http://www.e-journals.in
DOI:10.7598/cst2015.965

Chemical Science Transactions
2015, **4(1),** 113-120

RESEARCH ARTICLE

Enaminone Complexes: Synthesis, Characterization and Bioactivity

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Received 11 October 2014 / Accepted 17 October 2014

Abstract: Synthesis of enaminones, *viz*., 3-(dimethylamino)-1-(thiophen-2-yl)prop-2-en-1-one and 3-(dimethylamino)-1-phenylprop-2-en-1-one, and their chelating with different metal nitrates of Cu^{2+}, Ni^{2+}, Hg^{2+}, Pb^{2+} and Co^{2+} in ethnolic solution were reported. The bioactivity of ligands and metal complexes against eight types of bacteria and three types of fungi were investigated.

Keywords: Enaminone, Metal complex, Bioactivity

Introduction

Preparation and chemistry of enaminones have been reviewed by Elassar *et al*.[1] Enaminones have received more attention during last decade due to its using as intermediate for many useful synthetic compounds in addition, a lot of work has been done to explore new routes for the synthesis and use of enaminones[2-8]. The presences of carbonyl group connected by carbon–carbon double bond and an amino group or *N*-substituted amines in enaminones allow being act as bidentates system. The chemistry of carbonyl group in enaminone is an area of considerable scope[9]. Complexes of Fe(II) and Zn(II) ions with diethylamine-pent-3-ene-2-one, dipropylamine-pent-3-ene-2-one and dicyclohexylamine-pent-3-ene-2-one are reported[10]. BF_2 complex have been synthesized *via* reactions of 3-methylthioenaminones with $BF_3 \cdot Et_2O$ in the presence of Et_3N in good to excellent yields.[11] In this article we are aimed to synthesis enaminones and use as a ligand for complexation with different metal ions. The biological activity of ligands and metal complexes are also aimed to be studied against gram positive, gram negative and fungi.

Experimental

Melting points were recorded on a Gallenkamp apparatus. IR spectra were recorded using KBr pellets on a JASCO FTIR-6300 FT-IR spectrophotometer. ^1H and ^{13}C NMR spectra were recorded on Bruker DPX AvanceII 600 MHz super conducting NMR spectrometer with proton spectra measured at 600 MHz and carbon spectra at 150 MHz, respectively. Mass spectra were measured on a high resolution GC/MS DFS-Thermo. Microanalyses were performed on Elementar-Vario Micro cube Analyzer.

Materials

The starting materials and solvents used for the synthesis of ligands and complexes were used as received. The salts used are: $Co(NO_3)_2.6H_2O$; $Ni(NO_3)_2.6H_2O$; $Cu(NO_3)_2.3H_2O$; $Cd(NO_3)_2.4H_2O$; $Hg(NO_3)_2.H_2O$ and $Pb(NO_3)_2$.

Synthesis of Ligand

3-(Dimethylamino)-1-(thiophen-2-yl)prop-2-en-1-one (EN1); and 3-(dimethylamino) -1-phenylprop-2-en-1-one (EN2)

To a solution of 2-acetylthiophene or acetophenone (0.01 mol) in xylene (30 mL) dimethylformamide dimethylacetal, DMFDMA (0.01 mol) was added. The reaction mixture was heated under reflux for 8 h. The solvent was evaporated under vacuum. After that the reaction product was treated with ice-cold water. The solid product obtained was collected by filtration and crystallized from the ethanol. (For elemental analysis and spectral data see Tables 1-3).

Preparation of the complexes

A solution of 3-(dimethylamino)-1-(thiophen-2-yl)prop-2-en-1-one or 3-(dimethylamino)-1-phenylprop-2-en-1-one (0.01 mol) in 20 mL ethanol was added slowly with continuous stirring to a 10 mL of filtered aqueous ethanolic solution of the metal nitrate salt (0.01 mol) and then heated under reflux for 5 h. The product was collected by filtration and allowed to evaporate slowly at room temperature. (For elemental analysis and spectral data see Tables 1-3).

Table 1. IR of EN1, EN2 and their complexes

Compound	IR (cm^{-1})
EN1	3072 (CH), 1653 (CO),1545 (C-N)
$CuEN1(NO_3)_2$	3076(CH), 1650 (CO), 1575 (C-N)
$Co(EN1)_4(NO_3)_2$	3097 (CH), 1654 (CO), 1588 (C-N)
$Ni(EN1)_3(NO_3)_2.2H_2O$	3445 (H_2O),3096 (CH),1652 (CO),1587(C-N)
$CdEN1(NO_3)_2$	3551, 3448 (H_2O), 1657 (CO), 1594 (C-N)
$HgEN1(NO_3)_2$	3428 (H_2O), 1654 (CO), 1563 (C-N)
$PbEN1(NO_3)_2$	3093 (CH), 1653 (CO), 1619 1588 (C-N)
EN2	3054, 3020 (CH), 1650 (CO), 1583 (C-N)
$CuEN2(NO_3)_2$	3062, 3011 (CH), 1653(CO), 1567 (C-N)
$Co(EN2)_4(NO_3)_2$	3062 (CH), 1655 (CO), 1570 (C-N)
$Ni(EN2)_4(NO_3)_2.3H_2O$	3443(H_2O),3063 (CH),1651(CO), 1571 (C-N)
$Cd(EN2)(NO_3)_2.2H_2O$	3445 (H_2O),3081(CH), 1652 (CO), 1575 (C-N
$Hg(EN2)_2(NO_3)_2.10H_2O$	3445 (H_2O),3053 (CH),1657 (CO),1565(C-N)
$Pb(EN1)_2(NO_3)_2$	3050 (CH), 1659 (CO), 1596 (C-N)

Table 2. Formula, MS, melting point and elemental analysis of EN1, EN2 and their complexes

Compound	Formula (M.Wt)	MS *m/z*	Mp ^oC	C% Calcd/ found	H% Calcd/ found	N% Calcd/ found	S% Calcd/ found
EN1	$C_9H_{11}NOS$ (181.25)	181	110	59.64 59.74	6.12 5.99	7.73 8.06	17.69 17.41
$CuEN1(NO_3)_2$	$C_9H_{11}CuN_3O_7S$ (368.81)	369	135	29.31 29.44	3.01 3.03	11.39 11.42	8.69 8.83

$Co(EN1)_4(NO_3)_2$	$C_{36}H_{44}CoN_6O_{10}S_4$ (907.96)	908	175	47.62 47.99	4.88 4.70	9.26 9.56	14.13 14.48
$Ni(EN1)_3(NO_3)_2.2H_2O$	$C_{27}H_{37}N_5NiO_{11}S_3$ (762.50)	762	150	42.53 42.23	4.89 4.78	9.18 9.45	12.62 12.60
$CdEN1(NO_3)_2$	$C_9H_{11}N_3NiO_7S$ (417.68)	418	>250	25.88 25.78	2.65 3.01	10.06 9.98	7.68 7.46
$HgEN1(NO_3)_2$	$C_9H_{11}HgN_3O_7S$ (505.85)	506	>250	21.37 20.95	2.19 2.26	8.31 8.58	6.34 6.05
$PbEN1(NO_3)_2$	$C_9H_{11}N_3O_7PbS$ (512.46)	513	190	21.09 21.36	2.16 2.35	8.20 8.47	6.26 6.18
EN2	$C_{11}H_{13}NO$ 175.23	175	85	75.40 75.12	7.48 7.45	7.99 8.13	
$CuEN2(NO_3)_2$	$C_{11}H_{13}CuN_3O_7$ 362.78	363	165	36.42 36.24	3.61 3.56	11.58 11.85	
$Co(EN2)_4(NO_3)_2$	$C_{44}H_{52}CoN_6O_{10}$ 883.85	884	>250	59.79 59.65	5.93 5.65	9.51 9.31	
$Ni(EN2)_4(NO_3)_2.3H_2O$	$C_{44}H_{58}N_6NiO_{13}$ 937.66	937	>250	56.36 56.33	6.23 6.45	8.96 9.01	
$Cd(EN2)(NO_3)_2.2H_2O$	$C_{11}H_{17}CdN_3O_9$ 447.68	448	>250	29.51 29.45	3.83 4.11	9.39 9.46	
$Hg(EN2)_2(NO_3)_2.10H_2O$	$C_{22}H_{46}HgN_4O_{18}$ 855.21	855	>250	30.90 31.08	5.42 5.22	6.55 6.34	
$Pb(EN2)_2(NO_3)_2$	$C_{22}H_{26}N_4O_8Pb$ 681.66	682	>250	38.76 38.66	3.84 3.58	8.22 8.01	

Table 3. ^1H and ^{13}C NMR signals (ppm) of EN1, EN2 and their complexes

Compound	^1H NMR	^{13}C NMR
EN1	7.77-7.70, 7.14-7.12 (thiophene-H); 7.69, 5.80 (CH=CH); 3.15, 3.08 (2Me)	179.08 (CO); 153.56 (CH=); 91.42 (=CH); 148.12, 130.91, 128.57, 127.95 (thiophene-carbons); 44.40, 44.30 (NMe_2)
$CuEN1(NO_3)_2$	8.02-7.40 (thiophene-H); 7.77, 5.40 (CH=CH); 3.30, 3.23 (2Me)	188.77 (CO); 153.00 (CH=); 78.04 (=CH); 143.09, 130.94, 128.84, 127.89 (thiophene-carbons);39.50, 39.48 (Nme_2)
$Co(EN1)_4(NO_3)_2$	7.93-7.73, 7.15-7.16 (thiophene-H); 7.66, 5.76 (CH=CH); 3.10, 2.87 (2Me)	185.83 (CO); 148.56 (CH=); 85.79 (=CH); 143.52, 130.14, 129.86, 125.89 (thiophene-carbons); 39.56, 39.36 (Nme_2)
$Ni(EN1)_3(NO_3)_2.2H_2O$	7.52-7.34, 7.15-7.16 (thiophene-H); 7.26, 5.35 (CH=CH); 3.19, 2.72 (2Me)	183.24 (CO); 145.88 (CH=); 83.04 (=CH); 140.78, 136.59, 123.41, 121.06 (thiophene-carbons); 39.59, 39.39 (Nme_2)
$CdEN1(NO_3)_2$	8.42-7.91, 7.76-7.33 (thiophene-H); 7.67, 5.80 (CH=CH); 3.13, 2.90 (2Me)	185.87 (CO); 142.07 (CH=); 85.14 (=CH); 138.16, 136.85, 132.26, 128.75 (thiophene-carbons); 40.12, 39.92 (Nme_2)

Contd….

$HgEN1(NO_3)_2$	8.42-7.09 (thiophene-H); 7.26, 5.45 (CH=CH); 3.13, 2.89 (2Me)	188.00 (CO); 142.07 (CH=); 85.14 (=CH); 138.16, 129.40, 129.12, 128.75 (thiophene-carbons); 4013, 39.92 (NMe_2)
$PbEN1(NO_3)_2$	8.41-7.30 (thiophene-H); 7.32, 5.45 (CH=CH); 3.40, 3.41 (2Me)	185.89 (CO); 142.09 (CH=); 85.23 (=CH); 138.17, 136.79, 132.33, 129.15 (thiophene-carbons); 40.12, 39.91 (NMe_2)
EN2	7.97-7.90, 7.58-7.40 (Ar-H); 7.76, 5.85 (CH=CH); 2.89 (2Me)	185.71 (CO); 154.24 (CH=); 91.69 (=CH); 136.77, 130.76, 128.55, 126.52 (Ar-carbons); 44.47, 44.35 (NMe_2)
$CuEN2(NO_3)_2$	7.75-7.33(Ar-H); 7.76, 5.85 (CH=CH); 2.92 (2Me)	178.52 (CO); 146.01 (CH=); 91.60 (=CH); 143.19, 131.71, 124.67, 122.70 (Ar-carbons); 39.48, 39.36(NMe_2)
$Co(EN2)_4(NO_3)_2$	8.02-7.92, 7.39-7.24 (Ar-H); 7.69, 5.86 (CH=CH); 2.93 (2Me)	170.95 (CO)); 158.52 (CH=); 85.42 (=CH); 130.81, 125.23, 123.07, 121.86 (Ar-carbons); 39.67, 39.49(NMe_2)
$Ni(EN2)_4(NO_3)_2.3H_2O$	10.34 (br H_2O); 8.51-7.71, 7.51-7.25 (Ar-H); 7.68, 5.62 (CH=CH); 2.95 (2Me)	170.95 (CO)); 154.23 (CH=); 75.19 (=CH); 149.94, 128.11, 127.61, 124.47, 122.97 (Ar-carbons); 39.52, 39.53(NMe_2)
$Cd(EN2)\ (NO_3)_2.2H_2O$	10.34 (br H_2O); 8.32-7.84, 7.45-7.25 (Ar-H); 7.84, 5.62 (CH=CH); 3.35, 3.32 (2Me)	172.35 (CO)); 153.23 (CH=); 79.20 (=CH); 137.77, 131.76, 129.34, 126.52 (Ar-carbons); 44.45, 44.40 (NMe_2)
$Hg(EN2)_2(NO_3)_2.10H_2O$	9.87 (br H_2O); 8.27-7.86, 7.55-7.41 (Ar-H); 7.63, 5.82 (CH=CH); 3.40, 3.16 (2Me)	177.35 (CO)); 154.23 (CH=); 80.20 (=CH); 137.77, 131.76, 128.49, 126.52 (Ar-carbons); 40.12, 39.91 (NMe_2)
$Pb(EN2)_2(NO_3)_2$	8.25-7.70, 7.64-7.28 (Ar-H); 7.68, 5.82 (CH=CH); 3.47, 3.18 (2Me)	199.56, 194.52 (CO)); 154.23 (CH=); 80.20 (=CH); 137.57, 136.32, 134.02, 128.28 (Ar-carbons); 40.13, 39.92 (NMe_2)

Antimicrobial studies

The *in vitro* antibacterial activity of enaminones and their complexes were evaluated against gram positive and gram negative bacteria, (*Bacillus sp.* M3010, *Bacillus sp.* M3017, *Escherichia Coli*-PA149, *Escherichia Coli*-PA151, *Staphylococcus aureus*-PA128, *Staphylococcus aureus*-PA129, *Salmonella sp.*-PA392 *and Salmonella sp.*-PA393) and three fungi (*Candida albicans*-PA47, *Candida albicans*-PA48 and *Candida albicans*-PA49). The hole plate diffusion method[12] was adopted for the activity measurements. The bacterial strains were grown in nutrient agar slants. A suspension of the studied compounds (0.2 m L of each (10 μg/mL) was incubated at 36 ^{o}C for 36 h for the bacterial culture. After inoculation, the diameter (in mm) of the clear inhibition zone surrounding the sample is taken as a measure of the inhibition power against the particular organisms. The values recorded are the mean average for experiments repeated three times.

Results and Discussion

Characterization of Ligand

^{1}H NMR of 3-(dimethylamino)-1-(thiophen-2-yl)prop-2-en-1-one (EN1) (*cf.* Scheme 1) reveals the presence of thiophene protons as doublet of doublet at δ 7.77-7.70 and 7.14 -7.12 ppm. The ethylenic proton appears at δ 7.69 and 5.80 ppm in addition, the NMe_2 protons appeared at δ 3.08 and 3.15 ppm. ^{13}C NMR showed peaks at δ 179.08 (CO); 153.56 (CH=); 91.42 (=CH); 148.12, 130.91, 128.57, 127.95 (thiophene-carbons); 44.40, 44.30 (NMe_2). IR showed the carbonyl group at 1653 cm^{-1} other characteristic bands reported in Table 1. The mass spectrum showed the molecular ion peak at *m/z* 181 (M^+) with fragments at *m/z* 111 for thionylium ion $C_5H_3OS^*$ with other fragments at *m/z* 164, 148 and 70.

The mass spectrum of 3-(dimethylamino)-1-phenylprop-2-en-1-one (EN2) (*cf.* Scheme 1) showed the molecular ion peak at *m/z* 175 with different fragments at 158, 131, 98 and 77. ^{1}H NMR reveals the presence of aromatic protons at δ 7.97–7.90 and 7.58-7.41 ppm.

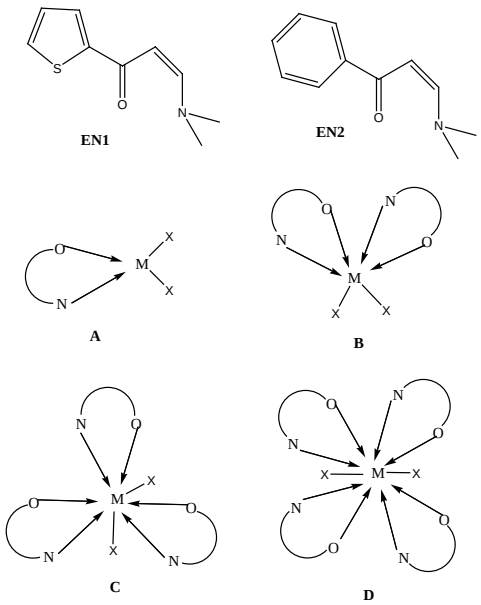
The ethylenic proton appears at δ 7.76 and 5.85 ppm in addition, the NMe_2 protons appeared at δ 2.89 ppm. ^{13}C NMR showed peaks at δ 185.71 for carbonyl group; 154.24 and 91.69 for ethylenic carbons; 136.77, 130.76, 128.55, 126.52 for aromatic carbons; 44.47, 44.35 for two methyl groups of NMe_2. IR showed the carbonyl group at 1650 cm^{-1} , in addition to other characteristic bands (*cf.* Table 1)

*Characterization of the complexe*s

Both EN1 and EN2 could be chelate from two centers, carbonyl group and NH group as a bidentate system. Different complexes were formed on the reaction of EN1 or EN2 with the nitrate salts of Cu(II), Co(II), Ni(II), Pb(II), Hg(II) and Cd(II). The IR spectra of the complexes showed that EN1 and EN2 are coordinate in the neutral bidentate mode. Bands at 1650 to 1659 cm^{-1} is assigned to carbonyl group and that at 1545 to 1596 cm^{-1} is assigned to C-N. Moreover, aromatic protons appeared in peaks more than 3000 cm^{-1} (*cf.* Table 1). The elemental analysis and spectral data results (*cf.* Tables 1-3) showed the formation of $CuEN1(NO_3)_2$; $CdEN1(NO_3)_2$, $HgEN1(NO_3)_2$, $PbEN1(NO_3)_2$, Scheme 1 structure A, while Ni(II) have the structure $Ni(EN1)_3(NO_3)_2.H_2O$ Scheme 1 structure C. EN2 complexes are $CuEN2(NO_3)_2$ (Scheme 1 structure A); $Co(EN2)_4(NO_3)_2$ and $Ni(EN2)_4(NO_3)_2.3H_2O$ (Scheme 1 structure D); $Cd(EN2)(NO_3)_2.25H_2O$ (Scheme 1 structure A); $Hg(EN2)_2(NO_3)_2.10H_2O$ and $Pb(EN1)_2(NO_3)_2$ (Scheme 1 structure B). All complexes obtained are colored either due d-d or charge transfer or charge transfer transitions.

Biological activity

The well-known diverse biological activities of enaminones[13-18] prompted us to test and study the antibacterial and antifungal activities of the synthesized products. Table 4 shows that most of the tested compounds had moderate to high activity against most investigated microorganisms. All prepared compounds are investigated against gram positive and gram negative bacterial (microorganisms undergoes investigation are *Bacillus sp.* M3010; *Bacillus sp.* M3017; *Escherichia Coli*-PA149*; Escherichia Coli*-PA151*; Staphylococcus aureus*-PA128*; Staphylococcus aureus*-PA129*; Salmonella sp.*-PA392 *and Salmonella sp.*-PA393) and antifungal (*Candida albicans*-PA47; *Candida albicans*- PA48 and *Candida albicans*-PA49). The complexes Co-EN1-complex; Ni-EN1-complex; Co-EN2-complex and Pb-EN2-complex have no any reactivity against all tested microorganisms (gram positive, gram negative and fungus).



Scheme 1

Table 4. Antibacterial and antifungal activity of ligand and complexes

	Chemical compound													
	Zone of inhibition, mm													
Bacteria	**EN1**	**Co1**	**Hg1**	**Pb1**	**Ni1**	**Cu1**	**Cd1**	**EN2**	**Co2**	**Hg2**	**Pb2**	**Ni2**	**Cu2**	**Cd2**
Bacillus sp. M3010	15	Nil	18	13	Nil	Nil	13	16	Nil	16	Nil	Nil	19	Nil
Bacillus sp. M3017	14	Nil	17	15	Nil	Nil	15	18	Nil	15	Nil	Nil	17	Nil
Escherichia Coli-PA149	18	Nil	16	16	Nil	Nil	18	21	Nil	21	Nil	Nil	Nil	Nil
Escherichia Coli-PA151	16	Nil	15	15	Nil	Nil	17	19	Nil	19	Nil	Nil	Nil	Nil
Staphylococcus aureus-PA128	Nil	Nil	21	21	Nil	Nil	16	Nil	Nil	18	Nil	Nil	19	Nil
Staphylococcus aureus-PA129	Nil	Nil	20	20	Nil	Nil	18	Nil	Nil	18	Nil	Nil	18	Nil
Salmonella sp.-PA392	16	Nil	16	16	Nil	Nil	21	17	Nil	19	Nil	Nil	16	Nil
Salmonella sp.-PA393	17	Nil	18	18	Nil	Nil	20	16	Nil	18	Nil	Nil	15	Nil
Candida albicans-PA47	20	Nil	19	23	Nil	16	16	18	Nil	21	Nil	Nil	21	23
Candida albicans- PA48	18	Nil	17	21	Nil	15	18	19	Nil	23	Nil	Nil	20	21
Candida albicans- PA49	17	Nil	15	22	Nil	18	19	18	Nil	21	Nil	Nil	18	20

Co1: Co-EN1-complex; Hg1: Hg-EN1-complex; Pb1: Pb-EN1-complex; Ni1: Ni-EN1-complex; Cu1: Cu-EN1-complex; Cd1: Cd-EN1-complex; Co2: Co-EN2-complex; Hg2: Hg-EN2-complex; Pb2: Pb-EN2-complex; Ni2: Ni-EN2-complex; Cu2: Cu-EN2-complex; Cd2: Cd-EN2-complex. Low effect: 13-15 mm; moderate effect: 16-18 mm; High effect: 19-23 mm

The data of EN1 and its complexes with different metal nitrate salts against gram positive bacteria can be summarized as follows: *Bacillus sp.* M3010 shows that the Hg has highest effect according to the following order Hg^{2+} > EN1 > Pb^{2+} = Cd^{2+}. Similarly, Bacillus *sp.* M3017 shows highest effect with Hg according to the order Hg > Pb = Cd > EN1.

Furthermore, both types of *Staphylococcus aureus*-PA128 and *Staphylococcus aureus*-PA129 showed high effect in case of Hg and Pb and both of them are equal in its effect. The order according to the inhibition zone can arranged as follows, *Staphylococcus aureus*-PA128: Pb = Hg > Cd and *Staphylococcus aureus*-PA129: Pb = Hg > Cd.

The effect of tested compounds against gram negative bacteria can be summarized as follows: *Escherichia Coli*-PA149 shows the highest effect with the ligand and can be order as follows, EN1> Cd^{2+} > Hg^{2+} = Pb^{2+}, while the highest effect of *Escherichia Coli*-PA151 observed with Cd complex and ordered as follows Cd > EN1 > Pb = Hg.

Both *Salmonella sp.*-PA392 and *Salmonella sp.*-PA393 are showed approximately the same effect with the tested compounds and can ordered with *Salmonella sp.*-PA392 as follows: Cd > Pb = Hg = EN1 and with *Salmonella sp.*-PA393 as follows: Cd > Pb = Hg > EN1.

All tested fungi highly effected by Pb complex and can be arranged as follows: in case of *Candida albicans*-PA47: Pb > EN1 > Hg > Cu = Cd; in case of *Candida albicans*-PA48: Pb > Cd > Cu > EN1 > Hg and in case of *Candida albicans*-PA49: Pb > Cd > Cu > EN1 > Hg

The data of EN1 and its complexes with different metal nitrate salts against gram negative bacteria can be ordered as follows: *Bacillus sp.* M3010: Cu > Hg = EN2; while in case of *Bacillus sp.* M3017: EN2 > Cu >Hg. In case of *Staphylococcus aureus*-PA128: Cu > Hg and with *Staphylococcus aureus*-PA129 showed similar effect with Cu = Hg. On the other hand, *Escherichia Coli*-PA149 and *Escherichia Coli*-PA151 are showed the same effect with EN2 and Hg-complex, EN2= Hg. Both types tested from *Salmonella sp.*-PA392 and *Salmonella sp.*-PA393 are showed the same effect on tested compounds, order as follows Hg > EN2 > Cu. All tested fungi against EN2 and its complexes are showed highly effected by Hg and Cd complexes and can be arranged as follows: in case of *Candida albicans*-PA47: Cd > Cu = Hg > EN2; in case of *Candida albicans*-PA48: Hg > Cd > Cu > EN2 and in case of *Candida albicans*-PA49: Hg > Cd > Cu = EN2

Generally the highest effected was observed in case of EN1 complexes as compared by that of EN2. This may be due the presence of thiophene ring in EN1- complexes as compared by phenyl group in EN2-complexes. High effect against different types of tested fungi was observed in case of Cd-EN2-complex, Pb-EN1-complex, Cd-EN2-complex, Hg-EN2-complex and Cu-EN2-complex. High effect against *Escherichia Coli*-PA149 was observed in case of Hg-EN2-complex, while Hg-EN1-complex showed high effect against *Staphylococcus aureus*-PA128 and *Staphylococcus aureus*-PA129. *Salmonella sp.*-PA392 and *Salmonella sp.*-PA393 showed high effect with Cd-EN1-complex.

Conclusion

In the light of the data one can conclude the following:

- Enaminone acts as a good chelating agent in aqueous ethanolic solution.
- Bioactivity of enaminones and most of their complexes showed a moderate to high effect on the tested bacteria and fungi.
- The enaminone which containing thiophene ring more effective on microorganisms rather than that containing aromatic phenyl group.

Acknowledgement

The authors are grateful to the Chemistry Department, and the Faculty of Science Kuwait University, and for the SAF facilities

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