

Synthesis, Structural Investigation, DNA interaction and Biological Evaluation of Cu(II) complexes with Pentadentate(N₂O₃ donor) Schiff base ligand

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Abstract: A potentially pentadentate Schiff base ligand H₃L and their binuclear copper complexes have been prepared by the condensation of 2,6-diformyl-4-methyl phenol and 2-aminophenol in the molar ratio 1:2. The Schiff base, H₃L, ligand with N₂O₃ pentadentate sites and can coordinate with two copper ions to form binuclear complexes after the deprotonation of the hydrogen atoms of the phenolic groups in all complexes. The ligand and the complexes were characterized by elemental analysis, conductivity measurements, ¹H NMR, ¹³C NMR, IR, UV-Vis and ESR spectral studies. All the complexes are non-electrolyte in DMF due to their low molar conductance value. UV-Visible and ESR spectral data proposed the square planar geometry for all Cu(II) complexes under investigation. Redox behaviour of the complexes has been investigated by cyclic voltammetry. The copper(II) complexes were screened for antibacterial activity against *Staphylococcus aureus*, *Escherichia coli* and *Bacillus subtilis* and antifungal activity against *Candida albicans*, *Aspergillus niger* and *Mucos indicus*. The results revealed that the synthesised compounds were more potent against all the microbes under investigation. DNA interaction of Schiff base complexes was monitored by electronic absorption spectra. It was found that the prepared complexes could bind to DNA through an intercalating mode.

Keywords: Antimicrobial activity, Copper(II) complexes, DNA binding, Pentadentate Schiff base, Redox property

I. Introduction

Schiff base and its metal complexes play a vital role in the field of medicinal chemistry. The compounds containing carbon nitrogen double bonds are known as Schiff bases and represent a novel class of medicinally and pharmacologically important compounds[1-3]. Due to chelating nature of the azomethine nitrogen atom of Schiff bases, these are well recognized as anti-bacterial[4-6], anti-fungal[7], anti-tumor[8], anti-tuberculosis[9], anti-cancer[10], anti-oxidant[11], DNA binding[12] and DNA cleaving[13] agent. Because of excellent complexation ability with different metal ions, Schiff base ligands have been employed intensively in analytical chemistry. In organic chemistry Schiff base transition metal complexes are used as catalysts to accelerate many reactions like polymerization and oxidation etc[14]. Thus the biological activity of complexes chiefly depend upon their molecular structure and types of metal ions with which they co-ordinate.

Presently, there is a growing interest in the design and synthesis of coordination compounds of Schiff base ligands with pentadentate substituents which are increasing, due to their potential applications in the areas such as MRI, imaging with isotopes and radiotherapy, luminescent probes and DNA cleaver. Pentadentate Schiff base complexes are well known to form stable complexes, where the coordination takes place through the N₂O₃ type donor set[15]. Especially dinucleating metal complexes with pentadentate substituents with N and O donor atoms have been a fascinating area of research, in view of their significance as biomimetic catalysts in the process of oxygenation. Discoveries of dinuclear cores at the active sites of some metalloproteins have aroused interest in the investigation of multimetallic systems[16]. Dinuclear copper complexes containing two metal centers in close proximity are the subject of recent extensive investigation since this structural unit is involved in a variety of important biochemical processes such as oxygen transport and oxygen activation by oxidase and mono-oxygenase enzymes[17]. The potential of the copper(II) complexes to act as therapeutic agents is already well established. These enormous biological applications have prompted to synthesize novel binuclear Schiff base copper(II) complexes with pentadentate arm.

In this paper, we report a synthetic approach and structural characterization of a Schiff base derived from condensation of 2,6-diformyl-4-methyl phenol and 2-aminophenol and their complexes with Cu(II). The synthesised binuclear Schiff base complexes have been characterized by elemental analysis, molar conductance, infrared, electronic spectra, cyclic voltammetry, NMR and EPR studies. The Schiff base ligand and its complexes were investigated for their DNA binding and antimicrobial activities.

II. Experimental

2.1. Materials and Reagents

All chemicals were of analytical grade and purchased from Merck and Sigma Aldrich. Commercial solvents were distilled and then used for the preparation of ligand and its complexes. DNA was purchased from Bangalore Genei (India). tris(hydroxymethyl)aminoethane-HCl (Tris-HCl) was purchased from sigma-aldrich and (tris-HCl) buffer solution was prepared using deionized, sonicated triply distilled water.

2.2. Instruments

Elemental analysis was performed using a Perkin-Elmer elemental analyzer. ^1H and ^{13}C NMR of the ligand in DMSO were recorded in BRUKER model 400MHz. Molar conductivity of the metal complexes were determined by using DMF as a solvent in Equiptronics digital conductivity meter at room temperature. FT-IR spectra of ligand and complexes were obtained on a Shimadzu IR-Affinity-I spectrometer with samples prepared using KBr pellets. UV-Visible spectra were recorded using Systronics spectrophotometer operating in the range of 200–800 nm with quartz cell. Electrochemical analyzer using a three-electrode cell in which a glassy carbon electrode was the working electrode, platinum wire was used as an auxiliary electrode and SCE was the reference electrode under inert condition. The concentration of the complexes was 10^{-3} M. Tetrabutylammonium perchlorate (TBAP) was used as the supporting electrolyte which was prepared and recrystallised from hot methanol (Caution! TBAP is potentially explosive; hence care should be taken in handling the compound). EPR spectra were recorded on powdered samples of complex-I, II and III using Bruker EPR spectrometer.

2.3. Synthesis of Pentadentate Schiff base Ligand (L)

2,6-diformyl-4-methylphenol (2.0 mmol) was dissolved in 15 ml ethanol and then mixed with o-aminophenol (4.0 mmol) in 15 ml of ethanol and the mixture was refluxed for one hour at 60°C and the reaction was monitored by TLC primarily using hexane as eluent. Then the reaction mixture was left to cool and the ligand was obtained in a high yield (80%) as a pinkish-red crystalline, m.p. (266°C) soluble in DMSO, DMF, ethanol but insoluble in dichloromethane or chloroform which was recrystallised with ethanol.

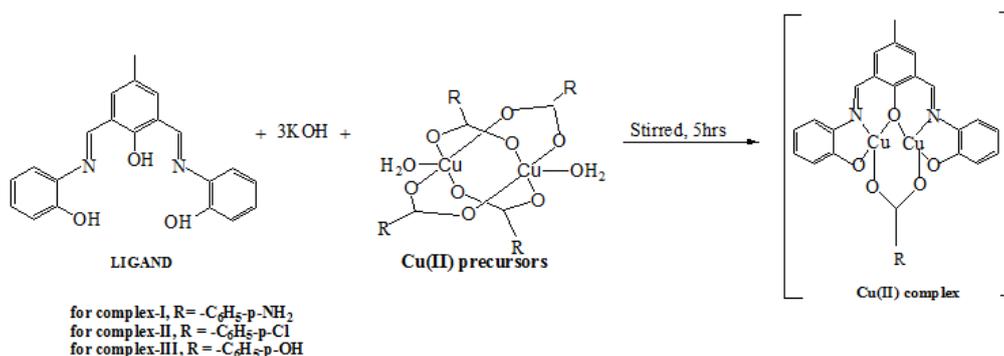
2.4. Synthesis of copper(II) precursors

The copper(II) precursors were synthesized using organic compounds like p-amino, p-chloro and p-hydroxy benzoic acids with NaOH and stirred well for 15 minutes using magnetic stirrer, then $\text{CuSO}_4 \cdot 5\text{H}_2\text{O}$ was added with the above mixture and stirred well for half an hour. The organic acid, base and metal was taken in the ratio of 2:2:1 for the synthesis of copper(II) precursors. The crude blue copper(II) precursors obtained was washed thoroughly with water and ethanol and dried well. The copper(II) precursors obtained was used for the synthesis of Copper(II) complexes as such.

2.5. Synthesis of copper(II) complexes

A general method was adopted for the preparation of copper(II) complexes. A solution containing the mixture of Schiff base ligand, KOH, various copper(II) precursors in 10ml of ethanol was placed in a round bottomed flask. The mixture was stirred for five hours. The precipitate obtained was reddish brown in colour which was filtered and washed with ethanol and dried. The complexes were highly stable under laboratory conditions and can be stored for a long time. The ratio of the ligand, KOH, Copper(II) precursors were taken as 1:3:1 for the synthesis of copper(II) complexes. The complexes formed were characterised by UV-Vis, FT-IR, ESR and Conductivity Measurement. The electrochemical behaviour was analysed using Cyclic Voltammetry. The complexes were subjected to antimicrobial activity.

General schematic representation of synthesis of the Copper (II) Complexes



2.6. DNA binding

2.6.1. Electronic Absorption Spectra

All the experiments involving the interaction of complexes with CT-DNA were conducted in Tris buffer (10 mm Tris-HCl-50 mm NaCl buffer, pH 7.4). The concentration of the DNA used for binding experiments was determined by measuring the absorption intensity at 260 nm with molar extinction coefficient value $6600 \text{ M}^{-1} \text{ cm}^{-1}$. The absorbance measurements were performed by keeping the concentration of the complex constant ($1 \times 10^{-5} \text{ M}$) while varying the DNA concentrations ($1 \times 10^{-5} \text{ M}$, 5, 10, 15, 20 and 25 μL)[18]. The intrinsic binding constant K_b for the interaction of these metal complexes with DNA has been calculated from the absorption spectral changes during the addition of increasing concentration of DNA by the following equation (1)

$$[\text{DNA}] / (\epsilon_a - \epsilon_f) = [\text{DNA}] / (\epsilon_b - \epsilon_f) + 1 / K_b(\epsilon_b - \epsilon_f) \text{ ----- (1)}$$

Where [DNA] is the concentration of DNA in base pairs, the apparent absorption coefficient ϵ_a , ϵ_f and ϵ_b correspond to $A_{\text{obs}} / [M]$, the extinction coefficient of the free and the extinction coefficient of the compound when fully bound to DNA, respectively.

2.7. Biological Studies

2.7.1. Antimicrobial activity of ligand and its complexes

The synthesized ligand and its complexes were tested for their *in-vitro* antimicrobial activity against the bacteria *Staphylococcus aureus*, *Escherichia coli* and *Bacillus subtilis* as well as against the fungi *Candida albicans*, *Aspergillus niger* and *Mucor indicus* using agar well diffusion method. The stock solutions ($10^{-2} \text{ mol L}^{-1}$) of the compounds were prepared in DMSO and the zone of inhibition values of the compound were determined by serial dilution method. For determination of zone of inhibition, the respective medium was poured into the petriplates and allowed to solidify at room temperature. Wells were made on the solidified medium and the serially diluted solutions were added on to the wells and allowed to diffuse into the wells. The indicator organisms were overlaid on to the agar medium and the plates were incubated for 37°C for 48 h. After incubation the zone of inhibition by the compound were measured and zone of inhibition was determined.

III. Results And Discussion

The synthesized ligand and its Cu(II) complexes were found to be air-stable. The ligand was soluble only in common organic solvents. The synthesized complexes were soluble in DMF and DMSO. The ligand and its complexes were characterized by the analytical and spectral techniques. Physical characterization, microanalytical and molar conductance data are given in **Table-1**.

TABLE-1: Analytical and physical data of Schiff base ligand and its complexes

Compound	Mol. formula	Melting Point	Found (Calc) (%)			A_m ($\square^{-1} \text{ cm}^2 \text{ mol}^{-1}$)
			C	H	N	
Ligand	[C ₂₁ H ₁₈ O ₃ N ₂]	266°C	72.71 (72.83)	5.13 (5.20)	8.00 (8.09)	-
Complex-I	[Cu ₂ C ₂₉ H ₂₂ O ₅ N ₂]	>360°C	57.55 (57.61)	3.54 (3.64)	4.66 (4.63)	53
Complex-II	[Cu ₂ C ₂₈ H ₂₁ O ₅ N ₃]	>360°C	56.60 (56.47)	3.61 (3.53)	7.11 (7.06)	44
Complex-III	[Cu ₂ C ₂₉ H ₂₂ O ₆ N ₂]	>360°C	56.20 (56.12)	3.60 (3.55)	4.59 (4.52)	41

3.1. Elemental analysis and Molar Conductance

The molar conductance (Table 1) values measured in DMF solution ($1 \times 10^{-3} \text{ mol dm}^{-3}$) fall in the range $41\text{-}53 \text{ ohm}^{-1} \text{ cm}^2 \text{ mol}^{-1}$. These observed values of the molar conductance are well within the expected range for non-electrolytes[19]. The elemental analysis data is in good agreement with the calculated values and suggested the 1:2 ligand to metal stoichiometry in all the synthesized metal complexes.

3.2. Infrared spectra

In order to study the binding mode of ligand to metal in the complexes, IR spectrum of the free Schiff base ligand was compared with the IR spectra of the metal complexes. The structurally significant IR peaks for free Schiff base ligand and its complexes are given in the **Table-2**. The free ligand exhibits IR peaks at 3373 cm^{-1} (O-H), 1616 cm^{-1} (C=N) and 1228 cm^{-1} (C-O). In the spectra of the complexes the peak due to (O-H) of the ligand disappeared indicating the coordination of phenolic oxygen to the metal ion via deprotonation. This was further supported by upward shift of the phenolic (C-O) mode. The peak at 1616 cm^{-1} was due to azomethine group of the ligand and it was shifted to lower frequency (by $10\text{-}15 \text{ cm}^{-1}$) after complexation. This shows the coordination of the metal with the azomethine nitrogen[20].

The binding mode of the benzoate ion in all complexes has been determined from the IR spectra by considering the difference in energy (Δ) between the asymmetric and symmetric carboxylate stretching frequencies. According to Deacon and Philips[21] for an unidentate coordination, the value of $\Delta\nu [\nu_{as}(\text{COO}) - \nu_s(\text{COO})]$ is more than that of free carboxylate anion value, where as for bidentate bridging or chelating carboxylate group, the separation value is less than the free carboxylate. For the current series of binuclear complexes the lower value of $\Delta\nu$ which is in the range of 150-175 cm^{-1} suggests bidentate bridging coordination mode of the carboxylate group.

TABLE-2: The vibrational Spectral data of the ligand and its complexes (cm^{-1})

Compound	$\nu(\text{C}=\text{N})$	$\nu(\text{C}=\text{O})$	carboxylate group		$\nu(\text{Cu}-\text{N})$	$\nu(\text{Cu}-\text{O})$
			$\nu_{as}(\text{COO})$	$\nu_s(\text{COO})$		
Ligand	1616	1228	-	-	-	-
Complex-I	1600	1253	1552	1388	557	470
Complex-II	1606	1249	1552	1381	571	476
Complex-III	1602	1255	1548	1402	538	464

Further the peaks observed in the region 538-571 cm^{-1} can be attributed to $\nu(\text{Cu}-\text{N})$ linkage and around 464-476 cm^{-1} $\nu(\text{Cu}-\text{O})$ linkage respectively.

3.3. Electronic Spectra:

The UV-Visible spectra of the ligand and its complexes were recorded in the DMF solution is given in the **Table-3**. The electronic spectrum of the ligand exhibit a band at 35842 cm^{-1} which is due to $\pi-\pi^*$ transition of the benzene ring and it was shifted to higher wavelength (red shift) upon complexation. The band at 27248 cm^{-1} which is due to $n-\pi^*$ transition of the azomethine group present in the ligand, upon complexation it undergoes a red shift in the complexes. This supports the coordination of metal with the azomethine nitrogen[22]. In all the complexes, the charge transfer bands were observed in the range 22573-22727 cm^{-1} and its broadness can be explained as due to the combination of $\text{O}\rightarrow\text{Cu}$ and $\text{N}\rightarrow\text{Cu}$ LMCT transitions. For a square planar Cu(II) complexes with $d_{x^2-y^2}$ ground state, three spin allowed transitions are possible, $d_{x^2-y^2}\rightarrow d_z^2$, $d_{x^2-y^2}\rightarrow d_{xy}$ and $d_{x^2-y^2}\rightarrow d_{xz}, d_{yz}$ (${}^2A_{1g}\leftarrow{}^2B_{1g}$, ${}^2B_{2g}\leftarrow{}^2B_{1g}$ and ${}^2E_g\leftarrow{}^2B_{1g}$) respectively. Since the four d-orbitals lie very close together, each transition cannot be distinguished by their energy and hence it is very difficult to resolve the bands into separate components. All the complexes gave d-d bands in the range 15000-17000 cm^{-1} . The ligand field parameters such as Dq and LFSE have been calculated and the values are listed in the Table-3.

TABLE-3: Electronic Spectral data and ligand field parameters for ligand and its copper(II) complexes

Compound	$\pi-\pi^*$ (cm^{-1})	$n-\pi^*$ (cm^{-1})	LMCT (cm^{-1})	d-d (cm^{-1})	Dq (cm^{-1})	LFSE K.cal.mol ⁻¹
Ligand	35842	27248	-	-	-	-
Complex-I	35714	27027	22573	17153	1715.3	49.04
Complex-II	35211	26737	22573	16863	1686.3	48.21
Complex-III	35714	26810	22727	15949	1594.9	45.60

3.4. ¹H NMR Spectra

The Ligand was characterized by ¹H NMR and the values were obtained in ppm, 2.3 δ (3H, methyl protons); 6-8 δ (10H, Aromatic protons); 7.87 δ (2H, HC=N-) of azomethine group; 9.04 δ (2H, Ar-OH) deshielded due to one hetero atom; 15.01 δ (1H,Ar-OH) deshielded due to two hetero atoms.

3.5. ¹³C NMR Spectra

The ¹³C NMR spectrum of the Schiff base ligand showed an aliphatic CH₃ signals at 20.3 ppm, Ar.C-OH signals at 157.2 ppm and HC=N signals at 161.7 ppm[23].

3.6. ESR Spectra

The ESR spectra of the copper(II) complexes in the polycrystalline state at 298K were recorded in the X band using DPPH as a reference standard. The observed ESR spectra for all copper(II) complexes is characteristic of square planar geometry. 'g' values averaged to overall directions and 'G' which is a measure of extent of exchange interaction between the metal ions have been calculated using the relations $g_{av}^2 = 1/3(2g_{\perp}^2 + g_{\parallel}^2)$ and $G = (g_{\parallel} - 2)/(g_{\perp} - 2)$. By observing the g-values it is clear that $g_e < g_{\perp} < g_{\parallel}$ which suggest that $d_{x^2-y^2}$ orbital is in the ground state and the d⁹ configuration is $(e_g)^4(a_{1g})^2(b_{2g})^2(b_{1g})^1$. The 'g' values are related to the axial symmetry and $g_{\parallel} > g_{\perp}$ suggests square planar geometry for Cu(II) complex[24]. The $g_{\parallel} > 2.3$ is characteristic of an ionic environment and $g_{\parallel} < 2.3$ indicates a covalent environment in metal ligand bonding. The g_{av} values for the complexes are less than 2.3, suggesting the environment is covalent.

The exchange coupling interaction between two Cu(II) ions is explained by Hathaway expression $G = (g_{\parallel} - 2.0023)/(g_{\perp} - 2.0023)$. According to Hathaway[25], if the value G is greater than four (G>4.0), the

exchange interaction is negligible; whereas when the value of G is less than four ($G < 4.0$), a considerable exchange coupling is present in the complex. The G values for all Cu(II) complexes are less than four indicate considerable exchange interaction in the complexes. Apart from this, a weak signal observed at lower field (near half of the resonance field) suggests a dimeric structure for the complex. This half field signal arises from the coupling of the two copper ions and corresponds to the forbidden transition $\Delta M_s = \pm 2$. The ESR spectra of the complexes are shown in Fig-1.

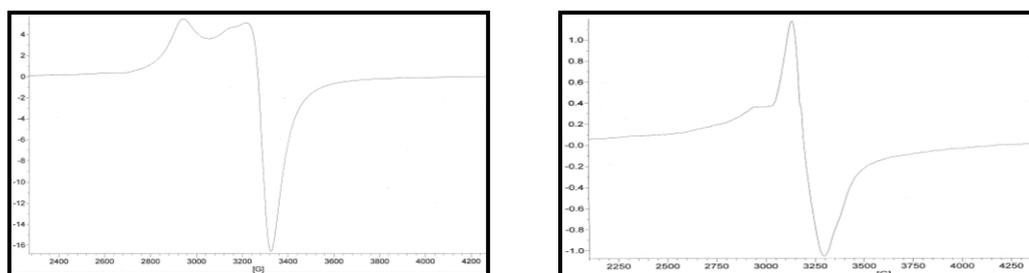


Fig-1 ESR spectra of the copper(II) complexes-I & II respectively

3.7. Electrochemical Studies

The electrochemical behaviour of binuclear copper(II) complexes have been studied by cyclic voltammetry (CV) in DMF containing TBAP as supporting electrolyte. The electrochemical data are summarized in **Table-4** and the CV of the copper(II) complexes depicted in Fig-2. The binuclear copper(II) complexes were associated with two quasireversible reduction waves[26]. -0.7179V and -1.0867V are the first reduction potential value for complex-I, II & III respectively. -1.0867V and -0.7625 V are the second reduction potential value for complex-I, II & III respectively. The first reduction wave consumed approximately one electron ($n \approx 0.86$). This indicates that each process corresponds to single electron-transfer process and this can be assigned to the redox couple $\text{Cu}^{\text{II}}\text{Cu}^{\text{II}}/\text{Cu}^{\text{II}}\text{Cu}^{\text{I}}$. The second quasi-reversible wave can be attributed to the formation of the mixed valent $\text{Cu}^{\text{II}}\text{Cu}^{\text{I}}/\text{Cu}^{\text{I}}\text{Cu}^{\text{I}}$ species. Based on these observations, it is reasonable to suggest that the reduction process may involve the stepwise redox processes as follows:

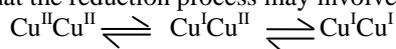


TABLE-4: Redox potentials of copper(II) complexes in DMF solution at 298 K

Complex	E_{PC}^1 (V)	E_{Pa}^1 (V)	E_{PC}^2 (V)	E_{Pa}^2 (V)
I	-0.7179	-0.8352	-1.1296	0.8576
II	-0.8625	0.6167	-0.9651	0.8998
III	-1.0867	0.4036	-0.7625	0.9212

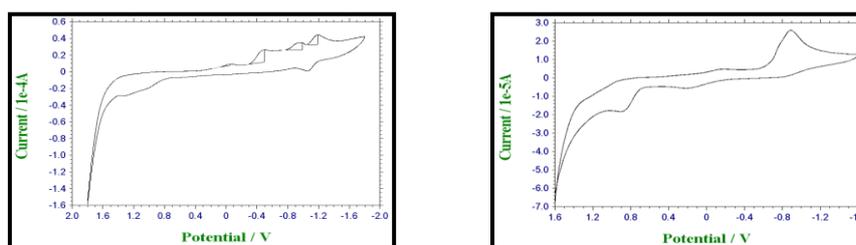


Fig-2 Cyclic Voltammogram of the copper(II) complexes-I & II respectively

3.8. DNA Binding ability

3.8.1. Absorption Spectroscopy

A complex bound to DNA through intercalation is characterized by the change in absorbance (hypochromism) and red-shift in wavelength. This may be due to the π^* orbital of the intercalated ligand which can couple with the π orbital of the DNA base pairs (stacking interaction between the aromatic chromophore and the DNA base pairs) thus, decreasing the $\pi \rightarrow \pi^*$ transition energy and resulting in the bathochromism[27]. The electronic spectra of the complexes in the presence and absence of DNA were monitored at a wavelength range of 250–600 nm as shown in Fig-3. The electronic absorption spectra of all the complexes exhibited broad absorption bands in the region 420-430 nm. Upon increasing the concentration of CT DNA, a considerable shift in the wavelength (bathochromicity) was observed for all the complexes. This bathochromicity (red shift) exhibits due to intercalative binding nature of the complexes with the base pair of DNA[28]. In order to compare the binding strength of the complexes with CT-DNA, the intrinsic binding constants, K_b were obtained by monitoring the changes in the absorbance of the complexes with increasing concentration of DNA. The K_b

values obtained for complexes Complexes-I, II & III were $4.46 \times 10^4 \text{ M}^{-1}$, $3.63 \times 10^4 \text{ M}^{-1}$ and $3.01 \times 10^4 \text{ M}^{-1}$ respectively.

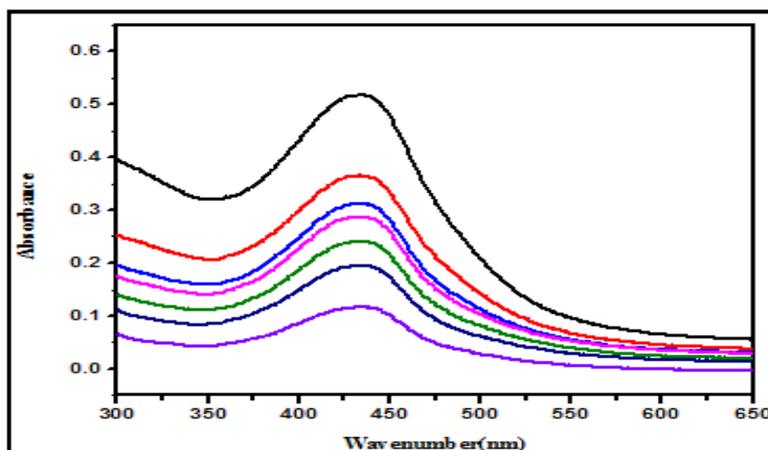


Fig-3: Absorption spectra of complex Cu(II) ($1 \times 10^{-5} \text{ M}$) in the absence and presence of increasing amounts of CT- DNA ($0-2.5 \times 10^{-5} \text{ M}$) at room temperature in 50 mM tris- HCl / NaCl buffer (pH = 7.4).

3.9. Biological Results

3.9.1. Antimicrobial activity

The Schiff base ligand and its metal complexes have been monitored for their antibacterial activity against various pathogenic bacteria such as *Staphylococcus aureus*, *Escherichia coli* and *Bacillus subtilis* and antifungal activity against *Candida albicans*, *Aspergillus niger* and *Mucus indicus*. Ciprofloxacin and Amphotericin-B were used as the standard for bacterial and fungal studies respectively. The antimicrobial activity of the Schiff base and its complexes were tested against human pathogenic bacteria as well as fungi and the zones of inhibition are given in Table-5 & 6. A comparative study of the growth inhibition zone values of Schiff base and its complexes show that metal complexes display higher antibacterial activity than the free ligand and this is probably due to the greater lipophilic nature of the complexes[29]. Metal complexes activity can be explained on the basis of Overtone’s concept and Tweedy’s chelation theory. According to the overtone concept of cell permeability, the lipid membrane surrounding the cell favours the passage of only lipid-soluble materials, which means that liposolubility is an important factor controlling antimicrobial activity. On chelation, the polarity of metal ion is reduced to a greater extent due to overlap of the ligand orbital and partial sharing of its positive charge with the donor groups[30]. In addition, it is also due to delocalization of the π -electrons over whole chelate ring, enhancing the penetration of the complexes into the lipid membranes and the blocking of the metal binding sites of the enzymes of the microorganisms.

TABLE-5: Antibacterial Activity of the Schiff base ligand and its copper(II) complexes

S.NO.	MICRO ORGANISMS	L	C1	C2	C3	Ciprofloxacin
1.	<i>Staphylococcus aureus</i>	16	20	21	20	20
2.	<i>Escherichia coli</i>	14	22	20	26	23
3.	<i>Bacillus subtilis</i>	13	17	20	18	21

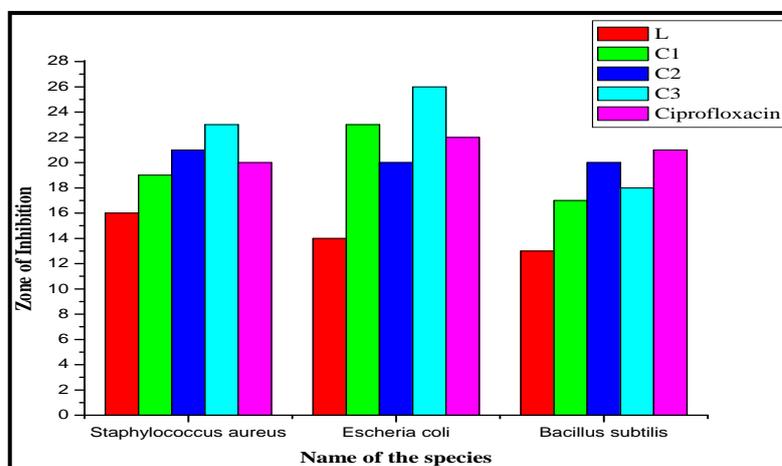


Fig-4 Graphical representation of Antibacterial activity

TABLE-6: Antifungal Activity of the Schiff base ligand and its copper(II) complexes

S.NO.	MICRO ORGANISMS	L	C1	C2	C3	Amphotericin-B
1.	<i>Candida albicans</i>	12	22	15	18	17
2.	<i>Aspergillus niger</i>	14	15	12	13	15
3.	<i>Mucus indicus</i>	16	21	22	18	19

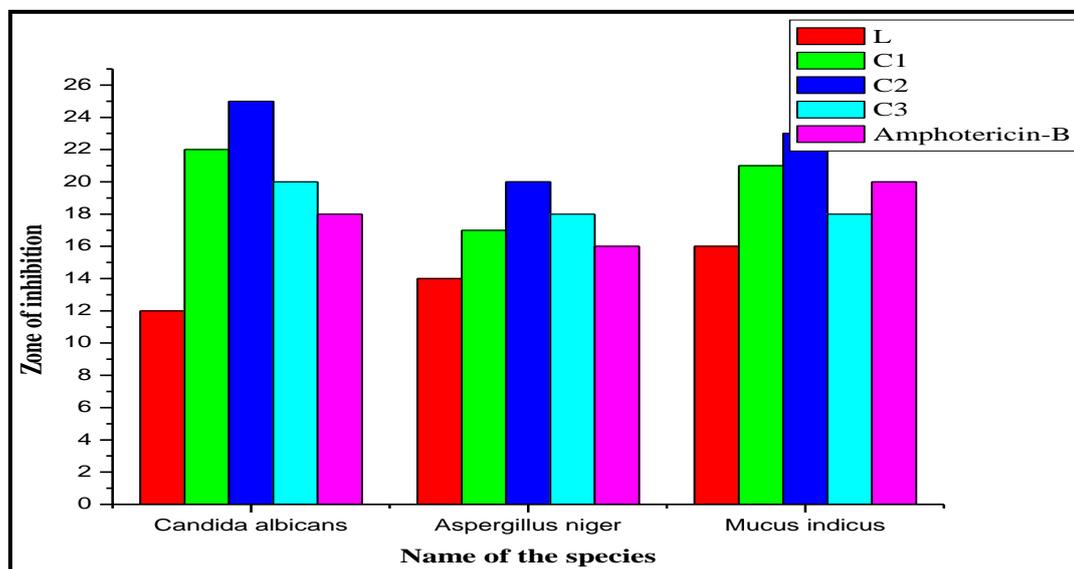


Fig-5 Graphical representation of Antifungal activity

IV. Conclusion

In the present study, the Schiff base, H₃L, ligand is dibasic N₂O₃ pentadentate sites. The Schiff base was allowed to react with metal ions in 1:2 molar ratio (ligand:metal ion) to form the binuclear complexes. The binding sites are the azomethine nitrogen atoms and the phenolic oxygen atoms respectively. The bonding of ligand to metal ion is confirmed by elemental analyses, spectral studies like UV-Vis, FT-IR, NMR, ESR and conductance measurements. The lower molar conductance values suggested the non-electrolytic nature of the complexes. The cyclic voltammogram of the complexes confirmed the redox property. From the analytical and spectral data, all the copper(II) complexes were shown to exhibit a square planar geometry. The binding behaviour of metal complexes with DNA was studied by UV absorption spectra which indicate that all the three synthesized complexes can strongly bind to CT-DNA via an intercalation mode. Antibacterial and antifungal studies of the ligand and complexes have also been studied which indicate that activity increases on chelation.

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