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Synthesis, Characterization and Antimicrobial Activity of Mn(II) and Co(II) Complexes from Mixed Antibiotics (Cephalexin and Cloxacillin)

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ABSTRACT

Metal(II) complexes from mixed antibiotics of cephalexin and cloxacillin and salts of Mn(II) and Co(II) were synthesized, respectively. The synthesized complexes were characterized by spectral and antimicrobial studies to determine their activity against bacterial and fungal isolates. From the spectral data of the IR and UV-Vis, the ligands acted as bidentate which coordinated to the metal ions through the carbonyls of amides and carboxylic acids; the complexes assumed an octahedral geometry. The molar conductance values for the Mn(II) and Co(II) complexes were found to be 30 and 22 $\Omega^{-1}cm^2mol^{-1}$ respectively. The values were less than 60, which rendered the complexes non-electrolytes in DMF. Elemental analysis values of the percentages of the C, H, N and S contents were 45.07, 6.09, 8.90 and 6.44 respectively for Mn(II) and 49.67, 3.16, 12.11 and 6.98 respectively for Co(II). These agree with the estimated values for the carbon, hydrogen, nitrogen and sulphur. Thus, the complexes could be represented as [M(Cep)(Clox)Cl_2]. The magnetic moment values of the complexes determined were 5.85 BM for Mn(II) and 3.89 BM for Co(II), showing that the complexes have octahedral geometries. The spectral studies values agreed with the proposed structure of the complexes. The complexes show strong antimicrobial activity.

KEY WORDS: Antimicrobial activity, characterization, cephalexin and cloxacillin, Mn(II) and Co(II) complexes

INTRODUCTION

The current problem of bacterial resistance to antibiotics or antimicrobial agents increases at an alarming rate globally due to wider usage of antibiotics in humans and animals. The resistance of bacterial isolates to some certain antibiotics has become a matter of global concern in the modern times. Therefore, such serious infections leading to high mortality rate has necessitated search for classes of effective drugs for curing bacteria with minimum toxicity [1].

A number of metallic ions drug combinations are being assayed to identify new novel agents that will fight the multi-resistant bacteria. Many compounds have been prepared based

on well-conceived idea of improving their efficacy and have been subsequently screened with few successfully passing clinical trials. There have been intensive efforts since many years ago towards designing novel compounds that will confront new strains of resistance microorganisms [2]

The synthesis, characterization, and antimicrobial activity of mixed antibiotics-vitamin metal complexes involving metronidazole and vitamin B1 (Thiamine) which focuses on the salts of Ni(II), Fe(II) and Zn(II) was reported. The antimicrobial activity of the synthesized complexes was tested against some bacterial strains. The results demonstrated that the metal complexes exhibited enhanced antibacterial and antifungal properties compared to the free ligands. The study highlights the potential of metal complexes as promising agents to combat antimicrobial resistance (AMR), providing a foundation for future research into drug development and clinical applications [3].

Synthesized metal complexes approaches and strategies have been adopted in order to find alternatives to the problem of bacterial resistance to antibiotics. These strategies include modifying the activities of the antibiotics or broadening their spectrum to be active against both Gram-positive and Gram-negative bacteria [4].

Although, numerous metal-schiff bases and metal-drugs complexes have been synthesized and tested for various biological activities, most existing studies remain limited to metals coordinated with single antibiotics as ligands to form complexes. There are few reports regarding metal complexes of mixed ligands [5].

Based on the various literatures reviewed, the researchers believed that no exact work on the selected metals (manganese and cobalt) as well as the mixed antibiotics (cloxacillin and cephalexin) ligands has been done. As such, this research is expected to fill a certain gap and add value to the academic and research fields

This research aimed at studying the antimicrobial activities of Mn(II) and Co(II) complexes of mixed antibiotics ligand which would be achieved through these objectives; to synthesize Mn(II) and Co(II) complexes using mixed antibiotics as ligands; to characterize the synthesized complexes using different spectroscopic techniques and finally to study the antimicrobial activity of the synthesized complexes.

Therefore, this study will contribute to the discovery of such novel metal-drug (antibiotics) complexes especially since those of mixed antibiotics are few compared to those coordinated with single antibiotics [5]. The research will contribute to the development of new

antimicrobial compounds, advancement of medicinal and coordination chemistry, provision of scientific data for pharmaceutical research which will support drug discovery efforts in Nigeria. The study may also serve as an avenue for further research in both synthetic and medicinal chemistry within Nigerian tertiary institutions and research centres.

MATERIALS AND METHODS

Materials

All the reagents were of analytical grade and used without any further purification. The active pharmaceutical ingredients (API), cephalexin and cloxacillin, as well as cobalt(II) and manganese(II) chlorides, were obtained from Sigma-Aldrich Nigeria.

Synthesis of Metal(II) Complexes

An aqueous (20 cm^3) solution of the antibiotics (10 mmol of trihydrate cephalexin and 10 mmol of cloxacillin monohydrate) was mixed in a 1:1 mole ratio. The solution of the mixed antibiotics was further mixed with 10 cm3 aqueous solution of $MnCl_2.6H_2O$, in a 1:1:1 mole ratio. The reaction mixture was refluxed for 5 hours on a hot plate magnetic stirrer at 50 °C. The volume of each solution was concentrated to half of the initial volume. The product was allowed to cool, washed with water, diethyl ether, and then dried in a vacuum over $CaCl_2$. The same method was followed for the synthesis of the complex of $CoCl_2.6H_2O$ [4]

Physical Properties of the Synthesized Complexes

Solubility

The solubility of the complexes was determined in different solvents ranging from polar to non-polar which included distilled water, methanol, ethanol, diethyl ether, acetone, CCl_4, dimethyl formamide (DMF) and dimethyl sulfoxide (DMSO), in which 0.1 g of each sample was tested in 10 ml of each solvent [6].

Melting point / Decomposition Temperature

Decomposition/melting temperatures were recorded using Stuart melting point apparatus (SMP 10) at decomposition temperature of the complexes were determined by introducing a pinch of each sample into a capillary tube and then inserted into the SMP 10. The temperature at which the ligand melts and the complexes decomposed were recorded, similar to the report of Dalia et al. [7].

Molar Conductance Measurement of the Ligand and their Complexes

Molar conductance measurement was done using DDS-307 conductivity meter using DMF as solvent at Central Laboratory, Bayero University Kano. Molar conductance of the ligand and the complexes were carried out in dimethyl formamide (DMF) by dissolving 0.001 g of each sample in 10 ml of the solvent in a test tube, the electrode was inserted and the reading taken. Results were compared with the one reported by Mustapha et al. [2].

Magnetic Susceptibility Measurement

Magnetic susceptibility measurement of the complexes was recorded using Magnetic Susceptibility balance of Sherwood Scientific Cambridge UK at Central Laboratory Bayero University Magnetic susceptibility measurement of the complexes was recorded using Magnetic Susceptibility balance of Sherwood Scientific The prepared metal complexes were introduced into the balance's capillary tube up to a given mark and the reading recorded using the magnetic susceptibility balance. The formula (Equation 1) was used to calculate the magnetic susceptibility (Xg).

$$Xg = \frac{C \times L(R-Ro)}{10^9 M} \quad (1)$$

Where C=1 (Constant of proportionality) , L = sample length in cm , R =reading obtained of the sample placed in tube, R0 = reading obtained of the pre-weight empty sample tube , M = W2-W1 (mass of sample in the tube in (g)),

The effective magnetic moment can then be calculated as reported by Ammar et al. [8]:

Xm = Xg x molar mass (molar magnetic moment)

Effective magnetic moment (μeff) =2.828(Xm X T)1/2

T=Absolute temperature

FT-Infra Red Method

Infrared spectra of the ligands and complexes were recorded using Fourier Transform Infrared Spectrophotometer of Shimadzu. The IR spectra were recorded on the IR spectrophotometer in

solid state. The sample of both the complexes and ligand were taken in the IR spectrophotometer of 4000-400 wave number in cm^{-1} range. A plot of transmittance against wave number in cm^{-1}. The result was interpreted by Fourier transform and computer manipulation of data [9].

UV-Vis Spectral Studies

Perkin Elmer Lambda 35 UV-Visible Spectrophotometer of 200-700 nm wavelengths was used for UV-absorbance measurement. The UV -Vis spectra were determined by UV visible spectrometer using DMF as solvent, 0.001 g of the ligands and complexes dissolved in 10 ml of DMF in a sample bottle and taken into the spectrometer of 200-700 nm wavelength. The outcome was recorded and interpreted [8].

Elemental Analysis (C.H.N, S)

Elemental analysis was recorded on a Perkin Elmer Elemental Analyzer (Series II CHNS/O 2400 Model). Also, the metal contents of the complexes were measured using flame atomic absorption spectroscopy at the same laboratory [4]

Antimicrobial Activity Method

Sensitivity discs were punched from Whatman no. 1 filter paper, sterilized in bijou bottles by autoclaving at 121 ^{o}C for 15 minutes. Sensitivity discs were prepared by weighing 0.008 mg of the extract or fraction and serial doubling dilution in DMF, followed by placing the improvised paper discs in the solution such that each disc took up 0.01 ml to make the disc potency of 500 µg, 1000 µg, 2000 µg and 4000 µg. Standardized inoculum of each isolate was swabbed onto the surface of Mueller-Hinton agar in separate Petri dishes, and discs of the extracts and standard antibiotic (Ciprofloxacin 500 µg). The plates were inverted and allowed to stand for 30 minutes to allow the extract to diffuse into the agar, after which the plates were incubated aerobically at 35 °C for 18 hours. This was followed by measuring the zones of inhibition formed by the test organisms around each of the extract and standard antibiotic discs. Antifungal screening was also conducted on the complexes with ketoconazole as a control antifungal using a similar approach [10].

RESULTS AND DISCUSSION

Table 1 shows some physical properties of the antibiotics and the synthesized complexes which include the molecular formulae, molar masses and colours of the ligands and the complexes. The table also shows the melting points of the ligands (antibiotics) as well as the decomposition temperature of the complexes.

Table 1: Physical properties of the antibiotics and their metal(II) complexes

Compound	Molecular Formula	Molar Mass (g/mol)	Colour	Melting Point (^oC)	Decomposition Temperature)
Cloxacin	$C_{19}H_{18}CIN_3O_5S$	435.9	White	170	___
Cephalexin	$C_{16}H_{17}N_3O_4S$	347.4	White	197	___
[Co(Cep)(Clox)Cl_2]	$C_{35}H_{35}Cl_3N_6O_9S_2Co$	9124	Yellow	___	278
[Mn(Cep)(Cl**o**x)Cl_2]	C_{35} $H_{35}Cl_3N_6O_9S_2Mn$	908.43	Pale green	___	267

From Table 1, some physical properties of the free ligands and that of the synthesized complexes. The mixed antibiotic ligands (cephalexin and cloxacillin) produced a yellow [Co(Cep)(Clox)Cl_2] complex. The colour is due to d-d transitions and reactivity between the ligands and the metal ion as asserted by Jabbi et al. [11].

The complex exhibits a higher melting/decomposition temperature than the individual free ligands, as presented in the Table 1. Cloxacillin melted at 170 °C, Cephalexin melted at 197 °C, while the complex decomposed at 278 °C. The same method was followed for the synthesis of the other complex, [Mn(Cep)(Clox)Cl_2], with a pale green colour, which decomposed at 267 ^oC. The higher values of the mixed complexes provide evidence of complexation of the ligands to the metal ions of the two respective complexes. It also revealed the more stable nature of the complexes. These values are in agreement with metal (II) complexes reported by Waziri et al. [4] and Jabbi et al. [11].

Table 2 presents the solubility of the ligands and the synthesized complexes in different solvents ranging from polar to non-polar ones.

Table 2: Solubility of the antibiotics and their metal(II) complexes

Compound	Distilled Water	CCl_4	Benzene	Diethyl ether	Acetone	Ethanol	Methanol	DMF	DMSO
Cloxacillin	S	IN	IN	SS	S	IN	IN	S	S
Cephalexin	S	IN	IN	SS	S	IN	IN	S	S
$[Co(Cep)(Clox)Cl_2]$	SS	SS	IN	SS	SS	SS	IN	S	S
$[Mn(Cep)(Clox)Cl_2]$	SS	IN	IN	SS	SS	SS	SS	S	S

Cloxacillin and cephalexin are both soluble in distilled water, acetone, DMF, and DMSO, slightly soluble in diethyl ether, while insoluble in CCl_4, benzene, ethanol, and methanol, respectively.

Co(II) complex prepared is insoluble in CCl_4, ethanol, and methanol, slightly soluble in distilled water, benzene, diethyl ether, and acetone, and soluble in DMF and DMSO.

It can be observed that the metal(II) complex is either insoluble or slightly soluble in some organic solvents such as ethanol, methanol, diethyl ether and acetone but soluble in DMF and DMSO. Likewise, the Mn(II) complex prepared is insoluble in CCl_4 and benzene, slightly soluble in distilled water, diethyl ether, acetone, ethanol and methanol, and soluble in DMF and DMSO. The values would be suitably used to conduct a conductivity test. This is because polar compounds are expected to be soluble in polar solvents and vice versa (like dissolves like), which is in agreement with the results reported by Yusha'u [10] and Lawal et al. [12].

Table 3 shows the Infra-red spectra data of the free ligands and that of the complexes indicating the different bonds stretching in hydroxyl, carboxyl and carbonyl groups of carboxylic acids and amides. The table also presents the metal to oxygen and metal to chlorine atoms in the synthesized complexes.

As presented in Table 3, the IR spectral data for the free ligands and their complexes were discussed and compared to predict the coordination mode and the expected final shapes, depending on ligand behavior and other coordinating molecules, such as chloride ions.

Table 3: The IR spectra (4000-400 cm^{-1}) of antibiotics and their metal(II) complexes

Compound	υ(O-H)	υ (C = O) of CO_2	υ (C = O) of amide	M – O	M – Cl
Cloxacillin	3677.85	1689.66	1771.53	--------	------
Cephalexin	3392.90	1687.77	1757.21	----------	-------
[Co(Cep)(Clox)Cl_2]	3404.47	1589.40	1776.50	470.65	839.06
[Mn(Cep)(Clox)Cl_2]	3404.47	1639.55	1755.28	470.65	854.49

Key: υ = wave number, M = metal, Clox = cloxacillin, Ceph = cephalexin

Based on the spectra, the absorption bands at 3677.85 cm^{-1} in cloxacillin and 3392.90 cm^{-1} in cephalexin are attributed to O–H stretching, which shifts to lower frequencies of 3404.47 cm^{-1} in the Co(II) complex and 3404.47 cm^{-1} in the Mn(II) complex, respectively. This is consistent with coordination through the oxygen of the carboxylic OH group in both ligands.

The bands at 1689.66 cm^{-1} and 1687.77 cm^{-1} are assigned to the carbonyl group (C=O) of the carboxylate groups in cloxacillin and cephalexin, respectively, and shift to 1589.40 cm^{-1} in [Co(Cep)(Clox)Cl2] and 1687.77 cm^{-1} in [Mn(Cep)(Clox)Cl2], indicating complexation through the carboxylate group with the two respective metal ions. The bands at 1771.53 cm^{-1} and 1776.50 cm^{-1} are assigned to the amide carboxyl group in the ligands (cloxacillin and cephalexin), respectively, and clearly differ from 1776.50 cm^{-1} in the Co(II) complex and 1755.28 cm^{-1} in the Mn(II) complex, respectively. The shifts in the complexes indicate complexation through the amide carboxyl group with the metal ion [4].

The complexes [Co(Cep)(Clox)Cl_2] and [Mn(Cep)(Clox)Cl_2] indicated new bands at 470.15 cm^{-1} and 470.65 cm^{-1}, which are assigned to υ (M – O) of Co(II) and Mn(II), respectively. Moreover, new bands at 839.06 cm^{-1} and 854.49 cm^{-1} which are assigned to (M – Cl) of the Co(II) and Mn(II) complexes, respectively, and could not be traced in the free ligands, prove the formation of the new compounds as reported by Eugene et al. [13].

Table 4 presents the electronic spectra, absorptions and transitions of the free ligands and the synthesized complexes. The table also presents the molar conductivity in dimethyl formamide (DMF), magnetic moments as well as the suggested geometries of the synthesized complexes.

Table 4: Electronic spectra, conductance in DMF solvent, and magnetic moment (B.M) for synthesized metal complexes with their suggested geometry

Ligands/Complex	Electronic spectra			Conductance ($\boldsymbol{\Omega^{-1}}$ cm^2mol^{-1})	Magnetic moment (BM)	Suggested geometry
	Wavelength ($\boldsymbol{nm}$)	Energy ($\boldsymbol{cm^{-1}}$)	Transition			
Cloxacillin	202	48309	$\boldsymbol{n-\pi^*}$			
	207	49505	$\boldsymbol{\pi-\pi^*}$			
	239	41841	CT band			
Cephalexin	220	45455	$\boldsymbol{n-\pi^*}$			
	233	42918	$\boldsymbol{\pi-\pi^*}$			
[Co (Cep)(Clox)Cl_2]	217	46083	$^4T_1g \rightarrow {}^4T_1g$	22.00	3.89	Octahedral
	231	43290	$^4T_1g \rightarrow {}^4T_2g$			
	244	40984	$^4T_1g \rightarrow {}^4A_2g$			
[Mn(Cep)(Clox)Cl_2]	224	44643	$\pi-\pi^*$	30.00	5.85	Octahedral
	232	43103	MLCT			
	238	42017	$^6A_1g \rightarrow {}^6A_1g$			

Table 4 presents the molar conductance in 1×10^{-3} DMF .Conductivity measurements have been used in elucidating the structure of complexes within the limits of their solubilities in a given solvent, as reported by [1],which suggested that values less than 60 in DMF are considered to be non-electrolytes The Co (II) complex has molar conductance of 22 $\Omega^{-1}cm^2mol^{-1}$ while Mn (II) complex has molar conductance of 30 $\Omega^{-1}cm^2mol^{-1}$ these values indicate that both the two complexes are non-electrolytes which lie within octahedral geometries in DMF [14, 15].

The electronic spectra of both the ligands and their complexes are presented in the Table 4. The free ligand of cloxacillin exhibits three bands at 202 nm, 207 nm and 239 nm while the free ligand of cephalexin exhibits two bands of 220 nm and 233 nm respectively. These were

assigned to $n - \pi^*, \pi - \pi^*$, CT- band, $n - \pi^*$ and $\pi - \pi^*$. These absorption bands also appeared in the electronic spectra of the complexes, but they are shifted to different values, which proves the coordination of the ligands to the central metallic ions [1].

Co(II) complex showed three bands in the regions 217 nm, 231 nm and 244 nm which are attributed to $^4T_1g, \rightarrow ^4T_1g, ^4T_1g \rightarrow ^4T_2g$ and $^4T_1g \rightarrow ^4A_2g$ transitions for an octahedral Co(II) complex [11]. Likewise, new absorption bands appeared for Mn(II), which showed three bands at the regions 224 nm, 232 nm and 238 nm which are assigned to $n - \pi^*$, metal-to-ligand charge transfer (MLCT) and $^6A_1g \rightarrow ^6A_1g$ transitions for the octahedral Mn(II) complex [3].

Moreover, the results of the magnetic properties of cephalexin and cloxacillin complexes as presented in the table 4, from the values of the magnetic susceptibility obtained, paramagnetic properties are due to presence of unpaired electrons in the partially filled d-orbital of the central metal ion as reported by Adekunle [15]. The suggestion of the likely geometry of complexes can also be provided by their magnetic moment. The magnetic moment values of the complexes synthesized are found to be 3.89 BM on Co(II) shows presence of three unpaired electrons and 5.85 BM on Mn(II) which shows the presence of five unpaired electrons. These values suggest that both the synthesized complexes are paramagnetic and have octahedral geometries, the values agree with those reported by Ferec et al. [16]. Also, the magnetic moment values of 5.85 BM for Mn(II) and 3.89 BM for Co(II) lie within the expected range for high spin octahedral geometry [16].

Table 5 presents the molecular formulae of the synthesized complexes and results of the elemental and metal analyses of the complexes. Both the calculated and percentage values of the carbon, hydrogen, nitrogen, sulphur and the metal (Mn and Co) are presented in the Table. From the result, the percentages of C, H, N and S are in conformity with the proposed structures. Based on the evaluation of the elemental analysis data, it shows that the compound analysed as [M(Cep)(Clox)Cl2)] where M = Mn(II) and Co(II). While Cep and Clox represent cephalexin and cloxacillin antibiotic ligands respectively. The percentages of the metal ions also agree with the proposed structures. The result is in line with that reported by Lawal et al. [12] and Waziri et al. [4].

Table 5: C.H.N.S. Elemental analysis and metal content of the synthesized complexes

Compounds	Molecular formula / Molar mass (g/mol)	Elemental and metal analysis found (calculated) %				
		C	H	N	S	M
$[Mn(Cep)(Clox)Cl_2]$	$C_{35}H_{35}N_6S_2O_9Mn$ (801.94)	46.07 (52.37)	6.09 (52.37)	8.09 (10.47)	6.49 (7.9)	6.00 (6.85)
$[Co(Cep)(Clox)Cl_2]$	$C_{35}H_{35}N_6S_2O_9Co$ (805.93)	49.67 (52.11)	3.16 (4.34)	12.11 (10.42)	6.98 (7.94)	8.00 (7.31)

The result of the antimicrobial (antibacterial) sensitivity test of the synthesized complexes against some bacterial isolates using agar well diffusion method is presented in Table 6. The result of the antibacterial test shows that the free ligands as well as the mixed complexes were active against all three isolates of bacteria at all concentrations, especially at higher ones. However, at the lowest concentration of 500 µg | agar well, inactivity was observed for the cephalexin ligand against Staphylococcus aureus. It can be observed that the metal(II) complexes of the mixed antibiotics have shown better antibacterial activity than the individual antibiotics (ligands). A similar result was reported by Jibril et al. [9] and Bamigboye and Ahmad [17]. The result shows that the free ligands as well as their mixed complexes were active against all the three isolates of bacteria especially at higher concentrations. But, the activity is more pronounced in the synthesized complexes (since they show higher activity) than the individual ligands as shown in Table 6. At the lowest concentration of 500 µg| agar-well, inactivity was observed by the ligands as well as their complexes against some of the bacterial isolates. However, all the ligands and complexes were found to be very active at higher concentrations of 4000, 2000 and 1000 µg| agar-well as presented in the Table 6. Similar result was reported by Satyawan et al. [19].

Table 6: Antibacterial test of the antibiotics and their metal(II) complexes

Compounds	Concentration (μg)	Staph. aureus (mm)	Salmonella typhi (mm)	E. coli (mm)
Cloxacillin	4 000	10	10	10
	2 000	12	9	11
	1 000	7	8	10
	500	00	9	9
Cephalexin	4000	10	12	11
	2000	11	10	12
	1000	10	9	11
	500	6	8	00
[Mn (Cep)(Clox)Cl_2]	4 000	16	15	13
	2 000	11	13	11
	1 000	10	12	11
	500	7	8	7
[Co (Cep)(Clox)Cl_2]	4 000	14	15	14
	2 000	14	13	14
	1 000	13	10	12
	500	7	9	6
Standard Ciprofloxacin	500	30	27	25
	200	-	-	-

Table 7 presents result of antimicrobial (antifungal) sensitivity test of the complexes against fungal isolates using agar well diffusion method.

As presented in Table 7 the ligands and the synthesized complexes show better antifungal activity at higher concentrations. However, the ligands and some of the complexes show inactivity against some fungal isolates at the lowest concentration of 500 μg| agar well. Cephalexin and Co(II) complex show inactivity against *Aspergillus fumigatus* isolate. The Co(II) complex shows inactivity against *Aspergillus flavus* at such a concentration. Finally, Mn(II) complex is inactive against *Candida albicans* at the lowest concentration of 500 μg| agar well.

In conclusion, all the synthesized complexes have shown improved antimicrobial activity, especially at higher concentrations. Similar results were reported by Jibril et al. [9].

Table 7: Antifungal Test of Cloxacillin and Cephalexin and their Mixed Ligands of Metal(II) Complexes

Compounds	Concentration (μg)	Aspergillus flavus (mm)	Candida albicans (mm)	Aspergillus fumigatus (mm)
Cloxacillin	4 000	8	8	7
	2 000	6	7	7
	1 000	9	8	6
	500	7	7	0
Cephalexin	4 000	8	7	9
	2 000	9	7	9
	1 000	8	6	7
	500	6	6	6
$[Mn(Cep)(Clox)Cl_2]$	4 000	14	13	14
	2 000	13	12	12
	1 000	11	9	10
	500	7	00	6
$[Co(Cep)(Clox)Cl_2]$	4 000	16	15	14
	2 000	12	13	10
	1 000	13	12	11
	500	00	8	00
Control Antifungal (Ketoconazole)	General (500 μg)	19	21	25

Based on the analytical data obtained, such as melting point, UV spectroscopy, elemental analysis, magnetic susceptibility, and FTIR spectral studies, the tentatively proposed structure of the metal(II) complex of the mixed antibiotics can be illustrated in Figure 1:

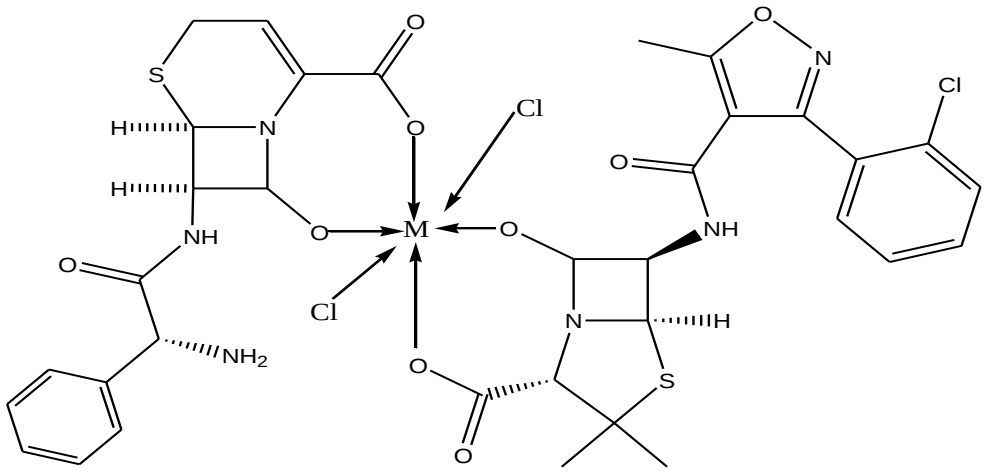


Figure 1: Proposed Structure of the Synthesized Metal(II) Complexes
(Where M = Co(II) or Mn(II))

CONCLUSION

Results of the characterization of the synthesized complexes showed that the products are identical and have an octahedral geometry. Thus, from the FTIR spectrum as presented in Table 3, it is concluded that cloxacillin and cephalexin ligands which coordinated to the metal(II) ions of cobalt and manganese in a bidentate manner through the oxygen atom of carbonyl groups of amide and that of the carboxylic group present in the two respective ligands [13]

The structures of the mixed complexes of cloxacillin and cephalexin with Mn(II) and Co(II) have been confirmed from the ultraviolet visible spectroscopy, FT-IR spectroscopy, magnetic moment, conductivity measurement and melting point. According to the analytical data of the ligands and their complexes, the complex exhibits a higher melting/decomposition temperature than the individual free ligands, as presented in Table 1. Cloxacillin melted at 170 °C, Cephalexin melted at 197 °C, while the complex decomposed at 278 °C. The higher decomposition values of the mixed complexes provide evidence of complexation of the ligands to the metal ions of the two respective complexes. It also revealed the more stable nature of the complexes. These values are in agreement with metal(II) complexes reported by Waziri et al. [4] and Jabbi et al. [11]

The Co(II) complex has molar conductance of 22 $\Omega^{-1}cm^2mol^{-1}$while Mn(II) complex has molar conductance of 30 $\Omega^{-1}cm^2mol^{-1}$ these values indicate that both the two complexes are non-electrolytes which lie within octahedral geometries in DMF [14, 15].

It has been suggested that the complexes are in octahedral geometry. It has been confirmed that the complexes have active antibacterial and antifungal activity some even more than that of

their parent ligands. The magnetic moment values of the synthesized complexes as presented in Table 4 are found to be 3.89 BM for Co(II) shows presence of three unpaired electrons and 5.85 BM on Mn(II)w shows the presence of five unpaired electrons. These values suggest that both the synthesized complexes are paramagnetic and have octahedral geometries, the values agree with those reported by Ferec et al. [16].

The result of the elemental analysis of the metal (II) complexes is presented in Table 5. From the result, the percentages of C, H, N and S are in conformity with the proposed structures [12].

Cloxacillin and cephalexin are among the interesting antibiotics that are used as ligands in synthesizing metallic complexes to improve their activity by many researchers using refluxing solution-based synthesis [18]. This work has demonstrated the use of such method to obtain similar results with effective antimicrobial activity.

RECOMMENDATION

Since the synthesized complexes have been found to be highly active against certain bacterial and fungal isolates, this research work therefore recommends that further research of this nature should be carried out to produce potent antimicrobial drugs. The research also recommends that, to fully characterize these complexes, further analyses like single crystal structure determination, x-ray powder diffraction, crystallography and HNMR are to be conducted.

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