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Synthesis, characterization and biological activities of 2-((E)-(benzo[d][1,3]dioxol-6-ylimino)methyl)-6-ethoxyphenol and its metal complexes

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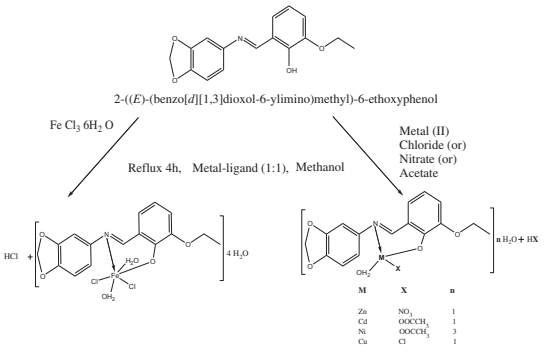
HIGHLIGHTS

- Schiff base and its metal complexes have been synthesized.
- The synthesized compounds were characterized by spectral and thermal analysis.
- All the compounds were tested for their antimicrobial activities.

GRAPHICAL ABSTRACT



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ABSTRACT

Metal complexes of Zn(II), Cd(II), Ni(II), Cu(II), and Fe(III) have been synthesized from the Schiff base ligand derived by the condensation of 3,4-(methylenedioxy)aniline and 3-ethoxy salicylaldehyde. The compounds have been characterized by using elemental analysis, molar conductance, IR, UV–Visible, ^{1}H NMR, ^{13}C NMR, mass spectra and thermal analysis (TG/DTA). The elemental analysis suggests the stoichiometry to be 1:1 (metal:ligand). The IR, ^{1}H NMR, ^{13}C NMR and UV–Visible spectral data suggest that the ligand coordinate to the metal atom by imino nitrogen and phenolic oxygen as bidentate manner. The mass spectral data also strengthen the formation of the metal complexes. The thermal behaviors of the complexes prove the presence of lattice as well as coordinated water molecules in the complexes. The *in vitro* biological screening effects of the synthesized compounds are tested against five bacterial species and three fungal species by well diffusion method. Antioxidant activities have also been performed for all the compounds. Metal complexes show more pronounced biological activity than the free ligand.

Introduction

The bioinorganic chemistry field has increased the interest in Schiff base complexes. These compounds have numerous applications, such as, in the treatment of cancer [1], as anti bactericide agents [2], as antivirus agents [3], as fungicide agents [4] and other biological properties [5]. The interaction of Schiff bases derived from salicylaldehyde moiety and primary amines, especially amino acids with variety of transition metals have been reported [6–9]. Methylenedioxy is the functional group in organic chemistry, which is generally found attached to an aromatic structure such as phenyl, where it forms the methylenedioxy or benzodiazole functional group. Organic compounds with methylenedioxy

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Table 1
Elemental analysis, percentage of metal, color and molecular weight of Schiff base metal complexes.

Ligand/complexes	Empirical formula	Color	Mol. wt	Yield (%)	Elements found (calc)			% of metal found (calc)
					C	H	N	
A1E	$C_{16}H_{15}NO_4$	Brown	285.29	68	67.18 (67.35)	5.25 (5.29)	5.05 (4.91)	
A1E–Zn	$C_{16}H_{18}ZnN_2O_9$	Grey	447.71	57	43.02 (42.92)	3.92 (4.05)	6.37 (6.25)	14.48 (14.60)
A1E–Cd	$C_{18}H_{21}CdNO_8$	Grey	491.77	68	44.08 (43.96)	4.13 (4.3)	2.78 (2.84)	22.92 (22.85)
A1E–Ni	$C_{18}H_{25}NiNO_{10}$	Green	474.08	68	45.44 (45.57)	5.23 (5.31)	2.85 (2.95)	12.42 (12.37)
A1E–Cu	$C_{16}H_{18}ClCuNO_6$	Brown	419.31	90	45.70 (45.83)	4.39 (4.32)	3.27 (3.34)	15.23 (15.15)
A1E–Fe	$C_{16}H_{26}Cl_2FeNO_{10}$	Brown	519.13	80	37.01 (37.08)	5.14 (5.05)	2.72 (2.69)	10.66 (10.75)

moiety is widely found in natural products, including Safrole, drugs and chemicals such as tadalafil, MDMA (3,4-methylenedioxymethamphetamine), and piperonyl butoxide [10–13]. Moreover, methylenedioxy functional group in organic compounds posses biological activities [14–18]. Metal ions play a vital role in a vast number of biological processes [19–21]. Keeping in view of the pronounced biological activity of the metal complexes of Schiff bases derived from salicylaldehyde based compounds, it was thought of worthwhile to synthesize and characterize some Schiff base metal complexes of Zn(II), Cd(II), Ni(II), Cu(II), and Fe(III) derived from 3,4-(methylenedioxy)aniline and 3-ethoxy salicylaldehyde. The biological screening of free ligand and its metal complexes against different bacteria, fungi and antioxidant activities are reported.

Materials and instrumentation

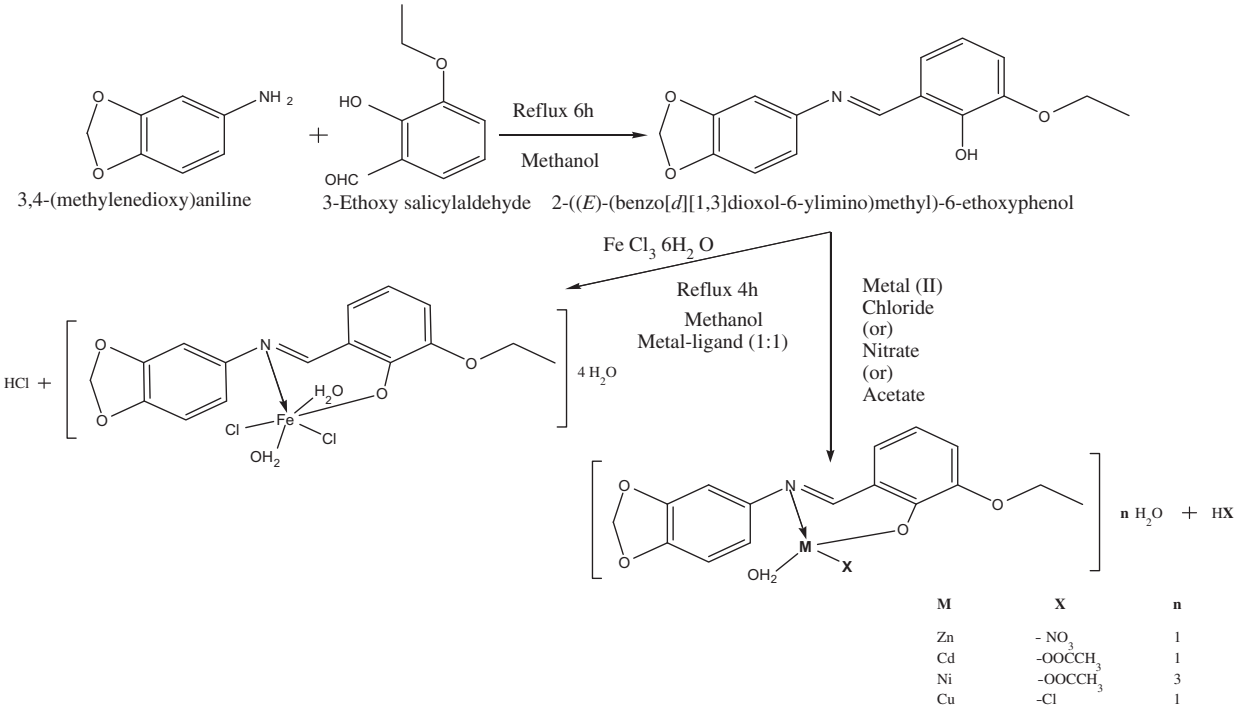
All chemicals used in the present work viz., 3-ethoxysalicylaldehyde, 3,4-(methylenedioxy)aniline, $Zn(NO_3)_26H_2O$, $Cd(CH_3COO)_22H_2O$, $Ni(CH_3COO)_24H_2O$, $CuCl_2{\cdot}2H_2O$, $FeCl_36H_2O$, ethanol and methanol were analytical reagent grade (Aldrich) and used without further purification.

Instrumentation

The microanalysis of C, H, and N were estimated by Perkin Elmer 240 (USA) elemental analyzer and the metal content were determined by atomic absorption spectrophotometer (Perkin Elmer 5000). Infrared spectra of ligand and its metal complexes were recorded on Avatar 330FT-IR, in the range of 4000–400 cm^{-1} using KBr pellets. The UV–Visible spectra of the ligand and the metal complexes were recorded on a Shimadzu UV-1650PC spectrophotometer in the range of 200–800 nm. ^1H NMR and ^{13}C NMR spectra (at room temperature) were recorded on a Bruker magnet system (400 MHz/54 mm) ultra shield plus using $CDCl_3$ as a solvent and TMS as internal standard. Thermal analysis (TG/DTA) was carried out on TA instruments, Model: Q600SDT TG/DTA in the temperature range 20–1000 °C, in nitrogen atmosphere at a heating rate of 20 °C/min. The Mass spectra were recorded by using JEOL GCMATE II GC–MS. Melting points were determined using Gallenkamp melting point apparatus. Molar conductance of the Schiff-base ligand and its transition metal complexes were determined in $CHCl_3$ at room temperature using a CMD 750 WPA conductivity meter.

Antibacterial activity

Antibacterial activity of acetone, methanol, ethanol and chloroform extracts of five different marine microalgal strains was evaluated. All the synthesized compounds were screened for their *in vitro* antibacterial activity by agar well diffusion method [22] against bacterial strains such as *Escherichia coli, Staphylococcus aureus, Enterococcus faecalis, Pseudomonas fluorescens,* and *Klebsiella sp.*



Scheme 1. Synthesis of Schiff base and its metal complexes.

Table 2
UV–Vis spectral data, molar conductivity and melting point of Schiff base metal complexes.

Ligand/ complexes	UV–Visible bands (nm)	κm Ohm^{-1} cm^2 mol^{-1}	Melting point °C
A1E	266, 356, 402	3.42	108
A1E–Zn	264, 360, 420	5.57	224
A1E–Cd	263, 359, 414	6.19	92
A1E–Ni	264, 362, 436	5.67	>300
A1E–Cu	266, 387, 426	5.27	128
A1E–Fe	263, 360, 453	6.00	>300

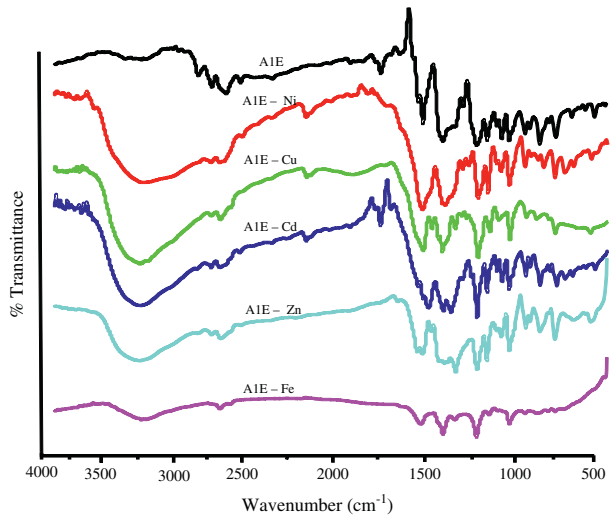


Fig. 1. IR spectra of Schiff base metal complexes.

Standard antibiotics, ampicillin was used as control. Stock solutions (100 mg/ml) of each compound were diluted in DMSO to produce 10 mg/ml. Schiff base and its metal complexes were tested against different concentrations in DMSO solution range from 20 μL to 200 μL (10 mg/ml) to find out the minimum inhibition concentrations (MIC). From the results we concluded that 100 μL is suitable for all the test samples. 20 ml of nutrient agar was poured onto a pre-sterilized petri dish and test microorganisms were spread on the plates using sterile L-rod. Five wells were punched using a sterile cork borer and filled with 100 μL test sample. The inoculated plates were incubated for 24 h at 37 °C. After incubation, the diameter of the inhibition zone was measured and the results were recorded in millimeters. Each solvent extracts were tested separately in triplicates.

Antifungal activity

The free ligand, its metal complexes (10 mg/ml) and control-solvent mixture were screened for their antifungal activity against various fungi *viz.*, *Candida albicans, Fusarium* sp. and *Trichosporon* sp. Each fungal inoculum was swab spread on Muller Hinton agar. Five wells of 4 mm diameter were cut into agar plates and 50 μL (MIC) of microalgal extracts and positive control (Streptomycin) were added to each well. The inoculated plates were incubated for 3 days at 30 °C. The growth inhibition zone was measured in millimeters. Tests were carried out in triplicate [23].

Antioxidant activity

Antioxidant activities of the synthesized compounds (10 mg/ml) were expressed from their radical scavenging ability against the stable free radical, 2,2́-diphenyl-1-picryl hydrazyl (DPPH·). The DPPH· scavenging capacity was determined spectrophotometrically [24]. DPPH (0.004%) was prepared in methanol and 1 ml of 0.004% DPPH-methanol solution was mixed with 2 ml of methanol-compound mixture. The reaction tubes were wrapped in aluminium foil and kept in dark for 30 min. The reduction of the DPPH· was monitored by observing the decrease in absorbance at 517 nm using UV–Vis spectrophotometer with solvent and DPPH as blank. The percentage inhibition was calculated using the formula

$$\text{Percent } (\%) \text{ inhibition of DPPH activity} = \frac{A_{control} - A_{sample}}{A_{control}} \times 100$$

where $A_{control}$ is the absorbance of DPPH· in methanol without an antioxidant and A_{sample} the absorbance of DPPH· in the presence of an antioxidant.

Table 3
IR spectral data of Schiff base metal complexes.

Ligand/complexes	ν(OH)/(H_2O) (cm^{-1})	ν_{asym}(C—H)[a] (cm^{-1})	ν_{sym}(C—H)[b] (cm^{-1})	ν(C=N) (cm^{-1})	ν(C—OH) (cm^{-1})	ν(—O—CH_2—O—) (cm^{-1})
A1E	3438	2976	2883	1629	1248	931
A1E–Zn	3446	2975	2917	1635	1245	929
A1E–Cd	3432	2978	2920	1630	1246	929
A1E–Ni	3407	2980	2893	1603	1242	935
A1E–Cu	3446	2980	2921	1601	1243	929
A1E–Fe	3433	2969	2922	1614	1250	948

[a] Asymmetric stretching.
[b] Symmetric stretching.

Table 4
^{1}H NMR and ^{13}C NMR spectral data of Schiff base and its Zn (II), Cd(II) metal complexes.

Compounds	—CH_3	—CH_2	—O—CH_2—O—	Aromatic proton/Aromatic carbon	—HC=N—	—OH
^{1}H NMR functional groups with chemical shift in (δ, ppm)						
A1E	1.504	4.135	6.011	6.794–7.000	8.575	13.742
A1E–Zn	1.509	4.139	6.020	6.825–7.265	8.583	
A1E–Cd	1.509	4.138	6.019	6.803–7.266	8.583	
^{13}C NMR functional groups with chemical shift in (δ, ppm)						
A1E	14.93	64.62	101.47	101.65–151.45	160.59	
A1E–Zn	14.94	64.62	101.47	101.65–151.47	160.59	
A1E–Cd	14.93	64.62	101.47	101.65–151.44	160.59	

Synthesis of Schiff base (A1E)

The Schiff base was prepared by refluxing of 3-ethoxy salicylaldehyde (3.32 g; 0.02 mol) with 3,4-(methylenedioxy)aniline (2.74 g; 0.02 mol) in methanol solution (50 ml) for 6 h. The resulting solution was evaporated under vacuum to remove the solvent. The product was collected by filtration, washed several times with methanol and recrystallized from hot methanol. The recrystallized product was dried under vacuum.

Synthesis of complexes

A methanolic (50 ml) solution of Schiff base (0.002 mol) was mixed with metal chloride or nitrate or acetate (0.002 mol) in methanol (50 ml) solution keeping metal–ligand ratio 1:1. The mixture was refluxed for 4 h. The solid product precipitated on cooling was collected by filtration and washed with hot methanol until the washing becomes colorless. The product was dried in vacuum over $CaCl_2$. All the metal complexes are colored and stable to air and moisture. The elemental analysis data, color, percentage of metal and molecular weight of Schiff base (A1E) and its metal complexes (A1E–Zn, A1E–Cd, A1E–Ni, A1E–Cu, and A1E–Fe) are given in Table 1.

Results and discussions

The condensation reaction of 3-ethoxy salicylaldehyde with 3,4-(methylenedioxy)aniline in a 1:1 M ratio yields 2-((E)-(benzo[d][1,3]dioxol-6-ylimino)methyl)-6-ethoxyphenol which further react with the metal salts [$Zn(NO_3)_2 6H_2O$, $Cd(CH_3COO)_2 2H_2O$, $Ni(CH_3COO)_2 4H_2O$, $CuCl_2 2H_2O$, $FeCl_3 6H_2O$] in metal–ligand ratio 1:1 yielded the corresponding complexes. The general reaction

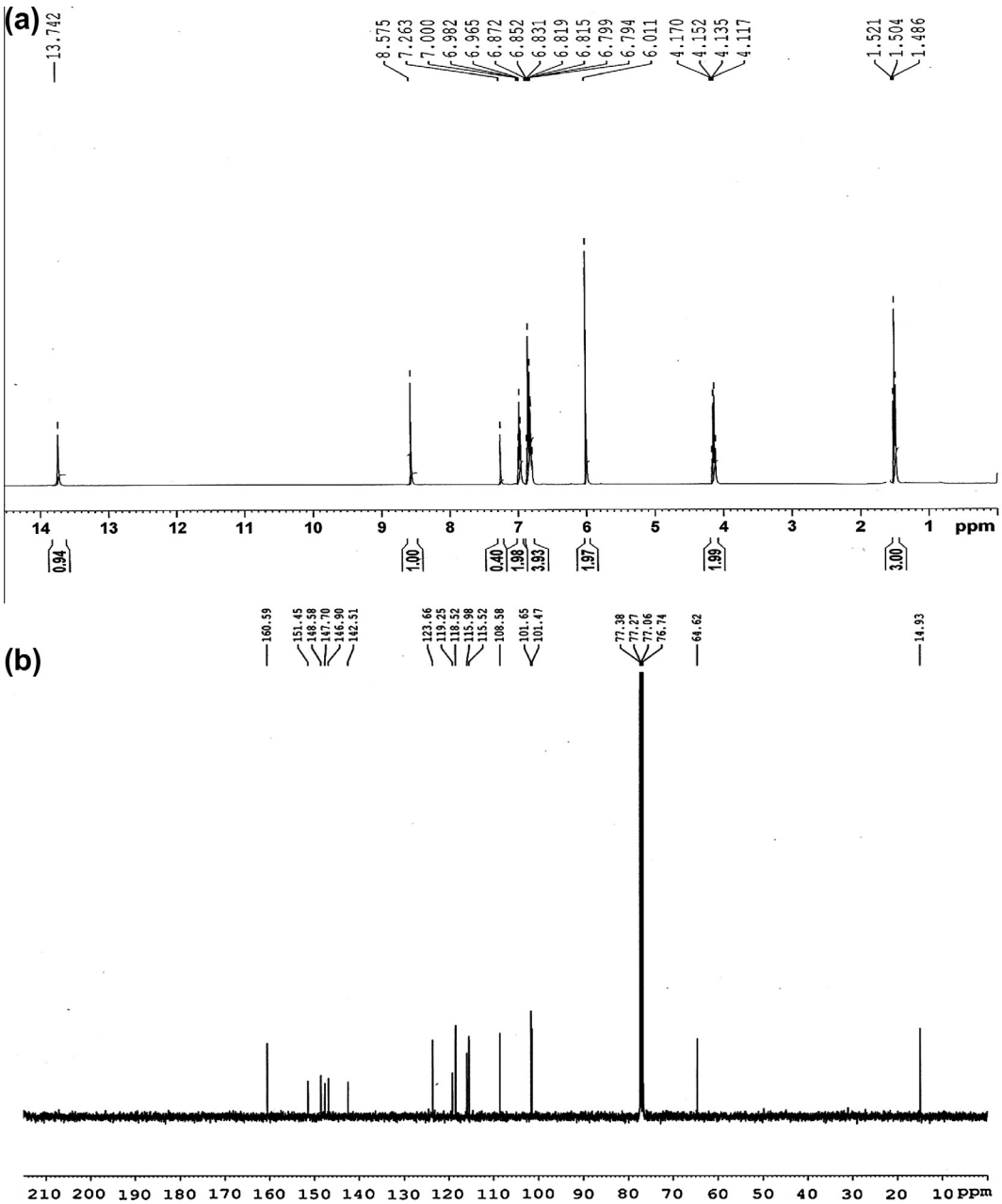


Fig. 2. (a) ^1H NMR and (b) ^{13}C NMR spectra of Schiff base ligand (A1E).

performed in synthesis of the title compound and its metal complexes are shown in the following scheme (Scheme 1).

Physical properties

Elemental analysis

The elemental analysis results are agree with the calculated values (Table 1) showing that the complexes have 1:1 metal/ligand ratios and the Schiff base ligand is formed by the condensation of 0.02mol of 3,4-(methylenedioxy)aniline with 0.02mol of 3-ethoxy salicylaldehyde.

UV–Vis spectra, molar conductance of ligand and its complexes

UV–Vis spectra provide the most detailed information about the electronic structure of a compound. The UV–Vis spectra of the ligand and all the complexes were recorded in $CHCl_3$ at room temperature. The UV–Vis spectrum of the Schiff base ligand (A1E) exhibits two bands at 266 nm and 402 nm attributed to π–π^* and n–π^* transition within the Schiff base ligand. In the spectra of the complexes, the band at 266 nm remains as such, in agreement with the π–π^* transition of the Schiff base ligand. The band observed at 402 nm in the spectrum of the free ligand (A1E) is red shifted to 414–453 nm in complexes in the form of ligand to metal charge transfer (LMCT) transition. The spectra of the entire complexes showed intense band at 414–453 nm, which could be assigned to the charge transfer of ligand–metal charge transfer [25]. Since it is masked by the high-intensity charge transfer transitions, the d–d transition could not be observed in the visible region for complexes with aromatic imines [26]. The UV–Vis spectral data, melting point of the ligand and their complexes are given in Table 2.

The observed molar conductance of the complexes in chloroform (Table 2) for $\sim 10^{-3}$M solutions at room temperature are consistent with the non-electrolytic [27] nature of the complexes due to no counter ions in the proposed structure of the Schiff base

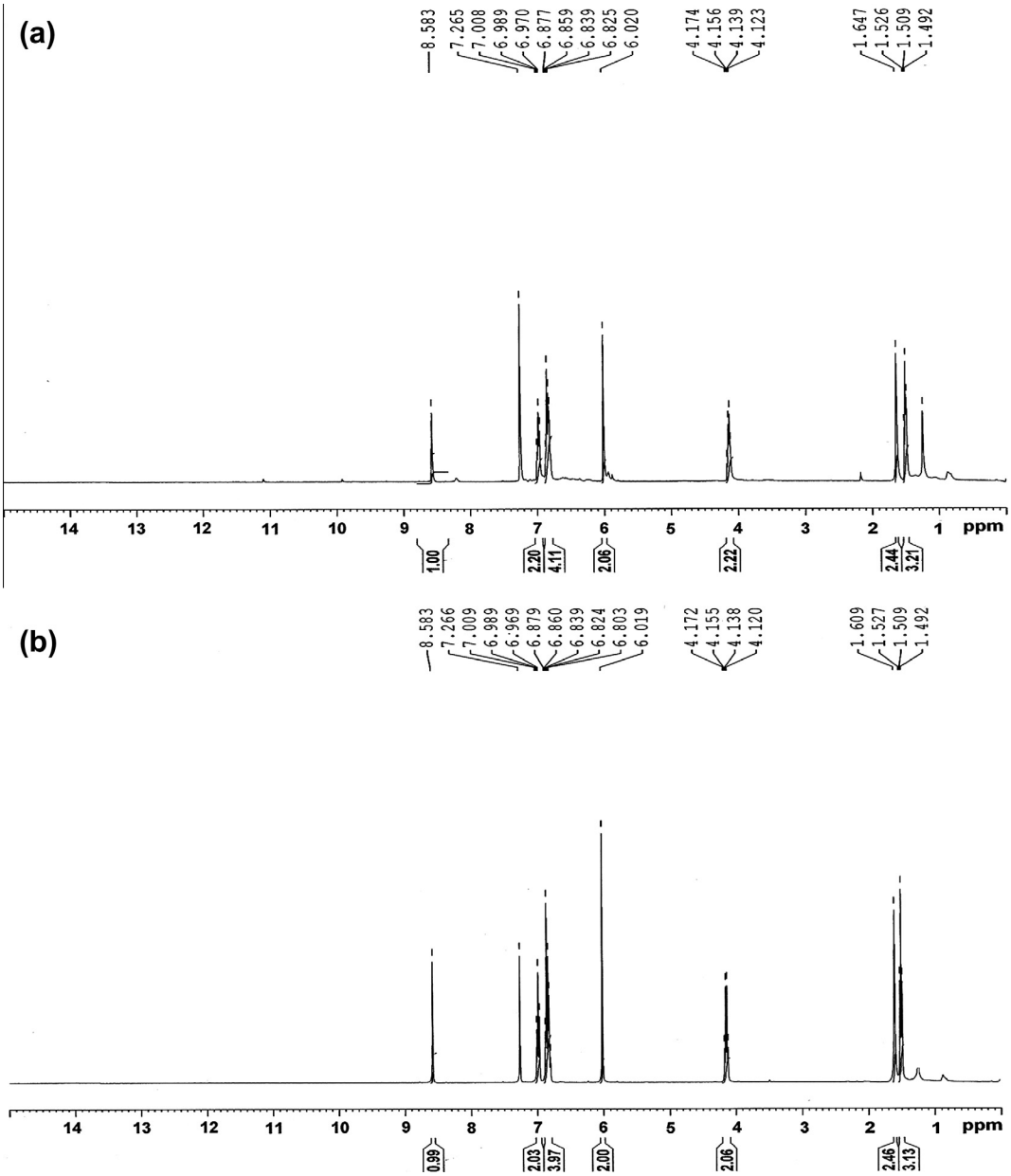


Fig. 3. ^{1}H NMR spectra of Schiff base metal complexes (a) A1E–Zn and (b) A1E–Cd.

metal complexes. From the electronic spectra and molar conductance results, A1E–Zn, A1E–Cd, A1E–Ni, A1E–Cu complexes are found to be tetrahedral structure and A1E–Fe is in octahedral structure (Scheme 1).

Table 5
Mass spectral data of Schiff base metal complexes.

Ligand/complexes	Calculated *m*/*z*	Found *m*/*z*	Peak assignment
A1E	285.29	285.68	Ligand
[A1E–Zn(NO_3)(H_2O)] H_2O	447.71	448.86	[M + 1]
[A1E–Cd($COOCH_3$)(H_2O)]H_2O	491.77	492.78	[M + 1]
[A1E–Ni($COOCH_3$)(H_2O)]3H_2O	474.08	474.27	[M]
[A1E–Cu(Cl) (H_2O)] H_2O	419.31	420.89	[M + 1]
[A1E–Fe(Cl_2)2H_2O]4H_2O	519.13	519.29	[M]

IR Spectra

The IR spectra of the complexes are compared with that of the free ligand to determine the changes that might have taken place during complexation (Fig. 1). IR spectra of the ligand exhibit ν(C═N) vibration at 1629 cm^{-1}. The absorption bands at 3066 cm^{-1}, 2976 cm^{-1} and 2883 cm^{-1} is attributed to aromatic ν(C—H), aliphatic ν_{asym}(C—H), and ν_{sym}(C—H) respectively. A sharp band observed at 931 cm^{-1} assigned due to ν(—O—CH_2—O—)methylenedioxy moiety [28], medium to sharp band appeared at 1248 cm^{-1} [29] is due to ν(C—OH) stretching vibration of phenol. This ν(C—OH) stretching vibration of phenol shifted to ±1–5 cm^{-1} on complexation, which indicates that phenolic group (OH) involved in the complex formation.

All the metal complexes show a broad band at 3446 cm^{-1} (A1E–Cu), 3407 cm^{-1}(A1E–Ni), 3446 cm^{-1}(A1E–Zn), 3432 cm^{-1}

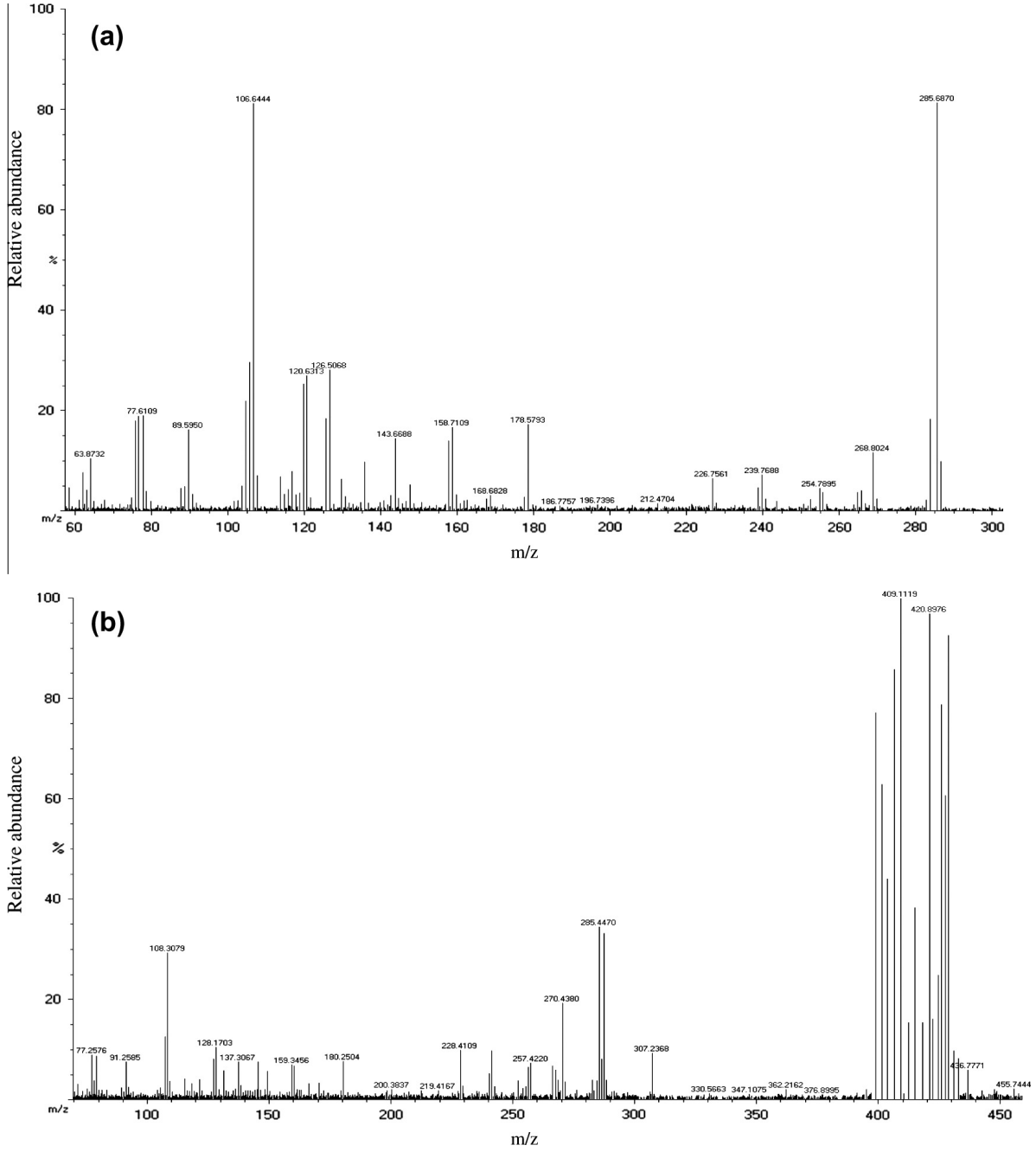


Fig. 4. Mass spectra of (a) Schiff base (A1E) and (b) metal complex (A1E–Cu).

(A1E–Cd), and 3433 cm^{-1}(A1E–Fe), may be due to ν(OH) of water molecule. The band at 1629 cm^{-1} due to azomethine group of Schiff base shifted to ±1–28 cm^{-1} [1601 cm^{-1}(A1E–Cu), 1603 cm^{-1}(A1E–Ni), 1635 cm^{-1}(A1E–Zn), 1630 cm^{-1}(A1E–Cd), 1614 cm^{-1} (A1E–Fe)] on complexation suggesting the coordination of azomethine nitrogen with the metal atoms. This shifting can be explained by the donation of electron from lone pair of azomethine nitrogen to the empty d-orbital of the transition metal atom. However, shifting of band for azomethine and phenolic group to both higher and lower frequencies have been well documented in literature [30]. Moreover A1E–Cd and A1E–Ni complexes showed the coordination of acetato group by the appearance of new bands due to ν_{asym}(COO), and ν_{sym}(COO) at 1563–1588 $cm^{-1}$and 1338–1342 cm^{-1}respectively [31] and A1E–Zn complex shows three new bands at 1460 cm^{-1}, 1385 cm^{-1} and 1087 cm^{-1} due to the coordination of nitrato group in the coordination complex [32]. Furthermore, new band appeared at the lower frequency region; 614 cm^{-1}(A1E–Zn), 625 cm^{-1} (A1E–Cd), 619 cm^{-1}(A1E–Ni), 510 cm^{-1}(A1E–Cu), 575 cm^{-1} (A1E–Fe) and 508 cm^{-1} (A1E–Zn), 549 cm^{-1} (A1E–Cd), 503 cm^{-1} (A1E–Ni), 475 cm^{-1} (A1E–Cu), 482 cm^{-1} (A1E–Fe) is due to the metal nitrogen (M–N) and metal oxygen (M–O) coordination respectively. Therefore from the above details it is concluded that the ligand acts as a bidentate and coordinate to the empty d-orbital of metal ion through the azomethine nitrogen and phenolic oxygen atom. The IR spectral details are presented in Table 3.

^{1}H and ^{13}C NMR spectra

NMR spectroscopy is a useful tool to establish the structure and nature of many Schiff bases and their metal complexes. The ^{1}H NMR spectra of Schiff base (A1E) and its diamagnetic complexes A1E–Zn and A1E–Cd were recorded in $CDCl_3$, using tetramethylsilane (TMS) as internal standard and are presented in Table 4. ^{1}H NMR spectrum of ligand (A1E) showed signal at δ1.504 ppm corresponding to CH_3 proton. A sharp signal observed at δ4.135 ppm is due to CH_2 proton and a sharp singlet appeared at δ6.011 ppm is attributed to methylene dioxy moiety (—O—CH_2—O—). The multiple signals observed between δ6.794 and δ7.00 ppm are related to the aromatic protons. The peak at δ8.575 ppm is assigned to azomethine (—HC═N—) with an integration corresponding to 1 proton in the ligand. The sharp singlet observed at δ13.742 ppm is due to phenolic proton of the ligand [33]. ^{1}H NMR spectra of the complexes (A1E–Zn and A1E–Cd) was also recorded in $CDCl_3$. In the ^{1}H NMR spectra of the Zinc (II) and Cadmium (II) complexes, the signal for imine proton in the free ligand at δ8.575 ppm is shifted to downfield in the complexes indicates the formation of metal nitrogen bond. The signal at δ13.742 ppm in ligand is disappeared in metal complexes A1E–Zn and A1E–Cd confirms that the phenolic proton (—OH) is involved in coordination with Zn (II) and Cd (II). Thus the ^{1}H NMR spectral observations supported the bidentate nature of ligand in coordination with metal salts.

^{13}C NMR spectra of the Schiff base (A1E) and its two complexes A1E–Zn, A1E–Cd were recorded in $CDCl_3$ solution, using tetramethylsilane (TMS) as internal standard. ^{13}C NMR spectrum of ligand displayed characteristic signals at δ14.93 ppm, δ64.62 ppm, δ101.47 ppm, δ101.65–151.45 ppm and δ160.59 ppm are due to the —CH_3, —CH_2, —O—CH_2—O—, aromatic carbons and azomethine (—HC═N—) carbon respectively [34]. The ^{13}C NMR spectra of complexes A1E–Zn and A1E–Cd shows no appreciable changes compared with ligand. The spectral data are presented in Table 4. The ^{1}H NMR and ^{13}C NMR spectra of ligand (A1E) and ^{1}H NMR spectra of A1E–Zn and A1E–Cd are given in Figs. 2 and 3.

Mass spectra

The mass spectra of the ligand and its transition metal complexes are recorded at ambient temperature. Mass spectra are a useful technique to interpret the stoichiometric composition of ligand and its complexes. The Schiff base ligand (A1E) shows a molecular ion peak at *m*/*z* 285.68, which is very close to the calculated values of *m*/*z* 285.29. The peak assignment in mass spectra observed for ligand and the metal complexes are presented in Table 5. The mass spectral evidence reveals that the metal complexes have equimolar ratio of metal and ligand, as prescribed in Scheme 1. A representative mass spectrum is given in Fig. 4.

Thermal analysis

Thermo gravimetric analysis (TGA) and differential thermal analysis (DTA) are useful technique to determine the thermal stability of the metal complexes. In the present study, heating rates were suitably controlled at 20 °C/min, under nitrogen atmosphere and the loss in weight was measured up to 1000 °C. The stages of decomposition temperature range, decomposition product and weight loss percentage of complexes are given in Table 6. The first step at 30–125 °C with a weight loss (found) of 4.00% for A1E–Zn, 3.70% for A1E–Cd, 11.50% for A1E–Ni, 4.40% for A1E–Cu and 13.80% for A1E–Fe is attributed to lattice water molecule. The second step weight loss at 125–280 °C corresponds to removal of coordinated water molecule from the metal complexes of A1E–Zn, A1E–Cd, A1E–Ni, A1E–Cu, and A1E–Fe. Moreover, the third step observed

Table 6
Thermal analysis of metal complexes.

Complexes	TG range in °C	Mass loss in % Found(calc)	Assignment
[A1E–Zn(NO_3)(H_2O)] H_2O	30–210	4.00(4.02)	Loss of 1 lattice H_2O molecule
	210–250	4.00(4.02)	Loss of 1 coordinated H_2O molecule
	275–1000	63.70(63.72)	Decomposition of the ligand
[A1E–Cd($COOCH_3$)(H_2O)]H_2O	50–225	3.70 (3.66)	Loss of 1 lattice H_2O molecule
	225–275	3.70(3.66)	Loss of 1 coordinated H_2O molecule
	300–1000	58.00 (58.02)	Decomposition of the ligand
[A1E–Ni($COOCH_3$)(H_2O)]3H_2O	30–225	11.50(11.39)	Loss of 3 lattice H_2O molecule
	225–280	3.80 (3.79)	Loss of 1 coordinated H_2O molecule
	310–1000	60.20 (60.17)	Decomposition of the ligand
[A1E–Cu(Cl) (H_2O)] H_2O	50–125	4.40(4.29)	Loss of 1 lattice H_2O molecule
	125–225	4.40(4.29)	Loss of 1 coordinated H_2O molecule
	325–1000	68(68.03)	Decomposition of the ligand
[A1E–Fe(Cl_2)2H_2O]4H_2O	50–125	13.80(13.86)	Loss of 4 lattice H_2O molecule
	125–225	7.00(6.93)	Loss of 2 coordinated H_2O molecule
	250–1000	55.00(54.95)	Decomposition of the ligand

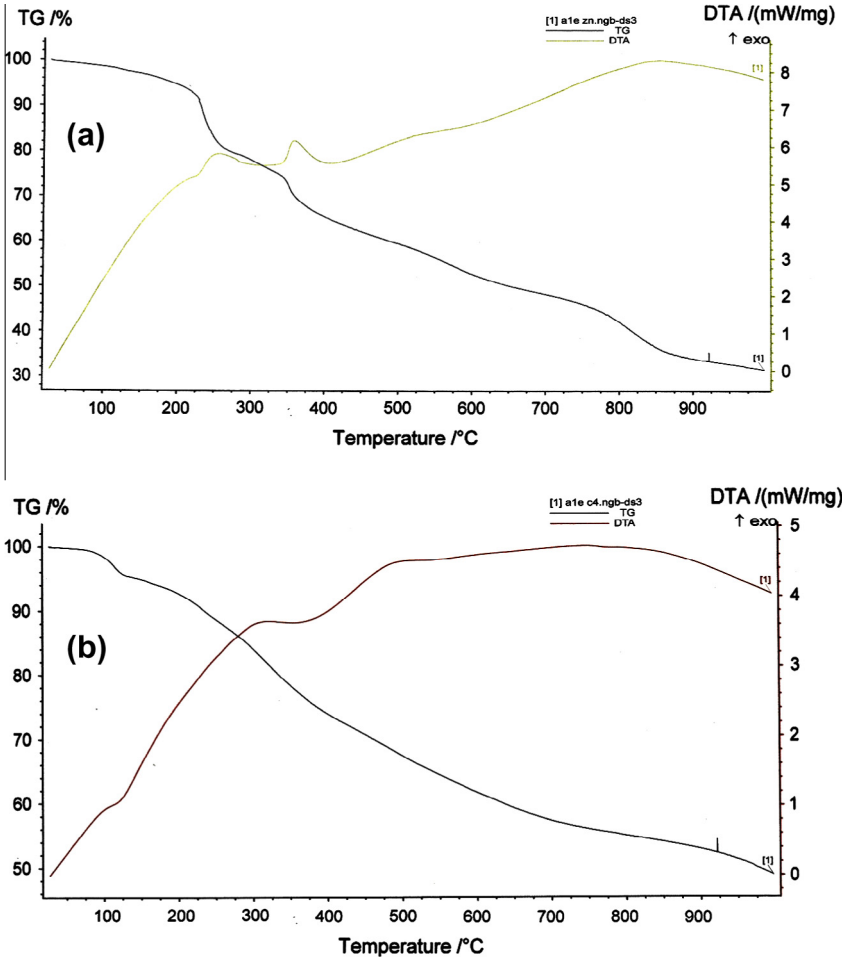


Fig. 5. Thermo gravimetric analysis of (a) A1E–Zn and (b) A1E–Cu Schiff base complexes.

at 250–1000 °C involved the ligand decomposition. The results obtained from thermal analysis suggest that all the complexes are more stable and also nonvolatile. A representative TG/DTA diagram is given in Fig. 5.

Antibacterial activity

The *in vitro* antibacterial activities of the ligand and its complexes were screened separately against five human pathogenic bacteria (*E. coli, S. aureus, E. faecalis* sp., *P. florescens* sp., and *Klebsiella* sp.,) by well diffusion method using ampicillin as standard. The susceptibility of the strain of bacteria towards the compounds is judged by measuring the size of inhibition diameter (Fig. 6). The inhibition zones of bacteria in the compounds are given in Table 7. The obtained results suggest that the metal complexes are more active than the ligand, as well as more active than the standard against all the bacteria tested. A1E–Ni, A1E–Zn and A1E–Fe are found to have moderate activity towards the bacteria

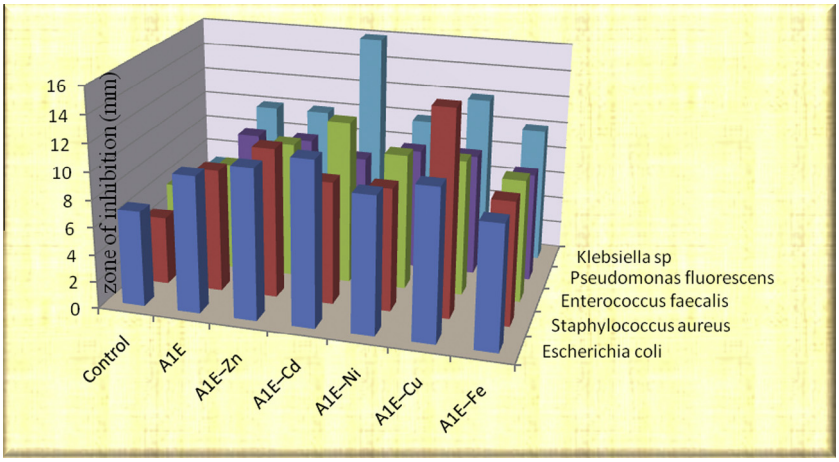


Fig. 6. Antibacterial activities of Schiff base metal complexes.

Table 7
Antimicrobial activity and antioxidant of Schiff base metal complexes.

Compound	Anti-Bacterial Activity Zone of inhibition (mm)					Anti fungal activity Zone of inhibition (mm)			Antioxidant Acitivity (%)
	a	b	c	d	e	f	g	h	
Control	**7**	5	6	5	5	5	6	1	
A1E	10	9	8	9	10	3	1	2	25.7
A1E–Zn	11	11	10	9	10	3	2	2	76.4
A1E–Cd	12	9	12	8	16	2	1	1	68.5
A1E–Ni	10	9	10	9	10	4	5	4	32.8
A1E–Cu	11	15	10	9	12	2	1	1	45.4
A1E–Fe	9	9	9	8	10	1	1	1	40.0

a – *Escherichia coli*, b – *Staphylococcus aureus*, c – *Enterococcus faecalis*, d – *Pseudomonas fluorescens*, e – *Klebsiella sp.* f – *Candida albicans*, g – *Fusarium* sp. h – *Trichosporon* sp.

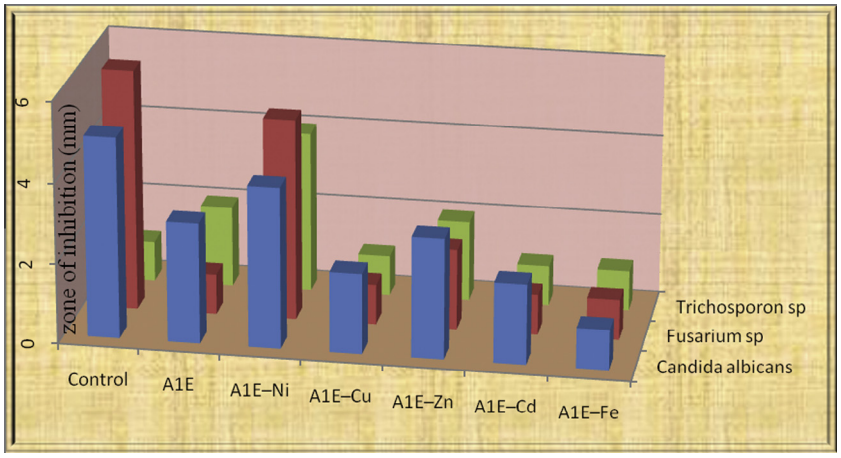


Fig. 7. Antifungal activities of Schiff base metal complexes.

tested whereas, A1E–Cd posses' higher activity towards *Klebsiella sp*., *E. faecalis sp., E. coli* and *S. aureus*, than the other metal complexes. *S. aureus* and *Klebsiella sp*., have higher activity for A1E–Cu.

The variation in the antimicrobial activity of different metal complexes against different microorganisms depends on their impermeability of the cell or the differences in ribosome in microbial cell [35]. Chelation reduces the polarity of the metal ion in the complexes considerably, mainly due to the partial sharing of its positive charge with the donor group. The possible electron delocalization over the chelate ring system in turn increases the hydrophobic character of the metal chelate thus favoring its permeation through lipoid layer of microorganism. Also the normal cell process may be affected by the formation of hydrogen bond through the azomethine nitrogen atom with the active centers of cell constituent [36]. Thus lipophilicity is an important factor controlling antimicrobial activity [37].

Antifungal activity

Antifungal activities of the synthesized compounds were tested against *C. albicans, Fusarium sp*., and *Trichosporon sp*., by well diffusion method. The growth inhibition zone of the compounds against microorganism are summarized in Table 7. The experimental results were compared with the standard antifungal drug streptomycin at the same concentration. All the metal complexes exhibited greater antifungal activity against *C. albieans*. However, they show

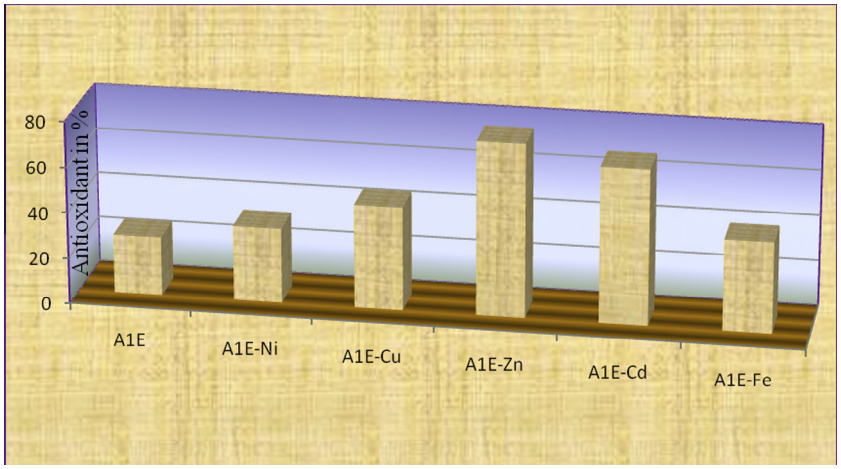


Fig. 8. Antioxidant activities of Schiff base metal complexes.

lesser activity against *C. albieans* and *Fusarium sp*., than the standard drug streptomycin. The complex A1E–Ni is more effective against *C. albieans, Fusarium sp*., and *Trichosporon sp*., whereas, A1E–Fe is less effective against all the three fungal strains (Fig. 7). From the result it has been observed that the fungal activity depends upon the nature of metal ion.

Antioxidant activity

The percentage antioxidant activity of the ligand and its metal complexes are given in Table 7. The DPPH$^{\cdot}$ radical was scavenged by antioxidants through the donation of hydrogen forming the reduced DPPH-H$^{\cdot}$. The color of the DPPH is changed from purple to yellow after reduction, which can be quantified by its decrease of absorbance at wavelength 517 nm. From the experimental results, the enhanced antioxidant activity is observed for all the metal complexes than the free ligand. Among all the metal complexes, A1E–Zn and A1E–Cd showed more antioxidant activity. The values imply that the activity of the compounds follows the order A1E–Zn > A1E–Cd > A1E–Cu > A1E–Fe > A1E–Ni > A1E (Fig. 8).

Conclusion

We synthesized Schiff base [2-((E)-(benzo[d][1,3]dioxol-6-ylimino)methyl)-6-ethoxyphenol] metal complexes and determined their structure and physical properties. The spectral studies suggest the bidentate nature of ligand, which coordinate with all the metal ions [Zn (II), Cd(II), Ni (II), Cu (II), and Fe(III)] through imine nitrogen and phenolic oxygen. Thermal analysis confirms that the metal complexes posses lattice as well as coordinated water molecules. The results indicate that Zn (II), Cd(II), Ni (II), and Cu (II) complexes are in tetrahedral structure and Fe(III) is in octahedral structure. The ligand and their metal complexes are tested for their antibacterial and antifungal inhibition potential against some pathogens reveals that, metal complexes are more biologically active than free ligand. The percentage activity of antioxidant also more for complexes than the ligand.

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