



# Synthesis, Spectral Investigations and Antimicrobial Potential of Co(II) and Zn(II) Complexes of a Pyridyl Based Schiff Base Derived from [N-(2-hydroxybenzylidene)-5-amino-2-methoxypyridine]

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**Abstract:** A pyridyl derived Schiff base [N-(2-hydroxybenzylidene)-5-amino-2-methoxypyridine] was synthesized and used as a tridentate (N,N,O) chelating ligand for the preparation of Co(II) and Zn(II) coordination complexes. The ligand and its complexes were systematically characterized by elemental analysis, molar conductance, magnetic susceptibility, FT-IR, Mass, TGA and UV-Visible spectroscopy. Significant shifts in the azomethine (C=N), pyridine nitrogen and phenolic (C-O) stretching frequencies confirmed tridentate coordination, while electronic spectral features supported an octahedral environment around the metal centers. The antimicrobial potential of the synthesized compounds was evaluated against selected Gram-positive and Gram-negative bacterial strains, and the metal complexes demonstrated enhanced activity compared to the free ligand, likely due to chelation-enhanced lipophilicity and metal-ligand interactions. The results highlight the promising pharmacological relevance of pyridyl based Schiff base metal complexes.

**Keywords:** Schiff base, Metal complex, Octahedral geometry, Spectroscopic characterization, Antimicrobial activity.

## 1. INTRODUCTION

Schiff bases incorporating pyridyl frameworks constitute a strategically important class of multidentate ligands in modern coordination chemistry, owing to their structural rigidity, tunable electronic properties and strong metal-binding affinity [1-3]. The coexistence of azomethine ( $-C=N-$ ) nitrogen, heteroaromatic pyridine nitrogen and phenolic oxygen donor sites enables the formation of stable tridentate (N,N,O) chelate system capable of enforcing well-defined coordination geometries around transition metal centers [4]. Such structural control significantly modulates electronic distribution, redox behavior and thermodynamic stability of the resulting complexes, thereby influencing their catalytic and biological performance [5]. The deliberate design of pyridyl derived Schiff bases has therefore emerged as an effective strategy for constructing metal based functional materials with enhanced activity profiles [6-8]. Coordination of metals with ligands often improves biological activity [9]. Chelation reduces the polarity of the metal ion and increases electron delocalization and enhances lipophilicity which helps the complex pass through cell membranes more easily [10-12]. Metal ligand interactions can also disturb microbial enzyme systems promote oxidative stress and affect normal cell functions [13].

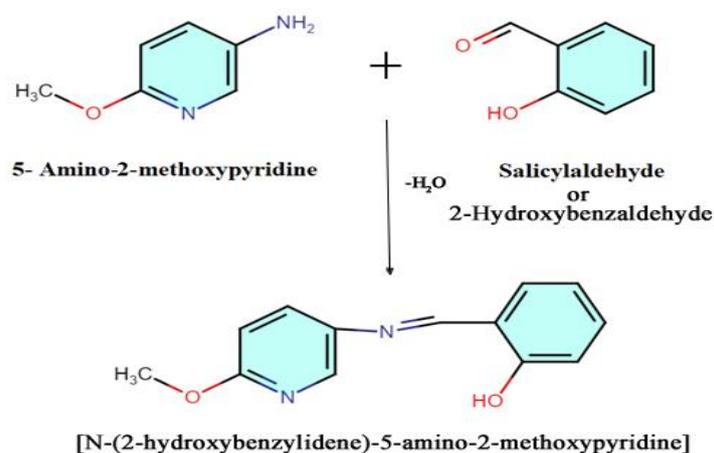
Pyridine based Schiff base metal complexes have shown better antimicrobial activity than free ligands which highlights the importance of proper ligand design [14-16]. In this study a pyridyl Schiff base ligand and its Co(II) and Zn(II) complexes were synthesized, characterized and tested for biological activity. The aim is to understand the relationship between structure or activity and to develop effective antimicrobial metal complexes [17].

## 2. Experimental

All the chemicals used were of AR/GR grade. Pure sample of 5-Amino-2-methoxypyridine, was obtained from Sigma Aldrich Ltd. Metal salts such as  $\text{CoCl}_2 \cdot 6\text{H}_2\text{O}$  and  $\text{ZnCl}_2$ , were of Loba Chemie. Solvents used were ethanol, acetone, DMF and DMSO.

### 2.1 Synthesis of Ligand (HBMP)

An equimolar solution of salicylaldehyde (0.01M) and 5-amino-2-methoxypyridine (0.01 M) were dissolved in 100 mL of ethanol–distilled water (60:40, v/v). The reaction mixture was refluxed at 65–75 °C for 3 hours. After cooling to room temperature, the solution was concentrated to approximately one-third of its original volume and left to stand for slow crystallization. The resulting pale-yellow solid was filtered, washed with cold ethanol and recrystallized from absolute ethanol. The product was dried over anhydrous  $\text{CaCl}_2$  in a desiccator. The melting point was determined by the open capillary method. The Schiff base ligand was obtained as a yellow crystalline solid in 75% yield.



### 2.2 Synthesis of Metal Complexes

The metal complexes were synthesized by reacting an ethanolic solution of the ligand HBMP (0.02 M) with ethanolic solutions of Co(II) (0.01 M) and Zn(II) (0.01M) respectively. The reaction mixtures were stirred, and the pH was adjusted by adding a few drops of N/10 NaOH solution. The solutions were refluxed for 4 hours and then allowed to stand for 2 to 3 days to enable crystallization. The solid crystalline complexes thus formed were filtered, washed thoroughly with the same solvent and dried over anhydrous  $\text{CaCl}_2$  in a desiccator. The melting points of the complexes were recorded.

### 2.3 Analysis and Instrumentation

Elemental (C, H, N) analyses were performed on a Vario MICRO V2.20 (Elementar Analyse Systeme GmbH) at IIM, Jammu. Metal contents were determined gravimetrically. FT-IR spectra ( $4000\text{--}400\text{ cm}^{-1}$ ) were recorded using KBr pellets on a PerkinElmer RZX spectrophotometer at SAIF, Panjab University, Chandigarh. Mass spectra were obtained on an LC-MS (Q-TOF Micro, Waters) at SAIF/CIL, Panjab University, Chandigarh.

*In-vitro* biological activity assays were conducted at Scan Laboratory, Bhopal, following standardized protocols to evaluate the antimicrobial potential of the synthesized compounds.

## 3. Results and Discussion

The Schiff base ligand (HBMP) was synthesized via a condensation reaction between the primary amino group of 5-amino-2-methoxypyridine and salicylaldehyde under reflux conditions in ethanolic medium. The resulting ligand was subsequently coordinated with metal ions to afford the corresponding Co(II) and Zn(II) complexes. Both the ligand and its metal complexes were obtained in appreciable yields and isolated in analytically pure form. The free ligand exhibited a pale yellow coloration, whereas the Co(II) and Zn(II) complexes were isolated as blue-green and bone white solids, respectively. Elemental (C, H, N and metal) analyses corroborated a 1:2 metal-to-ligand stoichiometric ratio, consistent with the general formulation  $[\text{M}(\text{L})_2]$  ( $\text{M} = \text{Co}(\text{II}), \text{Zn}(\text{II})$ ). The synthesized complexes are air-stable, non-hygroscopic solids, exhibiting no observable decomposition under ambient conditions. Solubility studies revealed that the complexes are insoluble in water and most common organic solvents, but readily soluble in polar coordinating solvents such as DMF and DMSO. The molar conductance values, measured in  $10^{-3}$  M DMF solution, were found to lie within the range  $(4.3\text{--}5.2)\ \Omega^{-1}\text{ cm}^2\text{ mol}^{-1}$ , indicating their non-electrolytic nature and suggesting the absence of counter ions in the coordination sphere. Magnetic susceptibility measurements demonstrated that the Co(II) complex is paramagnetic, consistent with a high-spin  $d^7$  configuration, whereas the Zn(II) complex exhibited diamagnetic behavior as expected for a  $d^{10}$  system. The comprehensive physicochemical parameters, analytical results, and molar conductance data are summarized in Tables 1 and 2.

Table 1: Physicochemical Characteristics of HBMP and its Complexes

S. No	Ligand/Complexes	Colour	%Yield	M.P °C	Molar Conductance $\Omega^{-1} \text{ cm}^2 \text{ mol}^{-1}$	Magnetic Moment B.M
1.	HBMP	Pale yellow	68	140	-	-
2.	[Co(HBMP) <sub>2</sub> ].2H <sub>2</sub> O	Blue Green	56	238	14.2	4.84
3.	[Zn(HBMP) <sub>2</sub> ]	Bone White	67	255	12.7	-

Table 2: Analytical Data of HBMP and its Complexes

S. No	Molecular Formula (Molecular Weight)	Elemental Analysis (%) Found (Calculated)			
		C	H	N	Metal
1.	C <sub>13</sub> H <sub>12</sub> N <sub>2</sub> O <sub>2</sub> (228.24)	68.34 (68.42)	5.18 (5.30)	12.24 (12.27)	- -
2.	C <sub>26</sub> H <sub>26</sub> N <sub>4</sub> O <sub>6</sub> Co (549.43)	56.72 (56.84)	4.60 (4.77)	10.10 (10.20)	10.69 (10.73)
3.	C <sub>26</sub> H <sub>22</sub> N <sub>4</sub> O <sub>4</sub> Zn (519.85)	59.98 (60.07)	4.14 (4.27)	10.34 (10.78)	12.34 (12.58)

### 3.1 Magnetic Measurements

The Co(II) complex exhibited a magnetic moment of 4.84 B.M., consistent with a high-spin octahedral complex. The Zn(II) complex was found to be diamagnetic, as expected for a d<sup>10</sup> electronic configuration with no unpaired electrons [18-20].

### 3.2 IR Spectra

The IR spectrum of the Schiff base ligand (HBMP) exhibited a broad band at 3416 cm<sup>-1</sup> attributed to the  $\nu_{\text{phenolic(O-H)}}$  stretching vibration. In the spectra of the Co(II) and Zn(II) complexes, the disappearance of the  $\nu_{\text{phenolic(O-H)}}$  band indicates deprotonation and coordination through the phenolic oxygen atom. The azomethine  $\nu_{\text{(C=N)}}$  band shifting at (1620 cm<sup>-1</sup> for Co(II) and 1628 cm<sup>-1</sup> for Zn(II)), as compared to Schiff base at 1618 cm<sup>-1</sup>, suggest coordination via the azomethine nitroge. A characteristic  $\nu_{\text{phenolic (C-O)}}$  stretching vibration was observed at 1285 cm<sup>-1</sup>. The aromatic  $\nu_{\text{C-H}}$  and  $\nu_{\text{C=C}}$  stretching vibrations were recorded around 3020 cm<sup>-1</sup> and 1489 cm<sup>-1</sup>, respectively.

The  $\nu_{\text{C-O (phenolic)}}$  band also shifted slightly (1288 cm<sup>-1</sup> for Co(II) and 1282 cm<sup>-1</sup> for Zn(II)), supporting metal-oxygen bond formation. New bands appearing in the low-frequency region around 630–470 cm<sup>-1</sup> are assigned to  $\nu_{\text{(M-O)}}$  and  $\nu_{\text{(M-N)}}$  vibrations, further confirming coordination of the ligand to the metal ions through the phenolic oxygen and azomethine nitrogen atoms. These spectral changes substantiate the tridentate chelating behavior of the Schiff base ligand in both complexes [21-22].

Table-3: IR Spectral Bands of HBMP and its Metal Complexes in cm<sup>-1</sup>

S.No.	Group	HBMP	[Co(HBMP) <sub>2</sub> ].2H <sub>2</sub> O	[Zn(HBMP) <sub>2</sub> ]
1	$\nu_{\text{(Phenolic) OH}}$	3416s	-	-
2	$\nu_{\text{(HC=N)}}$	1618m	1620s	1628s
3	$\nu_{\text{H}_2\text{O}}$	-	3414sb	-
4	$\nu_{\text{C-N}}$	1136w	1139m	1148s
5	$\nu_{\text{(Phenolic) CO}}$	1285s	1288m	1282s
6	$\nu_{\text{C-H (Pyridine) Str.}}$	3020s	3061sb	3050w
7	$\nu_{\text{C-H Str.}}$	2722w	2700w	2854mb
8	$\nu_{\text{C=C (aromatic)}}$	1489w	1514s	1510s
9	$\nu_{\text{M-N}}$	-	470w	479w
10	$\nu_{\text{M-O}}$	-	630m	622m

s= strong, m= medium, w= weak, b= broad

### 3.3 Mass Spectra

The mass spectrum of the cobalt(II) complex (C<sub>26</sub>H<sub>26</sub>N<sub>4</sub>O<sub>6</sub>Co) display a molecular ion peak at m/z 549.43. The fragmentation pattern supports a bis-ligand coordination environment. The ion at m/z 535 arises from demethylation (-CH<sub>3</sub>) of the parent ion, followed by decarbonylation (-CO) to generate the fragment at m/z 521. A significant peak at m/z 321 corresponds to the loss of one Schiff base ligand (228 Da), while the base peak at m/z 228 is attributed to the protonated free ligand. Subsequent ligand-centered fragmentations produce ions at m/z 200 (-CO), m/z 184 (-CH<sub>3</sub>CN), m/z 171 (-C<sub>2</sub>H<sub>4</sub>O) and m/z 144 (-CO). The low-mass peak at m/z 59 is assignable to Co<sup>+</sup>, indicating progressive ligand dissociation and exposure of the metal center. Overall, the mass

spectral data strongly corroborate the proposed stoichiometry and coordination architecture of the Co(II) Schiff base complex [23-24].

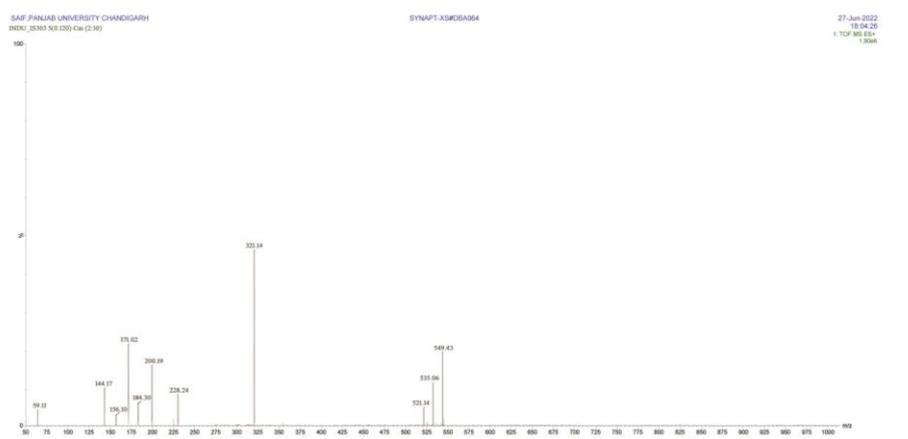


Fig 1: Mass Spectra of HBMP-Co Complex

#### 4. Antibacterial Activities

The antibacterial potential of HBMP and its corresponding metal complexes was evaluated against Gram-positive (*S. aureus*, *S. mutans*) and Gram-negative (*E. coli*, *K. pneumoniae*) strains using the agar well diffusion method. The free ligand exhibited moderate inhibition zones (6–8 mm), whereas the Co(II) and Zn(II) complexes showed enhanced activity (9–12 mm), demonstrating improved efficacy upon coordination. The HBMP-Co complex showed comparatively higher inhibition against *S. mutans*, *E. coli* and *K. pneumoniae*, while HBMP-Zn displayed slightly better activity against *S. aureus*. However, all synthesized compounds exhibited lower antibacterial potency than the reference drug ciprofloxacin (20–24 mm). The observed enhancement after complexation may be attributed to chelation-induced increases in lipophilicity and improved interaction with bacterial cell membranes [25-28].

Table 4: Showing the % Inhibition of HBMP and its derived metal complexes in mm.

Compound	<i>S. aureus</i>	<i>S. mutans</i>	<i>E. coli</i>	<i>K. pneumoniae</i>
HBMP	8 ± 0.36	7 ± 0.26	6 ± 0.18	7 ± 0.18
HBMP-Co	10 ± 0.42	12 ± 0.54	11 ± 0.39	11 ± 0.59
HBMP-Zn	11 ± 0.30	9 ± 0.32	11 ± 0.26	10 ± 0.20
CIPROFLOXACIN	22 ± 0.46	24 ± 0.69	20 ± 0.70	24 ± 0.12

Antibacterial activity of Schiff Base (HBMP) and its metal complexes

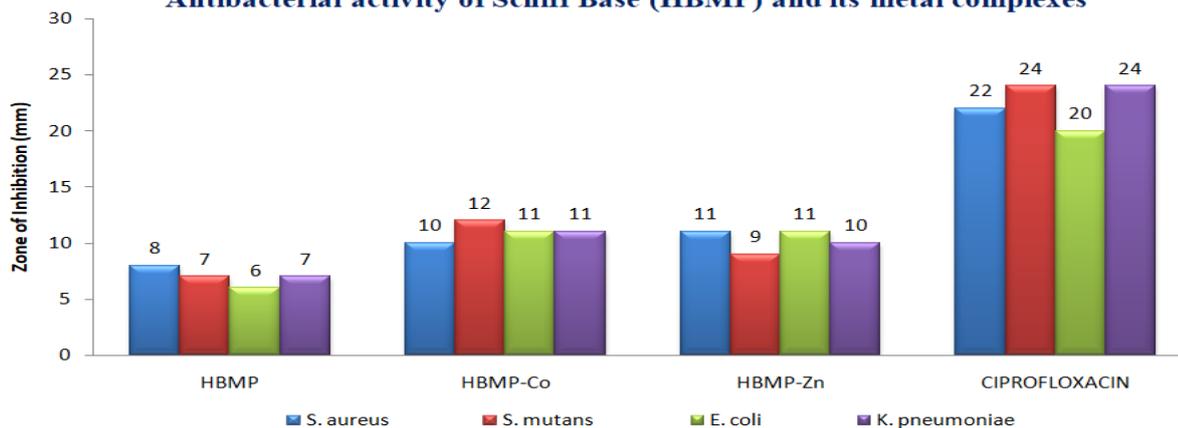
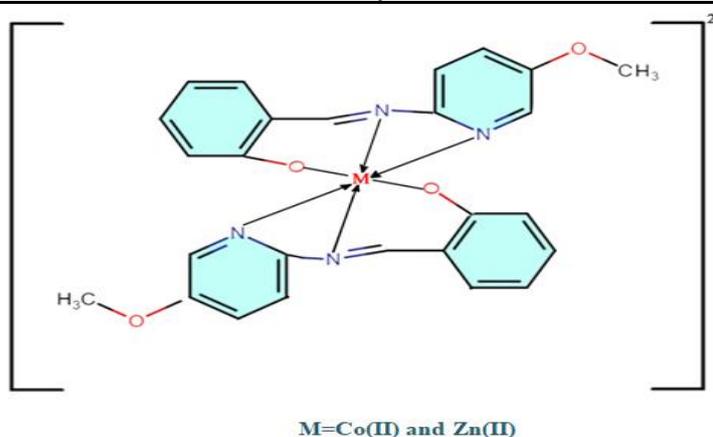


Fig 2: Antibacterial activity of Schiff Base (HBMP) and its metal complexes

#### 5. Conclusion

A pyridyl based Schiff base ligand and its Co(II) and Zn(II) complexes were successfully synthesized and characterized. Spectral data confirmed tridentate coordination through azomethine nitrogen and phenolic oxygen atoms. Magnetic studies indicated a high spin octahedral geometry for the Co(II) complex, while the Zn(II) complex was diamagnetic. The metal complexes showed enhanced antimicrobial activity compared to the free ligand, demonstrating the beneficial effect of metal coordination and their potential as antimicrobial agents.



**Fig 3: Proposed Structure of the complexes**

## 6. Acknowledgement

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## 7. References

1. Cozzi, P. G. 2004. Metal–salen Schiff base complexes in catalysis. *Chemical Society Reviews*, 33, 410–421.
2. Singh, A., Malik, S., & Teli, S. A. 2018. Complexation behaviour of Schiff base derived from o-phenylenediamine and 5-bromosalicylaldehyde with some transition metals. *International Journal of Recent Trends in Science and Technology, Special Issue: ACAEE*, 229–231.
3. Mishra, A. P., & Pandey, L. R. 2010. Synthesis, characterization and biological activity of Schiff base metal complexes. *Journal of Coordination Chemistry*, 63, 326–336.
4. Tshuva, E. Y., & Crans, D. C. 2005. Coordination chemistry of multidentate Schiff base ligands. *Coordination Chemistry Reviews*, 249, 987–1012.
5. Dadoria, A., Malik, S., Singh, A. & Rajpoot, G. S. 2025. Synthesis, Spectroscopic Characterization and Biological Evaluation of Transition Metal Complexes Derived from Pyridyl-Based Schiff Bases. *JETIR*, 12(11), h487-h493.
6. Kumar, S., Dhar, D. N., & Saxena, P. N. 2009. Applications of metal complexes of Schiff bases. *Journal of Scientific and Industrial Research*, 68, 181–187.
7. Elmali, A., Kabak, M., & Elerman, Y. 1999. Structural aspects of Schiff base metal complexes. *Journal of Molecular Structure*, 477, 151–158.
8. Maurya, R. C., & Patel, P. 2003. Synthesis and antimicrobial studies of Schiff base complexes. *Indian Journal of Chemistry Section A*, 42A, 1520–1525.
9. Malik, S., Ghosh, S., & Jain, B. 2010. Synthesis, characterization and antimicrobial studies of Zn(II) complex of Schiff base of chemotherapeutic importance. *Archives of Applied Science Research*, 2(2), 304–308.
10. Tweedy, B. G. 1964. Plant extracts with metal chelation properties. *Phytopathology*, 55, 910–914.
11. Clarke, M. J. 2002. The coordination chemistry of metal complexes in biological systems. *Coordination Chemistry Reviews*, 232, 69–93.
12. Chohan, Z. H., & Pervez, H. 2004. Antibacterial Schiff base metal complexes. *Journal of Enzyme Inhibition and Medicinal Chemistry*, 19, 85–90.
13. Sigel, A., & Sigel, H. (Eds.). 1996. *Metal Ions in Biological Systems*. Marcel Dekker, New York.
14. Chandra, S., & Kumar, R. 2004. Spectral and antimicrobial studies of Co(II) and Zn(II) complexes. *Spectrochimica Acta Part A*, 60, 1563–1571.
15. Nath, M., & Pokharia, S. 2001. Antimicrobial evaluation of transition metal Schiff base complexes. *Synthetic and Reactive Inorganic and Metal-Organic Chemistry*, 31, 165–177.

16. Lever, A. B. P. 1984. *Inorganic Electronic Spectroscopy* (2nd ed.). Elsevier, Amsterdam.
17. Chandra, S., & Kumar, U. 2011. Structure–activity relationship in Schiff base metal complexes. *Journal of Molecular Structure*, 1000, 52–60.
18. Chandra, S., & Gupta, L. K. 2005. Spectroscopic and magnetic studies on Co(II) and Zn(II) complexes with Schiff bases. *Spectrochimica Acta Part A*, 62, 1089–1094.
19. Raman, N., Kulandaisamy, A., & Thangaraja, C. 2003. Redox and antimicrobial studies of transition metal Co(II) and Zn(II) Schiff base complexes. *Transition Metal Chemistry*, 28, 29–36.
20. Lever, A. B. P. 1968. Electronic spectra and magnetic properties of transition metal complexes. *Coordination Chemistry Reviews*, 3, 119–140.
21. Singh, A. K., Pandey, O. P., & Sengupta, S. K. 2007. Synthesis, spectral and biological studies of Co(II), Ni(II) and Zn(II) complexes with Schiff bases. *Spectrochimica Acta Part A*, 68, 516–523.
22. Tyagi, M., & Chandra, S. 2012. Synthesis and spectroscopic characterization of transition metal complexes of Schiff bases derived from salicylaldehyde. *Journal of Molecular Structure*, 1030, 1–7.
23. Gudasi, K. B., Vadavi, R. S., & Shenoy, R. V. 2005. Synthesis and spectral investigations of Co(II) and Zn(II) complexes with O,N donor Schiff bases. *Transition Metal Chemistry*, 30, 910–916.
24. Chandra, S., & Kumar, U. 2012. Spectroscopic and mass spectral studies on Co(II) and Zn(II) Schiff base complexes. *Spectrochimica Acta Part A*, 98, 210–215.
25. Kumar, S., Dhar, D. N., & Saxena, P. N. 2009. Applications of metal complexes of Schiff bases: A review. *Journal of Scientific and Industrial Research*, 68, 181–187.
26. Jarrahpour, A., Khalili, D., De Clercq, E., Salmi, C., & Brunel, J. M. 2007. Synthesis, antibacterial, antifungal and antiviral activity evaluation of Schiff bases and their metal complexes. *European Journal of Medicinal Chemistry*, 42, 787–793.
27. Agarwal, R. K., Prakash, S., & Kumar, D. 2006. Synthesis, spectral and biological studies of Co(II) and Zn(II) Schiff base complexes. *Polyhedron*, 25, 1081–1088.
28. Chandra, S., & Kumar, R. 2005. Synthesis and antibacterial evaluation of Co(II) and Zn(II) complexes with Schiff bases. *Spectrochimica Acta Part A*, 61, 219–224.