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Synthesis, Characterization and Antibacterial Evaluation of Mn (II), Co (II) and Cu (II) Complexes of Schiff Base Derived from 3-aminophenol and Benzaldehyde

Usman Abubakar Adamu[1], Buhari Magaji[1*], Muhammad Nazifi Ibrahim[1] and Mukhtar Muhammad Sani[1]

[1]*Department of Chemistry, Gombe State University, P.M.B. 127, Gombe, Nigeria.*

Authors' contributions

This work was carried out in collaboration among all authors. Authors UAA and BM designed and supervised the study. Authors MNI and MMS managed the experimental analyses of the study and wrote the first draft of the manuscript. All authors read and approved the final manuscript.

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ABSTRACT

Schiff base was prepared by the condensation of 3-aminophenol and benzaldehyde in a 1:1 ratio and its complexes of Mn(II), Co(II) and Cu(II) were synthesized in a 1:2 ratio (Metal: Ligand) and the Schiff base and the complexes were characterized by using the different techniques. The infrared spectral data revealed that the Schiff base behaved as a bidentate ligand and the molar conductivity value indicated that the complexes were non-electrolytes. Furthermore, the *in vitro* antibacterial activity of the Schiff base and its complexes was evaluated against one gram-negative and one gram-positive bacteria to indicate that Mn (II) complex demonstrated a good broad-spectrum activity against all the tested bacterial strains.

**Corresponding author: E-mail: bmagaji@gsu.edu.ng, magaji.buharii@gmail.com;*

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1. INTRODUCTION

Metals are very important in living organism because they play a very important role in proper functioning of living organism hence they are also called metals of life [1]. Four metals including sodium, magnesium, calcium and potassium are essentials because they play important roles in the mechanisms of living things; however, transition metals such as chromium manganese, iron, cobalt, nickel, copper and zinc are also very important in living organisms in performing their proper functioning [2]. Over the years, various metal containing compounds have received significant attention in various biological applications, especially anticancer and antimalarial therapy; however, less attention has been given to develop the metal containing antibacterial drugs [3]. To be specific, metal complexes of Schiff base ligand possess a variety of applications in the biological, analytical, clinical, and industrial areas [4-9]. In recent times, transition metal complexes of Schiff base ligand have gained considerable attention, not only due to their spectroscopic properties and applications [10,11], but also their remarkable antifungal, antibacterial and antitumor activities [12]. Schiff bases have had a vital position in metal coordination chemistry for even almost a century since their discovery. A number of complexes of Schiff bases have been suggested as antibacterial, antifungal, cytotoxic, anti-inflammatory and cytostatic agents [12,13]. Here, Schiff base ligand of 3-aminophenol and aromatic aldehyde and its Mn (II), Co (II) and Cu (II) complexes were synthesized and characterized. Since the Schiff base and its metal (II) complexes have a broad range of applications and biological activities, these compounds were screened for their antibacterial potential against gram-positive and gram-negative bacteria.

2. MATERIALS AND METHODS

All chemical reagents, 3-Aminophenol, Benzaldehyde, $MnCl_2.6H_2O$, $CoCl_2.4H_2O$, $CuCl_2.4H_2O$ and solvents were of analytical grade were from LOBA Chemie and JHD and used without any purification. The molar conductivity of the Schiff base and its metal (II) complexes was examined by digital conductivity meter AVI-848, FTIR transmission spectra were checked in the 4000 - 400 cm^{-1} range, using Perkin Elmer version 10.03.09 and the standard KBr techniques. The decomposition temperatures of the ligand and its metal (II) complexes were obtained using Electro Thermal Melting Point, (SMP10).

2.1 Preparation of the Schiff Base and its Metal (II) Complexes

The Schiff base and the metal (II) complexes were synthesized according to the method described by Alyaa [14] with modifications shown in scheme 1.

2.2 Preparation of the Schiff Base

The target ligands were synthesized by adding 3-aminophenol (0.001 mmol) to benzaldehyde (1 mmol) in methanol (20 cm^3). This was followed by dropwise addition of aqueous solution of 25% NaOH (20 mL) and the reaction mixture was stirred and refluxed at 60°C till formation of distinct precipitate was observed. Progress of the reaction was monitored with TLC. The resulting solid was then filtered, washed with cold water and dried over anhydrous $CaCl_2$.

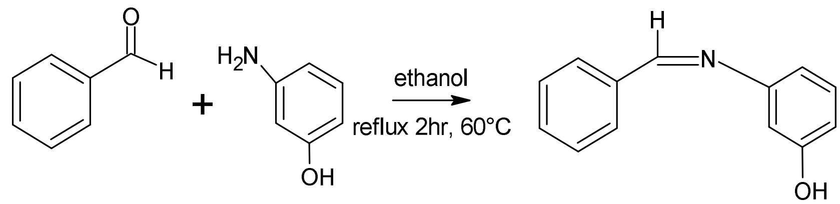
2.3 Synthesis of Metal Complexes

The complex was prepared by adding a solution of manganese (II) chloride (1 mmol, 0.233 g) to a solution of the synthesized ligands (2 mmol, 0.394 g) in a hot methanol. The mixture was then refluxed for 2 hr. The resulting precipitate was washed with ethanol, filtered and dried over anhydrous $CaCl_2$.

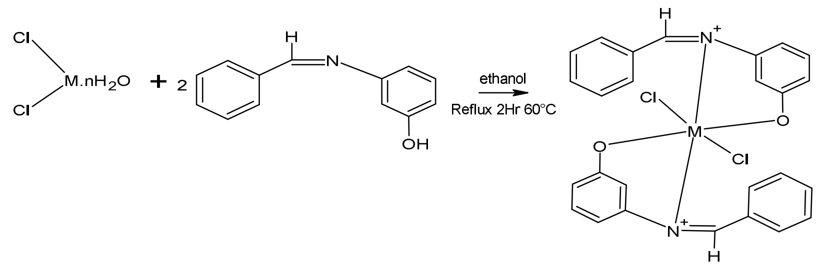
The same procedure was followed for the synthesis of cobalt and copper complexes.

2.4 Antibacterial Screening

The synthesized ligand and the complexes were screened for antibacterial activity against one gram-positive strain, *Staphylococcus aureus* (*S. aureus*) and one gram-negative strain, *Escherichia coli (E. coli*). Gentamycin sulfate was used as control for comparison. Dimethyl sulfoxide (DMSO) was also tested and found to be not active against any of the bacterial strains. The bacteria were grown overnight in Nutrient Broth at 37°C in a shaking incubator (100 rpm). The bacterial concentration was adjusted to 0.5 McFarland's Standard with sterile distilled water by using a DEN-1B McFarland densitometer.



Scheme 1. Condensation reaction to form the target ligand



Scheme 2. Synthetic route to the complex of interest

Mueller-Hinton Agar (MHA) plates were also inoculated with the prepared bacterial suspensions by using a cotton swab and a volume of 5 µL each of the ligand and the complexes (1 mg/mL in DMSO) was spotted onto the MHA plates. The plates were incubated at 37°C for 24 h and after incubation; the plates were read to determine the antibacterial activity which was denoted by clear zone of inhibition in the area where the ligand and the complexes were spotted.

3. RESULTS AND DISCUSSION

The melting points of the compounds are presented in Table 1. The melting point ranges between 140 - 248°C which are in agreement with the values reported elsewhere [15]. The melting point of the ligand was lower than that of the metal complexes. This could be attributed to the different structural arrangements and bond strengths within the compounds.

The molar conductivity of the ligand and its metal (II) complexes were recorded in Table 1. The lower molar conductivity in the range of 3.2 - 6.4 µS cm^{-1} indicates that the compounds are non-electrolyte [16].

The results of the solubility of the synthesized Schiff base ligand and it metal (II) complexes in studied solvents are presented Table 2. The solubility of the ligand and its metal (II) complexes were considered in the following solvents (distilled water, acetone, chloroform, dimethyl sulfoxide and diethyl ether) both at room and elevated temperature. The ligand and its metal (II) complexes were all insoluble in distilled water at both room temperature and elevated temperature whereas, the ligand and its metal (II) complexes were all soluble in acetone and dimethyl sulfoxide as shown in Table 2.

The infrared spectral data (selected) of the synthesized ligand and its metal (II) complexes are presented in Table 3. The peaks observed in the range of 3375 - 3389 cm^{-1} were assigned to O-H vibration. A peak recorded at 1621 cm^{-1} was assigned to azomethine which shifted to 1624, 1627 and 1622 cm^{-1} for the manganese (II), cobalt (II) copper (II) complexes respectively. Thus, indicating the coordination of the azomethine nitrogen to the metals (II) ions [17]. The bands at 669 cm^{-1}, 697 cm^{-1} and 699 cm^{-1} which were absent in the spectra of the ligand indicate the metal to nitrogen bond [18]. Similarly, the bands recorded at 558 cm^{-1}, 548 cm^{-1} 597 cm^{-1} which were also not found in the spectra of the ligand indicates the coordination of the hydroxyl oxygen to the manganese (II), cobalt (II) and copper (II) complexes respectively.

The synthesized Schiff base ligand and its Mn (II) Co (II) and Cu (II) complexes were screened for antibacterial activity against *S. aureus* and *E. coli* From the results in Figs. 1 and 2, the ligands and the complexes showed a very good promising antibacterial activity against *S. aureus* and *E. coli*. The antibacterial results evidently show that the activity of the Schiff base is pronounced when coordinated to the metal ions especially Mn (II) complex. The Mn (II) complex in good agreement with chelation theory [16,19-

21] and may be explained on the basis of Tweedy's chelation theory [22,23]. Apart from this, other factors such as conductivity, solubility and dipole moment influenced by the presence of the metal ions may also be the reasons for the increased antibacterial activity [21].

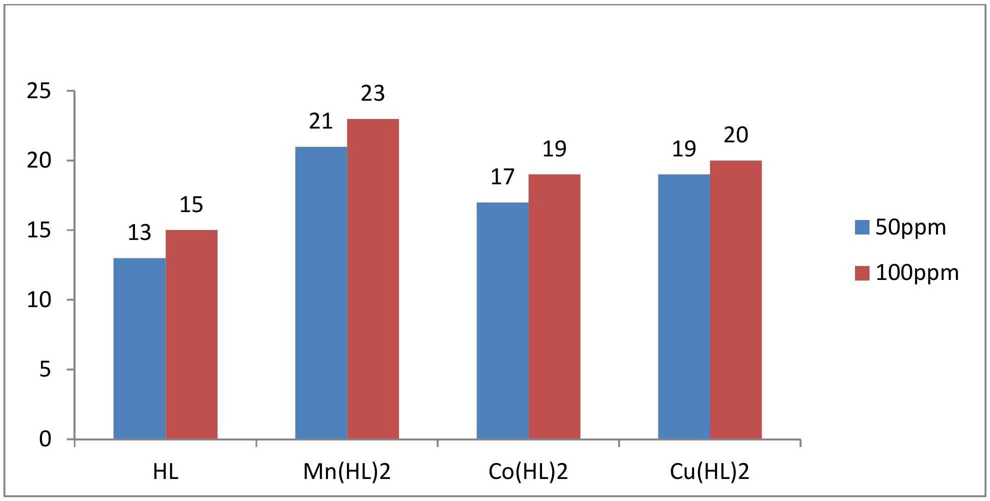


Fig. 1. Inhibition zone of *S. aureus*

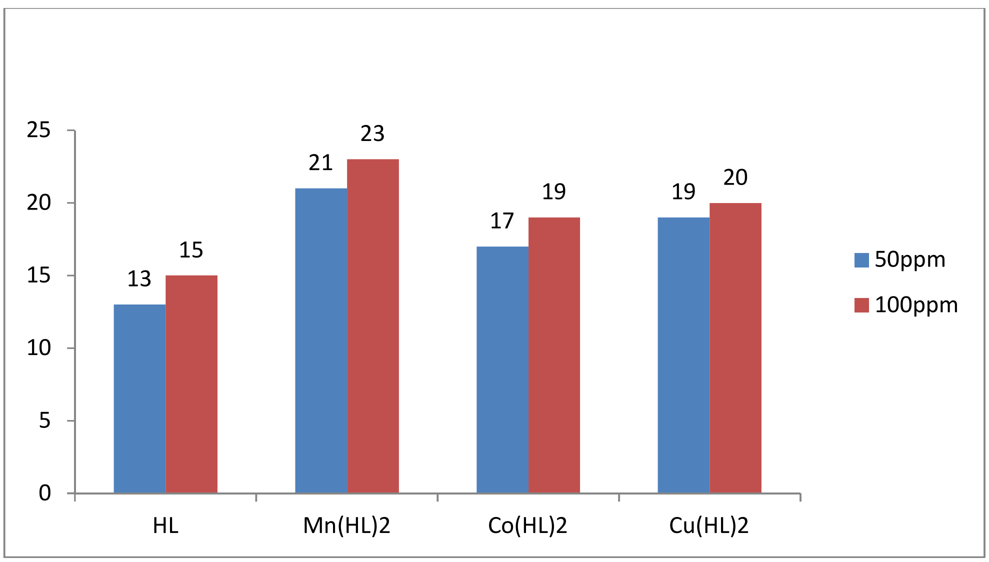


Fig. 2. Inhibition zone of *E. coli*

Table 1. Physicochemical parameters for schiff base ligand and it metal (II) complexes

Compounds	Melting point (°C)	Color	Conductivity (Mhoscm^{-1})	% Yield
HL	140-160	Orange	3.2×10^{-6}	87
[MnL_2Cl_2]	238-243	Dark Brown	9.4×10^{-6}	68
[Co L_2Cl_2]	236-242	Red-Brown	7.2×10^{-6}	78
[Cu L_2Cl_2]	243-248	Brown	6.4×10^{-6}	63

**HL= Schiff Base*

Table 2. Solubility test of the ligand and the complexes in different solvents

Compounds	Dstilled water		Acetone		Chloroform		Dimethyl sulfoxide		Diethyl ether	
	RT	ET	RT	ET	RT	ET	RT	ET	RT	ET
HL	IS	IS	S	S	SS	S	S	S	IS	IS
$[MnL_2Cl_2]$	IS	IS	S	S	SS	S	S	S	SS	SS
$[CoL_2Cl_2]$	IS	IS	S	S	SS	SS	S	S	IS	IS
$[CuL_2Cl_2]$	IS	IS	S	S	IS	IS	S	S	IS	IS

**RT = Room Temperature, ET = Elevated Temperature, S = Soluble SS = Slightly Soluble, IS = Insoluble*

Table 3. FTIR result of schiff base ligand and its metal (II) complexes

Compounds	*v*(C=N) cm^{-1}	*v*(C=C) cm^{-1}	*v*(O-H) cm^{-1}	*v*(M-N) cm^{-1}	*v*(M-O) cm^{-1}
HL	1621	1598	3375	-	-
$[CoL_2Cl_2]$	1624	1492	3377	669	558
$[CoL_2Cl_2]$	1627	1578	3389	697	548
$[CuL_2Cl_2]$	1622	1511	3389	699	597

** HL = Schiff Base*

4. CONCLUSIONS

The Schiff base ligand of 3-aminophenol and aromatic aldehyde and its Mn (II), Co (II) and Cu (II) complexes were successfully synthesized and characterized. The IR spectral studies revealed that the ligand coordinated to the metal ions *via* phenolic -OH and -CH=N and the conductivity measurement shows that the complexes are non-electrolyte. Moreover, the melting point of the complexes were greater than that of the ligand which reflect the formation of complexes. The metal (II) complexes showed improved broad-spectrum antimicrobial activity against gram-positive and gram-negative bacteria; therefore, they should be considered as possible lead compounds to be developed into antibiotics against the tested bacterial strains *E. coli* and *S. aureus*.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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