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Original research Articles

Transition metal complexes of 4-aminobenzenesulfonamide 1,3-benzodioxole-5-carbaldehyde: Synthesis, characterization and biological activities

ABSTRACT

Cu(II), Zn(II), Ni(II) and Cd(II) complexes with Schiff base ligand derived from piperonal and sulfanilamide have been synthesized and characterized by elemental (C, H and N) analysis, UV-Vis, IR, ^1H and ^{13}C NMR, mass spectra, thermal analysis (TG/DTA) and molar conductance measurements. The spectral data suggest that the coordination of metal ion with ligand is only through imine nitrogen ($-\text{CH}=\text{N}-$) as monodentate manner. Thermal analysis indicates the presence of lattice and coordinated water molecules in the complexes. Mass spectral data further support the formula mass and structure of the compounds. Biological activities of all the compounds were evaluated.

Keywords: Sulfanilamide; Piperonal; Schiff base; Metal complexes

1. INTRODUCTION

In coordination chemistry, Schiff bases are familiar chelating agents because of their complexation capability with transition metals [1,2]. Many of the Schiff base complexes were biologically active, due to this activity it increases to do the research in the field of bioinorganic chemistry [3,4]. Schiff base ligands receive significant attention due to their interesting properties viz., catalytic activity, selective recognition of metal ions, photochromic properties, antifungal and antibacterial activity [5-6].

25 Sulfanilamide is a well known simplest molecule that belongs to sulfa drugs,
26 which are synthetic antimicrobial agents that contain sulfonamide group.
27 Sulfonilamides were effectively used as chemotherapeutic agents for the
28 prevention and cure of bacterial infections in human [7]. The metal complexes,
29 derived from sulfa drugs have gained valuable importance due to their
30 pronounced biological activity [8]. In literature several reports are available on Schiff
31 base metal complexes derived from sulfa drugs [9–10].

32 The choice of piperonal for aldehyde moiety in this preparation stemmed
33 from the fact that many compounds containing the 3,4-methylenedioxy group
34 have good biological activity [11, 12]. The biological activity of the ligands
35 derived from 3,4-(methylenedioxy)aniline with 3-ethoxysalicylaldehyde and 5-
36 bromosalicylaldehyde and their metal complexes was reported in our previous
37 paper [13, 14]. As a continuation of our interest in the biological activity of
38 complexes containing methylenedioxy moiety, here we synthesized Cu(II), Zn(II),
39 Ni(II) and Cd(II) complexes of Schiff base derived by condensing sulfanilamide
40 with piperonal. All the compounds were characterized by spectral (UV-Vis, IR, ^1H ,
41 ^{13}C NMR, mass) and thermal analysis. Biological activities of the ligand and its
42 metal complexes were also reported.

43 2. MATERIALS AND INSTRUMENTATION

44 All chemicals used in the present work viz., sulfanilamide, piperonal,
45 $\text{Cu}(\text{NO}_3)_2 \cdot 3\text{H}_2\text{O}$, $\text{Zn}(\text{NO}_3)_2 \cdot 6\text{H}_2\text{O}$, $\text{Ni}(\text{CH}_3\text{COO})_2 \cdot 4\text{H}_2\text{O}$ and $\text{Cd}(\text{CH}_3\text{COO})_2 \cdot 2\text{H}_2\text{O}$
46 were of analar grade (Sigma - Aldrich). Ethanol and methanol were used after
47 distillation. The remaining reagents were procured from commercial sources.

48 2.1. Instrumentation

Carbon, hydrogen and nitrogen (C, H & N) analysis were performed by Thermofinnigan elemental analyzer and the metal content was determined by Perkin Elmer 5000 atomic absorption spectrophotometer. UV-Visible spectra of the ligand and metal complexes were recorded in the range of 200–800 nm using Shimadzu UV-1650 spectrophotometer. Infrared spectra were recorded on Avatar 330 FT-IR, in the range of 4000–400 cm^{-1} using KBr pellets. ^1H and ^{13}C NMR spectra (at room temperature) were recorded on a Bruker Magnet System in 400 MHz/54 mm (Ultra Shield Plus) using DMSO as a solvent and TMS as internal standard. Thermal analysis (TG/DTA) was carried out using, SDT Q600 thermal analyzer in the temperature range 20–1000 $^{\circ}\text{C}$, in nitrogen atmosphere at a heating rate of 20 $^{\circ}\text{C min}^{-1}$. The mass spectra were recorded by using JEOL GCMATE II GC-MS. Melting point was measured using Gallenkamp melting point apparatus. Molar conductance of the Schiff base ligand and its transition metal complexes was determined in DMSO at room temperature using a CMD 750 WPA conductivity meter.

Synthesis of 4-aminobenzenesulfonamide 1,3-benzodioxole-5-carbaldehyde (L)

The Schiff base ligand was synthesized by refluxing piperonal (0.02 mol) with sulfanilamide (0.02 mol) in methanol (50 mL) for 6 h. the solvent was removed by evaporation in vacuum. The resultant product was filtered, dried, washed several times with hot methanol and recrystallized. The recrystallized product was dried under vacuum over anhydrous CaCl_2 . Yellow colour solid. Yield 80 %. **m.p. 182 - 184 $^{\circ}\text{C}$** . Anal. Calc. for $\text{C}_{14}\text{H}_{12}\text{N}_2\text{SO}_4$ (%): C (55.31), H (3.96), N (9.19); found (%): C (54.89), H (3.83), N (9.33). MW: 304.71. $\text{K } (\Omega^{-1} \text{ cm}^2 \text{ mol}^{-1})$: 4.76.

73 IR (KBr, cm^{-1}): 3293 $\nu_{\text{sym}}(\text{NH}_2)$, 1575 $\nu_{\text{bend}}(\text{NH}_2)$, 1610 $\nu(\text{C}=\text{N})$, 1331
 74 $\nu_{\text{sym}}(\text{SO}_2)$, 1153 $\nu_{\text{asym}}(\text{SO}_2)$, 928 $\nu(-\text{O}-\text{CH}_2-\text{O})$.

75 2.2. Synthesis of complexes

76 A methanolic solution of ligand (0.002 mol) was mixed with metal nitrate or
 77 acetate (0.002 mol) keeping metal ligand ratio 1:1. The mixture was refluxed for 4
 78 h. The solid product precipitated on cooling was collected by filtration and washed
 79 with hot methanol until the washings become colourless. The product was dried
 80 in vacuum over CaCl_2 . All metal complexes are coloured and stable to air and
 81 moisture.

82 4-Aminobenzenesulfonamide 1,3-benzodioxole-5-carbaldehyde copper
 83 complex (L-Cu): Brown colour solid. Yield 53 %. m.p. 158 - 160°C. Anal. Calc.
 84 for $\text{C}_{14}\text{H}_{18}\text{N}_3\text{CuSO}_9$ (%): C (35.93), H (3.87), N (8.97); found (%): C (35.96), H
 85 (3.25), N (8.92). MW: 484.30. $K (\Omega^{-1} \text{ cm}^2 \text{ mol}^{-1})$: 3.50. IR (KBr, cm^{-1}): 3293
 86 $\nu_{\text{sym}}(\text{NH}_2)$, 1576 $\nu_{\text{bend}}(\text{NH}_2)$, 1619 $\nu(\text{C}=\text{N})$, 1332 $\nu_{\text{sym}}(\text{SO}_2)$, 1154 $\nu_{\text{asym}}(\text{SO}_2)$, 928
 87 $\nu(-\text{O}-\text{CH}_2-\text{O})$, 3448 $\nu(\text{OH})$.

88 4-Aminobenzenesulfonamide 1,3-benzodioxole-5-carbaldehyde zinc
 89 complex (L-Zn): Grey colour solid. Yield 58 %. m.p. >300 °C. Anal. Calc.
 90 for $\text{C}_{14}\text{H}_{18}\text{N}_3\text{ZnSO}_{10}$ (%): C (34.62), H (3.73), N (8.65); found (%): C (34.48), H
 91 (3.62), N (8.77). MW: 486.14. $K (\Omega^{-1} \text{ cm}^2 \text{ mol}^{-1})$: 2.53. IR (KBr, cm^{-1}): 3293
 92 $\nu_{\text{sym}}(\text{NH}_2)$, 1576 $\nu_{\text{bend}}(\text{NH}_2)$, 1627 $\nu(\text{C}=\text{N})$, 1331 $\nu_{\text{sym}}(\text{SO}_2)$, 1153 $\nu_{\text{asym}}(\text{SO}_2)$, 929
 93 $\nu(-\text{O}-\text{CH}_2-\text{O})$, 3448 $\nu(\text{OH})$.

94 4-Aminobenzenesulfonamide 1,3-benzodioxole-5-carbaldehyde nickel complex
 95 (L-Ni): Green colour solid. Yield 62 %. m.p. 234 - 236 °C. Anal. Calc. for

96 $C_{16}H_{21}N_2NiSO_9$ (%): C (40.27), H (4.43), N (5.87); found (%): C (39.09), H
 97 (4.62), N (6.32). MW: 476.48. $K (\Omega^{-1} cm^2 mol^{-1})$: 2.16. IR (KBr, cm^{-1}): 3293
 98 $\nu_{sym}(NH_2)$, 1575 $\nu_{bend}(NH_2)$, 1632 $\nu(C=N)$, 1331 $\nu_{sym}(SO_2)$, 1153 $\nu_{asym}(SO_2)$, 928
 99 $\nu(-O-CH_2-O)$, 3444 $\nu(OH)$.

100 4-Aminobenzenesulfonamide 1,3-benzodioxole-5-carbaldehyde cadmium
 101 complex (L-Cd): Grey colour solid. Yield 69 %. m.p. >300 °C. Anal. Calc. for
 102 $C_{16}H_{17}N_2CdSO_7$ (%): C (38.92), H (3.47), N (5.67); found (%): C (38.68), H
 103 (3.27), N (5.65). MW: 494.17. $K (\Omega^{-1} cm^2 mol^{-1})$: 2.57. IR (KBr, cm^{-1}): 3294
 104 $\nu_{sym}(NH_2)$, 1577 $\nu_{bend}(NH_2)$, 1621 $\nu(C=N)$, 1331 $\nu_{sym}(SO_2)$, 1154 $\nu_{asym}(SO_2)$, 932
 105 $\nu(-O-CH_2-O)$, 3496 $\nu(OH)$.

106 2.3. Biological activities

107 The antibacterial activity of our synthesized complexes were determined
 108 against five bacterial strains viz., *Escherichia coli* (*E. coli*), *Staphylococcus aureus*
 109 (*S. aureus*), *Enterococcus faecalis* (*E. faecalis*), *Pseudomonas fluorescens* (*P.*
 110 *fluorescens*) and *Klebsiella sp.* Ampicillin was used as reference antibacterial agent.
 111 *In vitro* antibacterial activity was determined by agar well diffusion method [15]
 112 as described in our previous work [14].

113 Antifungal activity of the ligand (L) and its metal complexes was screened
 114 against three fungi viz., *Candida albicans* (*C. albicans*), *Fusarium sp.* and
 115 *Trichosporon sp.*, according to the guidelines in the National Committee for
 116 Clinical Laboratory Standards (NCCLS) approved standard document M27-A2
 117 [16]. Streptomycin was used as reference antifungal agent. MIC of the
 118 synthesized compounds was determined by serial dilution tube method as
 119 mentioned in our previous work [14].

120 The scavenging ability of the stable 2,2'-diphenyl-1-picrylhydrazyl radical
121 (DPPH[•]) is used intensively in evaluation of antioxidant activity of the compounds,
122 which was determined spectrophotometrically [17].

123 3. RESULTS AND DISCUSSION

124 The condensation reaction of piperonal with sulfanilamide in 1:1 molar ratio
125 yields Schiff base which on further reaction with metal salts Cu(NO₃)₂·3H₂O,
126 Zn(NO₃)₂·6H₂O, Ni(CH₃COO)₂·4H₂O and Cd(CH₃COO)₂·2H₂O in metal ligand
127 ratio 1:1 yielded the corresponding complexes. The general reactions performed
128 in synthesis of ligand and its metal complexes are depicted in Scheme 1.

129 3.1. Physical properties

130 The elemental analysis results agree with the calculated values.
131 Complexes have 1:1 metal/ligand ratio and the ligand is formed by the
132 condensation of piperonal and sulfanilamide.

133 The observed molar conductance of the complexes in DMSO solutions (10⁻³
134 M) at room temperature are consistent with the non-electrolytic [10] nature of
135 the complexes due to no counter ions in the proposed structure of Schiff base
136 metal complexes.

137 3.2. UV-Vis spectra

138 UV-Vis spectra provide information about the electronic structure of ligand
139 and its metal complexes. The spectra were recorded in DMSO at room
140 temperature. The UV-Vis spectrum of the ligand (L) exhibits two bands at 279.5
141 and 306.5 nm attributed to π - π^* and n- π^* transition within the ligand. The spectra
142 of complexes remain unaltered in π - π^* band. Meanwhile n- π^* band is blue shifted

143 between 266–301 nm region due to the polarization within the $>C=N$
144 chromophore which caused by the formation of covalent metal-nitrogen band
145 [18]. Obviously the above observations confirm the transfer of ligand to metal
146 charge transition (LMCT) [2].

147 3.3. FT-IR spectra

148 The IR spectra of the complexes are compared with that of free ligand to
149 determine the changes that might have taken place during complexation. IR
150 spectrum of the ligand exhibit $\nu(C=N)$ vibration at 1610 cm^{-1} . The absorption
151 bands at 3293 and 1575 cm^{-1} are attributed to NH_2 stretching and bending
152 vibration, respectively. A sharp band observed at 928 cm^{-1} is due to
153 methylenedioxy moiety ($-O-CH_2-O-$) [19]. Sharp bands observed at 1331 and
154 1153 cm^{-1} are due to SO_2 stretching vibration, which remains unaltered in all the
155 complexes, indicate the non-involvement of SO_2 and NH_2 groups in coordination
156 [19].

157 All metal complexes show a broad band at 3448 (L-Cu), 3448 (L-Zn),
158 3444 (L-Ni) and 3496 cm^{-1} (L-Cd), may be due to $\nu(OH)$ of water. A band at
159 1610 cm^{-1} due to azomethine group in ligand has been shifted between 9 and
160 22 cm^{-1} higher frequency [1619 (L-Cu), 1627 (L-Zn), 1632 (L-Ni) and 1621 cm^{-1}
161 (L-Cd)] on complexation suggesting the coordination of azomethine nitrogen with
162 the metal atom. This shifting can be explained by the donation of electron from
163 lone pair of azomethine nitrogen to the empty d -orbital of the transition metal
164 atom. However, the shifting of band due to azomethine group to higher
165 frequencies is well documented in literature [20]. Moreover, the coordination of
166 acetato group in L-Ni and L-Cd complexes was confirmed by the appearance of

new bands at 1419 and 1272 cm^{-1} , due to $\nu_{\text{sym}}(\text{COO})$ and $\nu_{\text{asym}}(\text{COO})$, respectively. In L-Ni and L-Cd, $\Delta\nu(\text{COO})$ value 147 cm^{-1} suggests the bidentate mode of coordination of acetato group with metal ions [21].

L-Zn and L-Cu complexes show new bands at 1388 and 1098 cm^{-1} are due to $\nu_{\text{sym}}(\text{NO})$ and $\nu_{\text{asym}}(\text{NO})$, respectively. The separation of two NO stretching bands reveal information regarding the mode of coordination of nitrato ion. Indeed, $\Delta\nu(\text{NO})$ value 290 cm^{-1} suggests a bidentate mode of coordination of nitrato ion. Furthermore a new band appears at lower frequency region 472 (L-Cu), 470 (L-Zn), 471 (L-Ni) and 471 cm^{-1} (L-Cd) is due to the metal nitrogen (M–N) coordination, respectively. IR spectra of Schiff base and its metal complexes are shown in Fig. 1.

3.4. ^1H and ^{13}C NMR spectra

^1H NMR spectra of ligand (L) and its diamagnetic complexes (L-Zn and L-Cd) were recorded in DMSO using tetramethyl silane (TMS) as internal standard (Table 1). A representative spectrum is given in Fig. 2. ^1H NMR spectrum of ligand (L) shows a sharp singlet at 6.144 ppm attributed to methylenedioxy moiety ($-\text{O}-\text{CH}_2-\text{O}-$). The multiple signals observed between 7.077 and 7.843 ppm are related to aromatic protons. The peak at 8.525 ppm is assigned to imine proton ($-\text{HC}=\text{N}-$) with an integral value corresponding to one proton in the ligand. The signal appeared at 7.356 ppm with an integral value two is due to $-\text{NH}_2$ proton [22]. However, the signal appeared for imine proton in free ligand at 8.525 ppm is shifted to downfield in Zn(II) and Cd(II) complexes, indicated the formation of metal-nitrogen bond. The signals at 6.144 and 7.356 ppm remains unaltered in metal complexes such as L-Zn and L-Cd which confirms the non-involvement of methylenedioxy as well as amine group in coordination. In L-Cd, a sharp peak

191 obtained at 1.763 ppm indicates the involvement of acetate group in coordination.
192 Thus, with the above observations, we suggest that the ligand is coordinated with
193 metal ion only through azomethine nitrogen and act as monodentate.

194 ^{13}C NMR spectrum of ligand shows signals at 101.83, 106.32–154.37 and
195 161.14 ppm are due to methylenedioxy ($-\text{O}-\text{CH}_2-\text{O}-$), aromatic and azomethine
196 ($-\text{HC}=\text{N}-$) carbons, respectively [23]. The ^{13}C NMR spectrum of complex L-Zn
197 shows no progressive changes with free ligand. In L-Cd, a signal obtained at
198 16.77 ppm, confirms the involvement of acetate group in coordination. The ^{13}C
199 NMR spectral data are presented in Table 1 and a representative spectrum is
200 shown in Fig. 3.

201 3.5. Mass spectra

202 The mass spectra of the ligand and its transition metal complexes were
203 recorded at ambient temperature. The observed molecular ion peaks in the mass
204 spectra of the ligand and its metal complexes have been used to confirm the
205 proposed formula mass (Scheme 1). A representative electron impact mass
206 spectrum is shown in Fig. 4.

207 Mass spectrum of the ligand shows peak at m/z 304.19 is corresponding to
208 molecular ion M. The ligand has fragmented up to 63.51 mass number. The mass
209 spectra of complexes L-Cu, L-Zn, L-Ni and L-Cd show a prominent peak at
210 467.84, 486.87, 476.27 and 495.21 respectively, which are consistent with the
211 molecular mass of the respective metal complexes. The spectral data are
212 listed in Table 2, which prove that the ratio between metal and ligand is 1:1 as
213 described in Scheme 1.

214 3.6. Thermal analysis

215 Thermogravimetric analysis (TG) of transition metal complexes was useful
216 in identification of the status of water molecules in complexes as well as to know
217 the stability of the metal complexes. In the present study, heating rates were
218 controlled at 20 °C min⁻¹ under nitrogen atmosphere and weight loss was
219 measured up to 1000 °C.

220 The Zn(II) and Ni(II) complexes exhibit three stages of decomposition and
221 Cd(II), Cu(II) complexes exhibit two stages of decomposition within the
222 temperature range 20–1000 °C (Fig. 5). In Zn(II) and Ni(II) complexes, first stage
223 decomposition within the temperature range 20–197 °C (mass loss Δ_m = 7.41%
224 found; 7.40% calcd. and 7.56% found; 7.56% calcd.) is attributed to loss of lattice
225 water molecule. The second stage at temperature range 217–250 °C (L-Zn) and
226 170–201 °C (L-Ni) shows weight loss 3.70% (found); 3.70% (calcd.) and 3.78%
227 (found); 3.78% (calcd.), respectively due to removal coordinated water molecules
228 from the coordination sphere. In Cd(II) and Cu(II) complexes, first stage weight
229 loss (3.63% found; 3.64% calcd. and 4.01% found; 4.01% calcd.) at temperature
230 range 20–250 °C and 20–219 °C, respectively is due to loss of coordinated water
231 molecule. Moreover the last step observed in all four complexes at 250–1000
232 °C involved the decomposition of ligand moiety. Thus the thermal analysis
233 results obtained herein are in agreement with the proposed structures in Scheme
234 1 and confirm the stability of complexes (Table 3).

235 3.7. Antibacterial activity

236 The *in vitro* antibacterial activity of the ligand and its complexes was
237 screened separately against five pathogenic bacteria of human such as *E. coli*, *S.*
238 *aureus*, *E. faecalis*, *P. fluorescens* and *Klebsiella* sp. by well diffusion method

239 Ampicillin was used as reference. The susceptibility of bacterial strain towards
240 the compounds is predicted by measuring the inhibition diameter in mm (Fig.
241 6a). The inhibition zones of selected bacteria due to the compounds are given in
242 Table 4. The minimum inhibition concentration (MIC) values of the compounds and
243 reference against the respective bacterial strains were ranging 15–100 and 6–12.5 μg
244 mL^{-1} , respectively. The zone of inhibition values suggest that the metal complexes
245 are more active than ligand, against all the bacteria tested. In L-Ni and L-Cd,
246 moderate activity was found towards the bacteria tested whereas, L-Zn possess
247 higher activity towards *Klebsiella* sp., *E. faecalis*, *E. coli* and *S. aureus*, than the
248 other metal complexes. Meanwhile, L-Cu shows more activity on *S. aureus* and
249 *Klebsiella* sp.

250 The synthesized compounds show not same antimicrobial activities due to
251 their impermeable ability of cell or ribosome in microbial cell [24]. In metal
252 complexes, the chelation increases the lipophilic nature of the central metal atom
253 and thus favours the penetration of the complexes into lipid membranes of
254 microorganism. Infact, lipophilicity is the factor, which controls the antimicrobial
255 activity of the compounds [25].

256 3.8 Antifungal activity

257 Antifungal activity of our compounds was tested with *C. albicans*, *Fusarium*
258 sp. and *Trichosporon* sp. by well diffusion method. The growth inhibition zone
259 against microorganism of our compounds is summarized in Table 4. The
260 experimental results were compared with the standard antifungal drug
261 streptomycin under similar conditions followed in test compounds. All our
262 synthesized metal complexes exhibited greater antifungal activity against *C.*

263 *albicans*. However, they show lesser activity against *C. albicans* and *Fusarium*
264 sp. than the standard drug Streptomycin. L-Ni is more effective against *C.*
265 *albicans*, *Fusarium* sp. and *Trichosporon* sp. whereas, L-Cu is less effective
266 against all the three fungal strains (Fig. 6b). From the above results it clearly
267 observed that the fungal activity depends upon the nature of metal ion.

268 3.8. Antioxidant activity

269 Antioxidant activity of the compounds was determined in terms of either
270 hydrogen donating or radical scavenging capacity against stable radical
271 DPPH[•]. The colour of the DPPH[•] is changed from purple to yellow after reduction,
272 which can be quantified by its decrease of absorbance at wavelength 517 nm.
273 From the experimental results, the enhanced antioxidant activity is observed for
274 all the metal complexes compared to that of free ligand. Among the complexes,
275 L-Ni and L-Cu showed more antioxidant activity. The values imply that the
276 antioxidant activity of the synthesized compounds follows in the order L < L-Cd <
277 L-Ni < L-Zn < L-Cu (Fig. 6c). The percentage antioxidant activity of the ligand and
278 its metal complexes is given in Table 4.

279 4. CONCLUSIONS

280 We synthesized Cu(II), Zn(II), Ni(II) and Cd(II) complexes with a
281 monodentate ligand formed by the condensation of piperonal and sulfanilamide.
282 The physico-chemical evidences including elemental analysis suggest 1:1
283 (metal:ligand) stoichiometry, mass spectral and thermal analysis report further
284 strengthen this statement. IR, ¹H and ¹³C NMR spectral data prove the
285 monodentate coordination of ligand with metal ion through imino nitrogen alone.
286 The bidentate mode of coordination of anion viz., CH₃COO⁻ or NO₃⁻ is also

inferred by the IR spectral data. From the antibacterial, antifungal and antioxidant activity data, we conclude that the metal complexes are more active than the free ligand.

REFERENCES

1. A. M. El-Hendawy, A. E. G. El-Kourashy, M. M Shanab, *Polyhedron*. **11** (1992) 523–530.
2. D.A. Chowdhury, M.N. Uddin, F. Hoque, *Chiang Mai J. Sci*, **37**(3) (2010) 443-450.
3. D.A. Chowdhury, M.N. Uddin, N. Lucky, *Bull. of Pure and Appl. Sci.* **22** (1) (2003) 39-45.
4. J. Byeong-Goo, Chae-Pyong, C. Hee-Nam, C. Ki-Hyung, C. Yohng-Kook. *Bull. Korean. Chem. Soc.*, **17** (1996) 687–693.
5. P. A. Vigato, S. Tamburini. *Coord. Chem. Rev.*, **248** (2004) 1717–2128.
6. T. S. Baul, S. Bau, D. DeVos, A. Linden. *Invest. New Drugs.*, **27** (2009) 419-431.
7. P. A. Ajibade, G. A. Kolawole , P. O'Brien, M. Helliwell, J. Raftery. *Inorg. Chim. Acta.*, **359** (2006) 3111-3116.
8. R.C. Maurya, P. Patel. *Spectrosc. Lett.*, **32** (1999) 213–236.
9. R. C. Maurya, P. Patel, S. Rajput. *Synth. React. Inorg. Met-Org. Chem.*, **33** (2003) 801–816.
10. R. C. Maurya, S. Rajput. *J. Mol. Struct.*, **794** (2006), 24–34.
11. M. L. Vaca Ruiz, P. G. Silva, A. L. Laciara. *Afr. J. Microbiol. Res.*, **3** (2009) 319–324.
12. J. Thomas, B. Veda. *Afr. J. Infect. Dis.*, **1** (2007) 36–41.
13. M. L. Sundararajan, J. Anandakumaran, T. Jeyakumar. *Spectrochim. Acta A.*, **125** (2014) 104–113.
14. M. L. Sundararajan, J. Anandakumaran, T. Jeyakumar, B. Karpanai Selvan. *Spectrochim. Acta A.*, **131** (2014) 82-93.

15. A. U. Rahman, M. I. Choudhary, W. J. Thomsen. *Bioassay techniques for drug development*. Harwood Academic Publishers, Amsterdam, The Netherlands, p 16 **2001**.
16. National Committee for Clinical Laboratory Standards, **2002**, Reference method for broth dilution antifungal susceptibility testing of yeasts. Approved Standard, 2nd edn., NCCLS Document M27-A2, NCCLS, Wayne, PA, USA
17. M. P. Rajesh, J. P. Natvar. *J. Adv. Pharm. Edu. Res.*, **1** (2011) 52–68.
18. C. Saxena, R. V. Singh. *Synth. React. Inorg. Met-Org. Chem.*, **22** (1992) 1061–1072.
19. W. N. W. Ibrahim, M. Shamsuddin, B. M. Yamin. *Malaysian J. Anal. Sci.*, **11** (2007) 98–104.
20. B. Anupama, C. Gyana Kumari. *Int. J. Res. Chem. Environ.*, **3** (2013) 172–180.
21. A. K. Yadava, H. S. Yadav, U. S. Yadav, D. P. Rao. *Turk. J. Chem.*, **36** (2012) 624 – 630.
22. R. R. Coombs, M. K. Ringer, J. M. Blacquiere, J. C. Smith, J. S. Neilsen, Y. S. Uh, J. B. Gilbert, L. J. Leger, H. Zhang, A. M. Irving, S. L. Wheaton, C. M. Vogels, S. A. Westcott, A. Decken, F. J. Baerlocher. *Transition Met. Chem.*, **30** (2005) 411–418.
23. N. A. Salih. *Turk. J. Chem.*, **32** (2008) 229–235.
24. N. Dharmaraj, P. Viswanathamurthy, K. Natarajan. *Transition Met. Chem.*, **26** (2001) 105–109.
25. G. Kumar, D. Kumar, C. P. Singh, A. Kumar, V. B. Rana. *J. Serb. Chem. Soc.*, **75** (2010), 629–637.

TABLE I ¹H and ¹³C NMR spectral data (ppm) of ligand (L) and its Zn(II) and Cd(II) metal complexes

Ligand/complex	¹ H NMR spectra					¹³ C NMR spectra			
	–CH ₃	–O–CH ₂ – O–	Arom. proton	HC= N	NH ₂	–CH ₃	–O–CH ₂ – O–	Arom. carbon	HC=N
L	–	6.144	7.077– 7.843	8.525	7.35 6	–	101.83	106.32– 154.37	161.7 4
[L-ZnNO ₃ (H ₂ O)]·2H ₂ O	–	6.150	7.084– 7.846	8.532	7.34 9	–	101.84	106.32– 154.37	161.7 5
[L-Cd(CH ₃ COO)H ₂ O]	1.76	6.146	7.078–	8.535	7.35	16.7	101.83	106.29–	161.9

3 7.840 3 7 150.62 6

344

345

346 **TABLE II** Mass spectral data of ligand and its metal complexes

Ligand/complex	Calculated (m/z)	Found (m/z)	Peak assignment
L	304.71	304.19	[M]
[L-CuNO ₃ (H ₂ O)]·H ₂ O	467.91	467.87	[M]
[L-ZnNO ₃ (H ₂ O)]·2H ₂ O	485.69	486.18	[M]
[L-Ni(CH ₃ COO)H ₂ O]·2H ₂ O	477.10	476.27	[M]
[L-Cd(CH ₃ COO)H ₂ O]	493.76	495.21	[M ⁺]

347

348 **TABLE III** Thermal analysis of metal complexes

Complex	TG range (°C)	Mass loss (%) found (calcd.)	Assignment
[L-CuNO ₃ (H ₂ O)]·H ₂ O	20–219	4.01 (4.01)	Loss of one coordinated H ₂ O molecule
	220–1000	67.76 (67.98)	Decomposition of the ligand
[L-ZnNO ₃ (H ₂ O)]·2H ₂ O	20–197	7.41 (7.41)	Loss of two lattice H ₂ O molecules
	217–250	3.70 (3.70)	Loss of one coordinated water molecule
	250–1000	62.56 (62.67)	Decomposition of the ligand
[L-Ni(CH ₃ COO)H ₂ O]·2H ₂ O	20–168	7.56 (7.56)	Loss of two lattice H ₂ O molecules
	170–201	3.78 (3.78)	Loss of one coordinated H ₂ O molecule
	210–1000	63.86 (63.95)	Decomposition of the ligand
[L-Cd(CH ₃ COO)H ₂ O]	20–250	3.63 (3.64)	Loss of one coordinated H ₂ O molecule
	250–1000	61.42 (61.66)	Decomposition of the ligand

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350 **TABLE IV** Antibacterial, antifungal and antioxidant activities of ligand and its metal
351 complexes

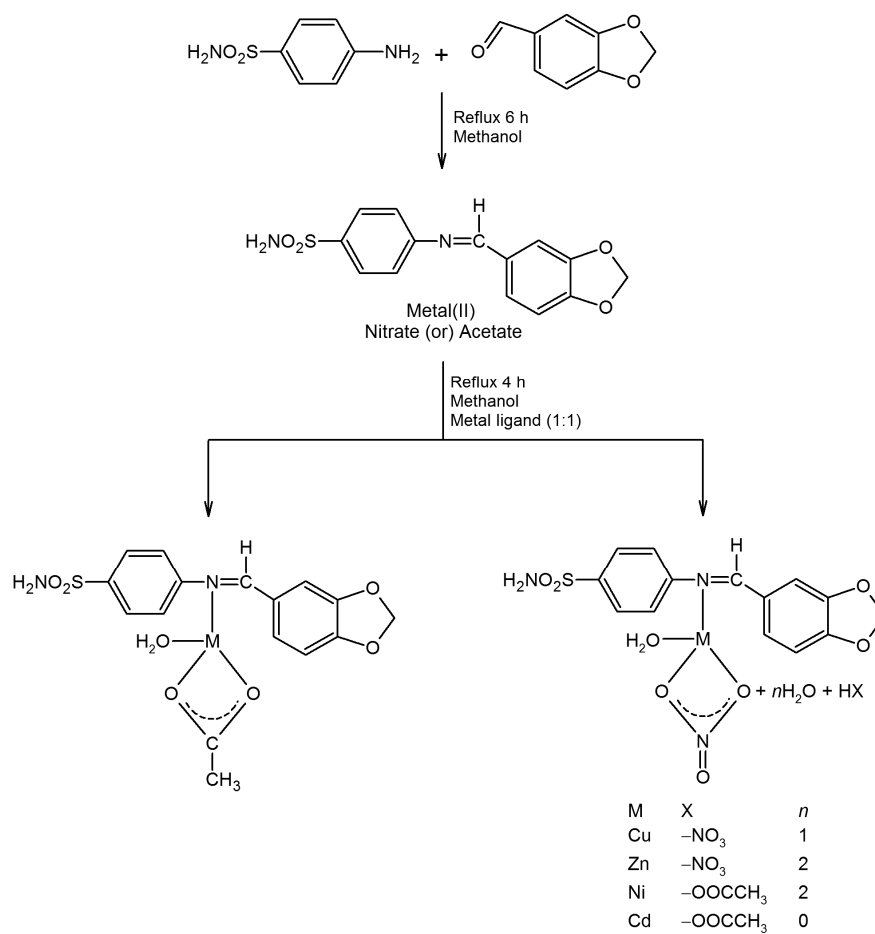
Ligand/complex	Zone of inhibition (mm)								Antioxidant activity (%)
	Antibacterial activity					Antifungal activity			
	a	b	c	D	e	f	g	h	
L	2	1	2	1	1	2	1	1	12
[L-CuNO ₃ (H ₂ O)]·H ₂ O	4	5	4	2	5	1	2	2	26.8
[L-ZnNO ₃ (H ₂ O)]·2H ₂ O	6	7	5	5	10	2	1	1	23.3
[L-Ni(CH ₃ COO)H ₂ O]·2H ₂ O	3	4	2	1	4	3	2	2	18.0
[L-Cd(CH ₃ COO)H ₂ O]	5	6	3	2	3	2	1	2	14.5
Ampicillin	7	5	5	6	6	—	—	—	—
Streptomycin	—	—	—	—	—	5	6	1	—

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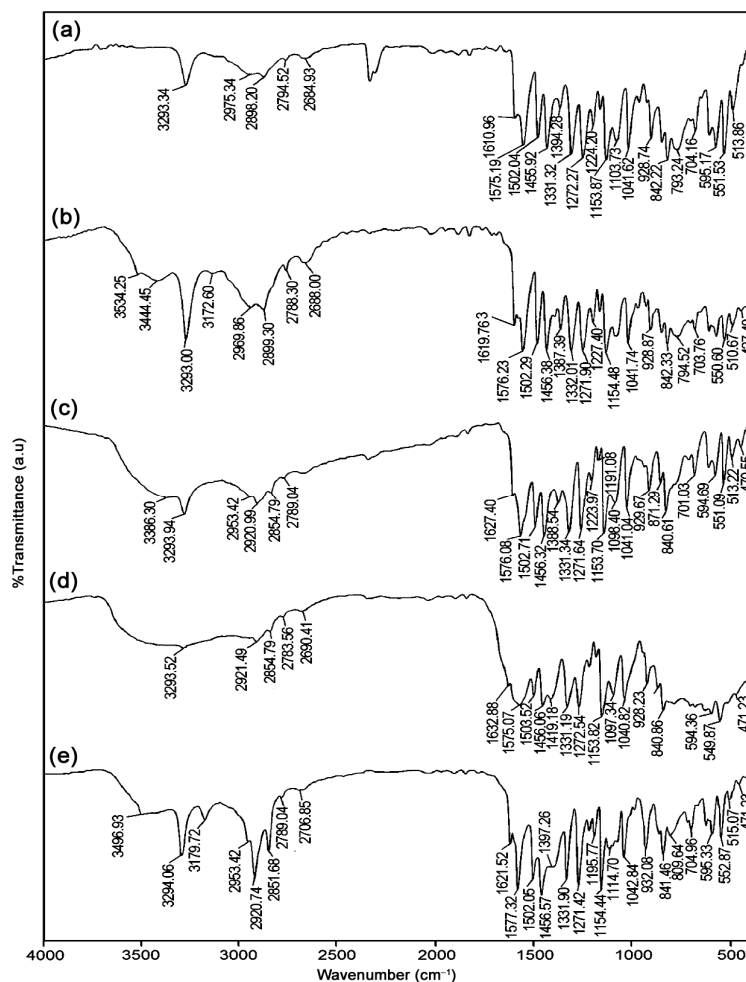
a – *E. coli*; b – *S. aureus*; c – *E. faecalis*; d – *P. fluorescens*; e – *Klebsiella* sp.; f – *C. albicans*; g – *Fusarium* sp.; h – *Trichosporon* sp.



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Scheme 1 Synthesis of ligand (L) and its metal complexes



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358 **Fig. 1** IR spectra of ligand and its metal complexes: (a) L, (b) L-Cu, (c) L-Zn,

359 (d) L-Ni and (e) L-Cd

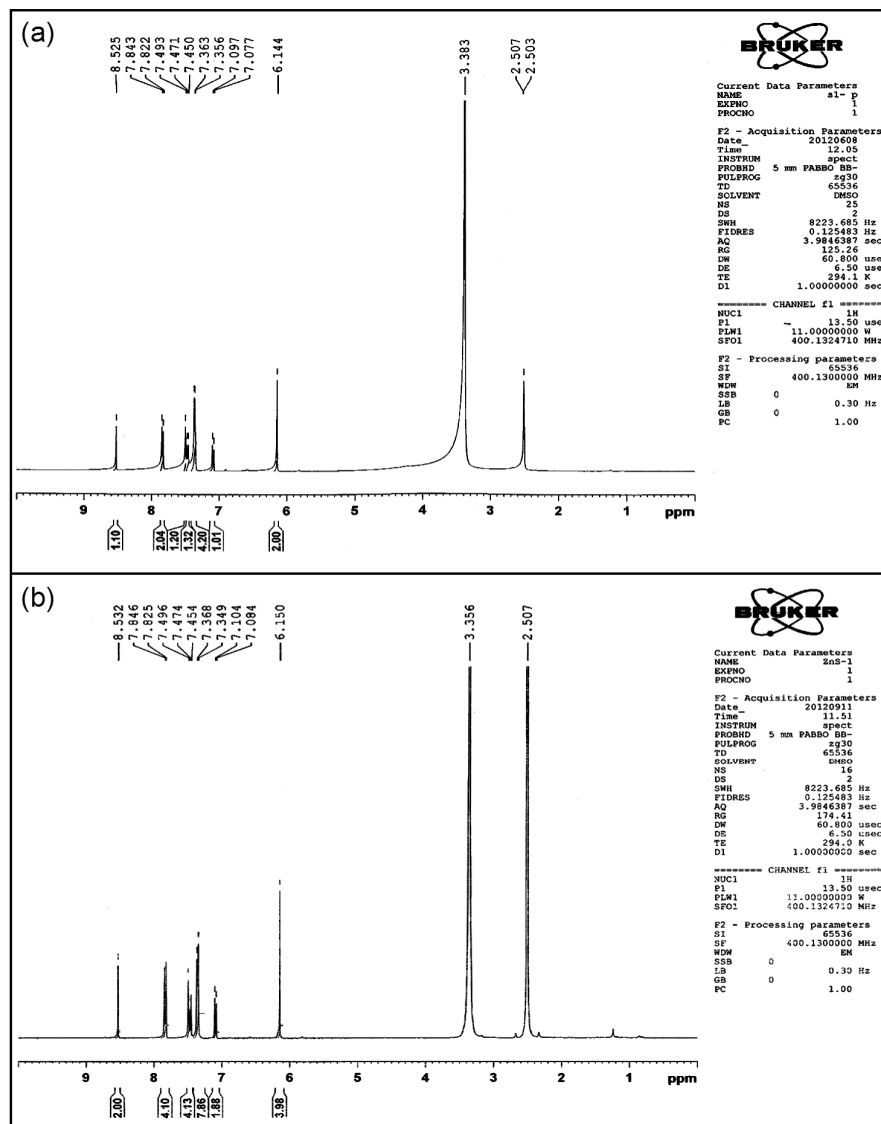


Fig. 2 ^1H NMR spectra of ligand and its metal complex: (a) L and (b) L-Zn

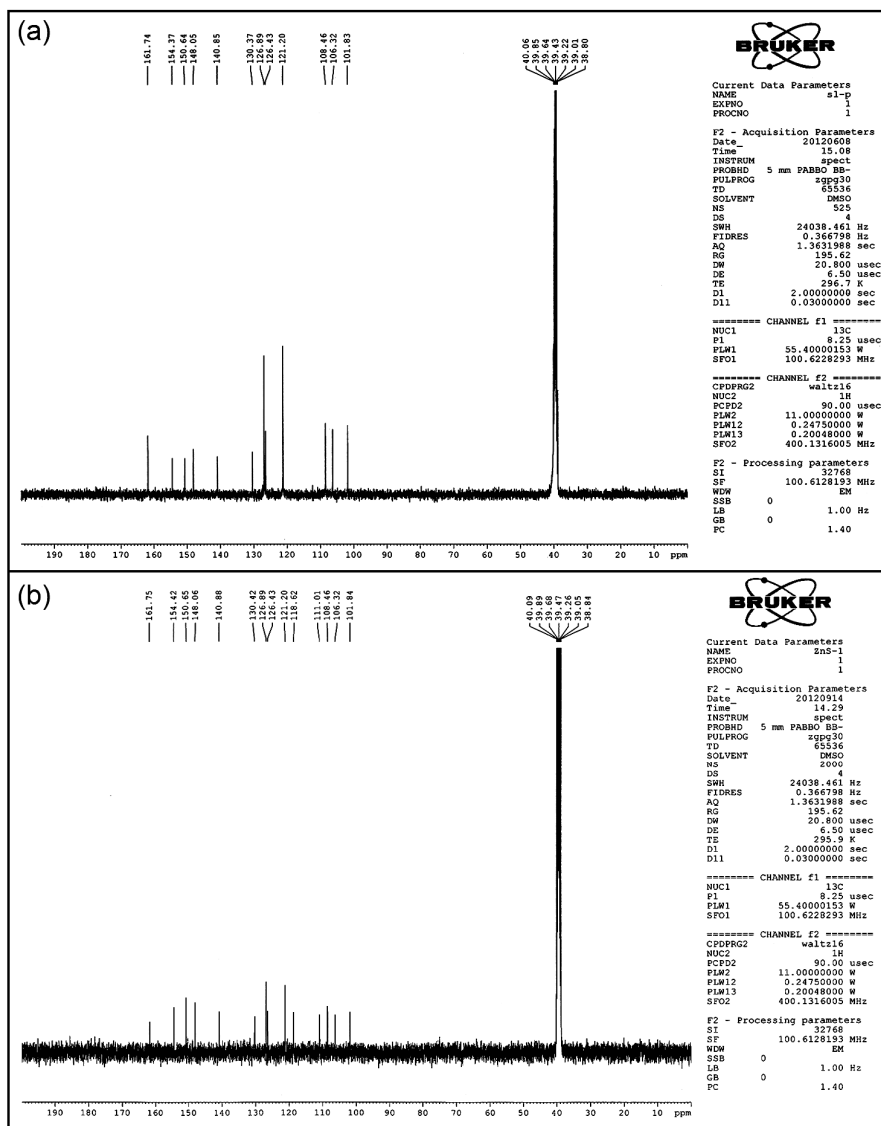


Fig. 3 ^{13}C NMR spectra of ligand and its metal complex: (a) L and (b) L-Zn

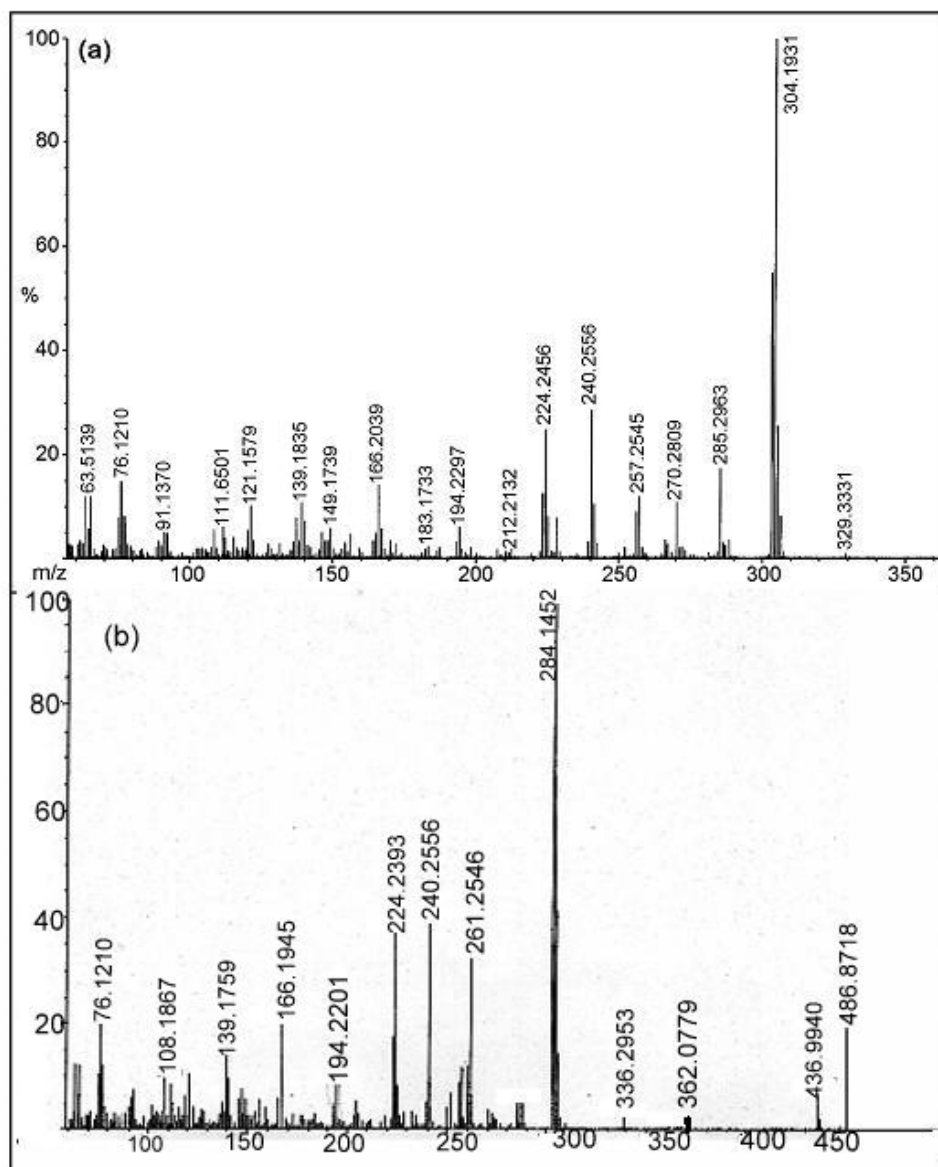
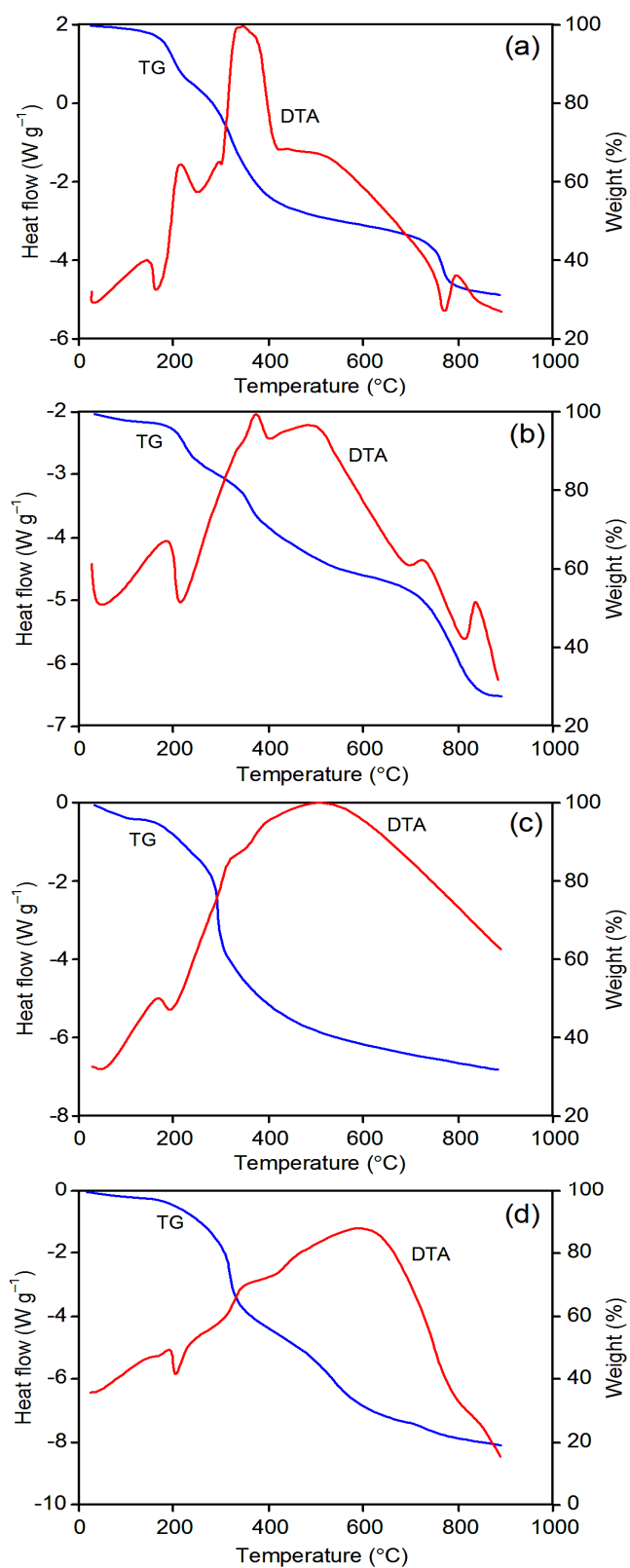
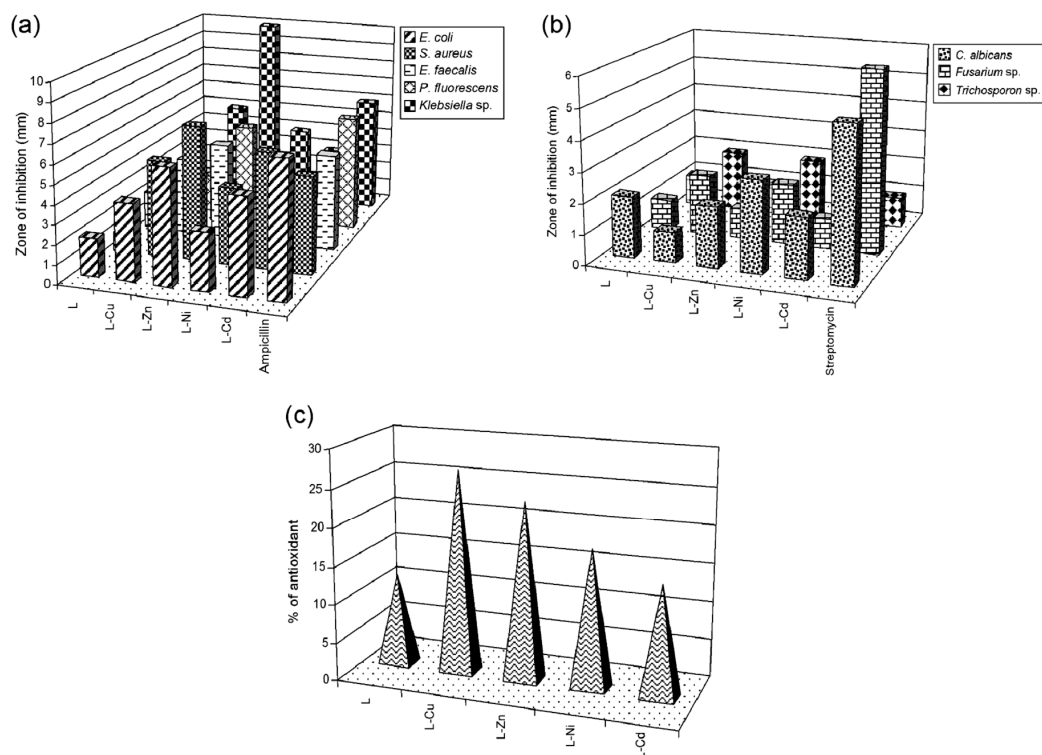


Fig. 4 GC-MS spectra of ligand and its metal complex: (a) L and (b) L-Zn



366

367 **Fig. 5** TG/DTA of metal complexes: (a) L-Cu, (b) L-Zn, (c) L-Ni and (d) L-Cd



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369 **Fig. 6** (a) Antibacterial, (b) antifungal and (c) antioxidant activities of ligand and its
 370 metal complexes

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