

Original Research Article

Synthesis and evaluation of antioxidant and antimicrobial activities of Schiff base tin (II) complexes

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Abstract

Purpose: To synthesize and evaluate Schiff base Tin (II) complexes for antioxidant and antimicrobial activities

Methods: The complexes of Tin (II) chloride with various Schiff base derivative of 2-Hydroxy-1-naphthaldehyde (HN) were synthesized and characterized by various physicochemical techniques, including elemental analysis, ultraviolet-visible (UV-Vis) spectrophotometry, Fourier transform infrared spectroscopy (FTIR), proton nuclear magnetic resonance (¹H-NMR), carbon-13 nuclear magnetic resonance (¹³C-NMR), electron ionization mass spectrometry (EIMS) and conductance studies. Agar-well diffusion and agar-well dilution techniques were used for antimicrobial assessment. Evaluation of the antioxidant activity of the ligands and complexes was accomplished by DPPH radical scavenging assay.

Results: The results indicate coordination of deprotonated phenolic oxygen and nitrogen of azomethine with Tin (II) chloride led to the formation of stable complexes. The Tin (II) complexes showed good antimicrobial and antioxidant activities. Compounds (HNPA and [Sn(HNPA)Cl₂(H₂O)₂]) were noteworthy (*p* < 0.05) in this regard with antibacterial activity against *Staphylococcus aureus*, while [Sn(HNCA)Cl₂(H₂O)₂] and [Sn(HNPT)Cl₂(H₂O)₂] were active against *Klebsiella pneumoniae*.

Conclusion: All synthesized Schiff bases and their Tin (II) complexes showed high antimicrobial and antioxidant activities than their corresponding ligands.

Keywords: Schiff base, Ligand, Tin (II) complexes, Antimicrobial, Antioxidant, Deprotonated phenolic oxygen

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INTRODUCTION

Various metal complexes with bi- and tridentate Schiff bases containing nitrogen and oxygen donor atoms play important role in biological system [1]. Schiff base complexes have numerous applications, such as in the treatment of cancer, as bactericide agent, as antiviral agents, as fungicide agent anti-inflammatory and antipyretic agent in the treatment of diseases

such as trypanosomiasis and jaundice and as analytical reagent [2-5]. The importance of metal ion in biological system as macrocyclic compounds is well established because of their catalytic behavior in a number of redox reactions of biological significance [6]. 2-Hydroxy-1-naphthaldehyde Schiff base complexes are widely studied for its antimicrobial, catalytic and redox properties [7]. These results have led us to derive Schiff bases of 2-Hydroxy-1-

naphthaldehyde and its Sn (II) complexes. These complexes derived from 2-Hydroxy-1-naphthaldehyde were studied in detail for their applications in diverse areas such as antimicrobial and antioxidant activities.

EXPERIMENTAL

Preparation of ligands and complexes

Ligands and complexes were prepared according to the available methods in literature [1,8]. Their physical state, melting points, colour, and yield of ligands and complexes are shown in Table 1.

Preparation of HNPA

Equimolar ethanolic solution of 2-Hydroxy-1-naphthaldehyde (HN) 0.01 mole (1.7218 g) with 0.01 mole (1.0814g) of o-phenylenediamine (PA) were refluxed with constant stirring for 40 min. The precipitate formed were separated by sintered glass crucible which were dried in vacuum oven. The ligand was reprecipitated with ethanol.

Preparation of HNPT

Equimolar ethanolic solution of 2-Hydroxy-1-naphthaldehyde (HN) 0.01 mole (1.7218 g) with 0.01 mole (1.2758g) of 4-Chloroaniline (CA) were refluxed with constant stirring for 40 min. The ligand was reprecipitated with ethanol.

Preparation of HNPT

Equimolar ethanolic solution of 2-Hydroxy-1-naphthaldehyde (HN) 0.01 mole (1.7218 g) with 0.01 mole (1.079g) of p- Toludine (PT) were refluxed with constant stirring for 40 min. The precipitate formed was separated by sintered glass crucible which was dried in vacuum oven.

Preparation of HNOT

Equimolar ethanolic solution of 2-Hydroxy-1-naphthaldehyde (HN) 0.01 mole (1.7218 g) with

0.01 mole (1.0814 g) of o-Toludine (OT) were refluxed with constant stirring for 40 min. The precipitate formed was separated by sintered glass crucible which was dried in vacuum oven.

Preparation of complexes

Equimolar 0.0025mole ethanolic solution of ligands (HNPA, HNCA, HNPT, and HNOT) and 0.0025mole $\text{SnCl}_2 \cdot 2\text{H}_2\text{O}$ were refluxed with constant stirring for 2 h. The precipitate formed was separated by filtering through sintered glass crucible washed with ethanol for the removal of non-reacted material afterwards samples were dried in vacuum oven.

Antibacterial assay

All synthesized Schiff bases and their Tin (II) complexes were screened *in vitro* for their antibacterial activity against Gram-negative (*Klebsiella pneumoniae* and *Escherichia coli*) and Gram-positive (*Staphylococcus aureus*, *Staphylococcus epidermidis* and *Bacillus subtilis*) bacterial strains by the agar-well diffusion method [9].

Antifungal assay

Synthesized Schiff bases and their Tin (II) complexes were investigated for antifungal activity against three fungal strains, i.e. *Aspergillus niger*, *Aspergillus flavus* and *Alternaria solani* by using the agar tube dilution method [10]. Nutrient agar was used for culturing of fungal strains. Nutrient agar media (28 g/1000 mL) was prepared in dH_2O and sterilized in an autoclave for 15 min at 121 °C and 1.5 pounds pressure.

Determination of antioxidant activity

Antioxidant activities of the synthesized ligands, complexes as well as of the standard used were determined by the method of 1, 1-diphenyl-2-picryl- hydrazyl (DPPH) free radical activity [11].

Table 1: Physical properties of the ligands and its complexes

Compound	Physical state	Melting point	Color
HNPA	Powder	121-123.8	Brownish
$[\text{Sn}(\text{HNPA})\text{Cl}_2(\text{H}_2\text{O})_2]$	Powder	285	Bright Orange
HNCA	Powder	118.7	Bright Yellow
$[\text{Sn}(\text{HNCA})\text{Cl}_2(\text{H}_2\text{O})_2]$	Powder	290	Dull Yellow
HNPT	Powder	90.2-91.3	Bright Yellow
$[\text{Sn}(\text{HNPT})\text{Cl}_2(\text{H}_2\text{O})_2]$	Powder	295	Brown
HNOT	Powder	86.1	Yellow
$[\text{Sn}(\text{HNOT})\text{Cl}_2(\text{H}_2\text{O})_2]$	Powder	287	Pale Yellowish

RESULTS

Spectroscopic studies

FTIR spectral bands of the relevant ligands and their tin complexes are given in Table 2.

In ligand HNPA and its complex $[\text{Sn}(\text{HNPA})\text{Cl}_2(\text{H}_2\text{O})_2]$, the ν C=N bands of free ligand at 1600 cm^{-1} are shifted to higher wave numbers ($1618, 1653\text{ cm}^{-1}$) in the spectra of the complex, indicating coordination of ligand to the tin ion via the azomethine nitrogen atom. The bands at 3471 and 3373 cm^{-1} are un-shifted in complex, indicating the free N-H bond in complex. A new band in IR of complex appeared in the region of 561 cm^{-1} , indicating the Sn-O bond in complex. In ligand HNCA and its complex $[\text{Sn}(\text{HNCA})\text{Cl}_2(\text{H}_2\text{O})_2]$, the ν C=N bands of free ligand at 1604 and 1558 cm^{-1} are shifted to higher wave numbers ($1618, 1593\text{ cm}^{-1}$) in the spectra of the complex, indicating coordination of ligand to the tin ion via the azomethine nitrogen atom. A band at 3028 cm^{-1} for hydrogen bond by OH group is shifted to 3061 cm^{-1} , indicating the deprotonation of -OH and its involvement in coordination with metal ion. A new band in IR of complex appeared in the region of 537 cm^{-1} , indicating the Sn-O bond in complex. In ligand HNPT and its complex $[\text{Sn}(\text{HNPT})\text{Cl}_2(\text{H}_2\text{O})_2]$ the ν C=N bands of free ligand at 1618 and 1581 cm^{-1} are shifted to higher wave numbers ($1622, 1593$

cm^{-1}) in the spectra of the complex, indicating coordination of ligand to the tin ion via the azomethine nitrogen atom. A band at 3028 cm^{-1} for hydrogen bonded OH group is shifted to 3061 cm^{-1} , indicating the deprotonation of O-H and its involvement in coordination with metal ion. A new band in IR of complex appeared in the region of 536 cm^{-1} , indicating the Sn-O bond in complex. In ligand HNOT and its complex $[\text{Sn}(\text{HNOT})\text{Cl}_2(\text{H}_2\text{O})_2]$, the ν C=N bands of free ligand at 1610 cm^{-1} are shifted to higher wave numbers (1622 cm^{-1}) in the spectra of the complex, indicating coordination of ligand to the tin ion via the azomethine nitrogen atom. A new band in IR of complex appeared in the region of 543 cm^{-1} , indicating the Sn-O bond in complex. DMSO-d₆ used as solvent for Proton NMR study. The ligand "exhibited signals that have been identified from the integration curve and found to be equivalent to the total number of protons deduced from their proposed structures. These were compared with the reported signals of known identical compounds data". The ^1H NMR data of the four Schiff bases studied are summarized in Table 3.

The phenolic hydroxyl proton in all structures appears in the range of 15-16 ppm. The azomethine protons appear in the range of 8.4 - 9.6 ppm which is characteristics of these protons. Signals in the region 7.0 - 7.9 ppm were assigned to the aromatic protons.

Table 2: FTIR data for ligands and its complexes

Compound	IR spectra (cm^{-1})				
	ν (NH)	ν (OH)	ν (C=N)	ν (C-H)	ν (Sn-O)
HNPA	3471,3373	-----	1600	1485-1406	-----
$[\text{Sn}(\text{HNPA})\text{Cl}_2(\text{H}_2\text{O})_2]$	3471,3373	-----	1618,1653	1485-1406	561
HNCA	-----	3028	1604,1588	1485-1406	-----
$[\text{Sn}(\text{HNCA})\text{Cl}_2(\text{H}_2\text{O})_2]$	-----	3061	1618,1593	1485-1406	537
HNPT	-----	3028	1618,1581	1485-1406	-----
$[\text{Sn}(\text{HNPT})\text{Cl}_2(\text{H}_2\text{O})_2]$	-----	3061	1622,1593	1485-1406	536
HNOT	-----	-----	1610	1485-1406	-----
$[\text{Sn}(\text{HNOT})\text{Cl}_2(\text{H}_2\text{O})_2]$	-----	-----	1622	1485-1406	543

Table 3: ^1H NMR Spectral Data (δ , ppm) of ligands and complexes

Compound	^1H NMR Spectral Data (δ , ppm)				
	-HC=N	-OH	-CH ₃	Aromatic hydrogen	-NH ₂
HNPA	9.6	15.6	2.4	6.8-7.9	5.1
$[\text{Sn}(\text{HNPA})\text{Cl}_2(\text{H}_2\text{O})_2]$	10.11	-----	2.3	7.2-7.9	-----
HNCA	9.64	15.53	2.4	7.0-7.9	-----
$[\text{Sn}(\text{HNCA})\text{Cl}_2(\text{H}_2\text{O})_2]$	9.66	15.56	2.3	7.0-8.5	-----
HNPT	9.61	15.9	2.3	6.9-7.9	-----
$[\text{Sn}(\text{HNPT})\text{Cl}_2(\text{H}_2\text{O})_2]$	9.62	15.8	2.2	6.7-7.8	-----
HNOT	9.63	16	2.4	6.9-7.9	-----
$[\text{Sn}(\text{HNOT})\text{Cl}_2(\text{H}_2\text{O})_2]$	9.66	15.5	2.4	7.0-7.9	-----

Three protons of the methyl group in the ligands HNPT and HNOT appear in the range of 2.3 - 2.4 ppm. Signal of the two protons of NH_2 - group in the ligand HNPA appears at 5.12 ppm. The signals for azomethine proton appear in the range of 9.61-9.94 ppm for ligands shift downfield in the spectra of Tin (II) complexes. "The de-shielding is probably due to the donation of the lone pair of electrons on the azomethine nitrogen to tin, resulting in the formation of a coordinate bond". The signal for one proton in the range of 15-16 ppm for the ligands corresponds to the $-\text{OH}$ group attached to aromatic system. The signals shifts downfield in the spectra of the complexes $[\text{Sn}(\text{HNCA})\text{Cl}_2(\text{H}_2\text{O})_2]$, $[\text{Sn}(\text{HNPA})\text{Cl}_2(\text{H}_2\text{O})_2]$ and $[\text{Sn}(\text{HNOT})\text{Cl}_2(\text{H}_2\text{O})_2]$ showing the coordination of oxygen with tin metal without the deprotonation of the $-\text{OH}$ group. In the case of $[\text{Sn}(\text{HNPA})\text{Cl}_2]$ complex the $-\text{OH}$ signal disappears indicating the deprotonation of oxygen atoms of the ligand on complexation. The multiplets between 6.8 - 8.5 ppm in the spectra of ligands are assigned to the naphthylidene group protons. These multiplets have downfield shift in the spectra of the complexes attributed to increased conjugation upon complex formation. In all the complexes new peak appear in the region of 3.0-3.4 ppm were assigned for coordinated water ^{13}C NMR Spectra of the four ligands were recorded in DMSO-d_6 and these spectra also support the authenticity of the proposed structures (Table 4).

The signals observed at 167-171.8 ppm are due to azomethine carbons. The peak for the $-\text{OH}$ group appears at 154.5-156.6 ppm. The aromatic carbon directly attached with azomethine carbon shows peak at 39.2-39.7 ppm. The aromatic carbon directly attached with azomethine nitrogen shows peak at 141 - 143.3 ppm. The methyl carbons in the ligands HNPT and HNOT

appears in the range of 17.7 - 20.5 ppm. The carbon having chlorine atom in I-2 showed signal at 130.63 ppm. Carbon attached with the unreacted $-\text{NH}_2$ group shows signal at 141.76 ppm. All other aromatic carbons showed peak in the range of 121 - 133 ppm. In the ^{13}C -NMR spectra of the ligands, the signals observed in the range of 167 - 171.8 ppm are due to azomethine carbons.

These signals shift (δ 168.9 - 169.4 ppm) in the case of Tin (II) complexes, indicating the coordination of azomethine nitrogen to the tin. Signals in the range of δ 154 - 157.4 ppm are assigned to the aromatic carbons attached to the $-\text{OH}$ group in various ligands. The shifts were observed in these signals (δ 154-159.3 ppm) when the free ligands are coordinated to the tin atom indicating the involvement of $-\text{OH}$ group in complex formation. In the ^{13}C -NMR spectra of the ligands, the signals observed in the range of δ 141.08 - 143.38 ppm are due to aromatic carbons attached to azomethine nitrogen. The shift in these signal are observed in the range of δ 141.10 - 157.41 ppm.

Elemental analysis and atomic absorption data

"The close agreement in the calculated and found values of the elemental analysis" shows the formation of ligands (HNPA, HNCA, HNPT and HNOT) and complexes ($[\text{Sn}(\text{HNPA})\text{Cl}_2(\text{H}_2\text{O})_2]$, $[\text{Sn}(\text{HNCA})\text{Cl}_2(\text{H}_2\text{O})_2]$, $[\text{Sn}(\text{HNPT})\text{Cl}_2(\text{H}_2\text{O})_2]$ and $[\text{Sn}(\text{HNOT})\text{Cl}_2(\text{H}_2\text{O})_2]$) as seen in Table 5. The atomic absorption data for tin metal is also shown in Table 5. The data establishing the general formula of complexes is $[\text{Sn}(\text{L})\text{Cl}_2.n\text{H}_2\text{O}]$ "where L is ligand, and $n=1$ or 2 , is the number of coordinated water".

Table 4: ^{13}C -NMR spectral data (δ , ppm) for ligands and its complexes

Compound	^{13}C -NMR spectral data (δ , ppm)				
	$-\text{HC}=\text{N}$	Aromatic carbon attached with $-\text{OH}$ group	Aromatic carbon attached with azomethine Nitrogen	Aromatic carbon attached with $-\text{NH}_2$ group	$-\text{CH}_3$
HNPA	167.04	155.65	141.76	135.59	-----
$[\text{Sn}(\text{HNPA})\text{Cl}_2(\text{H}_2\text{O})_2]$	168.98	159.30	157.41	140.47, 133.94	-----
HNCA	169.37	156.59	143.38	-----	-----
$[\text{Sn}(\text{HNCA})\text{Cl}_2(\text{H}_2\text{O})_2]$	169.21	156.64	143.43	-----	-----
HNPT	170.82	154.59	141.08	-----	20.54
$[\text{Sn}(\text{HNPT})\text{Cl}_2(\text{H}_2\text{O})_2]$	170.75	154.65	141.54	-----	20.54
HNOT	171.80	154.49	142.09	-----	38.67
$[\text{Sn}(\text{HNOT})\text{Cl}_2(\text{H}_2\text{O})_2]$	169.46	156.66	143.39	-----	39.0

Table 5: Elemental analysis and atomic absorption data for ligands and complexes

Compound	Molecular formula	Elemental analysis and atomic absorption data							
		%C		%N		%H		%Sn	
		Cal	Obs	Cal	Obs	Cal	Obs	Cal	Obs
HNPA	C ₆ H ₄ (NH ₂) ₂	80.75	78.79	11.63	10.64	4.84	4.84	-----	-----
[Sn(HNPA)Cl ₂ (H ₂ O) ₂]	C ₂₈ H ₂₀ Cl ₂ N ₂ O ₂ Sn.H ₂ O	47.0	46.70	4.10	3.98	2.1	1.54	17.11	16.97
HNCA	C ₆ H ₄ NH ₂	74.47	73.96	4.97	4.91	2.99	2.48	-----	-----
[Sn(HNCA)Cl ₂ (H ₂ O) ₂]	C ₁₇ H ₁₂ Cl ₃ NO Sn. H ₂ O	40.94	40.30	2.90	2.70	2.5	1.96	10.99	10.78
HNPT	CH ₃ C ₆ H ₄ NH ₂	86.73	86.26	5.4	5.31	3.36	3.47	-----	-----
[Sn(HNPT)Cl ₂ (H ₂ O) ₂]	C ₁₈ H ₁₅ Cl ₂ NO Sn. H ₂ O	45.77	45.14	3.10	2.89	2.9	2.36	21.96	21.56
HNOT	CH ₃ C ₆ H ₄ NH ₂	82.73	82.14	5.36	5.28	3.36	3.91	-----	-----
[Sn(HNOT)Cl ₂ (H ₂ O) ₂]	C ₁₈ H ₁₅ Cl ₂ NO Sn. H ₂ O	45.77	45.35	3.10	2.84	2.9	2.31	21.96	21.52

Molar conductance

In Table 6 the molar conductance data of synthesized complexes are given which indicate that all of them are non-electrolytic in nature in the solvent. Because in electrolytic complexes the anion bonded outside the coordination sphere with metal. Also low conductance results support the reality that the "Schiff bases are coordinated to the tin atom in their deprotonated anionic forms" and that the two chlorides ligands are also coordinated to the tin atom.

Electronic spectra

The electronic absorption spectra of ligands and their Sn (II) complexes in DMF solution were carried out in the range of 200-1000 nm at room temperature (Table 7).

There is a shift of the bands to longer λ in spectra of all Sn (II) complexes is a good evidence of complex formation. The ligand HNPA chromophore HC=N which absorbs at 270 nm, due to n- π^* transition of azomethine group. The shift to the longer wavelength at 310 nm in the spectra of tin (II) complex [Sn(HNPA)Cl₂(H₂O)₂] is a good evidence of complex formation and coordination of azomethine nitrogen in the complex. The complex absorption showed two sharp bands at 340 nm and 360 nm and these may be assigned as charge transfer bands. It has been reported that the metal is capable of forming dn- $\pi\pi^*$ bonds with ligands containing nitrogen as the donor atom. The Tin atom has its 5d orbital completely vacant and hence Sn-N bonding can take place by the acceptance of the lone pair of electrons from the nitrogen of the ligands.

Table 6: Molar conductance analysis of complexes

Complex	Solvent	Weight taken (mg)/solvent added (40 mL)	Molar conductance Ohm ⁻¹ cm ² mol ⁻¹	Inference
[Sn(HNPA)Cl ₂ (H ₂ O) ₂]	DMF	1.8	2.5	Non-electrolyte
[Sn(HNCA)Cl ₂ (H ₂ O) ₂]	DMF	2.2	4.6	Non- electrolyte
[Sn(HNPT)Cl ₂ (H ₂ O) ₂]	DMF	2.1	5.3	Non-electrolyte
[Sn(HNOT)Cl ₂ (H ₂ O) ₂]	DMF	2.4	8.6	Non- electrolyte

Table 7: Electronic spectral data of complexes

Compound	Solvent	Absorption maximum (nm)
HNPA	DMF	270
[Sn(HNPA)Cl ₂ (H ₂ O) ₂]	DMF	310,340-360
HNCA	DMF	220,240
[Sn(HNCA)Cl ₂ (H ₂ O) ₂]	DMF	230,250
HNPT	DMF	360
[Sn(HNPT)Cl ₂ (H ₂ O) ₂]	DMF	390
HNOT	DMF	320,360
[Sn(HNOT)Cl ₂ (H ₂ O) ₂]	DMF	310,370

In the electronic spectra of the ligand HNCA, a band at 220 nm was observed which may be

assigned to 1B band of phenyl ring. The electronic spectra of the ligand consist of a band

at 240 nm have been assigned $\theta-\theta^*$ transitions within the benzenoid ring. This band remains almost unchanged in the electronic spectra of the complex $[\text{Sn}(\text{HNCA})\text{Cl}_2(\text{H}_2\text{O})_2]$. The UV/Vis spectrum of the ligand HNPT showed three bands. One is at 360 nm which is assigned to $n-\pi^*$ transition. Second band at 400 nm is due to $n-\pi^*$ electronic transitions of azomethine. In Sn (II) complex $[\text{Sn}(\text{HNPT})\text{Cl}_2(\text{H}_2\text{O})_2]$ a band appears at 390 nm is possibly due to the polarization in C=N bond caused by the metal-ligand electronic interaction. The electronic spectra of the free ligand HNOT, the bands recorded at 320 nm and 360 nm are assigned to $n-\pi^*$ transitions of azomethine group. These bands shifted to higher wavelength on coordination through azomethine nitrogen in the complex $[\text{Sn}(\text{HNOT})\text{Cl}_2(\text{H}_2\text{O})_2]$. The band at 310 nm are due to $\pi-\pi^*$ transitions within the azomethine. The band at 370 nm in complex is possibly due to polarization of the C=N bond caused by the metal-ligand interaction.

Antimicrobial activity

The antimicrobial activities results clearly showed that the synthesized ligands and their tin complexes are biological active as shown in Table 8 and Table 9. From the data obtained, it is evident that some of these complexes exhibited significant activity ($p < 0.05$) against the tested organisms. Compound $[\text{Sn}(\text{HNCA})\text{Cl}_2(\text{H}_2\text{O})_2]$ showed maximum activity against Gram-negative bacterial species (*Klebsiella pneumoniae* and *Escherichia coli*). $[\text{Sn}(\text{HNPA})\text{Cl}_2(\text{H}_2\text{O})_2]$ showed the highest antibacterial activity against Gram-positive (*Staphylococcus aureus*, *Staphylococcus epidermidis* and *Bacillus subtilis*) bacteria. The antifungal activity results showed that $[\text{Sn}(\text{HNPA})\text{Cl}_2(\text{H}_2\text{O})_2]$, $[\text{Sn}(\text{HNOT})\text{Cl}_2(\text{H}_2\text{O})_2]$ and HNPT showed highest activity against *Aspergillus niger*, *Aspergillus flavus* and *Alternaria solani* respectively.

Table 8: Antibacterial activity of ligands and its Tin (II) complexes

Compound	Zone of Inhibition (mm) \pm SEM				
	<i>Klebsiella pneumoniae</i>	<i>Escherichia coli</i>	<i>Staphylococcus aureus</i>	<i>Staphylococcus epidermidis</i>	<i>Bacillus subtilis</i>
HNPA	13 \pm 0.78	12 \pm 0.54	17 \pm 0.65	03 \pm 0.17	13 \pm 0.23
$[\text{Sn}(\text{HNPA})\text{Cl}_2(\text{H}_2\text{O})_2]$	15 \pm 0.43	14 \pm 0.69	18 \pm 0.45	15 \pm 0.53	14 \pm 0.33
HNCA	06 \pm 0.61	15 \pm 0.47	03 \pm 0.19	04 \pm 0.12	02 \pm 0.13
$[\text{Sn}(\text{HNCA})\text{Cl}_2(\text{H}_2\text{O})_2]$	20 \pm 0.23	18 \pm 0.66	06 \pm 0.21	06 \pm 0.24	03 \pm 0.10
HNPT	15 \pm 0.54	12 \pm 0.34	04 \pm 0.14	05 \pm 0.27	02 \pm 0.08
$[\text{Sn}(\text{HNPT})\text{Cl}_2(\text{H}_2\text{O})_2]$	17 \pm 0.73	15 \pm 0.41	07 \pm 0.41	07 \pm 0.33	03 \pm 0.10
HNOT	15 \pm 0.45	04 \pm 0.24	05 \pm 0.11	03 \pm 0.12	05 \pm 0.21
$[\text{Sn}(\text{HNOT})\text{Cl}_2(\text{H}_2\text{O})_2]$	19 \pm 0.87	06 \pm 0.12	06 \pm 0.15	04 \pm 0.10	06 \pm 0.13
Standard	24 \pm 0.92	25 \pm 0.77	24 \pm 0.56	26 \pm 0.67	24 \pm 0.54

Table 9: Antifungal activity of ligands and their Tin (II) complexes

Compound	Growth Inhibition (\pm SEM, %)		
	<i>Aspergillus niger</i>	<i>Aspergillus flavus</i>	<i>Alternaria solani</i>
HNPA	40 \pm 0.81	10 \pm 0.65	20 \pm 0.26
$[\text{Sn}(\text{HNPA})\text{Cl}_2(\text{H}_2\text{O})_2]$	60 \pm 0.50	30 \pm 0.73	30 \pm 0.45
HNCA	10 \pm 0.23	06 \pm 0.24	15 \pm 0.72
$[\text{Sn}(\text{HNCA})\text{Cl}_2(\text{H}_2\text{O})_2]$	15 \pm 0.54	25 \pm 0.63	30 \pm 0.77
HNPT	02 \pm 0.20	03 \pm 0.10	35 \pm 0.56
$[\text{Sn}(\text{HNPT})\text{Cl}_2(\text{H}_2\text{O})_2]$	35 \pm 0.74	20 \pm 0.46	20 \pm 0.49
HNOT	20 \pm 0.43	30 \pm 0.73	30 \pm 0.53
$[\text{Sn}(\text{HNOT})\text{Cl}_2(\text{H}_2\text{O})_2]$	45 \pm 0.33	33 \pm 0.82	32 \pm 0.49
Standard	0	0	0

Table 10: Antioxidant activity of ligands and its Tin (II) complexes

Compound	EC ₅₀ (ppm)	Inference
HNPA	-327.18	Inactive
[Sn(HNPA)Cl ₂ (H ₂ O) ₂]	220.94	Antioxidant
HNCA	-23233.85	Inactive
[Sn(HNCA)Cl ₂ (H ₂ O) ₂]	387.71	Antioxidant
HNPT	-1139.9	Inactive
[Sn(HNPT)Cl ₂ (H ₂ O) ₂]	208.87	Antioxidant
HNOT	47.447	Antioxidant
[Sn(HNOT)Cl ₂ (H ₂ O) ₂]	-175.25	Inactive

Antioxidant activity

Significant antioxidant potential was recorded for ligands and their Tin (II) complexes. Antioxidant activity for complexes was active EC₅₀ values are given in Table 10. Lower EC₅₀ value showed higher antioxidant potential of all the tested samples.

DISCUSSION

Schiff base complexes catch researcher's interest due to its significant role in biologically important species and in the bioinorganic chemistry development [12,13]. The carbon having chlorine atom in I-2 showed signal at 130.63 ppm. Carbon attached with the unreacted -NH₂ group shows signal at 141.76 ppm. All other aromatic carbons showed peak in the range of 121 - 133ppm. In the ¹³C-NMR spectra of the ligands, the signals observed in the range of 167 - 171.8 ppm are due to azomethine carbons. These signals shift (δ 168.9 - 169.4 ppm) in the case of tin (II) complexes, indicating the coordination of azomethine nitrogen to the tin [14].

Low conductance data also support the fact that the Schiff bases are coordinated to the tin atom in their deprotonated anionic forms and that the two chlorides ligands are also coordinated to the tin atom [15]. The tin atom has its 5d orbital completely vacant and hence Sn-N bonding can take place by the acceptance of the lone pair of electrons from the nitrogen of the ligands [16]. In the electronic spectra of the ligand HNCA, a band at 220 nm was observed which may be assigned to 1B band of phenyl ring [17].

Several Schiff base metal complexes were investigated for antibacterial assessment and revealed that metal complexes are more active as compared to free ligands [18]. Antioxidant activity for complexes was active at various EC₅₀ values. Lower EC₅₀ value was attributed to higher antioxidant potential of all the tested samples [19].

CONCLUSION

The complexes synthesized from 2-Hydroxyl-1-naphthaldehyde exhibit various biological activities. They possess potentials that can be further developed to exert strong antimicrobial and antioxidant activities.

DECLARATIONS

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Conflict of Interest

No conflict of interest associated with this work.

Contribution of Authors

The authors declare that this work was done by the authors named in this article and all liabilities pertaining to claims relating to the content of this article will be borne by them.

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