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Research Article

# New Carboxamide ligand and its metal complexes containing sulfonamide group: Synthesis, Characterization, DNA cleavage and antimicrobial activity

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**Abstract**

The new carboxamide ligand N-(4-(N-acetylsulfamoyl)phenyl)-2-benzoyl-3-oxo-3-phenylpropanamide (HL) and its Zn(II), Ni(II), Mn(II), Cu(II), Co(II), and Pd(II) complexes were synthesized and also characterized by using various analytical and spectroscopic techniques. While Cu(II) and Pd(II) complexes exhibited square planar geometry, the others displayed octahedral geometry. Newly synthesized compounds were performed for antioxidant, DNA cleavage and antimicrobial activities. Tested compounds exhibited great potential antioxidant activity, especially Zn and Pd complexes. DNA cleavage results indicated that DNA could cleave with compounds through interaction. These compounds were investigated for their antimicrobial activity against seven microorganism species and showed moderate antimicrobial activity.

**Keywords:** *N*-carboxamide ligand; metal complexes; DNA cleavage; antimicrobial activity.

**Sülfonamid Grubu İçeren Yeni Karboksamid Ligand ve Metal Kompleksleri: Sentez, Karakterizasyon, DNA Bölünmesi ve Antimikrobiyal Aktivite**

**Öz**

Yeni karboksamid ligand *N*-(4-(*N*-asetilsülfamoil)fenil)-2-benzoil-3-okso-3-fenilpropanamit (HL) ve Zn(II), Ni(II), Mn(II), Cu(II), Co(II) ve Pd(II) kompleksleri sentezlenmiş ve çeşitli analitik ve spektroskopik teknikler kullanılarak karakterize edilmiştir. Cu (II) ve Pd (II) kompleksleri kare düzlem geometri sergilerken, diğerleri oktahedral geometri sergilemiştir. Yeni sentezlenen bileşiklerin, antioksidan, DNA bölünmesi ve antimikrobiyal aktiviteleri incelenmiştir. Test edilen bileşikler, özellikle Zn ve Pd kompleksleri, büyük potansiyel antioksidan aktivite sergilemiştir. DNA bölünmesi sonuçları, DNA'nın etkileşim yoluyla bileşiklerle parçalanabileceğini göstermiştir. Bu bileşikler, yedi mikroorganizma türüne karşı antimikrobiyal aktiviteleri açısından araştırılmış ve orta düzeyde antimikrobiyal aktivite gösterdiği bulunmuştur.

**Anahtar Kelimeler:** *N*-karboksamit ligand; metal kompleksler; DNA bölünmesi; antimikrobiyal aktivite.

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## 1. Introduction

Amides, which are the basic components of vital organisms, have the feature of strong coordination with different transition metals (Ravinder et al., 1985). Many studies have been done with carboxamides used in synthesizing coordination compounds and different metal complexes have been synthesized (Sönmez, 2001). These complexes were found to be of pharmacological, industrial and biological importance (Ravinder et al., 1985). The effective antimicrobial activity of carboxamide compounds has recently increased the interest in these compounds (Owa and Nagasu, 2000; Drew, 2000; Eze et al., 2019; Supuran and Scozzafava, 2000; Supuran and Scozzafava, 2002; Boyd III, 1988; Thornber, 1979; Ogden and Flexner, 2001). Moreover, oxidative stress is associated with production of reactive oxygen species that are responsible for the damage of a range of cellular components (Bilgin et al., 2012). In recent years there is a great importance in the synthesize of new organic and inorganic compounds with effective biological activity, due to their potential applications in biological systems, such as antioxidant, DNA binding/cleavage and antimicrobial activity (Bajpai et al., 2017; Gali et al., 2015). Metal ions play an important role in biological systems (German et al., 2016). In addition, metal complexes of many compounds have been observed to be more biologically active than ligands (Sönmez et al., 2010; Gülcan et al., 2012; Amjad et al., 2016). The O and N atoms on the carboxamide group can act as donor atoms and easily coordinate to the metal. The complexation ability of the carboxamide compounds has been well established and the bioactivity of the different metal complexes of these compounds has been investigated for antibacterial and antifungal effects against pathogenic bacteria and fungi (Hanif et al., 2014; Balaban Gündüzalp et al., 2012). To expand the function of metal ions in biological systems, we participate in a study of the effect on complexes of the first row transition metals (Balaban Gündüzalp et al., 2012; Hanif et al., 2014; Sumrra et al., 2016). Therefore, the newly synthesized compounds serve in molecular biotechnology, genetic engineering, drug designing etc.

Here we presented the synthesis of a new derivative of N-carboxamide compound bearing sulfonamide group and its Zn(II), Ni(II), Mn(II), Cu(II), Co(II) and Pd(II) complexes. Their characterization have made by using elemental analysis, UV-Vis, IR and NMR spectra for only ligand. Their antioxidant, DNA cleavage and antimicrobial activity have also, been investigated and discussed.

## 2. Material and Methods

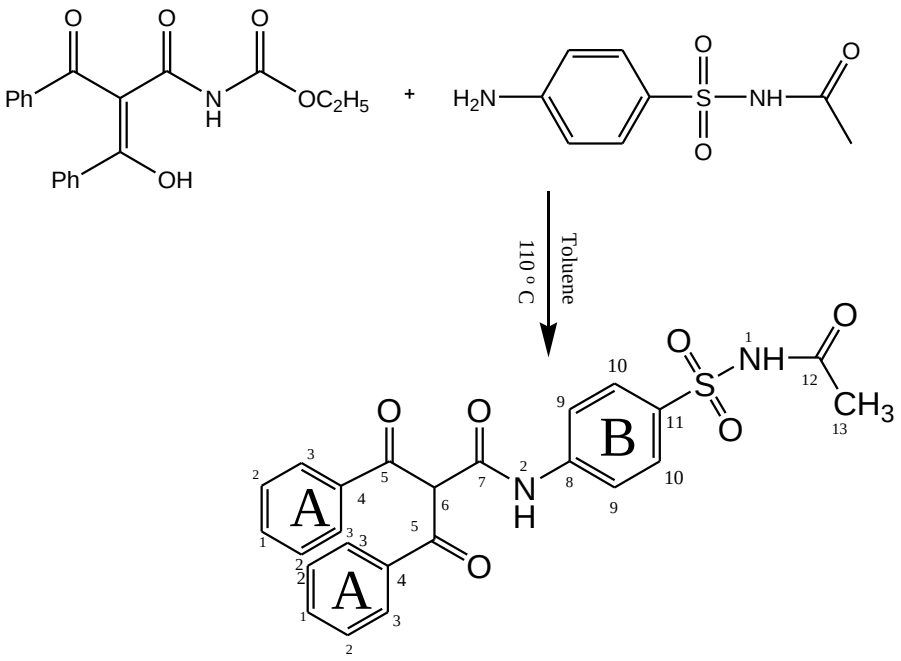
### 2.1.Instruments

All the reactants and solvents (95-99 % purity) were obtained from Sigma&Aldrich or Merck. Elemental analyses were made using a Thermo Scientific Flash EA 2000 CHNS analyzer. The UV-visible absorption spectra were obtained using a PG Instruments T80+UV spectrometer at room temperature. Infrared spectra were recorded using a Perkin-Elmer Spectrum 100 FT-IR spectrometer on ATR. The $^{1}$H-NMR and $^{13}$C-NMR spectra were recorded on a Bruker High Performance Digital FT-NMR (400 MHz) spectrometer in DMSO-$d_6$ at room temperature.

### 2.2. Synthesis of the ligand (LH) (1)

The ligand, *N*-(4-(*N*-acetylsulfamoyl)phenyl) -2-benzoyl-3-oxo-3-phenylpropanamide was synthesized by the condensation method, in which a solution of dibenzoylaceticacid-*N*-carboxyethylamide (1 mmol, 0.325 g) (Fabian et al., 1992) in dry ethanol (25 mL) was added to the equimolar *N*-(4-aminophenyl)sulfonylacetamide solution (1 mmol, 0.331 g) in ethanol

(10 mL). The solvent was removed by evoporation and then dry diethylether was added to the residue and the mixture was stirred for 3 hours. The precipitates were washed and filtered with cold methanol and diethyl ether. The filter product was purified in from dry ethanol. The chemical reaction drawing is given in Scheme 1.




**Scheme 1.** Protocol for synthesis of title compound.

Yield: 70%, m.p: 191-193 °C. Anal.Calc.For: $C_{24}H_{20}N_2O_6S$ (464,10 g/mol): C:62,06; H:4,34; N:6,03; S:6.90. Found: C:62,45; H:4,48; N:6,10; S: 6,98 %. IR(ATR) v, $cm^{-1}$ : 3252 (NH), 3100 (C-$H_{Ar}$), 2986 (C-$H_{Alp}$), 1696, 1681, 1668, 1613 (C=O), 1346 ($SO_2$ asym.), 1162 ($SO_2$ sym.). $^1$H NMR δ, ppm. 11.97 (s, 1H, NH-1), 10,85 (s, 1H, NH-2), 7.96 (d, 4H, *J*= 4.8 Hz A ring C3-ArH), 7.86 (d, 2H, *J*= 6 Hz, B ring C10-ArH), 7.73 (d, 2H, *J*= 5.6 Hz B ring C9-ArH), 7.67 (t, 2H, A ring C1-ArH), 7.55 (t, 4H, A ring C2-ArH), 6.83 (s, 1H, C6), 1.89 (s, 3H, C13 aliphatic C-H). $^{13}$C NMR (DMSO-$d_6$, d ppm): 25.92 (methyl carbon C(13)); 62.47 (C(6)); 64.99-143.48 (aromatic carbons) 164.91 (amide carbonyl (C=O) C(7)); 169.10 (amide carbonyl (C=O) C(12)) 192.72 (A ring carbonyl (C=O) C(5)). UV-Vis (DMF) λmax (Abs): 270 (0.917), 325,00 (1,295) nm.

### 2.3. Synthesis of the metal complexes

General procedure for the synthesis of novel Zn(II), Ni(II), Mn(II), Cu(II), Co(II) and Pd (II) complexes. $CH_3OH/CHCl_3$ (15/15 mL) solution of the suitable metal(II) acetate salts (0.5 mmol) [$Zn(AcO)_2.2H_2O$, $Ni(AcO)_2.2H_2O$, $Mn(AcO)_2.4H_2O$, $Cu(AcO)_2.H_2O$, $Co(AcO)_2.4H_2O$ and $Pd(AcO)_2$] was added to an $CH_3OH$ (10 mL) solution of the ligand (1 mmol) in 1:2 (metal:ligand) molar ratio and refluxed at 60 ºC for 1-2 hours during which time the colored metal complexes precipitate out from the reaction medium. The resulting solids were washed by cold methanol and $H_2O$ and left to dried and purified in from chloroform/diethylether. The chemical structure is given in Figure 1.

**[$ZnL_2(H_2O)_2$] Complex (2):** Yield: 37%, m.p: 154-156 °C. $\mu_{eff}$: dia. Anal.Calc.For: $C_{48}H_{42}ZnN_4O_{14}S_2$ (1028,39 g/mol): C:56,06; H:4,12; N:5,45; S:6.24. *Found:* C:55,88; H:4,11;

N:5,28; S: 5,91%. IR(ATR) v, $cm^{-1}$: 3383 (N-H), 3290 (O-H), 3049 (C-$H_{Ar}$), 2972 (C-$H_{Alp}$), 1721, 1673 (C=O), 1334 ($SO_{2\ asym.}$); 1156 ($SO_{2\ sym.}$); 527 (M-N); 481 (M-O). UV-Vis data, λmax (Abs): 270 (0.944), 275 (0.765), 340 (0.807), 375 (0.362), 355 (0.715) nm.

**[$NiL_2(H_2O)_2$] Complex (3):** Yield: 46%, m.p: 192-194 °C. $\mu_{eff}$: 3.15 B.M. Anal.Calc.For: $C_{48}H_{42}NiN_4O_{14}S_2$ (1021,69 g/mol): C:56,43; H:4,14; N:5,48; S:6.28. *Found:* C:55,91; H:4,39; N:5,35; S: 5,98%. IR(ATR) v, $cm^{-1}$: 3341 (N-H), 3264 (O-H), 3174 (C-$H_{Ar}$), 2941 (C-$H_{Alp}$) 1720 (C=O), 1334 ($SO_{2\ asym.}$); 1156 ($SO_{2\ sym.}$); 541 (M-N); 454 (M-O)**.** UV-Vis (DMF) λmax (Abs): 270 (1,415), 275 (1.319), 325 (0,985), 355 (0.518) nm.

**[$MnL_2(H_2O)_2$] Complex (4):** Yield: 43%, m.p: 178-180 °C. $\mu_{eff}$: 5.86 B.M. Anal.Calc.For: $C_{48}H_{42}MnN_4O_{14}S_2$ (1017,93 g/mol): C:56,64; H:4,16; N:5,50; S:6.30. *Found:* C:56,21; H:4,19; N:5,55; S: 6,37%. *FT IR ($cm^{-1}$):* 3341 (N-H), 3265 (O-H), 3011 (C-$H_{Ar}$); 2939 (C-$H_{Alp}$); 1721 (C=O); 1334 ($SO_{2\ asym.}$); 1156 ($SO_{2\ sym.}$); 539 (M-N); 493 (M-O). *UV-Vis (DMF) λmax (Abs):* 270 (1.831), 275 (1.722), 325 (1.316), 340 (1.160), 365 (0.484), 385 (0.099) nm.

**[$CuL_2$] Complex (5):** Yield: 70%, m.p: 191-193 °C. $\mu_{eff}$: 1.76 B.M. Anal.Calc.For: $C_{48}H_{38}CuN_4O_{12}S_2$ (990,51 g/mol): C:58,20; H:3,87; N:5,66; S:6.47. *Found:* C:57,95; H:3,81; N:5,76; S: 6,12 %. IR(ATR) v, $cm^{-1}$: 3203 (N-H), 3044 (Ar-CH), 2973 (Alp-CH), 1690 (C=O), 1339 ($SO_{2\ asym.}$); 1178 ($SO_{2\ sym.}$); 540 (M-N); 461 (M-N). UV-Vis data , λmax(Abs): 270 (1.431), 275 (1.361), 285 (1.189), 315 (1.255), 335 (0.930), 355 (0.475) nm.

**[$CoL_2(H_2O)_2$] Complex (6):** Yield: 40%, m.p: 161-163 °C. $\mu_{eff}$: 4.55 B.M. Anal.Calc.For: $C_{48}H_{42}CoN_4O_{14}S_2$ (1021,93 g/mol): C:56,41; H:4,14; N:5,48; S:6.28. Found: C:56,35; H:4,19; N:5,27; S: 6,02%. *IR(ATR) v, $cm^{-1}$*: 3360 (N-H), 3209 (O-H), 3053 (Ar-CH), 2972 (Alp-CH), 1695 (C=O), 1339 ($SO_{2\ asym.}$); 1155 ($SO_{2\ sym.}$); 539 (M-N); 409 (M-O). *UV-Vis (DMF) λmax (Abs):* 270 (1,097), 275 (1.009), 325 (0.346), 350 (0.312), 370 (0.216) nm.

**[$PdL_2$]·$2H_2O$ Complex (7):** Yield: 37%, m.p: 154-156 °C. $\mu_{eff}$: dia. Anal.Calc.For: $C_{48}H_{42}PdN_4O_{14}S_2$ (1069,42 g/mol): C:53,91; H:3,96; N:5,24; S: 6,00. *Found:* C:53,47; H:4,23; N:4,95; S:6.24%. IR(ATR) v, $cm^{-1}$: 3340 (N-H), 3235 (O-H), 3060 (Ar-CH), 2972 (Alp-CH), 1721 (C=O), 1337 ($SO_{2\ asym.}$); 1156 ($SO_{2\ sym.}$); 543 (M-N); 450 (M-O). UV-Vis data, λmax (Abs): 350 (1,023), 260 (1,34) nm.

### 2.4. DPPH radical scavenging assay

The DPPH scavenging activity of carboxamide compounds was investigated as described by Blois method (Blois, 1958). Different concentrations (10-200 mg/L) of stock solution were make up to 0.5 mL with dimethylformamide (DMF) and 2 mL of 2,2- diphenyl-1-picrylhydrazyl radical (DPPH) were kept waiting in the dark for half an hour. DPPH scavenging activity was detected spectrophotometrically at 517 nm. A control reaction without test compounds was performed under the same conditions. DMF was utilized as blank. Trolox and Ascorbic Acid were performed as standards in order to compare with the results. DPPH radical scavenging ability was evaluated applying the following formula:

*DPPH scavenging activity (%)=[1-($A_{sample}/A_{control}$ )]x100*

### 2.5. Ferrous ion chelating activity

Metal chelating activityies of carboxamide compounds were investigated as described by Hsu et al. (Hsu et al., 2003). Ethylenediamine tetraacetic acid (EDTA) was performed as the positive control. Ferrous chelating activity was evaluated according to following formula:

*Metal chelating effect (%)=( $A_{control}$ - $A_{sample}$ )/ $A_{control}$ x100*

### 2.6. DNA cleavage activity

The DNA cleavage activity on pBR 322 plasmid DNA was performed by applying agarose gel electrophoresis. Supercoiled pBR 322 plasmid DNA (0.1 mg/mL) was dissolved in 50 mM Tris buffer (pH 7.2) and compounds (100mg/L). The mixtures were kept waiting at 37 °C for 1.5 hour and then mixed with the loading buffer. The reaction mixture were run for 1.5 hour at 80 V by using agarose gel. Tris-boric acid-EDTA was used as an electrophoresis buffer. The electrophoretic bands were visualized by UV-A light.

### 2.7. Antimicrobial activity

The carboxamide ligand (1) and complexes (2-7) were tested *in vitro* antimicrobial activity against *Bacillus cereus*, *Enterococcus hirae* (ATCC 10541), *Legionella pneumophila* subsp. p*neumophila* (ATCC 33152), *Staphylococcus aureus* (ATCC 6538), *Pseudomonas aeruginosa* (ATCC 9027), *Escherichia coli* (ATCC 10536) and *Candida albicans* by using disk-diffusion method (Kalemba and Kunicka, 2003).

## 3. Results and Discussion

The novel carboxamide ligand (LH) was synthesized by the reaction of dibenzoylaceticacid-*N*-carboxyethylamide with N-(4-aminophenyl)sulfonylacetamide in dry ethanol (Scheme 1). This ligand was soluble in chloroform, DMSO and DMF slightly soluble in THF and insoluble in diethyl ether and apolar solvents. LH is a bidentate, mono deprotonable and chelating ligand. Metal (II) complexes (2-7) were obtained by reaction of the ligand with metal ion [Zn(II), Ni(II), Mn(II), Cu(II), Co(II) and Pd(II)] in the stoichiometric ratio of M:L (1:2). First row transition elements were also chosen because they are economical. While Cu(II) and Pd(II) complexes exhibited square planar geometry, the others displayed octahedral geometry. All metal (II) complexes were stable in the air and humidity environment, soluble in DMF, THF and insoluble in water and diethylether. Although the Pd (II) and Zn (II) complexes are diamagnetic, these complexes could not be characterized by NMR since they were not fully dissolved by active solvents by NMR. The structure of the ligand was determined from analytical and spectroscopic measurements. The ligand and its metal complexes were purified by crystallization, but not a single crystal was obtained for the X-ray. These compounds have been investigated for in vitro antimicrobial activity against the microorganism species *E. hirae* (ATCC 10541), *B. cereus*, *S. aureus* (ATCC 6538), *L. pneumophila* subsp. *pneumophila* (ATCC 33152), *P. aeruginosa* (ATCC 9027), *E. coli* (ATCC 10536) and *C. albicans*. The ligand and its metal complexes have been also investigated antioxdant and the DNA cleavage activity which generally increased upon chelation/coordination with the metal(II) ions.

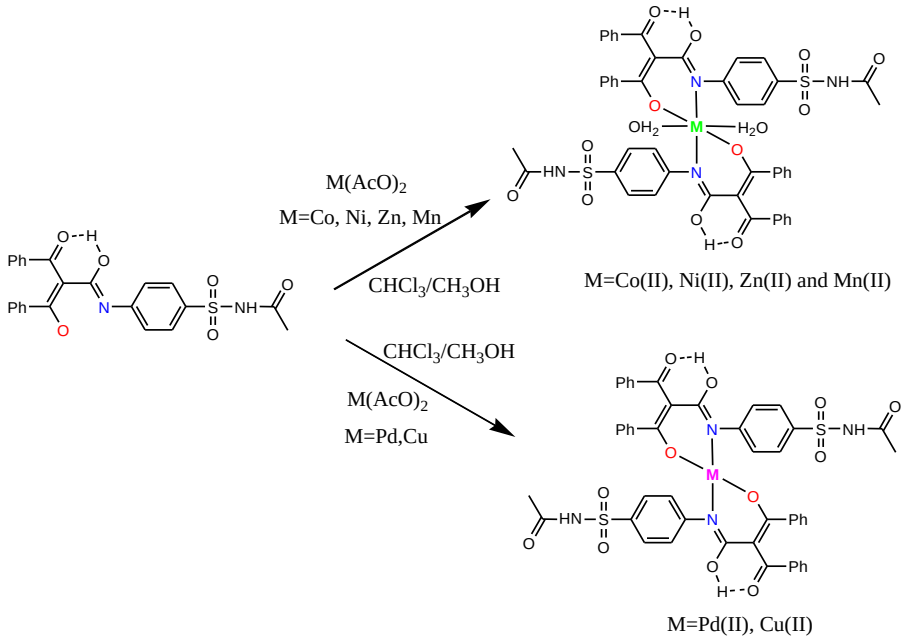



**Figure 1.** Suggested structures of the metal complexes

### 3.1. IR and NMR Spectra

Some typical IR spectrum bands of ligand (LH) and its complexes (2-7) are reported in the experimental section. The IR spectrum of the carboxamide ligand showed a strong absorption band at 3252 $cm^{-1}$ assigned to NH vibrations and intermediate absorption bands at 1696, 1681-1613 and 1162/1346 $cm^{-1}$, due to carboxamide carbonyl (CO-$NH_2$), carbonyl (CO) groups and sulfur dioxide ($SO_2$) symmetric/assymetric vibrations, respectively, strongly supports the preparation of the new compound (Ravinder et al. 1985; Yalçın et al. 2015; Akkurt et al., 2013).

The coordination of the amide-nitrogen to metal ions was indicated by the shifting of the v(N-H) bands to higher frequencies. The stretching vibration band of the C=O↔C-OH enolic group (1668 $cm^{-1}$) cannot be observed in the spectra of the metal complexes due to deprotonation of the ligand (HL) when it is bonded to the metal atom (Demir et al., 2016; Sarioglu et al., 2016). The FT-IR spectrum confirms complexation reaction with the shift of the N-H band and disappearance of the C=O bands. The spectra of complexes showed also new bands at 409-493 and 527-543 $cm^{-1}$ attributed to (M-O) and (M-N) vibration, respectively (Sönmez, 2001; Sarioglu et al., 2016; Sönmez et al., 2018). The carbonyl stretching mode is simultaneously influenced by the conjugation of C=O with amide nitrogen and the intermolecular hydrogen bonding. Therefore, the vibrational frequencies of some carbonyl groups are lost or due to intramolecular hydrogen bonds in the IR spectra of the complexes. These results are in good agreement with the literature containing previous similar studies.

The $^1$H-NMR spectra were in good agreement with the structure of *N*-(4-(*N*-acetylsulfamoyl)phenyl)-2-benzoyl-3-oxo-3-phenylpropanamide. In the $^1$H-NMR spectrum of the ligand, the aromatic protons appeared as a multiplet bands at $\delta$ 7.96-7.55 ppm. –CH proton among three carbonyl groups were observed at $\delta$ 6.83 ppm. The hydrogen atoms in the amide (CONH) group and sulfonacetamide ($SO_2$NHCO) group appears at higher chemical

shift of $\delta$ 10.85 and 11.97 ppm respectively (Figure S1) (Yalçın et al. 2015; Akkurt et al., 2013).

The $^{13}C$ NMR spectrum of the ligand is analyzed carbonyl (NH–C=O) and ($SO_2NHCO$) carbon resonance is observed characteristic peaks sequentially at 164.91 and 169.10 ppm carbonyl related to amide. C5 atoms in carbonyl groups appears at 192.72 ppm. In the compound, aromatic carbon atoms in phenyl rings were located at 143.48-64.99 ppm, C6 carbon atom at 62.47 ppm and C-H aliphatic methyl carbon(C(3)) at 25.92 ppm. Chemical shifts of the peaks of the carbon in the aromatic ring due to the effect substituents are compatible with the literature data (Figure S2).

### 3.2. UV-vis absorption spectra and Magnetic moment

The UV-Vis spectra of the ligand and its metal complexes in DMF were recorded within the 190-1100 nm range and representative spectra are shown in Figure 2. The main absorption bands are observed in the range 315-340 nm related to n- π* transition of the amide and benzoyl carbonyl groups. In addition, the π-π* transition of phenyl rings were consistently observed at 270 and 275 nm (Yalçın et al. 2015). During the formation of the complex, this band is shifted to lower and higher wavelength, suggesting that the nitrogen atom of the imine group is coordinated to the metal ion. During the formation of the complex, the n-π* transition of the –CH=N- and C=O groups is shifted to the lower and higher wavelength, indicating that the N atom of the –CH=N- group is coordinated to the metal(II) ion. The bands in the 350–385 nm range can be attributed to charge transfer between the metal complexes. However, d–d transition bands usually were not observed. This may be due to some of them being effectively masked by charge transfer bands (Uçan et al., 2005; Lever, 1980; Sönmez et al., 2014).

The effective magnetic moment at room temperature of Ni(II), Co(II) and Mn(II) complexes were measured to be 3.15, 4.55, 5.86 BM, respectively, which are the magnetic moment data of the these complexes suggest octahedral geometry (Çelik et al., 2018; Sönmez et al 2014). The Cu(II) complex possesses magnetic moment in the range $\mu_{eff}$=1.76 B.M. in agreement with square-planar geometry (Thaker et al., 2006). Also Pd(II) and Zn (II) metal complexes were found to be diamagnetic.

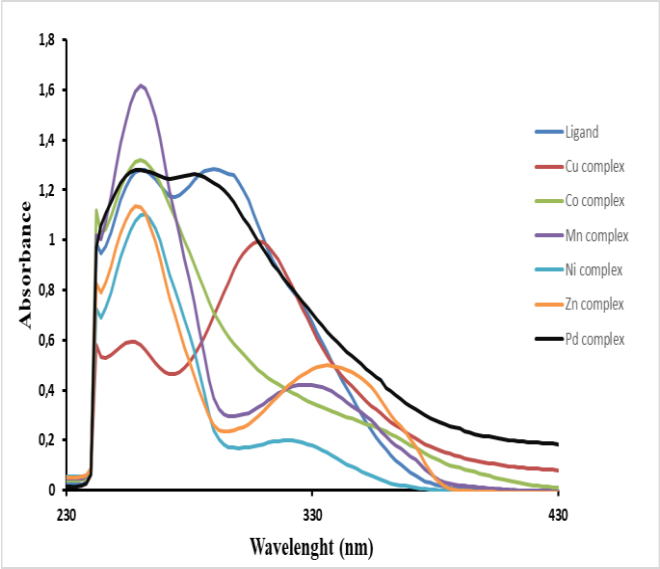



**Figure 2.** UV-*Vis* spectra of ligand and complexes in DMF.

### 3.3. Antioxidant studies

#### 3.3.1. DPPH scavenging activity

Free radicals are the most important contributors in inflammatory process. The free radicals scavenging ability on DPPH radicals assay was widely used as a screening method for study the antiradical activity of organic and inorganic compounds (Sharma and Bhat, 2009). Various concentrations of newly synthesized compounds were studied for determine DPPH scavenging activity. In order to comparing the obtained results Trolox and Ascorbic acid were used as standard. DPPH scavenging ability of the compounds increased with concentration (Fig.3). DPPH scavenging activity of seven compounds at 200 mg/L were 82.9%, 83.3%, 85.8%, 86.1%, 88.3%, 90.7% and 92.7% for Cu, Ni, HL, Mn, Co, Zn and Pd, respectively. At the same concentration, the standard antioxidants exhibited excellent activity as 99.0 % by ascorbic acid and as 98.6 % by Trolox. These results showed higher DPPH scavenging activity than Ilhan et al. (Ilhan et al., 2014). According to our findings, tested compounds can be used as antioxidant agents after further researches.

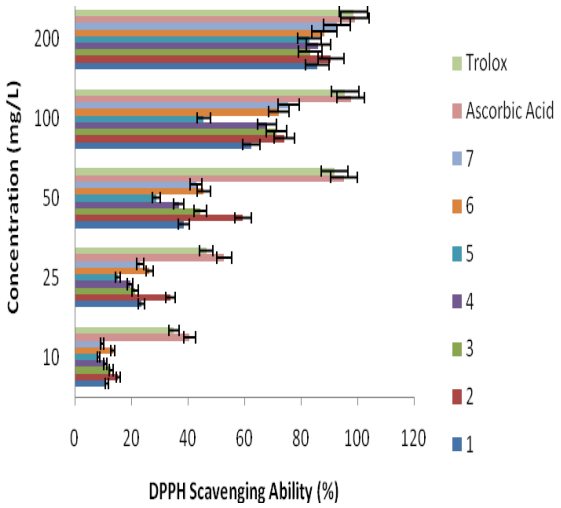



**Figure 3.** Free radical scavenging activity of the compounds on DPPH radicals.

#### 3.3.2. Metal chelating activity

Ferrous chelating capacity is significant due to reducing the quantity of the transition metals in lipid peroxidation (Hseu et al., 2008). $Fe^{2+}$ ion chelating activity at 200 mg/L of the seven compounds were in the order Zn>Pd>Ni>Co>Cu>HL>Mn (Fig. 4). The chelating activities were found 69.16%, 79.32%, 41.56%, 69.48%, and 76.23%, for HL, Ni, Mn, Cu, and Co, respectively at 200 mg/L. Compounds 2 and 7 were better chelators of ferrous ion (90.1 and 87.3%, respectively). EDTA displayed higher activity than the tested compounds. Some chemical modifications to the ligand structure may have made it a more powerful chelator. Therefore, 2 and 7 can be applied as standards for metal chelating ability.

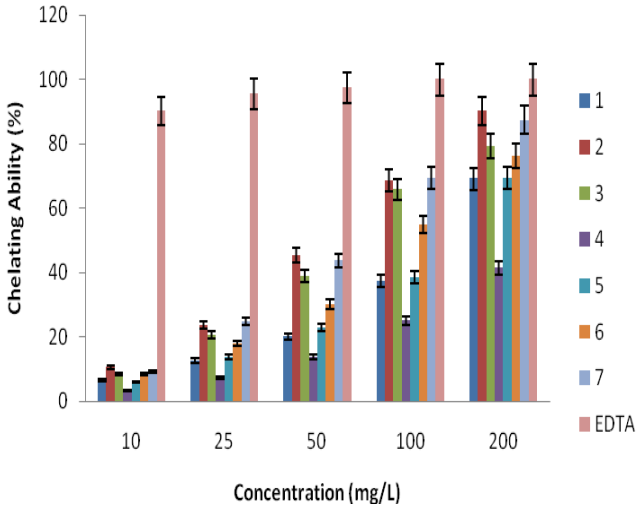



**Figure 4.** Metal chelating activity of compounds.

### 3.3.3. DNA cleavage studies

To detect the DNA cleavage capability of ligand and compounds gel electrophoresis studies were performed by using pBR 322 plasmid DNA. The obtained results (Fig. 5) reveal that all the compounds can interact with plasmid DNA. All tested compounds converted form I (supercoiled DNA) to form II (nicked circular DNA) and form III (linear DNA), except 1. The carboxamide ligand (1) converted form I (supercoiled DNA) to form II (nicked circular DNA). According to the results, we can say that metal complexes offer stronger chemical nuclease activity than ligand. Control experiments displayed pBR 322 plasmid DNA and DNA in 3% DMF did not exhibit any cleavage. Experimental results revealed that carboxamide ligand and its six metal complexes were active in cleavage.

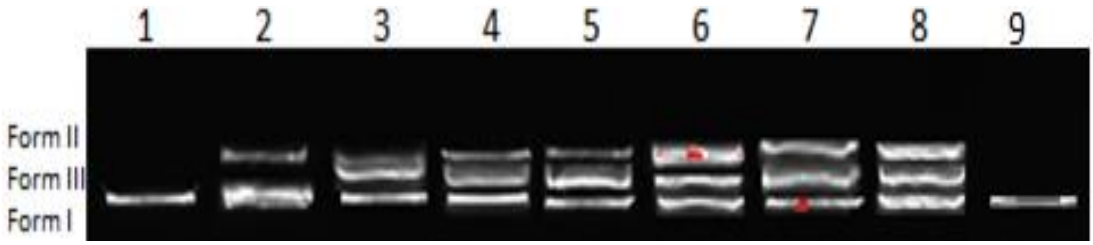



**Figure 5.** DNA Cleavage of compound and its metal complexes. Lane 1, pBR 322 DNA; Lane 2, pBR 322 DNA + 100 µg/mL of 1; Lane 3, pBR 322 DNA + 100 µg/mL of 2; Lane 4, pBR 322 DNA + 100 µg/mL of 3; Lane 5, pBR 322 DNA + 100 µg/mL of 4; Lane 6, pBR 322 DNA + 100 µg/mL of 5; Lane 7, pBR 322 DNA + 100 µg/mL of 6; Lane 8, pBR 322 DNA + 100 µg/mL of 7; Lane 9, pBR 322 DNA + %3 DMF.

### 3.3.4. Antimicrobial activity

In order to assess *in vitro* antimicrobial activity of carboxamide compounds were tested against the microorganism species *E. hirae* (ATCC 10541), *B. cereus*, *S. aureus* (ATCC 6538), *L. pneumophila* subsp. *pneumophila* (ATCC 33152), *P. aeruginosa* (ATCC 9027), *E. coli* (ATCC 10536) and *C. albicans*. Experimental results are given in Fig. 6. Compound Mn and Pd inhibited all microorganisms. The carboxamide ligand (1), Mn and Pd displayed the

highest antimicrobial activity with inhibition zone value equal to 13 mm against *L. pneumophila*, *S. aureus* and *E. hirae*, respectively. Besides, *L. pneumophila* subsp. *pneumophila* was the most sensitive microorganism for all compounds, while *C. albicans* was determined to be the most resistant. In the literature, it has been determined that the presence of heteroaromatic rings is effective on the antibacterial activity of carboxamides (Balaban Gündüzalp et al., 2012).

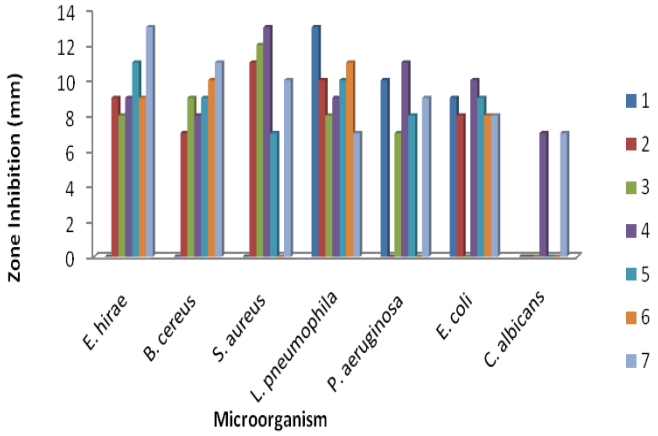



**Figure 6.** Antimicrobial activity of compounds.

## 4. Conclusion

The compound *N*-(4-(*N*-acetylsulfamoyl)phenyl)-2-benzoyl-3-oxo-3-phenylpropanamide (LH) and its metal complexes were synthesized and characterized by spectroscopic and analytical methods (NMR (only ligand), UV-Vis, FT-IR, elemental analysis and magnetic susceptibility). The fact that the metals used in the formation of the complex were selected from economical metals made the results even more interesting. In addition, the newly synthesized compounds have been investigated for their biological activity. These compounds displayed great potential antioxidant activity, especially Zn(II) and Pd(II) complexes. Obtained results of DNA cleavage study, all compounds were active in cleavage. Mn and Pd complexes were showed potential inhibition efficiencies against tested seven microorganisms. Also, *L. pneumophila* subsp. *pneumophila* was inhibited by all compounds.

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## Appendix A. Supplementary data

Supplementary data related to this article can be found, in the online version, at doi:

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