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Synthesis and Antibacterial Activity of Zn(II) Schiff Base Complexes Derived from 3-Acetyl-2*H*-chromen-2-one

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Zn(II) Schiff base complexes *viz.*, *bis*[(*E*)-3-(1-(*p*-tolylimino)ethyl)-2*H*-chromen-2-one]zinc(II), *bis*[(*E*)-3-(1-((4-chlorophenyl)-imino)ethyl)-2*H*-chromen-2-one]zinc(II) and *bis*[(*E*)-3-(1-((2-nitrophenyl)imino)-ethyl)-2*H*-chromen-2-one]zinc(II) derived from 3-acetyl-2*H*-chromen-2-one and *p*-toluidine, *p*-chloro aniline and 2-nitroaniline, respectively, have been synthesized and characterized. Physical properties like, infrared spectroscopy and λ_{max} are recorded and presence of metal is confirmed by atomic absorption spectroscopy. Infrared spectra reveal complex formation of Zn(II) with synthesized ligands. Both free Schiff bases and their Zn(II) complexes have been screened for antibacterial activity against Gram-positive *Bacillus subtilis*, *Staphylococcus aureus*, Methicillin-resistant *Staphylococcus aureus* (MRSA) and Gram-negative *E. coli*, *P. aeruginosa*, *S. typhi* by Agar plate diffusion method. All Schiff bases and their metal complexes appeared promising as antibacterial agents. Minimum inhibition concentrations were determined for each bacterial strain.

Keywords: Zn(II) complexes, 3-Acetyl-2*H*-chromen-2-one, *p*-Toluidine, *p*-Chloroaniline, 2-Nitroaniline, Antibacterial activity.

INTRODUCTION

Compounds containing -C=N- (imine group) are known as Schiff bases and are synthesized by condensing primary amines with active carbonyl groups. Schiff bases are famous for their biological applications[1-3]. Antibacterial agents inhibit the bacterial growth or distinguish bacteria[4]. Schiff bases which have chloro and cyano groups at C-2 are found very effective against a number of bacterial strains[5,6]. Nitrogen, oxygen and sulphur containing Schiff base ligands have shown a number of biological activities and have found of great interest because of its binding with metal ions. It has been reported that existence of metals in many biological active compounds increases their activity[7]. Schiff base metal complexes have shown infinite biological activities as antifungal[8-12], anti-HIV[13], anticonvulsant[14], antimicrobial[15-20], antiviral and anticancer[21] and antibacterial agents[22]. *bis*-Schiff bases form chelate rings after coordinating with a metal ion[23]. Copper(II) complexes synthesized from Schiff base ligands derived from isatin[24] have played very active role for oxidation of carbohydrates. Similarly, *bis*-Schiff base metal complexes are also used as inhibitors of human α-thrombin[25].

The present study aims the synthesis, characterization and study of antibacterial activity of *bis*-Schiff base metal complexes. We synthesized different Schiff bases by reacting 3-acetyl-2*H*-chromen-2-one (**4**) with *p*-toluidine (**5**), 4-chloroaniline (**7**) and 2-nitroaniline (**9**). Schiff bases were then reacted with Zinc(II) metal ion and metal complexes were synthesized. All the synthesized Schiff bases and their complexes were characterized by physical techniques including infra-red spectroscopy, UV-visible spectroscopy and atomic absorption spectroscopy. Both Schiff base ligands and zinc metal complexes were then investigated and found effective against different bacteria including both Gram-positive and Gram-negative strains.

EXPERIMENTAL

Salicylaldehyde, ethyl acetoacetate, *p*-toluidine, *p*-chloroaniline, 2-nitroaniline bacteriological agar, Tryptone (Fluka), yeast extract, sodium chloride, DMSO, ethanol and chloroform used in this work were purchased from Sigma Aldrich and were used as such as received. $Zn(CH_3COO)_2.H_2O$ was of the analytical grade from Fluka dried over phosphorous pentaoxide (P_2O_5). All bacterial strains were collected from the department of microbiology, University of Punjab Lahore, Pakistan.

Perkin-Elmer FT-IR 783 spectrophotometer was used to take IR spectra for all the synthesized ligands and complexes. ^1H NMR and ^{13}C NMR were recorded on Jeol ECS 300 NMR

spectrometer. Chemical shifts for protons were measured in comparison to tetramethylsilane (TMS) at δ = 0 ppm.

Synthesis of 3-acetyl-2*H*-chromen-2-one (4): 3-Acetyl-2*H*-chromen-2-one was prepared according to the reported method[26]. To a mixture of salicylaldehyde (**1**) (12.2 g, 0.1 mol) and ethylacetoacetate (**2**) (13 g, 0.1 mol) in 10 mL of ethyl alcohol few drops of piperidine (**3**) were added and stirred for 8 h at room temperature. Yellow coloured solid was formed and collected by filtration, washed with excess of chilled alcohol, dried and crystallized as silky needles of 3-acetyl-2*H*-chromen-2-one (**4**) (71.9 %) (Fig. 1).

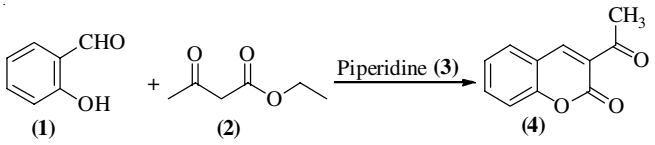

Fig. 1. Synthesis of 3-acetyl-2*H*-chromen-2-one

^{1}H NMR (400 MHz, $CDCl_3$) δ ppm 8.51 (1H, s, Ar*H*), 7.86 (1H, d, *J* = 7.16 Hz, Ar*H*), 7.71 (1H, t, *J* = 8.19 Hz, Ar*H*), 7.43-7.39 (2H, m, 2 × Ar*H*), 2.71 (3H, s, C*H*$_3$). ^{13}C NMR (75.5 MHz, $CDCl_3$) δ ppm 198.8 (1C, Ar*C*OCH$_3$), 159.4 (1C, *C*OO), 153.1 (1C, *C*O), 136.9 (1C, Ar*C*H), 131.1 (1C, Ar*C*CO), 128.3 (1C, Ar*C*H)), 127.6 (1C, Ar*C*H), 125.4 (1C, Ar*C*H), 118.1 (1C, Ar*C*), 116.0 (1C, Ar*C*H), 29.6 (1C, *C*H$_3$), IR (film, ν_{max}, cm^{-1}): 3056 (*sp*^{3} C-H), 1725 (C=O), 1200 (C-O); m.p.:120 °C.

Synthesis of ligands

General procedure: The Schiff bases (**6**, **8**, **10**) were synthesized by stirring a mixture of 25 mL of 3-acetyl-2*H*-chromen-2-one (**4**) ethanolic solution (0.0l mol, 1 eq) with aniline (**5**, **7**, **9**) (0.0l mol, 1 eq) in 25 mL of ethanol at 60-70 °C for 3 h. Progress of reaction was monitored by TLC. From the resulting solution, solvent was removed by evaporation under vacuum. The crystalline product was separated by filtration, washed several times with ethanol. After recrystallizing with hot ethanol, product was dried under vacuum. Its purity was confirmed by TLC technique[27].

Synthesis of (*E*)-3-(1-(*p*-tolylimino)ethyl)-2*H*-chromen-2-one (6): Schiff base (*E*)-3-(1-(*p*-tolylimino)ethyl)-2*H*-chromen-2-one (**6**) was synthesized from 3-acetyl-2*H*-chromen-2-one (**4**) (1.88 g; 0.0l mol, 1 eq) and *p*-toluidine (**5**) (1.07 g; 0.0l mol, 1 eq) as bright yellow crystalline solid (Yield 71.9 %) (Fig. 2).

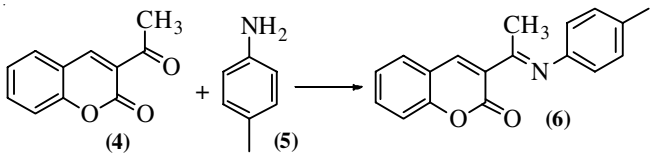

Fig. 2. Synthesis of (*E*)-3-(1-(*p*-tolylimino)ethyl)-2*H*-chromen-2-one

^{1}H NMR (400 MHz, $CDCl_3$) δ ppm 7.83 (1H, d, ArH, *J* = 8.3), 7.67-7.63 (1H, m, Ar*H*), 7.55 (1H, s, Ar*H*), 7.31-7.27 (2H, m, 2 × Ar*H*), 7.21 (2H, d, 2 × Ar*H*, *J* = 8.3), 7.12 (2H, d, 2 × Ar*H*, *J* = 8.2), 2.18 (3H, s, ArC*H*$_3$), 2.08 (3H, s, CH$_3$), ^{13}C NMR (75.5 MHz, $CDCl_3$) δ ppm 175.5 (1C, *C*=N), 159.4 (1C, *C*=O), 153.1 (1C, Ar*C*-O), 148.7 (1C, Ar*C*-N), 136.7 (1C, Ar*C*CH$_3$), 132.1 (1C, Ar*C*H), 130.4 (2C, 2 × Ar*C*H), 128.3 (1C, Ar*C*H), 128.2 (1C, Ar*C*H), 125.0 (1C, Ar*C*H), 122.0 (2C, 2 × Ar*C*H), 118.3 (1C, Ar*C*), 116.0 (1C, Ar*C*H), 113.5 (1C, Ar*C*), 21.6 (1C, Ar*C*H$_3$) 19.9 (1C, C*C*H$_3$), IR (film, ν_{max}, cm^{-1}): 3031 (*sp*^{2} C-H stretch), 2901 (*sp*^{3} C-H stretch), 1677 (C=O stretch), 1558 (C=N), 1209 (C-O stretch) m.p.: 125 °C.

Synthesis of (*E*)-3-(1-((4-chlorophenyl)imino)ethyl)-2*H*-chromen-2-one (8): 3-Acetyl-2*H*-chromen-2-one (**4**) (1.88 g; 0.0l mol, 1 eq) was reacted with 4-chloroaniline (**7**) (1.27 g; 0.0l mol, 1 eq) to synthesize (*E*)-3-(1-((4-chlorophenyl)imino)-ethyl)-2*H*-chromen-2-one (**8**) as light yellow crystalline solid (Yield 76.5 %) (Fig. 3).

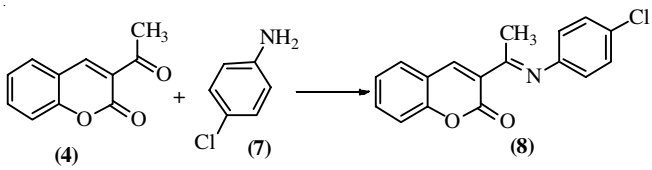

Fig. 3. Synthesis of (*E*)-3-(1-((4-chlorophenyl)imino)ethyl)-2*H*-chromen-2-one

^{1}H NMR (400 MHz, $CDCl_3$) δ ppm 7.81 (1H, d, Ar*H*, *J* = 8.3), 7.65-7.61 (1H, m, Ar*H*), 7.53 (1H, s, Ar*H*), 7.32-7.25 (4H, m, 4 × Ar*H*), 6.99 (2H, d, 2 × Ar*H*, *J* = 7.6), 2.10 (3H, s, C*H*$_3$). ^{13}C NMR (75.5 MHz, $CDCl_3$) δ ppm 175.4 (1C, *C*=N), 159.4 (1C, *C*=O), 153.0 (1C, Ar*C*-O), 148.8 (1C, Ar*C*-N), 132.0 (1C, Ar*C*Cl), 131.9 (1C, Ar*C*H), 130.4 (2C, 2 × Ar*C*H), 128.4 (1C, Ar*C*H), 128.1 (1C, Ar*C*H), 125.2 (1C, Ar*C*H), 122.0 (2C, 2 × Ar*C*H), 118.3 (1C, Ar*C*), 116.0 (1C, Ar*C*H), 113.5 (1C, Ar*C*), 19.9 (1C, C*C*H$_3$), IR (film, ν_{max}, cm^{-1}): 3085 (*sp*^{2} C-H stretch), 2940 (*sp*^{3} C-H Stretch), 1683 (C=O stretch), 1558 (C=N), 1228 (C-O stretch), m.p.: 131 °C.

Synthesis of (*E*)-3-(1-((2-nitrophenyl)imino)ethyl)-2*H*-chromen-2-one (10): (*E*)-3-(1-((2-nitrophenyl)imino)ethyl)-2*H*-chromen-2-one (**10**) was synthesized by reacting 3-acetyl-2*H*-chromen-2-one (**4**) (1.88 g; 0.0l mol, 1 eq) with 2-nitroaniline (**9**) (1.27 g; 0.0l mol, 1 eq) as golden yellow crystalline solid (Yield 77.1 %) (Fig. 4).

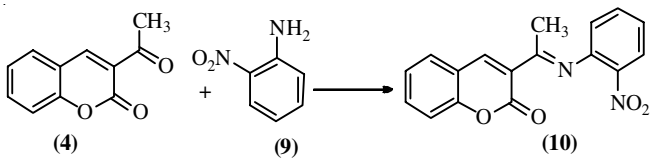

Fig. 4. Synthesis of (*E*)-3-(1-((2-nitrophenyl)imino)ethyl)-2*H*-chromen-2-one

^{1}H NMR (400 MHz, $CDCl_3$) δ ppm 8.07 (1H, d, Ar*H*, *J* = 8.1), 7.85-7.81 (2H, m, 2 × Ar*H*), 7.72-7.68 (3H, m, 3 × Ar*H*), 7.58 (1H, s, Ar*H*), 7.37-7.29 (2H, m, 2 × Ar*H*), 2.13 (3H, s, C*H*$_3$), ^{13}C NMR (75.5 MHz, $CDCl_3$) δ ppm 175.6 (1C, *C*=N), 159.3 (1C, *C*=O), 153.2 (1C, Ar*C*-O), 145.2 (1C, Ar*C*-NO$_2$), 142.2 (1C, Ar*C*-N), 132.6 (1C, Ar*C*H), 131.3 (1C, Ar*C*H), 130.0 (1C, Ar*C*H), 128.5 (1C, Ar*C*H), 128.4 (1C, Ar*C*H), 128.2 (1C, Ar*C*H), 124.8 (1C, Ar*C*H), 124.7 (1C, Ar*C*H), 118.4 (1C, Ar*C*), 115.9 (1C, Ar*C*H), 113.2 (1C, Ar*C*), 19.9 (1C, CCH$_3$), IR (film, ν_{max}, cm^{-1}): 3057 (*sp*^{2} C-H stretch), 2927 (*sp*^{3} C-H stretch), 1684 (C=O stretch), 1556 (C=N), 1200 (C-O stretch) m.p.: 127 °C.

Synthesis of Schiff base metal complexes

General procedure: The metal salt solution (0.005 mol) made in methanol (10 mL) was slowly added to a solution of the salicylaldehyde (0.01 mol) in methanol (10 mL). The reaction mixture was refluxed for 15 min at 60-70 °C with continuous stirring. After 15 min a solution of aromatic amine derivative (0.01 mol) was added into the reaction mixture dropwise with continuous stirring and was refluxed for 4 h at 60-70 °C with stirring. After cooling precipitates were formed, they were collected by filtration then washed several times with cold methanol and recrystallized from methanol.

Synthesis of *bis*[(*E*)-3-(1-(*p*-tolylimino)ethyl)-2*H*-chromen-2-one]zinc(II) (11): After refluxing zinc acetate solution (1.09 g, 0.005 mol, 1 eq) and 3-acetyl-2*H*-chromen-2-one (1.88 g, 0.01 mol, 2. eq) in methanol, *p*-toluidine (1.07 g, 0.01 mol, 2 eq) was added dropwise in the reaction mixture to obtain desired product as yellow precipitates (66 %). IR (film, ν_{max}, cm^{-1}) 3045 (sp^2 C-H stretch), 2960 (sp^3 C-H stretch), 1663 (C=O stretch), 1557 (C=N), 1232 (C-O stretch), 458 (Zn-N), 340 (Zn-O).

Synthesis of *bis*[(*E*)-3-(1-((4-chlorophenyl)imino)-ethyl)-2*H*-chromen-2-one]Zinc(II) (12): Zinc acetate solution (1.09 g, 0.005 mol, 1 eq) made in methanol (10 mL) was slowly added to the solution of 3-acetyl-2*H*-chromen-2-one (1.88 g, 0.01 mol, 2 eq) in methanol (10 mL). The reaction mixture was refluxed for 15 min at 60-70 °C with continuous stirring and *p*-chloroaniline (1.27 g, 0.01 mol, 2 eq) was added dropwise according to the method in section 2.4 and yellow precipitates of product were obtained (69.8 %). IR (film, ν_{max}, cm^{-1}): 3038 (sp^2 C-H stretch), 2938 (sp^3 C-H stretch), 1604 (C=O stretch), 1525 (C=N), 1248 (C-O stretch), 453 (Zn-N), 342 (Zn-O).

Synthesis of *bis*[(*E*)-3-(1-((2-nitrophenyl)imino)ethyl)-2*H*-chromen-2-one]zinc(II) (13): According to procedure in section 2.4, zinc acetate solution (1.09 g, 0.005 mol, 1 eq) in methanol (10 mL) was slowly added to the solution of 3-acetyl-2*H*-chromen-2-one (1.88 g, 0.01 mol, 2 eq) in methanol (10 mL). After refluxing for 15 min at 60-70 °C, a solution of 2-nitroaniline (1.38 g, 0.01 mol, 2 eq) was added dropwise to obtain desire product as lemon yellow solid (62.2 %). IR (film, ν_{max}, cm^{-1}): 3036 (sp^2 C-H stretch), 2931 (sp^3 C-H stretch), 1609 (C=O stretch), 1555 (C=N), 1209 (C-O stretch), 444 (Zn-N), 343 (Zn-O).

Antibacterial activity assay procedure: Agar plate diffusion technique[28] was used to develop L.B nutrient medium. Yeast extract (0.5 g), tryptone (1 g), sodium chloride (0.5 g) and agar (1.5-2 g) were weighed and each component was dissolved in 1 L Erlenmeyer flask. After maintaining the volume up to 1 L, solution was autoclaved to ensure that LB was sterilized of all foreign matter and contaminants. LB medium was used for bacterial culture growth in solution and bacterial growth on petri plates. After adding 25-30 mL of LB medium in petri-dish, it was allowed to solidify; then 1 mL of bacterial suspension was transferred to plate at 27 °C for 24 h. With the help of autoclaved pasture pipette, wells were made in plates and were then filled with solution of ligands/complexes (50 µg/mL) in DMSO. Inhibition zone were measured for both ligands and complexes. Each synthesized ligands and complexes were investigated according to pre mentioned concentrations dissolved in DMSO, while DMSO itself was used as control for comparison. Results are given in Table-2 and 3. For the determination of minimum inhibition concentrations values guidelines given in NCCLS document M27-A[29] were followed. 100 µg/mL solutions of ligands and complexes were made in DMSO and serial dilutions 50, 40, 30, 20, 10, 5 µg/mL were prepared to determine the minimum inhibition concentrations.

Concentrations of test ligands/complexes: 2 mg of each ligand and complex was dissolved in 1 mL of DMSO. From this stock three concentrations 0.2 mg/0.1 mL, 0.02 mg/0.1 mL and 0.002 g/0.1 mL were prepared and used for investigation of antibacterial activities.

RESULTS AND DISCUSSION

Schiff bases ligands ($4CH_3I2C$ (**6**), 4ClI2C (**8**), $2NO_2I2C$ (**10**) were prepared in good yields by reacting 3-acetyl-2*H*-chromen-2-one (**4**) with different derivatives of aniline (**5**, **7**, **9**). Yields of the Schiff bases $4CH_3I2C$ and 4ClI2C were 71.9 % and 76.5 %, respectively while yield (77.1 %) for $2NO_2I2C$ remained maximum among them (Table-1, entry 1, 2, 3). Zinc metal complexes gave lesser yields when compared with their respective ligands. Yields for zinc complexes, *bis*$4CH_3I2CZn$ (**11**), *bis*4ClI2CZn (**12**) and *bis*$2NO_2I2CZn$ (**13**) were 66, 69.8 and 62.2 %, respectively (Table-1, entry 4, 5, 6). Table-1 shows λ_{max} (nm), d.p of zinc complexes and m.p of ligands.

Schiff base ligands were characterized by spectroscopic studies including IR, ^1H and ^{13}C NMR while structures of zinc complexes were estimated by physical characterization. Presence of zinc metal was confirmed by atomic absorption spectroscopy (AAS).

The infrared spectral data of the Schiff bases and their complexes with Zn(II) ion are found in the expected range. Band in the range of 1557-1525 cm^{-1} is attributed to C=N

TABLE-1
PHYSIOCHEMICAL DATA OF SYNTHESIZED LIGANDS/COMPLEXES

S. no.	Ligands/complexes	m.f.	Abbreviations used	m.p/d.p (°C)	Yield (%)	λ_{max} (nm)	Zn (ppm)
1	(*E*)-3-(1-(*p*-tolylimino)ethyl)-2*H*-chromen-2-one	$C_{18}H_{15}NO_2$	$4CH_3I2C$	125	71.9	--	--
2	(*E*)-3-(1-((4-chlorophenyl)imino)ethyl)-2*H*-chromen-2-one	$C_{17}H_{12}ClNO_2$	4ClI2C	131	76.5	--	--
3	(E)-3-(1-((2-nitrophenyl)imino)ethyl)-2H-chromen-2-one	$C_{17}H_{12}N_2O_4$	$2NO_2I2C$	127	77.1	--	--
4	*bis*[(*E*)-3-(1-(*p*-tolylimino)ethyl)-2*H*-chromen-2-one]zinc(II)	$C_{36}H_{30}N_2O_4Zn$	*bis*$4CH_3I2CZn$	155	66.0	425	20.68
5	*bis*[(*E*)-3-(1-((4-chlorophenyl)imino)ethyl)-2*H*-chromen-2-one]zinc(II)	$C_{34}H_{24}Cl_2N_2O_4Zn$	*bis*4ClI2CZn	210	69.8	425	19.43
6	*bis*[(*E*)-3-(1-((2-nitrophenyl)imino)ethyl)-2*H*-chromen-2-one]zinc(II)	$C_{34}H_{24}N_4O_8Zn$	*bis*$2NO_2I2CZn$	215	62.2	485	18.80

TABLE-2
ANTIBACTERIAL ACTIVITY OF Zn(II) COMPLEXES

S. no.	Metal complexes (50 µg)	Diameter of zone of inhibition (mm)					
		Gram positive			Gram negative		
		MRSA	*Bacillus subtilis*	*S. aureus*	*P. aeruginosa*	*E. coli*	*S. typhi*
1	$4CH_3I2C$	-	-	75	-	-	25
2	4ClI2C	-	-	75	10	55	-
3	$2NO_2I2C$	10	10	25	-	-	-
4	*bis*$4CH_3I2CZn$	35	25	30	-	-	25
5	*bis*4ClI2CZn	-	-	75	15	115	-
6	*bis*$2NO_2I2CZn$	15	20	-	10	15	15

Note: Mean inhibition zones are measured in mm

TABLE-3
MIC DATA OF Zn(II) COMPLEXES

Sr. #	Metal complexes	Gram positive			Gram negative		
		MRSA	*Bacillus subtilis*	*S. aureus*	*P. aeruginosa*	*E. coli*	*S. typhi*
1	$4CH_3I2C$	-	-	10	-	-	25
2	4ClI2C	-	-	10 µg	10	55	-
3	$2NO_2I2C$	20 µg	20 µg	20 µg	-	-	-
4	*bis*$4CH_3I2CZn$	15 µg	20 µg	20 µg	-	-	25
5	*bis*4ClI2CZn	-	-	15 µg	15	115	-
6	*bis*$2NO_2I2CZn$	10 µg	20 µg	-	10	15	15

vibration in metal complexes. According to IR spectra, shifting of C=N group towards lower frequency when compared with free Schiff base (1558-1556 cm^{-1}) suggests the attachment of Zn(II) ion through nitrogen atom of imine. The bands in the range of 1663-1604 cm^{-1} are assigned to C=O stretching frequency which were found at 1684-1677 cm^{-1} in free Schiff base spectra. New bands at 343-340 cm^{-1} and 458-444 cm^{-1} assigned to Zn-O and Zn-N respectively vibrations in metal complexes were absent in free Schiff base spectra, it confirmed the involvement of oxygen and nitrogen atoms in complex formation.

The Schiff base ligands and zinc metal complexes have been screened for their antibacterial activities against different pathogenic bacteria including Gram-positive and Gram-negative strains. The results of anti-bacterial activity for both ligands and complexes are presented in Table-2. All ligands were found active against different experimental pathogens. Ligand $2NO_2I2C$ was found very active against Gram-positive bacterias as it showed zones of inhibition with diameter of 10, 10 and 25 mm for MRSA, *Bacillus subtilis* and *S. aureus,* respectively. While this ligand $2NO_2I2C$ was found passive against Gram-negative bacteria (Table-2, entry 3). Ligand 4ClI2C was not active against MRSA, *Bacillus subtilis* and *S. typhi* but it (4ClI2C) was found exceptionally active against *S. aureus*, *P. aeruginosa* and *E. coli* with zones of inhibition 75, 10 and 55 mm, respectively (Table-2, entry 2). Like ligand 4ClI2C, ligand $4CH_3I2C$ was also inactive against Gram-positive bacteria MRSA and *Bacillus subtilis*. On the other hand, it ($4CH_3I2C$) showed opposite behaviour towards *P. aeruginosa* and *E. coli* while it was quite active against *S. aureus* with inhibition zone of 75 mm and *S. typhi* with 25 mm zone of inhibition (Table-2, entry 1). When minimum inhibitory concentrations (MIC) were determined, ligand $2NO_2I2C$ showed the same minimum inhibition concentrations for MRSA, *Bacillus subtilis* and *S. aureus* (Table-3, entry 3). 4ClI2C was found very active against *S. aureus* and *E. coli* with minimum inhibition concentrations 10 µg while for *P. aeruginosa* minimum inhibition concentrations was little higher 20 µg (Table-3, entry 2). Ligand $4CH_3I2C$ was effective against only two bacterial species *S. aureus* and *S. typhi* with minimum inhibition concentrations 10 and 15 µg, respectively (Table-3, entry 1).

Zinc(II) complexes were also screened against mentioned bacterial strains. Complex *bis*4ClI2CZn was very effective against *E.coli* with zone of inhibition 115 mm. Similarly the zones of inhibition for *S. aureus* and *P. aeruginosa* were, respectively 75 and 15 mm for complex *bis*4ClI2CZn and had no effect on *S. typhi* (Table-2, entry 5). Complex *bis*$4CH_3I2CZn$ was more active against Gram-positive bacterias than Gram-negative bacteria. Zones of inhibition against Gram-positive bacteria MRSA, *Bacillus subtilis* and *S. aureus* of *bis*$4CH_3I2CZn$ were 35, 25 and 30 mm and for Gram-negative bacteria *S. typhi* the zone of inhibition was 25 mm while it had no effect on *P. aeruginosa* and *E. coli* (Table-2, entry 4). For *bis*$2NO_2I2CZn$, zones of inhibition for MRSA, *Bacillus subtilis*, *E.coli*, *P. aeruginosa* and *S. typhi* were 15, 20, 10, 15 and 15 mm while it was found inactive against *S. aureus* (Table- 2, entry 6).

Complex *bis*4ClI2CZn showed minimum inhibition concentrations 10 µg against *P. aeruginosa*; and for *S. aureus* and *E. coli*; minimum inhibition concentrations were 15 and 20 µg (Table-3, entry 5). Complex *bis*$4CH_3I2CZn$ was found equally effective for both MRSA and *S. typhi* with minimum inhibition concentrations 15 µg while its minimum inhibition concentrations values for *Bacillus subtilis* and *S. aureus* were 20 µg each (Table-3, entry 4). *bis*$2NO_2I2CZn$ complex showed good activity against many bacterial strains. Minimum inhibition concentrations for bacteria MRSA, *P. aeruginosa* and *E. coli* were found 10 µg while for *Bacillus subtilis* and *S. typhi* minimum inhibition concentrations were 20 and 15 µg, respectively (Table-3, entry 6).

Conclusion

Schiff base ligands were synthesized by reacting 3-acetyl-2*H*-chromen-2-one with different anils. Zinc metal chelates

were then prepared. Both ligands and metal complexes were screened for antibacterial activity and were found effective. Among the synthesized ligands, $4CH_3I2C$ showed minimum activity against selected bacterial strains with good minimum inhibition concentrations; 4ClI2C was effective against some of Gram-positive and Gram-negative bacteria with good minimum inhibition concentrations while $2NO_2I2C$ was only effective against Gram-positive strains. Among zinc(II) Schiff base complexes *bis*$2NO_2I2CZn$ was found most effective against Gram-negative and Gram-positive bacterial strains with excellent minimum inhibition concentrations while *bis*4ClI2CZn remained least effective. Complex *bis*$4CH_3I2CZn$ has been found fairly well against Gram-positive and only one of the Gram-negative strains with good minimum inhibition concentrations.

Supporting information: ^{1}H NMR, ^{13}C NMR and IR data for reported ligands and metal complexes is given in supporting information.

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REFERENCES

1. M. Nath, P.K. Saini and A. Kumar, *J. Organomet. Chem.*, **695**, 1353 (2010).
2. L. Cheng, J. Tang, H. Luo, X. Jin, F. Dai, J. Yang, Y. Qian, X. Li and B. Zhou, *Bioorg. Med. Chem. Lett.*, **20**, 2417 (2010).
3. R.V. Rao, C.P. Rao, E.K. Wegelius and K. Rissanen, *J. Chem. Crystallogr.*, **33**, 139 (2003).
4. Dorlands Medical Dictionary: Antibiotic; Archived from the Original On 2010-11-17; Retrieved 2010-10-29 (2010).
5. I.M. Mustafa, M.A. Hapipah, M.A. Abdulla and T.R. Ward, *Polyhedron*, **28**, 3993 (2009).
6. G. Ciciani, M. Coronnello, G. Guerrini, S. Selleri, M. Cantore, P. Failli, E. Mini and A. Costanzo, *Bioorg. Med. Chem.*, **16**, 9409 (2008).
7. A. Prakash, B.K. Singh, N. Bhojak and D. Adhikari, *Spectrochim. Acta A*, **76**, 356 (2010).
8. S.K. Bharti, G. Nath, R. Tilak and S.K. Singh, *Eur. J. Med. Chem.*, **45**, 651 (2010).
9. K.B. Gudasi, M.S. Patil, R.S. Vadavi, R.V. Shenoy, S.A. Patil and M. Nethaji, *Transtion Met. Chem.*, **31**, 580 (2006).
10. A. Cukurovali, I. Yilmaz and S. Kirbag, *Transtion Met. Chem.*, **31**, 207 (2006).
11. T. Ahamad, N. Nishat and S. Parveen, *J. Coord. Chem.*, **61**, 1963 (2008).
12. M. Fujiwara, H. Wakita, T. Matsushita and T. Shono, *Bull. Chem. Soc. Jpn.*, **63**, 3443 (1990).
13. S.N. Pandeya, D. Sriram, G. Nath and E. DeClercq, *Eur. J. Pharm. Sci.*, **9**, 25 (1999).
14. S.K. Sridhar, S.N. Pandeya, J.P. Stables and A. Ramesh, *Eur. J. Pharm. Sci.*, **16**, 129 (2002).
15. S. Mandal, T.K. Karmakar, A. Ghosh, M. Fleck and D. Bandyopadhyay, *Polyhedron*, **30**, 790 (2011).
16. J. Yusnita, S. Puvaneswary, H.M. Ali, W.T. Robinson and T. Kwai-Lin, *Polyhedron*, **28**, 3050 (2009).
17. R. Pignatello, A. Panico, P. Mazzone, M.R. Pinizzotto, A. Garozzo and P.M. Fumeri, *Eur. J. Med. Chem.*, **29**, 781 (1994).
18. G. Ceyhan, C. Çelik, S. Urus, I. Demirtas, M. Elmastas and M. Tümer, *Spectrochim. Acta A*, **81**, 184 (2011).
19. S.S. Tajudeen and E. Radha, *Asian J. Chem.*, **21**, 313 (2009).
20. G.B. Bagihalli, P.G. Avaji, S.A. Patil and P.S. Badami, *Eur. J. Med. Chem.*, **43**, 2639 (2008).
21. J.A. Zhang, M. Pan, J.Y. Zhang, B.S. Kang and C.Y. Su, *Inorg. Chim. Acta*, **362**, 3519 (2009).
22. E. Ispir, S. Toroglu and A. Kayraldiz, *Transition Metal Chem.*, **33**, 953 (2008).
23. G. Marcu, Chimica Complecsilor Coordinative; Academiei Bucuresti: Bucarest, pp. 44-73 (1984).
24. G. Cerchiaro, G.A. Micke, M.F.M. Tavares and A.M. da Costa Ferreira, *J. Mol. Catal. Chem.*, **221**, 29 (2004).
25. T. Takeuchi, A. Bottcher, C.M. Quezada, M.I. Simon, T.J. Meade and H.B. Gray, *J. Am. Chem. Soc.*, **120**, 8555 (1998).
26. J. March, Advanced Organic Chemistry Reactions, Mechanisms and Structure, John Wiley & Sons, Inc., New York, edn 3 (1985).
27. M.M. El-ajaily, A.A. Maihub, S.S. Hudere and S.M. Ben Saber, *Asian J. Chem.*, **18**, 2427 (2006).
28. National Committee for Clinical Laboratory Standards, NCCLS Approved Standard M27-A. Wayne: Pennsylvania, PA, USA (1997).
29. J. Tuite, Plant Pathological Methods, Fungi and Bacteria; Burgess Publishing Company: Minneapolis, MN, USA, p. 93 (1969).