Available online at www.derpharmachemica.com

Scholars Research Library

Der Pharma Chemica, 2010, 2(2): 116-128
(http://derpharmachemica.com/archive.html)

ISSN 0975-413X

2D HETCOR studies of 1,2-dihydroquinazolinone derivative: Synthesis characterization and anti-microbial study of its transition metal complexes

Rekha S. Hunoor, Basavaraj R. Patil, Dayananda S. Badiger, Ramesh S. Vadavi, Kalagouda B. Gudasi*

Department of Chemistry, Karnatak University, Dharwad, Karnataka, India

---

Abstract

Pyridine-2-ethyl-(3-carboxylideneamino)-3-(2-phenyl)-1,2-dihydroquinazolin-4(3H)-one (PECPDQ) having potential coordinating sites was synthesized and 2D HETCOR (^{1}H-^{13}C) NMR studies were successfully used to demonstrate the formation of 1,2-dihydroquinzolinone rather than Schiff base in the reaction between 2-acetylpyridine-2-aminobenzoylhydrazone and benzaldehyde. The transition metal complexes of Mn(II), Co(II), Ni(II), Cu(II), Zn(II) and Cd(II) of PECPDQ were prepared, characterized and subjected for antimicrobial activity along with the pro-ligand. The anti-microbial activity results show that the complexes exhibit higher activity compared to ligand due to their increased lipophilic character. Mn(II), Co(II) and Cd(II) complexes were found to be most potent inhibitors against bacterial strain and the activity is even more than the standard anti-bacterial drug Norfloxacin. Similarly, the anti-fungal activity of ligand has enhanced on complexation but not more than standard anti-fungal drug ie., Gresiofulvin used.

Keywords: 1,2-dihydroquinazolinone, metal complex, 2D HETCOR study, anti-bacterial activity, anti-fungal activity.

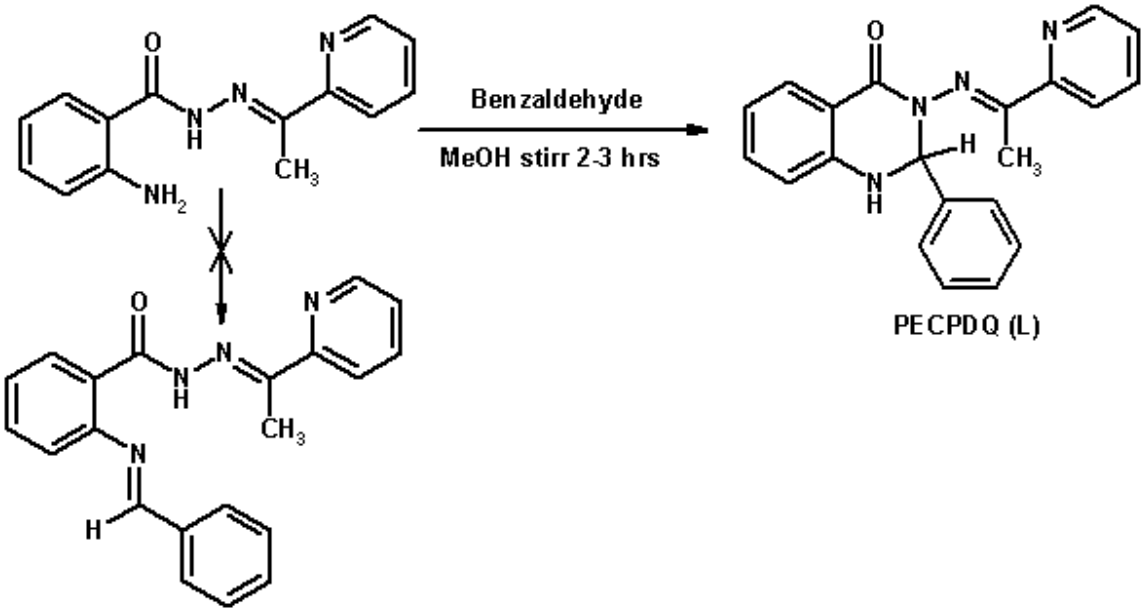
INTRODUCTION

Quinazolines form interesting class of heterocycles owing to their broad biological activity profile. Many of them have been widely investigated for their therapeutic uses especially for anti-microbial [1-3], anti-inflammatory [4-5], CNS depressant [6] and anticancer [7]. In particular, quinazoline-4(3H)-ones have attracted the attention of coordination chemists since they form a class of versatile ligands capable of generating varied coordination architecture, and

have been explored extensively for their ligational property towards transition as well as lanthanide metal ions [8-12]. In comparison, transition metal complexes of 1,2-dihydroquinazoline-4-(3H)-one are scanty [13-19]. It is proved beyond doubt that metal chelation is one of the excellent ways to increase the lipophilic character of the organic moiety. In our laboratory we are particularly interested to investigate coordination behavior of 1,2-dihydroquinazolin-4(3H)-ones towards metal ions and study the effect of various aromatic, heteroaromatic substituents on their activity profile. In this perspective, we now report a study on anti-microbial activity of pyridine-2-ethyl-(3-carboxylideneamino)-3-(2-phenyl)-1,2-dihydroquinazolin-4(3H)-one (PECPDQ) and the corresponding effect of complex formation.

RESULTS AND DISCUSSION

The pyridine-2-ethyl-(3-carboxylideneamino)-3-(2-phenyl)-1,2-dihydroquinazolin-4(3H)-one (PECPDQ) was obtained by refluxing 2-acetylpyridine-2-aminobenzyol hydrazone with benzaldehyde in 1:1 stoichiometric ratio for two hours in ethanolic medium and washing out the resultant precipitate successively by cold ethanol and ether, in higher yield (90%). The transition metal complexes of PECPDQ were prepared by the reaction of ligand with transition metal (II) chlorides in 1:1 molar ratio in ethanol-water medium at pH 7 and refluxing the reaction mixture on water bath over a period of 2 h as outlined in **Scheme**. The resulting complexes were washed by ethanol and benzene and dried in vacuum dessicator over anhydrous $CaCl_2$. All the complexes are stable at room temperature and are non-hygroscopic. The physical parameters of the complexes along with the complex are given in **Table 1**.



Scheme: Synthetic route for the preparation of Ligand (PECPDQ)

Table 1: Physical parameters of PECPDQ and its complexes

Sl. No.	Compound	Compound code	Colour	Yield (%)	Melting point (°C)
1	PECPDQ	**L**	Colourless	90	196-198
2	$[Mn(PECPDQ)Cl_2]$	**C1**	Yellow	60	>300
3	$[Co(PECPDQ)Cl_2]$	**C2**	Dark green	40	>300
4	$[Ni(PECPDQ)Cl_2]$	**C3**	Parrot green	45	>300
5	$[Cu(PECPDQ)Cl_2]$	**C4**	Brown	60	>300
6	$[Zn(PECPDQ)Cl_2]$	**C5**	Yellow	75	>300
7	$[Cd(PECPDQ)Cl_2]$	**C6**	Yellow	70	>300

The elemental analysis of ligand **L** is in agreement with the molecular formula $C_{21}H_{18}N_4O$. The mass spectrum of the ligand show a molecular peak at 342 (**Figure 1**) corresponding to the molecular weight of the compound.

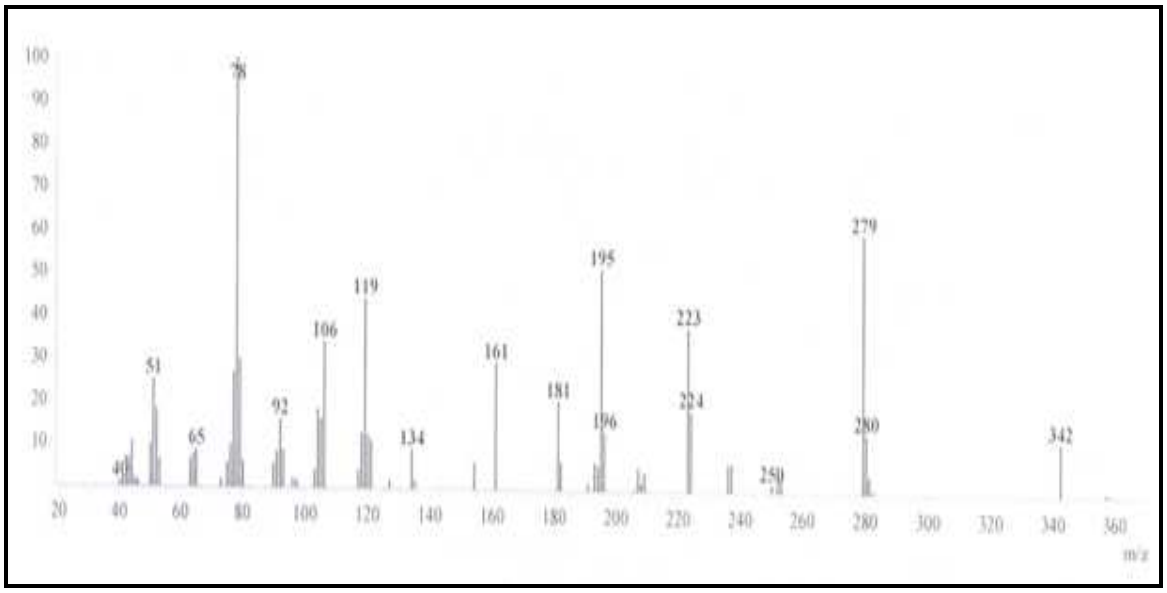


Figure 1: Mass spectrum of PECPDQ (L)

Infrared spectral studies

In order to ascertain the ligating behavior of the ligand, IR spectral bands of the free ligand are compared with those of metal chelates. The band of medium intensity at 3309 cm^{-1} in the IR spectrum of the free ligand is assigned to the ν(-NH) while the strong band at 1646 cm^{-1} which is at lower wave numbers than 2,3-disubstituted quinazolin-(3H)-4-ones [8-12] attributed to strong intermolecular hydrogen bonding between carbonyl oxygen and hydrogen of quinazoline ring nitrogen of another PECPDQ as shown by the crystallographic studies [22]. Upon metal complexation the stretching frequencies of the carbonyl and azomethine groups have shifted to lower wavenumbers (10-35 cm^{-1}) indicating their involvement in metal coordination. Similarly pyridine ring stretching vibrations observed between 1433-1582 cm^{-1} in PECPDQ ligand also exhibit slight displacement upon metal complexation indicating the involvement of pyridine nitrogen in coordination [13].

NMR studies

In our previous communication the formation of 1,2-dihydrquinazolinone was proved by single crystal X-ray diffraction studies (**Figure 2**). 2D HETCOR NMR serves as an excellent tool to prove the formation of cyclised 1,2-dihydroquinazolinones rather than Schiff base. The numbering scheme for the assignment of carbons and corresponding hydrogens is as shown in ORTEP diagram of **L**. ^{1}H and ^{13}C chemical shifts of **L** were done by comparing the corresponding data of 2-acetylpyridine-2-aminobenzoylhydrazone [21] and banzaldehyde [23].

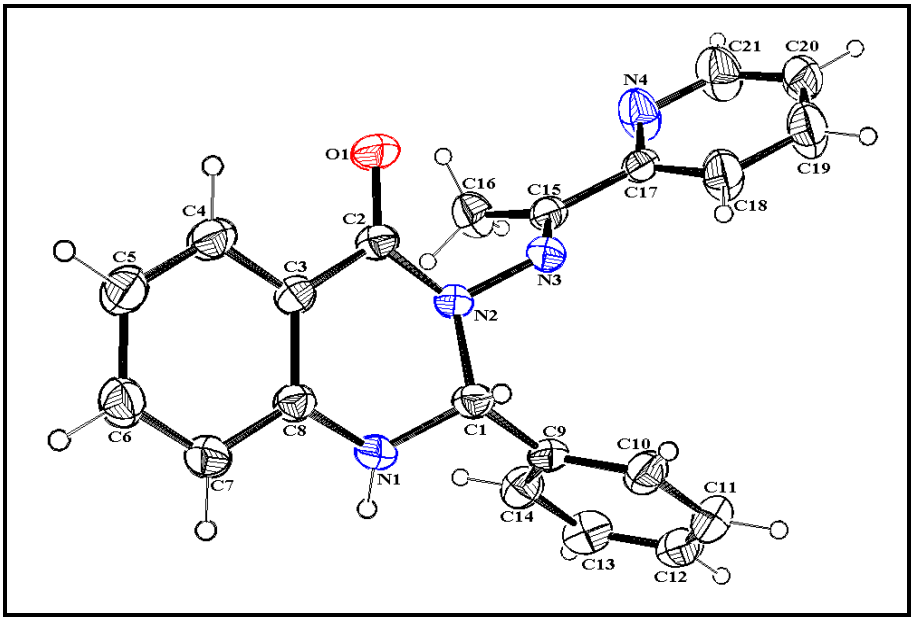


Figure 2: ORTEP diagram of PECPDQ (L)

^{1}H NMR of **L** in $CDCl_3$ exhibits three singlets at 6.29, 4.76 (D_2O exchangeable) and 2.38 δ ppm and are assigned to C1H, N1H, and $C16H_3$ respectively. Three doublets at 8.01, 6.70, 7.79 δ ppm were assigned to C4H, C14H, C18H and C21H respectively. Three triplets at 7.24, 6.90 δ ppm were assigned to C11H and C13H respectively. Remaining protons were observed in the expected aromatic region. ^{13}C NMR spectrum of **L** show a signal at 76.78 δ ppm assignable to a sp^3 hybridized carbon C1 atom and presence of this signal is a clear indication of formation of quinazoline rather than a Schiff base. Carbonyl carbon and azomethine carbons were observed at 171.02 and 155.31 δ ppm respectively. 2D HETCOR (^{1}H-^{13}C) spectral studies helps in complete assignment of chemical shifts of directly attached protons to carbon and this in turn will help to prove the formation of quinazolinone ring and also supports the coordination through pyridine nitrogen. The signal corresponding to C1H in the ^{1}H and ^{13}C NMR would have observed around 8 and 150 δ ppm respectively. But in the present case they were observed at 6.29 and 76.78 δ ppm in the ^{1}H and ^{13}C NMR respectively indicating the formation of quinazolinone ring. The signal at 4.76 δ ppm does not show corresponding ^{13}C signal in the 2D HETCOR NMR confirming it as N1H proton of quinazoline ring.

^{1}H NMR spectrum of Zn(II) complex of **L** in DMSO-d_6 show downfield shift of C16H3 protons indicating the coordination through azomethine nitrogen. Shift of C21H proton towards

downfield supports the coordination through pyridine nitrogen. The ^{1}H and ^{13}C NMR data of L and 1H NMR data of Zn(II) complex is summarized in Table 2. The ^{1}H and 2D HETCOR spectrum of **L** are displayed in **Figure 3** and **Figure 4**.

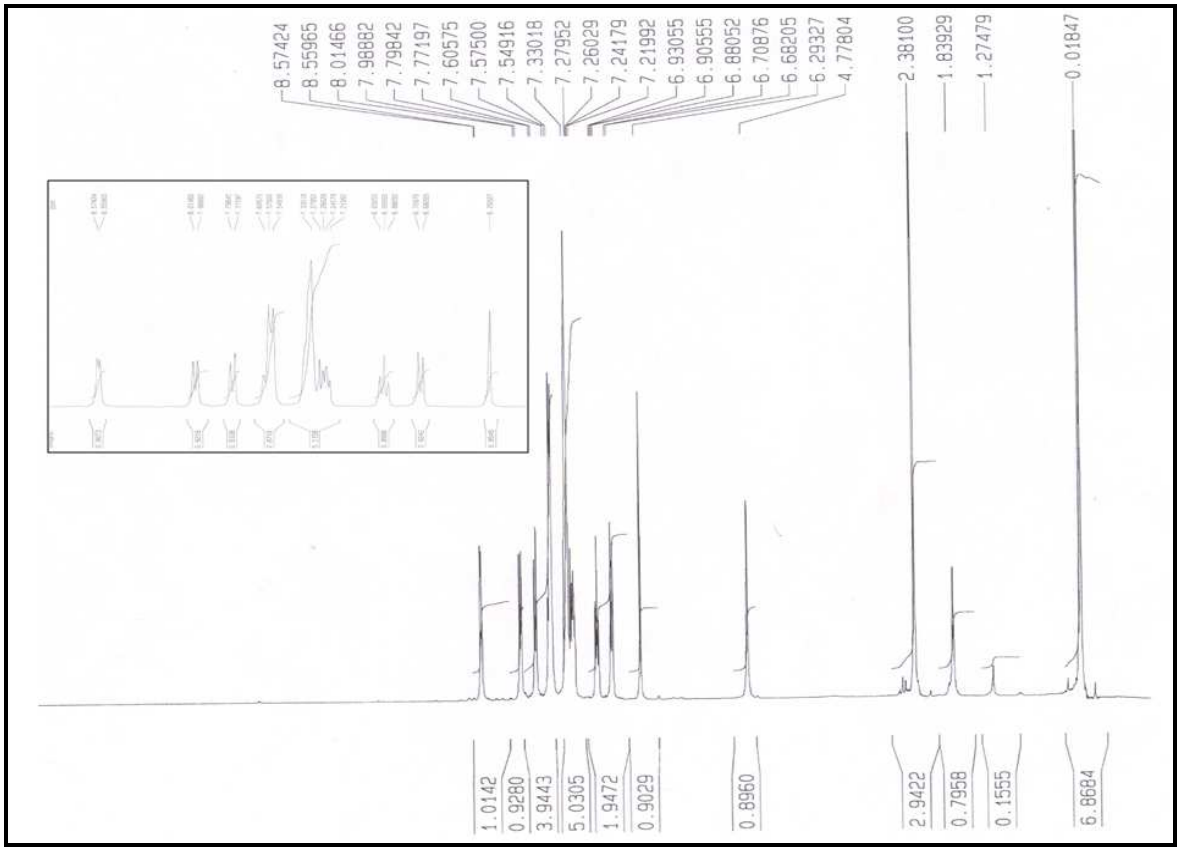


Figure 3: ^{1}H NMR spectrum of L with expansion of aromatic region in the box inset

Electronic spectral and magnetic magnetic moment studies

Magnetic moment measurements and electronic absorption spectral studies have been under taken in order to obtain the structural information of the paramagnetic complexes.

The electronic absorption spectrum of PECPDQ exhibits a strong band at around 300 nm with shoulder at 389 nm assignable to π-π* and n-π* transitions respectively [24]. The electronic spectrum of the Co(II) shows a transition at 415 nm assignable to $^{4}A^{1}{}_{2}\rightarrow{}^{4}E^{II}$ transition indicating the trigonal bipyramidal geometry supported by its μ_{eff} value. The μ_{eff} value shown by the Ni(II) complex at room temperature (3.27 BM) clearly indicates the trigonal bipyramidal environment[25]. Its electronic spectrum shows three absorptions at 696, 754 and 792 nm due to $^{3}E\rightarrow{}^{3}A_{2}$, $^{3}E\rightarrow{}^{3}A_{1}$ and $^{3}E\rightarrow{}^{3}A_{2}$ transitions respectively [25]. These transitions illustrates the trigonal bipyramidal geometry around Ni(II) ion [26]. The electronic spectrum of the Cu(II) complex shows broad absorption at 714 nm attributed to the $^{2}A^{I}{}_{1}\rightarrow{}^{2}E^{II}$ which illustrates the trigonal bipyramidal geometry around Cu(II) ion with D_{3h} symmetry which is further supplemented by its magnetic moment value of 1.94 BM. [25,26]. The effective magnetic moment

of 6.35 BM observed for Mn(II) shows the high spin state of the metal ion. Zn(II) and Cd(II) complexes are diamagnetic as expected for the d^{10} configuration and Zn(II), Cd(II) and Mn(II) complexes have not shown any d-d transitions.

Table 2: ^{1}H and ^{13}C NMR data of ligand (L) and its Zn(II) complex

Position	Ligand		Zn(II) complex
	^{1}H NMR	^{13}C NMR	^{1}H NMR
N1	4.76 (s, 1H)	---	6.29 (s,1H)
C1	6.29 (s, 1H)	76.87	4.75 (s, 1H)
C2	---	171.02	---
C3	---	121.95	---
C4	8.01(d, 1H) J=7.61Hz	129.63	8.18 (m)
C5	7.57(m, 1H)	136.41	7.57 (m)
C6	7.55 (m, 1H)	129.56	7.54 (m)
C7	7.33 (m)	128.28	7.33 (m)
C8	---	139.45	---
C9	---	139.45	---
C10	7.33(m) *	128.95*	7.33(m)
C11	7.24 (t, 1H) J=6.49	128.73	7.25(m)
C12	7.33(m)*	129.56*	7.35(m)
C13	6.90 (t, 1H) J=7.4 Hz	119.87	6.88(m)
C14	6.70 (d, 1H) J= 7.95	114.64	6.71(m)
C15	---	155.31	---
C16	2.38 (s, 3H)	17.7	2.60
C17	---	160.95	---
C18	7.79 (d, 1H) J=7.84 Hz	124.93	7.72(m)
C19	7.33 (m)*	129.56*	7.33 (m)
C20	7.60 (m, 3H)	134.22	7.60 (m)
C21	8.57 (d, 1H) J=6.5 Hz	148.94	8.65 (d,1H) J=5.8Hz

*m, multiplet; t, triplet; d, doublet; s, singlet; *might have appeared as single line.*

EPR Spectral Studies

The electron paramagnetic resonance spectral studies of the polycrystalline sample Cu(II) complex of PECPDQ was recorded at 298 K (**Figure 5**) exhibits the elongated rhombic pattern with g_1=2.071, g_2=2.083 and g_3=2.286 indicative of the unpaired electron being in the d_{xy} ground state [27]. The observed 'g' values are less than 2.3 indicative of covalent nature of metal-ligand bond.

Thermal Studies

The thermogram recorded for the copper complex shows the first weight loss of 14.76% (Calc. 14.75%) observed in the range of 220-280 ºC corresponding to the loss of two coordinated chlorines. The absence of lattice held water or solvent molecules is adjudged from the absence of any losses up to 120 ºC. The plateau obtained after heating above 684 ºC with the residual weight

of 16.87% (calc. 16.72%) accounts for the formation of stable CuO and corresponds with metal analysis 13.42% (TG 13.47%).

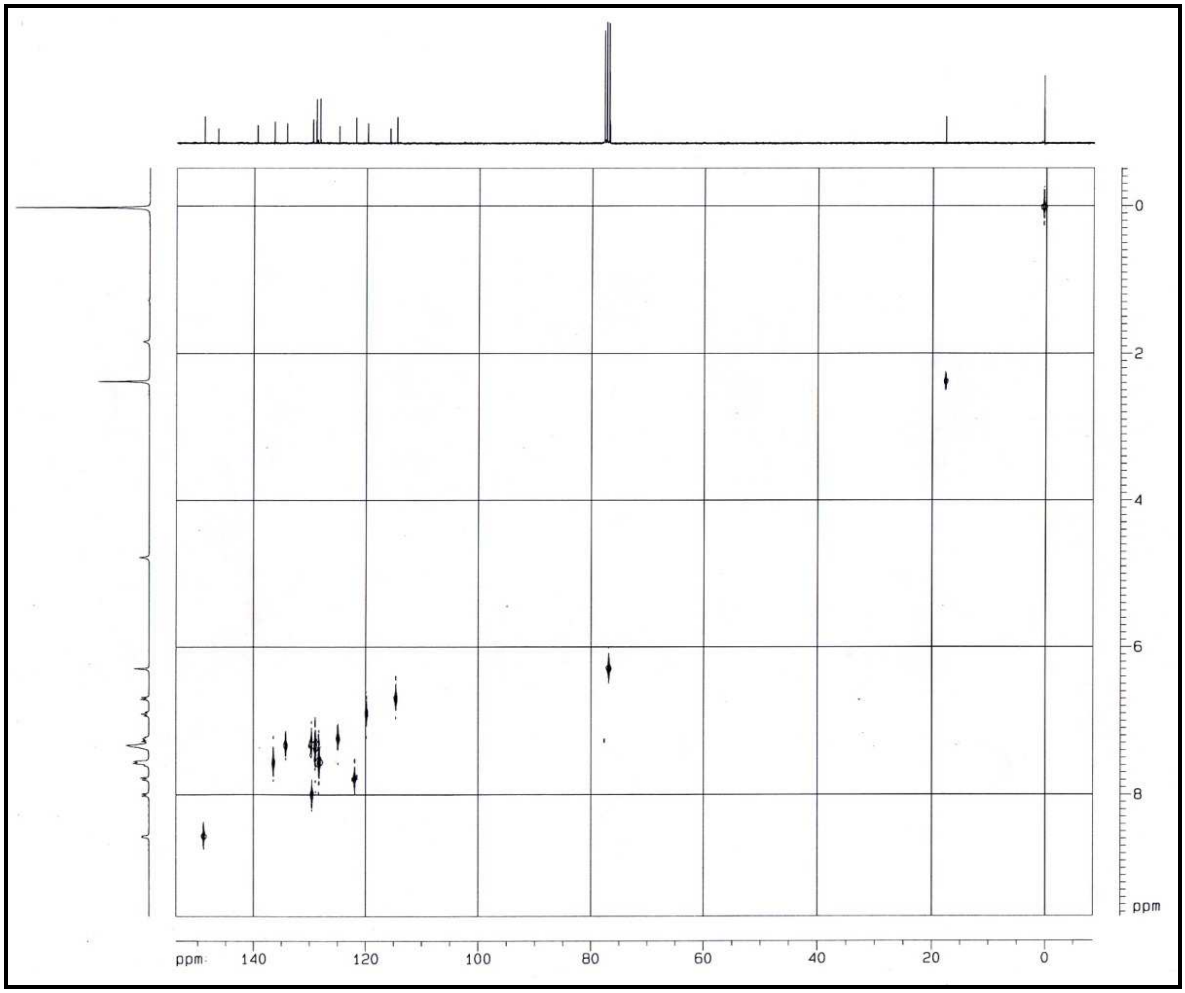


Figure 4: 2D HETCOR (^{1}H-^{13}C) NMR spectrum of PECPDQ (L)

Biological activity

The *in vitro* antimicrobial properties of PECPDQ, its transition metal complexes and corresponding metal chlorides are shown in **Table 2** together with those of Norfloxacin and Griseofulvin the antibacterial drug and the antifungal drug in use respectively.

The anti-microbial activity of the ligand which has a phenyl ring at C-2 position and a pyridyl substituent at N-3 position of the quinazoline ring is less compared to structurally similar qunazolinone [14] which has 2-pyridyl groups at both C-2 and N-3 position of the quinazolinone ring. Presumably the lipophilic behavior of these heteroaromatic rings (2-pyridyl) is involved in the biological activity mechanisms.

The antibacterial activity of the complexes is analyzed by comparing the results with free ligand, metal salts and Norfloxacine the antibacterial drug in use. The ligand is in-active against the bacterium *EC* but its complexation with transition metals increase in the activity. The inhibition of Mn(II), Co(II) and Cd(II) are more than the Norfloxacine. The inhibition of Ni(II), Cu(II) and Zn(II) complexes is also more compared to ligand and corresponding metal salts but less compared to the standard used. The anti-bacterial and anti-fungal activity of ligand and its complexes are displayed in the form of bar chart in **Figure 6** and **7** respectively.

Table 2: Antimibrobial activity of ligand and its complexes

Sl. No	Compound	Bacteria *(Escherichia coli)*		Fungus *(Candida Albicans)*	
		Mean zone of inhibition (standard deviation)	**Percentage zone of inhibition**	**Mean zone of inhibition (standard deviation)**	**Percentage zone of inhibition**
1	Norfloxacin	16.00 (0.00)	100	-	
2	Griseofulvin	-		18.00 (0.00)	100
3	**L**	4.16 (0.23)	26.00	4.72 (0.44)	26.22
4	**C1**	17.11 (0.56)	106.93	15.55 (0.53)	86.38
5	**C2**	17.77 (0.42)	111.06	13.00 (1.00)	72.22
6	**C3**	10.22 (0.79)	63.87	11.77 (0.44)	65.38
7	**C4**	12.00 (0.00)	75.00	13.22 (0.83)	73.44
8	**C5**	12.00 (0.00)	75.00	11.77 (0.44)	65.38
9	**C6**	16.33 (0.82)	102.06	15.33 (0.71)	85.16
10	$MnCl_2.6H_2O$	11.44 (0.49)	68.75	11.44 (0.52)	63.55
11	$CoCl_2.4H_2O$	9.62 (0.48)	62.50	10.77 (0.44)	59.83
12	$NiCl_2.6H_2O$	11.11 (0.50)	69.43	12.88 (0.33)	71.55
13	$CuCl_2.2H_2O$	10.95 (0.78)	68.43	12.11 (0.33)	67.27
14	$ZnCl_2.2H_2O$	10.44 (0.50)	65.25	9.44 (0.72)	52.44
15	$CdCl_2.2H_2O$	14.44 (0.49)	90.25	13.55 (0.72)	75.27

***Key for interpretation**: Inactive: 0-30%; weakly active: 30-60%; Moderately active: 60-75%; Highly active: 75-100%.*

The ligand is devoid of antifungal activity against tested strain *Candida Albicans*, but its complexes have shown increase in inhibition. None of the complexes have shown the inhibition more than the Griseofulvin the antifungal drug in use. Among these complexes Mn(II) and Cd(II) complexes have shown good activity with the relative inhibition of 83.33%. In case of Co(II) and Cu(II) complexes the activity is less compared to their metal salts. Ni(II) complex has the increased inhibition compared to ligand but is less compared to metal salt. Zn(II) complex has shown increased activity as compared to ligand as well as metal salt.

The antimicrobial screening evidences the stronger antibacterial and antifungal properties of the complexes. Several mechanisms are accountable for the cytotoxic effect of the metal chelates. After penetration of the complex into the organism, the cellular oxygen oxidizes the cellular mercapto compounds, and the electron transfer process is mediated through the central M^{+n} ion

of the complex. Probably, the intracellular M^{+n} complex undergoes reduction to a $M^{+(n-1)}$ complex by the different sulfhydryl group-containing compounds.

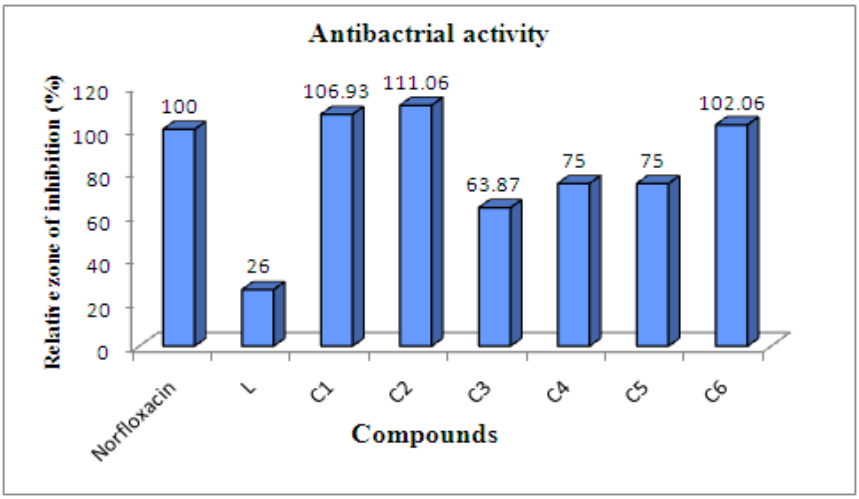


Figure 6: Bar chart showing anti-bacterial activity of compounds

The reduced $M^{+(n-1)}$ complexes may catalyze the reduction of O_2 to O_2^-, while M^{+n} complexes may catalyze the dismutation of O_2 to H_2O_2. In this situation, the $M^{+(n-1)}$/ M^{+n} couple is involved as a redox center. It is known that by changing the ligand environment around the central metal, the redox potential of the couple can be significantly changed. The O_2^- and H_2O_2 produced by such redox reactions cause cell toxicity by their potential oxidizing effect on vital cell components such as lipoic acid, etc. In addition, the reduced $M^{+(n-1)}$ complex may inhibit DNA synthesis, energy, or ATP production by inhibition of mitochondrial respiration and destruction of cell viability [12].

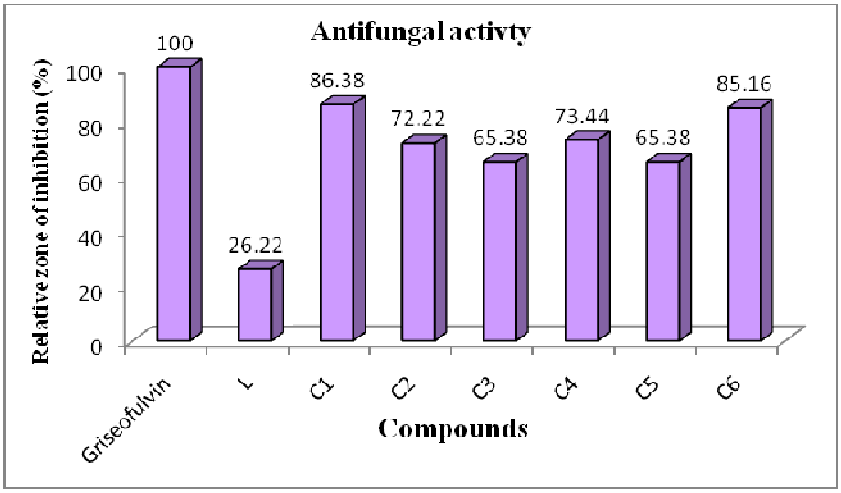


Figure 7: Bar chart for anti-fungal activity of compounds

The superiority of the complexes as compared to the free ligand can also be understood by considering the Overtone's concept and Tweedy's chelation theory [28, 29]. On chelation, the polarity of the metal ion is reduced to a greater extent due to the overlap of the ligand orbital and partial sharing of the positive charge of the metal ion with donor groups. Further, it increases the delocalisation of π-electrons over the whole chelate ring and enhances the lipophilicity of the complexes. This increased lipophilicity enhances the penetration of the complexes into lipid membranes and blocking of metal binding sites on the enzymes of the microorganisms. These complexes also disturb the respiration process of the cell and thus block the synthesis of the proteins that restricts further growth of the organism. Furthermore, the mode of action of the compounds may involve formation of a hydrogen bond through the azomethine group with the active centers of the cell constituents, resulting in interference with the normal cell process.

MATERIALS AND METHODS

Materials and general methods

Methylanthranilate (s.d. Fine Chemicals, India), hydrazinehydrate (Spectrochem, India), 2-acetylpyridine (Spectrochem, India), benzaldehyde (Rankem, India) and metal (II) chlorides were of A.R. grade and used without further purification. Solvents were distilled before use. 2-Aminobenzoylhydrazide [20] and 2-acetylpyridiene-2-aminobenzoylhydrazone [21] and title compound and its transition metal complexes were prepared following the literature procedures[22].

Elemental analyses were carried out on a Thermoquest CHN analyzer. The mass spectrum of the ligand was obtained on SHIMADZU GCMS-QP2010S. The IR spectra were recorded on a Nicolet 170 SX FT-IR spectrometer in the 4000–400 cm^{-1} region using KBr discs. The ^{1}H NMR spectrum of the ligand (in $CDCl_3$) and Zn(II) complex (DMSO-d_6) were recorded on a Bruker Avance 300 MHz spectrometer operating at 300.13 MHz. Electronic spectra were recorded on a CARY 50 Bio UV-visible spectrophotometer in the 200–1100 nm range in DMF solutions. Magnetic susceptibility measurements were carried out on a Faraday balance using Hg [Co $(NCS)_4$] as the calibrant. TG–DTA studies were carried out in the 25–1000 ^{o}C temperature range using a TGA7 ANALYSER, Perkin-Elmer, US with a heating rate of 10 ^{o}C per min in a N_2 atmosphere. The EPR spectrum of a polycrystalline Cu(II) complex was recorded at room temperature and liquid nitrogen temperature on a Varian E-4 X-band spectrometer using TCNE (tetracyanoethylene) as the "g" marker.

Anti-microbial activity

The *in-vivo* biocidal activities of free ligand, its metal complexes and corresponding metal salts were screened against fungus *Candida albicans*, and the bacteria viz. *Escherichia coli* by cup plate method. Proper temperature, pH, necessary nutrients, and growth media free from other microorganisms were used for the preparation of cultures of fungi and bacteria. Fresh solutions of PECPDQ, its complexes and corresponding metal salts (0.10%) were prepared in DMF just before use. The biocidal potency of these compounds was estimated by using the radial growth method in triplicate and determined the inhibition zones. DMF was taken as a control, and the incubation period for fungal and bacterium was 72 h at 28°C.

Nutrient agar medium was prepared by dissolving peptone (1%), yeast extract (0.6%), beef extract (0.5%), sodium chloride (0.5%) in distilled water. The pH of the solution was adjusted to 7.2 by adding 4% aqueous sodium hydroxide solution. Agar (2.4%) was then added and the whole solution was autoclaved for 20 minutes at 15 psi. Each test sample (1mg) was dissolved in DMF (1 ml) and 0.08 ml of this solution (80 µgm) was used for testing. Inoculation medium containing 24 hours grown culture was added aseptically to the nutrient medium and mixed thoroughly to get the uniform distribution. This solution was poured (25 ml in each dish) into petri dishes and then allowed to attain room temperature. Thereafter, punching the set of agar with a sterile cork borer and scooping out the punched part made the cups. The diameter of each cup was 3 mm. Norfloxacin and Griseofulvin were used as the standards and DMF as the solvent control. The entire test samples and the standard were tested at a concentration of 80 µg. The plates were allowed to stand for an hour in order to facilitate the diffusion of the drug solution. Then the plates were incubated at 37 °C for 48 hours. The zones of inhibition against all the microorganisms were measured in millimeters. The tests were conducted in triplicate and the experiment is repeated three times. The results are expressed as mean zone of inhibition (mm) with standard deviation.

CONCLUSION

A new quinazolinone derivative viz., pyridine-2-ethyl-(3-carboxylideneamino)-3-(2-phenyl)-1,2-dihydroquinazolin-4(3H)-one was synthesized, The formation of 1,2-dihydroquinazoline is confirmed by 2D HETCOR studies. The transition metal complexes of PECPDQ were synthesized and characterized. IR and NMR studies indicate the coordination through carbonyl carbon, azomethine nitrogen and pyridine nitrogen. Electronic spectral studies magnetic moments of the paramagnetic complexes suggest the trigonal bipyramidal geometry. The suggested structure for complexes is shown in **Figure 8**. Metal complexes were subjected for the anti-microbial screening along with the parent ligand and corresponding metal salts against bacterial and fungal strains. The complexes were found to be more active compared to parent ligand and corresponding metal salts. It is found that the heteroaromatic substituents on the quinazolinone have positive effect on activity.

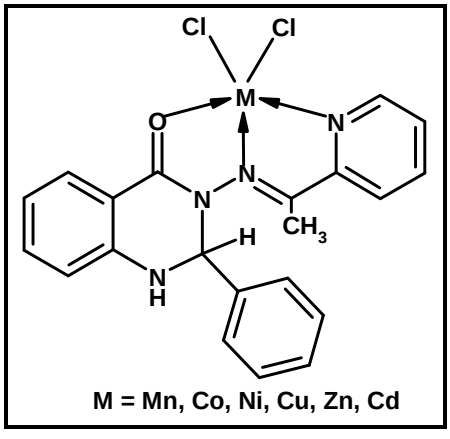


Figure 8: Tentatively proposed structure for the transition metal complexes of L

Acknowledgements
Authors are thankful to IIT Mumbai for EPR spectra, STIC Cochin for TGA studies. Thanks are also due to USIC Karnatak University Dharwad for IR, NMR and GCMS spectral studies. One of the authors R.S.H. acknowledges Karnatak University Dharwad, for the Research Fellowship.

REFERENCES

[1] S. K. Pandey, A. Singh, A. Singh, Nizamuddin, *Eur. J Med Chem*., **2009,** 44(3), 1188.
[2] R. Dahiya, A. Kumar, R. Yadav, *Molecules*., **2008**, 13(4), 958.
[3] F. Pereira Mde, R. Chevrot, E. Rosenfeld, V. Thiery, T. Besson, *J. Enzyme. Inhib. Med. Chem*., **2007,** 22(5), 577.
[4] R. Nigam, S Swarup, V. K. Saxena, *Indian Drugs*, **1990**, 27, 238.
[5] V. Alagarsamy, V. Muthukumar, N. Pavalarani, P. Vasanthanathan, and R. Revathi, *Biol. Pharm. Bull*., **2003**, 26(4), 557.
[6] V. Jatav, P. Mishra, S. Kashaw, J. P. Stables, *Eur. J. Med. Chem*., **2008**, 43(1), 135.
[7] E Pomarnacka, M. Maruszak, K. Langowska, P. Reszka, P. J. Bednarski, *Arch. Pharm., (Weinheim).* **2008**, 341(8), 485.
[8] Shi. Yang, Ma. Chunlin, R. Zhang, *J. Organomet. Chem.*, **2006**, 691(8), 1661.
[9] M. M. Bishop, L.F. Lindsay, B. W. Skeltonand, A. H. White, *J. Chem. Soc. Dalt. Trans*., **2002**, 377.
[10] B. K. Rai, A. Bulani, *Asian. J. Chem*., **2001**, 13(2), 725.
[11] J. Barleunga, L. A. Lopez, S. Martinez, M. Tomas, *Syn. Lett*., **1999**, 2, 219.
[12] A. M. Ramadan, *J. Inorg. Biochem*., **1997**, 65(3), 183.
[13] K. B. Gudasi, R. S. Vadavi, R. V. Shenoy, M. S. Patil, S. A. Patil and M. Nethaji, *Trans. Met. Chem*., **2005**, 30, 661.
[14] K. B. Gudasi, R. S. Vadavi, R. V. Shenoy, M. S. Patil, S. A. Patil and M. Nethaji, *Trans. Met. Chem*., **2006**, 31, 135.
[15] K. B. Gudasi, R. V. Shenoy, R. S. Vadavi, M. S. Patil, S. A. Patil and *Ind. J. Chem*., **2005**, 44A(11), 2247.
[16] K. B. Gudasi, R. S. Vadavi, R. V. Shenoy, M. S. Patil, S. A. Patil, M. Nethaji, *Trans. Met. Chem*., **2006**, 31, 374.
[17] K. B. Gudasi, S. A. Patil R. S. Vadavi, R. V. Shenoy, M. S. Patil, M. Nethaji, *Trans. Met. Chem*., **2006**, 31, 586.
[18] K. B. Gudasi, V. C. Havanur, S. A. Patil, B. R. Patil, *Metal Based Drugs*., **2007**, 37-348, 1-7.
[19] K. B. Gudasi, S. A. Patil, *Trans. Metal. Chem*., **2009**, 34, 325.
[20] K. K. Narang, J. P. Pandey, V. P. Singh, *Polyhedron.*, **1994**, 14, 529.
[21] R.V. Shenoy, thesis entitled "Synthetic and spectral studies of metal complexes" submitted to Karnatak University Dharwad **2005**.
[22] R. S. Hoonur, B. R. Patil, D. S. Badiger, R. S. Vadavi, K. B. Gudasi, P. R. Dandawate, M. M. Ghaisas, S. B. Padhye, M. Nethaji, *Eur. J. Med. Chem.*, DOI: 10.1016/j.ejmech.2010.01.072, **2010** (In press).
[23] http://riodb01.ibase.aist.go.jp/sdbs/cgi-bin/direct_frame_top.cgi SDBS No. 672HSP-01-832, 20-02-2010.
[24] B. Prabhakar, K.L. Reddy, P. Lingaiah, *Indian J. Chem*., **1988**, 27A, 217.

[25] G. Wilkinson, R.D. Gillard and J.A. McCleverty, Comprehensive Coordination Chemistry Vol 5 (Late Transition Metals), Pergamon press, Oxford, 1st edn (**1987**).
[26] D.N. Sathynarayana, "Electronic absorption spectroscopy and Related Techniques", Universities Press, India, Ltd. (**2001**).
[27] B. G. Tweedy, *Phytopathology.*, **1964**, 55, 910.
[28] N. Raman, A. Kulandaisamy, C. Thangaraja, P. Manisankar, S. Viswanathan, C. Vedhi, *Trans. Met. Chem.*, **2004**, 29, 129.