



Synthesis, Spectral characterization, antimicrobial activity and DNA binding studies of Co (II) complexes of (thiophen-2-yl)methanamine Schiff base ligand.

Udayalaxmi S,^{a,b} Mohan Rao G^{a*}, Ravikiran K^b and Ettaiah P^{b*}

^a Research Center, Department of Chemistry, C.K.M. Arts and Science College, Kakatiya University, Warangal – 506 006, Telangana

^b Department of Chemistry, Osmania University, Hyderabad, Telangana

ABSTRACT:

The present work involved the synthesis of Schiff base ligands of (thiophen-2-yl)methanamine derivatives with aromatic aldehydes. The synthesized ligands and complexes were characterized by elemental analysis, NMR, FTIR, electronic spectra, magnetic moments and conductivity measurements. The metal to ligand ratio is 1:2 and the antimicrobial studies indicate that the Co (II) schiffbase complexes exhibit more activity than ligands.

KEYWORDS: Cobalt, DNA, antimicrobial activity.

1. INTRODUCTION

Schiff base ligands with N₂O₂ donor atoms are well known to coordinate with a variety of metal ions. They have attracted much interest in recent years, due to their ease of synthesis. N, O donor atoms play an important role in the transformation mechanism of some reactions in biological systems in neutral biological systems, especially a functional group such as –OH is present near to the azomethine (–HC=N) group to form a five or six membered ring with the metal ion [1]. The imine (–C=N–) group of Schiff base ligands provide an opportunity for the stupendous biological activities and also have various applications in analytical chemistry, agrochemicals, catalysis, food and dye industry [2-6]. In this work we reporting the novel Schiff bases prepared from (thiophen-2-yl)methanamine with different substituted aromatic aldehydes, and their Co(II) complexes were synthesized and characterized by various techniques.

2. MATERIALS AND METHODS.

2.1 CHEMICALS:

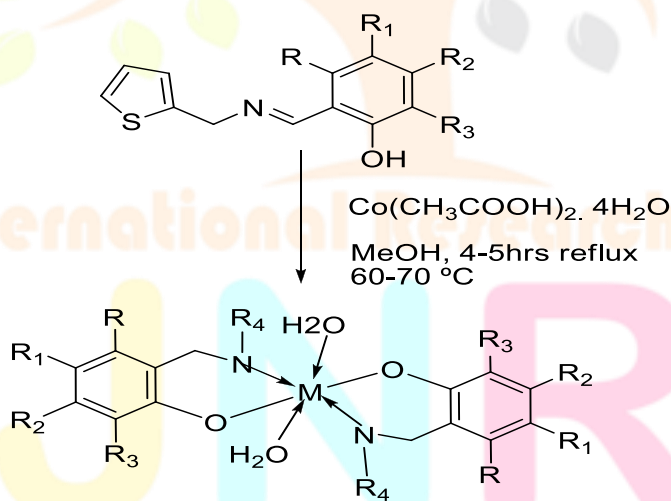
GR/AR grade quality chemicals obtained from sigma- Aldrich chemicals were used. All the solvent used were analytical grade and obtained from Finar , Merck, SD Fine-chem. Ltd.. The micro analytical data (C, H, and N) were collected using Perkin Elmer 240C instrument. IR spectra were obtained using Shimadzu IR Prestige-21 spectrophotometer. ^1H NMR spectrum was obtained using Bruker 400 MHz NMR spectrometer. Electronic spectra of the ligands and its complexes were obtained using Shimadzu UV-Visible 2600 spectrometer.

2.2 SYNTHESIS OF SCHIFFBASES:

The ligands are prepared by taking equimolar ratio of (thiophen-2-yl)methanamine and aromatic aldehydes like 5-fluoro-2-hydroxy-3-methoxybenzaldehyde, 5-fluoro-2-hydroxybenzaldehyde, 2-hydroxy-4,6-dimethoxybenzaldehyde, which are dissolved in hot methanol. It is then refluxed for 2-3 hour and solid product was cooled room temperature and isolated and washed with petroleum ether, recrystallized from methanol.

2.3 SYNTHESIS OF SCHIFFBASE COBALT COMPLEXES:

The metal complexes were prepared by adding Co(II) acetates in methanolic solution to the ligand in methanol in 1:2 molar ratios and refluxed in oil bath for about 4-5 hrs at 60-70 °C. The precipitated solids were washed with methanol and petroleum ether and finally dried under vacuum desiccators over anhydrous CaCl_2 .



3. RESULTS AND DISCUSSION

All the ligands and their complexes are stable at RT and are non-hygroscopic. The ligands are soluble in common organic solvents like Methanol, Acetonitrile, CHCl_3 , DCM, DMF and DMSO, whereas complexes are soluble only in DMF and DMSO but both are insoluble in water.

3.1 ELEMENTAL ANALYSIS:

The analytical data suggested that all the complexes are binuclear with the ligand coordinated to the central metal atom. The metal to ligand ratio in the complexes was 1:2 [7-9]. The details are given in Table 1.

Table 1: Physical characteristics and analytical data of the complexes

| Compound | Molecular formula | Mol.wt | Elemental Analysis Found (Calcd) % | | | |
|---|--|--------|---------------------------------------|----------------|----------------|------------------|
| | | | C | H | N | Co |
| TMMCFP | C ₁₂ H ₉ ClFNOS | 270 | 53.44 (53.51) | 3.36 (3.41) | 5.19 (5.23) | - |
| TMMFMOP | C ₁₃ H ₁₂ FNO ₂ S | 265 | 58.85 (58.90) | 4.56 (5.60) | 5.28 (5.34) | - |
| TMMFP | C ₁₂ H ₁₀ FNOS | 235 | 61.26 (61.30) | 4.28 (4.31) | 5.95 (6.00) | - |
| [Co(TMMCFP) ₂ (H ₂ O ₂) ₂] | [Co(C ₁₂ H ₉ ClFNOS) ₂ (H ₂ O ₂) ₂] | 632 | 45.63 (45.58) | 3.26 (3.19) | 4.47 (4.43) | 9.38 (9.32) |
| [Co(TMMFMOP) ₂ (H ₂ O ₂) ₂] | [Co(C ₁₃ H ₁₂ FNO ₂ S) ₂ (H ₂ O ₂) ₂] | 654 | 45.63 (45.58) | 3.24 (3.19) | 4.49 (4.43) | 9.35 (9.32) |
| [Co(TMMFP) ₂ (H ₂ O ₂) ₂] | [Co(C ₁₂ H ₁₀ FNOS) ₂ (H ₂ O ₂) ₂] | 563 | 51.21 (51.15) | 3.99 (3.94) | 5.02 (4.97) | 10.50 (10.46) |

* Values mentioned within the bracket are calculated

3.3. IR SPECTRA

The IR Spectrum provides the valuable information regarding the nature of functional groups coordinated to the metal atom. The selected IR spectral data of the ligand and complexes are given in Table-2. The IR spectra of the ligand showed a broad band in the region 3449 cm⁻¹ - 3462 cm⁻¹ due to OH group of phenolic moiety. The absorption band at 1616 cm⁻¹ to 1628 cm⁻¹ [10] can be assigned to C=N stretching. In all the complexes this bond is shifted to lower frequencies in the range 1612cm⁻¹-1631cm⁻¹ up on complexation with metal, which can be attributed to coordination to imine nitrogen to metal centre. In complex there is an broad band the region 3216cm⁻¹-3438 cm⁻¹ is due to OH group attached at Para position the bands in the region 1121-1273 cm⁻¹ is due to C- O stretching. The band in the region 580cm⁻¹ - 586 cm⁻¹ is due to M-O stretching frequency. Absorption peaks in the region 468cm⁻¹- 492cm⁻¹ of complexes is due to M-N stretching frequency.

Table 2: IR data (cm⁻¹) of Schiff bases and their metal complexes

| Compound | v(OH) | v(C=N) | v(C-O) | v(C-S-C) | v(M-O) | v(M-N) |
|---|-------|--------|--------|----------|--------|--------|
| TMMCFP | 3451 | 1628 | 1273 | 829 | - | - |
| TMMFMOP | 3462 | 1620 | 1247 | 853 | - | - |
| TMMFP | 3449 | 1616 | 1228 | 824 | - | - |
| [Co(TMMCFP) ₂ (H ₂ O ₂) ₂] | 3216 | 1620 | 1237 | 830 | 586 | 470 |
| [Co(TMMFMOP) ₂ (H ₂ O ₂) ₂] | 3417 | 1612 | 1121 | 851 | 580 | 492 |
| [Co(TMMFP) ₂ (H ₂ O ₂) ₂] | 3438 | 1626 | 1121 | 823 | 580 | 468 |

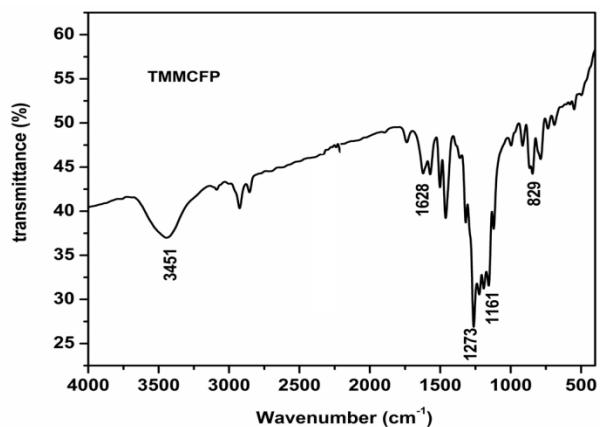


Figure 1: IR spectrum of TMMCFP

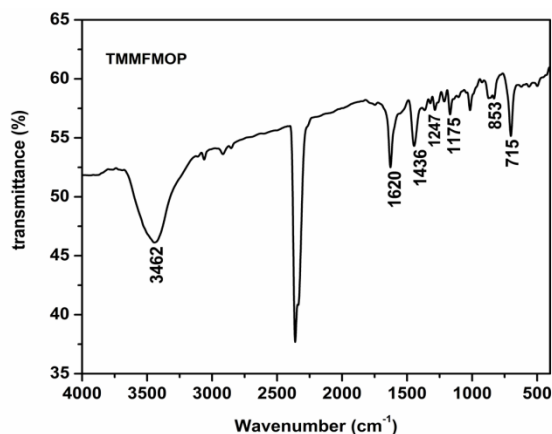


Figure 2: IR spectrum of TMMFMOP

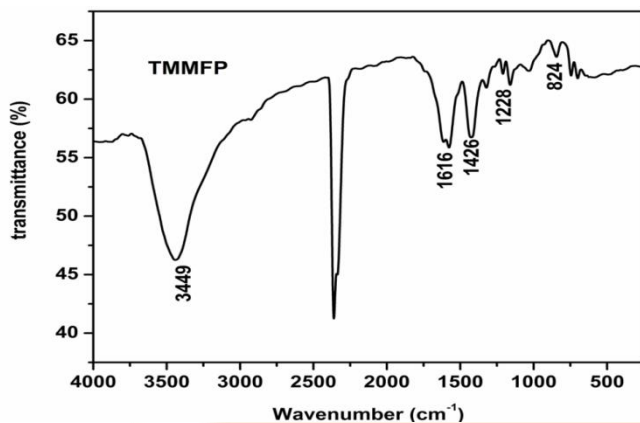


Figure 3: IR spectrum of TMMFP

3.4. UV-VISIBLE SPECTRA

The spectra of ligands show two broad band due to π - π^* transitions of aromatic ring and n - π^* transitions of imine group. These transitions are shifted in metal complexes due to coordination of ligand with metal during complexation. The cobalt complexes exhibit one band which may correspond to ${}^4T_{1g}$ ${}^4T_{2g}$ assign octahedral geometry.

→
Table 3: UV –Vis spectra data of Schiff bases and their complexes

| Compound | π - π^* | n - π^* | d-d transition |
|---------------------------|-----------------|---------------|----------------|
| TMMCFP | 280 | 340 | - |
| TMMFMOP | 277 | 391 | - |
| TMMFP | 263 | 393 | - |
| $[Co(TMMCFP)_2(H_2O)_2]$ | 259 | 314 | 581 |
| $[Co(TMMFMOP)_2(H_2O)_2]$ | 280 | 340 | 517 |
| $[Co(TMMFP)_2(H_2O)_2]$ | 266 | 422 | 530 |

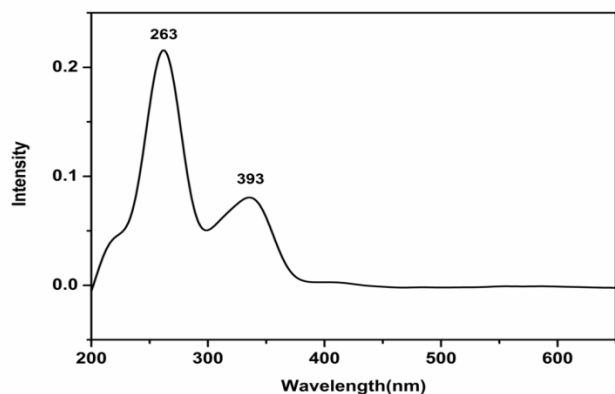


Figure 4. UV-Visible spectrum of ligand TMMFP.

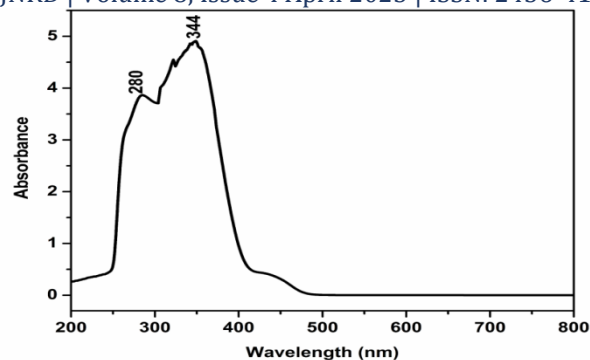
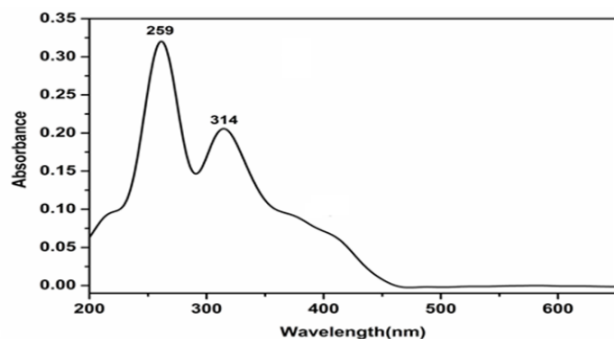
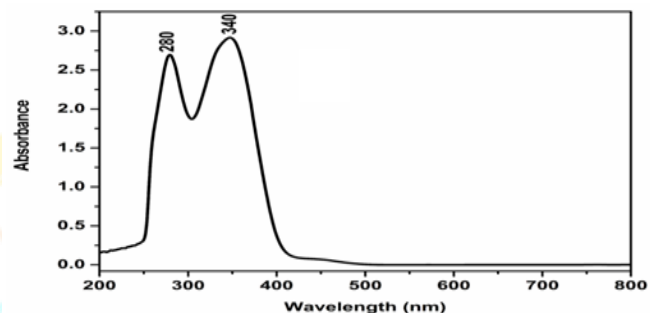
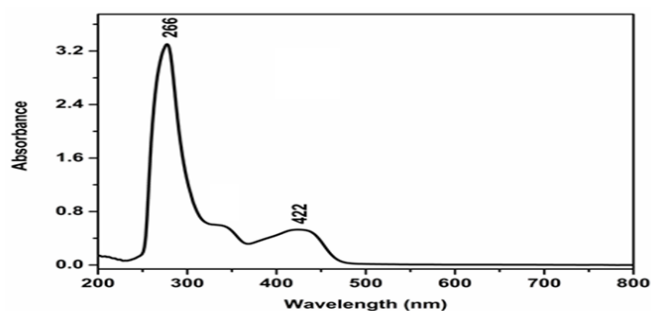


Figure 5. UV-Visible spectrum of ligand TMMDMOP.

Figure 6. UV-Visible spectrum of complex $[Co(TMMCFP)_2(H_2O)_2]$ Figure 7. UV-Visible spectrum of complex $[Co(TMMFMOP)_2(H_2O)_2]$ Figure 8. UV-Visible spectrum of complex $[Co(TMMFP)_2(H_2O)_2]$

3.5 MAGNETIC SUSCEPTIBILITY MEASUREMENT:

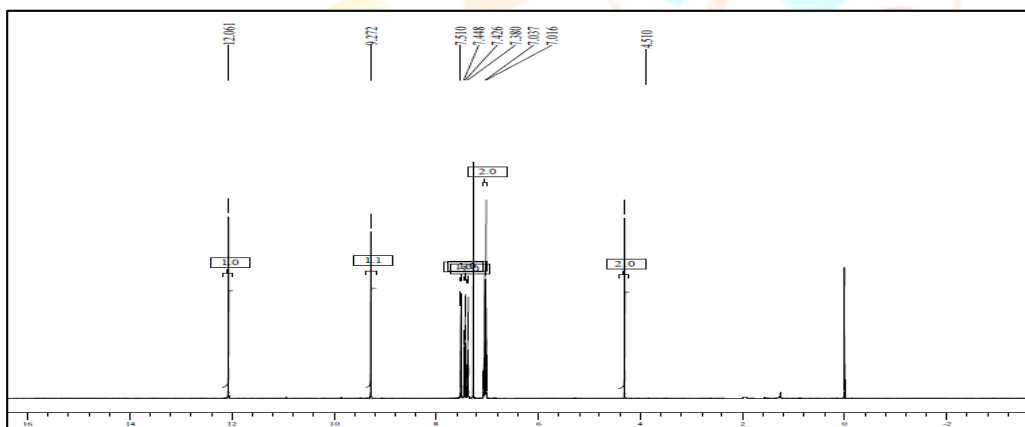
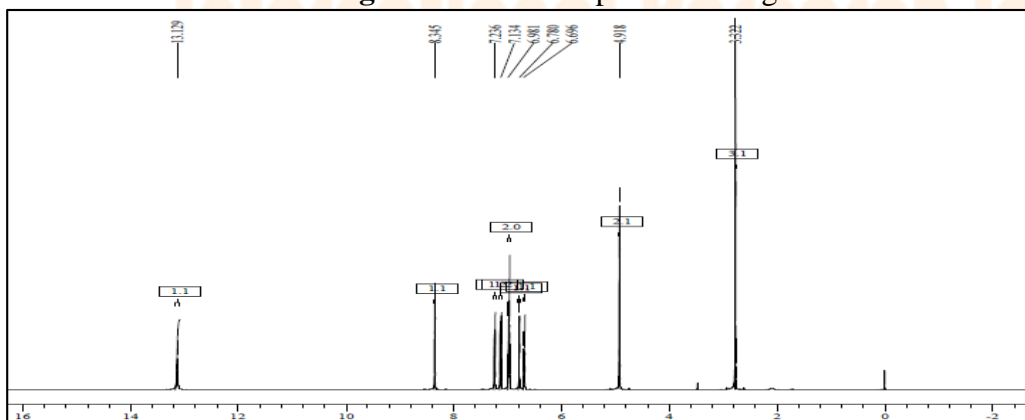
The magnetic moment values of the Co(II) complexes have paramagnetic character and suggested high spin values (4.11-4.16 BM) i.e., the studied Schiff base ligands are so weak that they exhibited low t_{2g} and e_g d-splitting of the octahedral structures of the Co(II) complexes [11]. From the electronic spectral data and magnetic moment values a octahedral geometry is assigned. Magnetic moment values of all the cobalt (II) complexes are listed in **Table 4**.

Table 4: Magnetic moment values of cobalt (II) complexes

| Complexes | Magnetic moment (BM) |
|---|----------------------|
| [Co(TMMCFP) ₂ (H ₂ O) ₂] | 4.13 |
| [Co(TMMFMOP) ₂ (H ₂ O) ₂] | 4.11 |
| [Co(TMMFP) ₂ (H ₂ O) ₂] | 4.16 |

3.6 ¹H-NMR :

1. 2-((E)-((thiophen-2-yl)methylimino)methyl)-6-chloro-4-fluorophenol (TMMCFP) : (400 MHz, CDCl₃) (δ): 12.06 (s, 1H), 9.27 (s, 1H), 7.51-7.01 (m, 5 H,s), 4.51 (s, 2H,)
2. 2-((E)-((thiophen-2-yl)methylimino)methyl)-4-fluoro-6-methoxyphenol (TMMFMOP): (400 MHz, CDCl₃) (δ): 13.12 (s, 1H), 8.34 (s, 1H), 7.23-6.69 (m, 5 s), 4.91 (s, 2H), 3.32 (s, 3H,)
3. 2-((E)-((thiophen-2-yl)methylimino)methyl)-4-fluorophenol (TMMFP) : (400 MHz, CDCl₃) (δ):14.23 (s, 1H), 8.26 (s, 1H), 7.56-7.00 (s), 5.00 (s, 2H),

**Figure 9.** ¹H NMR spectrum of ligand TMMCFP.**Figure 10.** ¹H NMR spectrum of ligand TMMFMOP.

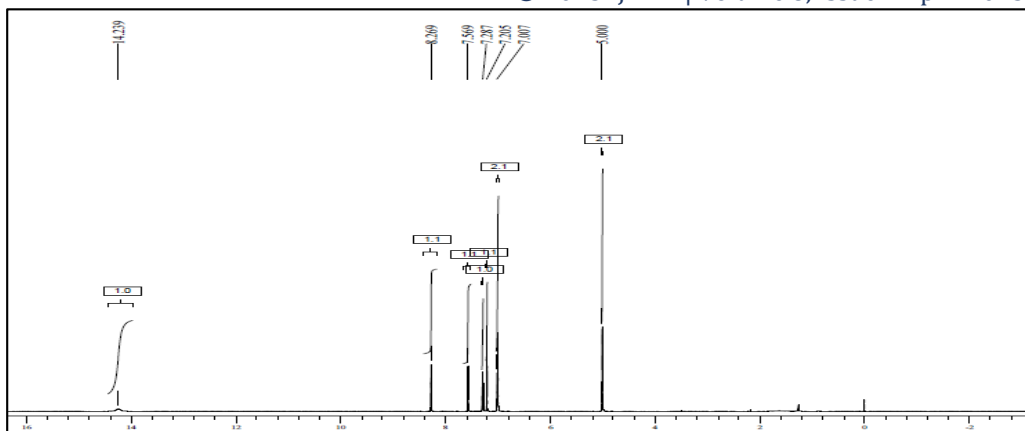


Figure 11. ^1H NMR spectrum of ligand TMMFP

4. ANTIMICROBIAL ACTIVITY:

The Cobalt (II) Schiff base complexes are widely studied for the antimicrobial and anticancer activity. The present investigation suggests that all the metal complexes of the ligand bearing metal ion, phenolic moiety, benzene ring, -N=CH- group have comparatively more biological activity. Antibacterial activities of the ligand, complexes and standard drugs were screened by disc diffusion method in DMSO as solvent. The results of antibacterial study are given in **Table-5**.

| Compound | Bacteria (mm) | | | Fungi (mm) | |
|---|-----------------------------|------------------|----------------|----------------------|------------------|
| | <i>B. amyloliquefaciens</i> | <i>S. aureus</i> | <i>E. coli</i> | <i>M. phaseolina</i> | <i>S. rolfii</i> |
| TMMCFP | 02±0.2 | 02±0.3 | 01±0.3 | 01±0.2 | 01±0.4 |
| TMMFMOP | 02±0.1 | 01±0.4 | 01±0.5 | 02±0.4 | 01±0.3 |
| TMMFP | 02±0.2 | 04±0.3 | 01±0.3 | 02±0.2 | 02±0.4 |
| $[\text{Co}(\text{TMMCFP})_2(\text{H}_2\text{O})_2] = \text{C3}$ | 28±0.2 | 27±0.4 | 28±0.3 | 27±0.2 | 27±0.2 |
| $[\text{Co}(\text{TMMFMOP})_2(\text{H}_2\text{O})_2] = \text{C6}$ | 29±0.3 | 29±0.6 | 28±0.2 | 26±0.2 | 26±0.2 |
| $[\text{Co}(\text{TMMFP})_2(\text{H}_2\text{O})_2] = \text{C9}$ | 29±0.2 | 28±0.4 | 28±0.3 | 26±0.2 | 28±0.2 |

Table 5: Zone of inhibition (mm) of the Schiff bases (TMMCFP, TMMFMOP & TMMFP) and their metal complexes and free metal salts at 500 $\mu\text{g}/\text{mL}$ concentration.

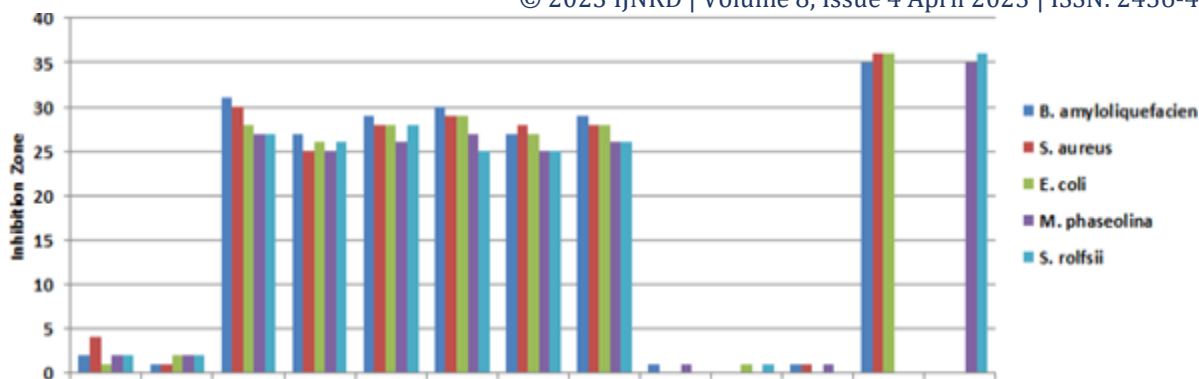


Figure 12. Zone of inhibition (mm) of the Schiff base ligands (TMMFP and TMMDMOP) and their metal complexes and free metal ions tested against antibacterial and antifungal strains.

5. DNA BINDING STUDIES :

The binding constant (K_b) values of compounds to CT DNA were calculated by monitoring π - π^* transition absorption band in the absence and presence of DNA, due to the combination between metal complexes and DNA, a clear hypochromism was occurred for the charge transfer peak which, as observed, has a slight shift in λ_{max} sometimes no shift is noticed This observation can be attributed to the intercalative type of interaction among the considered chelates and nucleotide pairing [12]. The intrinsic binding constant (K_b) of the complexes with CT-DNA is determined by the following equation,

$$[\text{DNA}]/(\varepsilon_a - \varepsilon_f) = [\text{DNA}]/(\varepsilon_b - \varepsilon_f) + 1/K_b(\varepsilon_b - \varepsilon_f),$$

Where, [DNA] is the concentration of DNA in base pairs, K_b is the intrinsic binding constant, ε_a is apparent coefficient of $A_{obs}/[\text{complex}]$, ε_f and ε_b correspond to the extinction coefficients of the free and fully bound forms of the complex, respectively. The binding constant, K_b is calculated from the ratio of slope to intercept, and K_b values are presented in **Table 6**.

Table 6. Binding constants of cobalt complexes

| Complex | Intrinsic binding constant, K_b (M^{-1}) |
|---|--|
| $[\text{Co}(\text{TMMCFP})_2(\text{H}_2\text{O})_2]$ | 4.04×10^4 |
| $[\text{Co}(\text{TMMFMOP})_2(\text{H}_2\text{O})_2]$ | 2.08×10^5 |
| $[\text{Co}(\text{TMMFP})_2(\text{H}_2\text{O})_2]$ | 1.51×10^5 |

6. CONCLUSION

Schiff base transition metal complexes Co(II) were synthesised from (thiophen-2-yl)methanamine and aromatic aldehydes and characterized on the basis of analytical and spectral data. Elemental analysis shows the metal to ligand ratio is 1:2. From electronic spectra the complexes are octahedral geometry with water molecule at parapositon Anti-bacterial study shows that all complexes are more active than ligand and Antifungal studies indicates their inactivity towards fungi.

References

1. E. Keskioglu, A.B. Gunduzalp, S. Cete, F. Hamurcu, B. Erk, *Spectrochim. Acta A* 70 (2008) 634–640.
2. M. Shabbir, Z. Akhter, P.R. Raithby, L.H. Thomas, H. Ismail, F. Arshad, B.Mirza, S.J. Teat, K. Mahmood. *J. Coord. Chem.*, 70, 2463 (2017).
3. Y. Hiromori, H. Yui, J. Nishikawa, H. Nagase, T. Nakanishi. *J. Steroid Biochem. Mol. Biol* 155, 190 (2016).
4. P. Kavitha, M. Rama Chary, B.V.V.A. Singavarapu, K. Laxma Reddy. *J. Saudi Chem. Soc.*, 20, 69 (2016).
5. S. Thakurta, R. J. Butcher, A. Frontera, S. Mitra. *J. Coord. Chem.*, 70, 3715 (2017).
6. S.S. Jawoor, S.A. Patil, S.S. Toragalmath. *J. Coord. Chem.*, 71, 271 (2018)
7. W.B. Lewis, M. Alei, L.O. Morgan, *J. Chem. Phys.* 45 (1966) 4003.
8. Z. Sroubek, K. Zdanský, *J. Chem. Phys.* 44 (1966) 3078.
9. R. N. Patel, N. Singh, K. K. Shukla, U. K. Chauhan, J. Nicols-Gutierrez, A. Castineiras, *Inorg. Chim.Acta.* 357 (2004) 2469-2476.
10. D. Kivelson, R. Neiman, *J. Chem. Phys.* 35 (1961) 149-155.
11. W.B. Lewis, M. Alei, L.O. Morgan, *J. Chem. Phys.* 45 (1966) 4003.
12. J.B. Lepecq, C. Paoletti, *J. Mol. Biol.* 27 (1967)87-106.

