanoglu, A. Kilic, Z. Kara, J. Coord. Chem. 59 (2006) 861-872.
[XXVI] M.V. Angelusiu, S.F. Barbuceanu, C. Draghici, G.L. Almajan, Eur. J. Med. Chem. 45 (2010) 2055-2062.
[XXVII] V.P. Singh, A. Katiyar, Pestic. Biochem. Physiol. 92 (2008) 8-14.
[XXVIII] A.L. Abuhijleh, C. Woods, I.Y. Ahmed, Inorg. Chim. Acta.190 (1991) 11-17.
[XXIX] D.P. Singh, R. Kumar, V. Malik, P. Tyagi, Trans. Met. Chem. 32 (2007) 1051-1055.
[XXX] I. de Pedro, J.M. Rojo, J.L. Pizarro, J. Rodríguez Fernández, M.I. Arriortua, T. Rojoa, J. Solid State Chem. 184 (2011) 2075-2082.

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