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# Microwave Solid Phase Synthesis, Characterization and Antimicrobial Activities of Manganese(II) Complex with 2-((Furan-3-ylmethylimino)methyl)phenol

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Mononuclear complex of manganese (**1**) has been designed and synthesized by 2-((furan-3-ylmethylimino)methyl)phenol (L) with $MnCl_2·4H_2O$ in microwave radiation. The complex was characterized by X-ray crystallography, confirming that the central mangances(II) was coordinated by two oxygen atoms and two nitrogen atoms from two L. The complex was assayed for *in vitro* antibacterial (*B. subtilis*, *S. aureus*, *S. faecalis*, *P. aeruginosa*, *E. coli* and *E. cloacae* ) activities and showed better antimicrobial activity against Gram positive strains than Gram negative strains.

**Keywords: Microwave solid phase synthesis, 2-((Furan-3-ylmethylimino)methyl)phenol ligand, Mononuclear mangancse(II) complex**

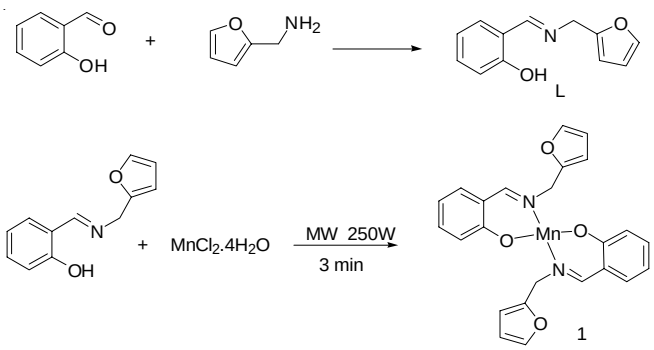
## INTRODUCTION

Salicylaldehyde type's Schiff base and the metal complexes thereof show a wide spectrum of antimicrobial properties[1-7]. Several researchers[8-12] studied the synthesis, characterization and structure-activity relationship (SAR) of Schiff bases. Although these methods synthesize reliable routes for the preparation of Schiff base type's complexes, most of them follow lengthy procedures and time. Therefore, the development of direct and efficient procedures for these classes of compounds from materials has been the target of synthetic organic chemistry. In this paper, one mononuclear complex (**1**) was synthesized by 2-((furan-3-ylmethylimino)- methyl)-phenol (L) with $MnCl_2·4H_2O$ in microwave radiation assistance. The complex were assayed for antibacterial activities against three Gram positive bacterial strains (*Bacillus subtilis*, *Staphylococcus aureus* and *Streptococcus faecalis*) and three Gram negative bacterial strains (*Escherichia coli*, *Pseudomonas aeruginosa* and *Enterobacter cloacae* ) by the 3-(4,5-dimethyl-2-triazyl)-2,5-diphenyl-2*H*-tetrazolium bromide (MTT) method.

## EXPERIMENTAL

All chemicals were of reagent grade and used as received. UV spectra were recorded on a U-3000 spectrophotometer. IR spectra were recorded on a Nexus 870 FT-IR. $^1$H NMR spectra were recorded on a Bruker DPX 300 model spectrometer (Bruker Bioscience,USA) in $CDCl_3$. ESI-MS spectra were recorded on a Mariner System 5304 mass spectrometer. Elemental analyses were performed on a CHN-O-Rapid instrument and were within ± 0.4 % of the theoretical values. Melting points were measured on a Boetius micro melting point apparatus.

**Synthesis of compound L and complex 1:** Compound L was designed and synthesized from salicylaldehyde and furfurylamine in ethanol. The ligand and $MnCl_2·4H_2O$ were mixed together and microwave radiated 3 min in 250 W. The green powder was dissolved in ethanol/DMF(1/1) and afforded *bis*(2-((furan-3-ylmethylimino)methyl)phenol)-manganese(II) (**1**) (**Scheme-I**).




**Scheme-I:** synthesis of L and 1

**Synthesis of compound L:** A mixture of salicylaldehyde (20 mmol) and furfurylamine (20 mmol) in 30 mL ethanol was refluxed for 2 h. After filtration, the yellow solid was washed with athanol and water, dried and recrystallized from

ethanol. Yield: 78 %, m.p.: 65-68 °C. UV (l nm): 370; 256. Selected IR data (KBr, $\nu_{max}$, $cm^{-1}$): 3143(m), 3010(m), 2904(s), 1624(s), 1537(s), 1471(s), 1426(m), 1400(s), 1337(s), 1200(m), 1150(s), 1128(m), 1010(s), 902(s), 812(m), 749(m); $^1$H-NMR ($CDCl_3$) δ ppm: 11.45 (s,1H), 8.20 (s, 1H), 7.45 (d, *J* = 6.8 Hz, 1H), 7.23 (d, *J* = 7.2 Hz, 1H), 7.12 (s, 2H), 6.85 (m, *J* = 16.6 Hz, 1H), 6.74 (d, *J* = 8.2 Hz, 1H), 6.12 (d, *J* = 12.0 Hz, 1H), 4.83 (s, 2H). ESI-MS: 202.10 ($C_{12}H_{12}NO_2^+$, [M + H]$^+$). Anal. Calcd for $C_{12}H_{11}NO_2$(%): C, 71.63; H, 5.51; N, 6.96. Found (%): C, 71.60; H, 5.54; N, 7.00.

**Synthesis of complex 1:** Compound L (10 mmol) and $MnCl_2{\cdot}4H_2O$ (5 mmol) were mixed together and microwave radiated 3 min in 250 W. The green powder was dissolved in ethanol/DMF(1/1). After standing for 7 days, the single crystals of complex **1** were obtained, were separated by filtration, washed with ethanol thrice and dried. Yield: 70 %, m.p.: 249-251 °C. UV (l nm): 375; 252. Selected IR data (KBr, $\nu_{max}$, $cm^{-1}$): 3019(m), 2924(s), 1613(s), 1540(s), 1471(m), 1453(m), 1429(m), 1329(s), 1211(s), 1149(m), 1127(s), 1076(m), 1009(s), 971(m), 903(m), 818(m), 761(m), 751(m). Anal. Calcd for $C_{24}H_{20}N_2O_4Mn$ (%): C, 63.30; H, 4.43; N, 6.15. Found (%): C, 63.36; H, 4.40; N, 6.17.

**Crystal structure determinations and refinements:** The crystallographic date for **1** was collected on a Bruker Smart 1000 CCD area detector diffractometer equipped with $MoK_\alpha$ (λ = 0.71073 Å) radiation using ω-scan mode. Empirical absorption correction was applied to the data. Unit cell dimensions were obtained with least-squares refinements and all structures were solved by direct methods with SHELXL-97. All non-hydrogen atoms were located from the trial structure and then refined anisotropically. All hydrogens were generated in idealized positions. All calculations were performed with SHELXL-97 programs[13]. Other relevant parameters of the crystal structure are listed in Table-1.

**Antimicrobial activity:** The antibacterial activity of **L** and **1** was tested against *B. subtilis*, *S. aureus*, *S. faecalis*, *P. aeruginosa*, *E. coli* and *E. cloacae* using MTT medium. The MICs of the test complexes were determined by a colourimetric method using the dye MTT[14]. A stock solution of the synthesized complex (50 μg/mL) in DMSO was prepared and graded quantities of the test complexes were incorporated in specified quantity of sterilized liquid medium. A specified quantity of the medium containing the complex was poured into microtitration plates. Suspension of the microorganism was prepared to contain approximately 105 cfu/mL and applied to microtitration plates with serially diluted complexes in DMSO to be tested and incubated at 37 °C for 24 h for bacterial. After the MICs were visually determined on each of the microtitration plates, 50 mL of PBS (phosphate buffered saline 0.01 mol/L, pH 7.4: $Na_2HPO_4{\cdot}12H_2O$ 2.9 g, $KH_2PO_4$ 0.2 g, NaCl 8 g, KCl 0.2 g, distilled water 1000 mL) containing 2 mg/mL of MTT was added to each well. Incubation was continued at room temperature for 4-5 h. The content of each well was removed and 100 mL of isopropanol containing 5 % 1 mol/L HCl was added to extract the dye. After 12 h of incubation at room temperature, the optical density (OD) was measured with a microplate reader at 570 nm. The observed MICs were presented in Table-2.

TABLE-1
CRYSTALLOGRAPHIC AND EXPERIMENTAL DATA FOR COMPLEX **1**

| | |
|---|---|
| Empirical formula | $C_{24}H_{20}N_2O_4Mn$ |
| Formula weight | 455.36 |
| Crystal system | Monoclinic |
| Space group | C2/c |
| a (Å) | 20.302(3) |
| b (Å) | 5.7528(8) |
| c (Å) | 17.357(2) |
| α (°) | 90 |
| β (°) | 94.790(3) |
| γ (°) | 90 |
| V (Å$^3$) | 2020.1(5) |
| Z | 4 |
| T (K) | 296(2) |
| Density (g/cm$^3$) | 1.497 |
| μ ($mm^{-1}$) | 0.689 |
| F(000) | 940 |
| Data/restrains/parameters | 2367/0/142 |
| θ range (°) | 2.01 to 27.85 |
| Reflections collected/unique | 13014/2367 |
| $R_{int}$ | 0.0247 |
| Final R indices [I >2σ(I)] | $R_1$ = 0.0512, $wR_2$ = 0.1701 |
| $(\Delta\rho)_{max}$, $(\Delta\rho)_{min}$ (e/Å$^3$) | 0.733 and -0.613 |

[a]$R = \sum||F_o|-|F_c||/\sum|F_o|$, [b]$wR = [\sum[w(F_o^2-F_c^2)^2]/\sum[w(F_o^2)^2]]^{1/2}$

## RESULTS AND DISCUSSION

The Mn(II) complex having m.f. $C_{24}H_{20}N_2O_4Mn$ was prepared in moderate yield (70 %). IR spectra of compound **L** show four bands at 3143 and 1624 $cm^{-1}$, characteristic of the mixed modes of vibrations arising from normal coordinates having contributions from $\nu_{(OH)}$ and $\nu_{(C=N)}$[15]. The infrared spectra of complex **1** (KBr pellets) display an intense absorption band at about 1613 $cm^{-1}$ attributable to the $\nu_{(C=N)}$ shifted *ca.* 11 $cm^{-1}$ lower wave-number compared with 1624 $cm^{-1}$ of **L**. The UV spectra of the complex display an intense absorption peak at 252 nm ($\pi\rightarrow\pi^*$) and 375 nm ($n\rightarrow\pi^*$). The structure of complex **1** were confirmed by a single-crystal X-ray diffraction and is shown in Figs. 1 and 2. The crystal structure consists of

TABLE-2
MICS (MINIMUM INHIBITORY CONCENTRATIONS) OF THE SYNTHETIC COMPOUNDS

| Compound | Microorganisms MICs (μg/mL) | | | | | |
|---|---|---|---|---|---|---|
| | Gram positive | | | Gram negative | | |
| | *B. subtilis* | *S. aureus* | *S. faecalis* | *P. aeruginosa* | *E. coli* | *E. cloacae* |
| **1** | 3.125 | 6.25 | 6.25 | 12.5 | 6.25 | 12.5 |
| **L** | 12.5 | 25 | 12.5 | 25 | 12.5 | 25 |
| Penicillin | 1.562 | 1.562 | 1.562 | 6.25 | 6.25 | 3.125 |
| Kanamycin | 0.39 | 1.562 | 3.125 | 3.125 | 3.125 | 1.562 |

TABLE-3
SELECTED BOND LENGTHS (Å) AND BOND ANGLES (°) OF COMPLEX **1**

| Bond | Dist. | Bond | Dist. | Bond | Dist. |
|---|---|---|---|---|---|
| Mn(1)-O(1) | 1.829(3) | Mn(1)-O(1)#1 | 1.829(3) | Mn(1)-N(1) | 1.920(2) |
| Mn(1)-N(1)#1 | 1.920(2) | N(1)-C(7) | 1.288(4) | N(1)-C(8) | 1.498(4) |
| O(1)-C(2) | 1.308(4) | O(2)-C(12) | 1.382(9) | | |
| Angle | (°) | Angle | (°) | Angle | (°) |
| O(1)-Mn(1)-O(1)#1 | 180.000(1) | O(1)-Mn(1)-N(1) | 92.23(11) | O(1)#1-Mn(1)-N(1) | 87.77(11) |
| O(1)-Mn(1)-N(1)#1 | 87.77(11) | O(1)#1-Mn(1)-N(1)#1 | 92.23(11) | N(1)-Mn(1)-N(1)#1 | 180.00(14) |
| C(7)-N(1)-Mn(1) | 124.8(2) | C(8)-N(1)-Mn(1) | 120.3(2) | C(2)-O(1)-Mn(1) | 129.5(2) |

Symmetry transformations used to generate equivalent atoms: #1 -x + 1/2, -y + 1/2, -z + 2

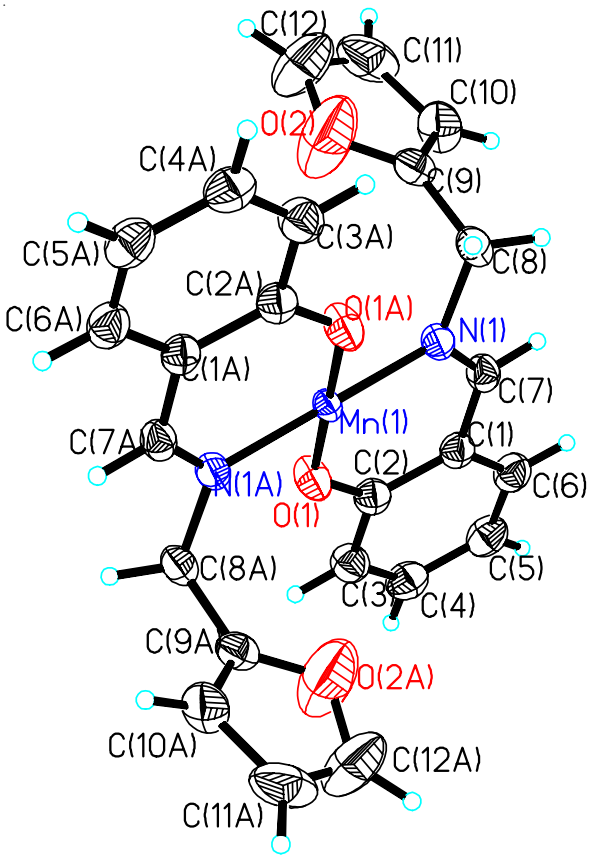



Fig. 1. Crystal structure of complex **1**, showing 30 % probability displacement ellipsoids (arbitrary spheres for the H atoms)

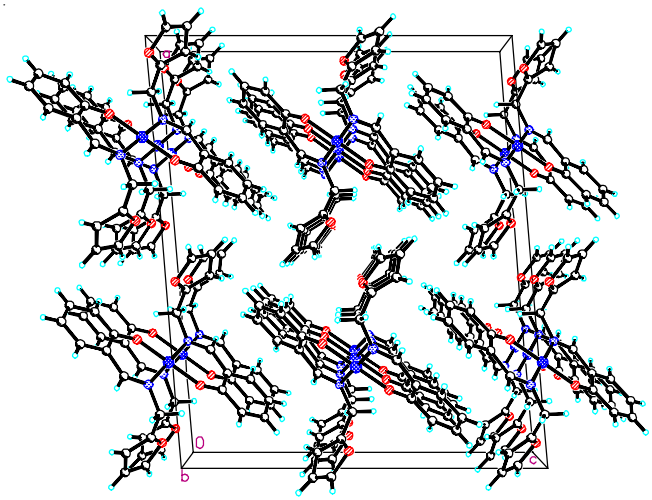


Fig. 2. Packing structure of complex **1** the b-axis

mononuclear complex. The molecular structure of complex **1** crystallize in triclinic with space group C2/c; bond distances and angles are provided in Table-3. The complex **1** is electronically neutral mononuclear compound. The central metal (Mn), on an inversion center, are in quadrilateral coordination geometry with oxygen and nitrogen donors from two **L**. The general Mn-O and Mn-N bond lengths are in the range 1.829(3) Å and 1.920(2) Å, unexceptional and similar to the corresponding bonds in other manganese Schiff base complexes[16,17]. As shown in Table-4, intermolecular H-bonds (C-H…O) formed between adjacent molecules.

TABLE-4
HYDROGEN BONDS FOR COMPLEX **1** [(Å) AND (°)]

| D-H...A | d(D-H) | d(H...A) | d(D...A) | ∠(DHA) |
|---|---|---|---|---|
| C(8)-H(8A)...O(1) | 0.97 | 2.17 | 2.6996 | 113 |

From MIC values, the complex was more toxic towards Gram positive strains than Gram negative strains when compared to the positive controls penicillin and kanamycin, respectively (Table-2). The reason may be the difference in the structures of the cell walls[18]. The walls of the Gram negative cells are more complex than those of Gram positive cells. Lipopolysaccharides form an outer lipid membrane and contribute to the complex antigenic specificity of Gram negative cells. Antimicrobial activity of complexes is due to either killing the microbes or inhibiting their multiplication by blocking their active sites[19]. Since the molecular structure is quite similar, the antibacterial activity of complex **1** is quite similar.

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