Schiff bases as an antimicrobial agent: A review

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Abstract

Schiff bases are versatile ligands and known to be synthesized from the condensation of an amino compound with carbonyl compounds. These compounds along with their metal complexes are considered to be an important as catalysts in various biological processes. Also Schiff base complexes are gaining popularity among the various industries including polymers, dyes and pharmaceutical. This review summarizes the applications of Schiff bases and their complexes as potent antimicrobial agents.

Key words: Schiff bases, metal complexes, antimicrobial agent.

Introduction

The first preparation of imines was reported in the 19th century by Hugo Schiff [1- 3]. The synthesis reported by Schiff involves the condensation of a carbonyl compound with an amine under azeotropic distillation. A Schiff base is a nitrogen analog of an aldehyde or ketone in which the C=O group is replaced by C=N-R group as shown in Scheme [1]. It is usually formed by condensation of an aldehyde or ketone with a primary amine [2-4].

The formation of a Schiff base from an aldehydes or ketones is a reversible reaction. Schiff bases derived from an amino and carbonyl compound are an important class of ligands that coordinate to metal. In azomethine derivatives, the C=N linkage is essential for biological activity, several azomethines were reported to possess remarkable antibacterial, antifungal, anticancer and diuretic activities. Schiff bases have wide applications in food industry, dye industry, analytical
chemistry, catalysis, fungicidal, agrochemical and biological activities. However with growing incidences of infectious diseases, there has been increasing emphasis on the screening of new and more effective antimicrobial drugs with low side effects. Schiff base complexes are considered to be among the most important stereochemical models in main group and transition metal coordination chemistry due to their preparative accessibility and structural variety. A considerable number of Schiff base complexes have potential biological interest, being used as more or less successful models of biological compounds. They have not only played a seminal role in the development of modern coordination chemistry, but also considered as key points in the development of inorganic biochemistry, catalysis and optical materials. The present review describes the current updates in the synthesis of Schiff base compounds.

\[ R\text{-NH}_2 + R\text{-C}=R \rightarrow C=NR + H_2O \]

Scheme 1

Where R, may be an alkyl or an aryl group. Schiff bases that contain aryl substituent are substantially more stable and more readily synthesized, while those which contain alkyl substituents are relatively unstable. Schiff bases of aliphatic aldehydes are relatively unstable and readily polymerizable while those of aromatic aldehydes having effective conjugation are known to be more stable.

**Areas of Applications of Schiff Bases:**

- Nitro and halo derivatives of Schiff bases are reported to have antimicrobial and antitumor activities. Antimicrobial and antifungal activities of various Schiff bases have
also been reported. Some derivative of Schiff base & Beta- Lactam acts as good antimicrobial agents [5].

- Schiff base ligand & metal complexes of sulphur & nitrogen acts as good antibacterial agents [1, 6].
- The crown ethers of shiff bases are also examined to have a very good potential to act as anti microbial agent [7].
- Some Schiff base Copper (II) complexes with phenanthroline and bipyridyl shows better antifungal activity to control the fungal diseases in human and plants [8].
- Thiazole containing Schiff’s bases and their transition metal complexes were shown to be extensive range of biological activities.
- In a similar way there are many compounds of Schiff base with transition metals that shows a wide range of antimicrobial activity [10-12].
- The order of increasing activities is ligand < MeSnL < PhSnL < BZ3SnL, the results matched with the previously reported data for the biological activity of organotin complexes [13].

Fakruddin & co worker synthesized Schiff base metal complexes of Cr(III), Co(II), Ni(II) and Cu(II) derived from 2, 6-pyridine dicarboxaldehyde-Thiosemicarbazone (PDCTC) by conventional as well as microwave methods. In conventional method the metal complexes was prepared by the mixing of equal moles of metal salts dissolved in the methanol followed by addition of NaOAc (metal: ligand)in 1:1ratio. The precipitated complex was, filtered washed with ether and recrystallized with ethanol and dried under the reduced pressure over anhydrous CaCl2 in a desiccator while in microwave method the ligand and the metal salts was mixed in 1:1 (metal: ligand) ratio in a grinder. The Schiff base and metal complexes displayed good activity against the Gram-positive bacteria *Staphylococcus aureus*, the Gram-negative bacteria *Escherichia coli* and the fungi *Aspergillus niger* & *Candida albicans*. The antimicrobial results also indicated that the metal complexes displayed better antimicrobial activity as compared to the Schiff bases ligand. Chelation tends to make the ligand act as more powerful (Fig. 1) and potent bactericidal agent [14].
Similarly they synthesized another novel metal complexes with Schiff base 2, 5-Thiophene Dicarboxaldehyde-Thiosemi carbazone from 2,5-Thiophene dicarboxaldehyde-Thiosemi-carbazone (TDATC) by conventional as well as microwave methods. The Schiff base and metal complexes displayed good activity against the Gram-positive bacteria Staphylococcus aureus, the Gram-negative bacteria, Escherichia coli and the fungi Aspergillus niger [15].

R. Selwin Joseyphus & co worker prepared Schiff base ligands metal complexes with Zn(II). The Zn(II) complex was prepared by dissolving Zn(II) nitrate with ligand in methanol [16]. The in vitro biological screening effects of the investigated compounds were tested against the bacterial species Staphylococcus aureus, Escherichia coli, Klebsiella pneumoniae, Proteus vulgaris and Pseudomonas aeruginosa and fungal species Aspergillus niger, Rhizopus stolonifer, Aspergillus flavus, Rhizoctonia bataicola and Candida albicans by the disc diffusion method (Fig.2).
Pillutla Sambasiva et al. Synthesize & characterize the antimicrobial activity of tridentate Schiff base ligands containing pyrazolone moiety and their transition metal complexes of VO(II), Cu(II), Fe(III), and Co(II). The metal complexes of these ligands with VO(II), Cu(II), Fe(III), and Co(II) show varying geometries. (Fig. 3-5). The ligands and metal complexes show extensive antibacterial and antifungal activity. In general Fe(III) and Co(II) complexes are more potent than other complexes and ligands. The complexes show enhanced antibacterial and anti-fungal activity against various microbes compared to the ligands[17].

Fig. 2 [Schiff base metal complex formed after condensation of glycylglycine with indole-3-carboxaldehyde. Synthesized by R. Selwin Joseyphus & co worker in 2008]
Fig. 3 [Schiff base ligand was prepared by reacting 3-methyl-1-phenyl-4-acetylpyrazolin-5-ol with 1,2-diaminobenzene, and 2-aminophenol by Pillutla Sambasiva et al in 2010]

Fig. 4 [Metal complex of above Schiff base ligand prepared by Pillutla Sambasiva et al in 2010]
M. B. Fugu et al [18] prepared transition metal complexes of Mn(II), Co(II), Ni(II), Cu(II) and Zn(II) with Schiff base ligand. The Schiff base ligand was prepared by condensation of vanillin with 2-aminophenol in ethanol. Schiff base metal (II) complexes was prepared by adding drop metal(II) salts [MnCl2.4H2O, CoCl2.6H2O, NiCl2.6H2O, Cu(CH3COO)2.H2O and Zn(CH3COO)2.2H2O] in boiling ethanol. The Schiff base ligands and the metal complexes were assayed with the bacteria Escherichia coli, Salmonella typhi, Klebsiella pneumoniae, Pseudomonas aeruginosa, Staphylococcus aureus, Streptococcus pyogenes, Corynebacterium specie, and Basillus subtilis using disc diffusion method. The metal complexes were found to be more effective against these microorganisms.

**Fig. 5** [Condensation of two molecules of given ligand to form a new metal complex synthesized by Pillutla Sambasiva et al in 2010]
K. R. Joshi & co workers [19] synthesized Schiff Base Metal Complexes from 2-Hydroxy-3-methoxy-5-nitrobenzaldehyde & newly synthesized compound was tested for their antibacterial activities & found to be very affective. Neelakantan et al, synthesized Metal complexes with Schiff bases derived from o phthalaldehyde (opa) and amino acids viz., glycine (gly) l-alanine (ala), l-phenylalanine (pal) [20]. The antimicrobial activities of the Schiff base metal complexes were tested in vitro against eleven microbes by the modified disc diffusion method. Cu(II) and Ni(II) complexes exhibit inhibition towards all the studied microorganisms. However, Co(II) and Mn(II) complexes exhibit less inhibition and VO(II) complexes have no activity towards the microorganisms. Four new N₂O₂ type tetradentate Schiff base complexes of Co(III), derived from the condensation of meso-1,2 diphenyl-1,2-ethylenediamine (mesostilbenediamine) with salicylaldehyde derivatives, were synthesized [20]. The in vitro antimicrobial activity of the Schiff base complexes was tested against various human pathogenic bacteria [Fig.7].
Fig. 7 [Schiff Base Metal Complexes derived from 2-Hydroxy-3-methoxy-5-nitrobenzaldehyde synthesized by K.R.Joshi and co-worker in 2007]

Pallavi Goel & co workers [21] synthesized schiff base ligand & their transition metal complex (Mn (II),Cu (II),Co(II)) & appropriate balance between broad spectrum pharmacological profile. Tetradequate macrocyclic ligand [1,2,5,6tetaoxo-3,4,7,8 tetraaza-(1,2,3,4,5,6,7,8) tetrabenzene] and its transition metal complex of Mn(II) [Fig. 8]. The LD50 values of the ligand and its metal complex has been. The screened antimicrobial Activity also examined against different bacteria and plant fungi. The result was showing that macrocyclic ligand was potentially more active towards tested microbial species than metal complex.
Fig. 8 (Mn(II) complex of 1,2,5,6tetraoxo-3,4,7,8tetraaza- (1,2,3,4,5,6,7,8) tetrabenzene synthesized by Pallavi Goel & co workers in 2014).

Another example is Tetraaza macrocyclic Cu(II) complexes of composition [CuLX2] (where L = N4 donor macrocyclic ligands) and (X = Cl−, NO3−). The biological activity of all the complexes against gram-positive and gram-negative bacteria was compared with the activity of existing standard antibacterial drugs like Linezolid and Cefaclor [Fig. 9]. Metal complexes were found to be most potent against both gram-positive as well as gram-negative bacteria due to the presence of thio group in the parent ligands [21].

Fig. 9 [Cu(II) complex of Tetraaza macrocyclic ligand prepared by Pallavi Goel & co workers in 2014.]
Ajay R. Patil & co workers [22] synthesized Co(II) complexes of Schiff base 2-amino-4-nitrophenol-N-salicylidene with some amino acids. The Schiff base and mixed ligand complexes were preliminary scanned against various strains of microbes to study their biological effect [Fig. 10]. It has been observed that the compounds showed very good antibacterial and antifungal activity. In comparison with the activity of ligand, activity of the metal complexes was more. This indicated that activity increases with introduction of metal ion. The compounds showed very good antibacterial and antifungal activity at 12.5, 25, 50, 100 and 200 ppm.

**Fig. 10 [Co(II) complexes of Schiff base 2-amino-4-nitrophenol-N-salicylidene with amino acids was prepared by Ajay R. Patil & co workers in 2012]**

Benedict O Achugbu & co workers synthesized metal(M(II)) complexes of the Schiff base 2-(6-methoxybenzothiazol-2-ylimino)methyl)-4-nitrophenol and characterized. The complexes mostly exhibit good in-vitro antibacterial activities against *S. aureus, E. coli* and *P. mirabilis* with inhibitory zones range of 16.0-27.0 mm, 13.0-15.0 mm and 17.0-20.0 mm respectively [23].

N.K. Chaudhary & co workers [24] prepared novel Schiff base ligand by condensation of 2-aminophenol with furan-2- Carbaldehyde using distilled ethanol. The resulting solution was allowed to evaporate by slow diffusion process in air for a week. The crystals of novel ligand were collected, washed several times with distilled ethanol and recrystallized from hot ethanol.
Then to make a metal complex the synthesized novel ligand in hot ethanol was added to hot ethanolic solution of metal chlorides drop wise to make Ni(II) & Cu(II) complexes. A good crystalline form of the complexes was obtained. Physical and analytical data suggest that the Schiff base acts as tridentate ligand towards metal ions via azomethine-N, deprotonated-O of 2-aminophenol and O-atom of furan moiety. The synthesized ligand, along with its metal complexes were screened for their in-vitro antibacterial activity against four bacterial pathogens (*E. coli, Bacillus subtilis, Staphylococcus aureus* and *P. vulgaris*). The results of these studies revealed that the free ligand and its metal complexes showed significant antibacterial potency [Fig. 11].

K. S. Prasad & co workers synthesized and characterized Novel oxovanadium(IV) complexes with 2-methyl-3-(pyridine-2-ylmethyleneamino)quinazolin-4(3H)-one or 3-(2-hydroxy-3-methoxybenzyldene amino)-2-methylquinolin-4(3H)-one by elemental analysis [25]. The synthesized compounds were tested for antimicrobial activity by disc diffusion method. The results indicate the enhanced activity of metal complexes over their parent ligands. The DNA binding and nuclease activity of the synthesized compounds were also studied. The investigation of the interaction of the complexes with calf thymus DNA has been performed with absorption spectroscopy which showed that the complexes are avid binders of calf thymus DNA [Fig. 12].

![Fig. 11](schiff_base_nickel_complex_prepared_using_2-aminophenol_with_furan-2-carbaldehyde_by_nk_chaudhary_co_workers_in_2013.png)
K. Siddappa & co workers [26] synthesized a new compound named 3-2-(1-(1-Hydroxynaphthalene-2-yl) Methylene amino) Phenyl) -2-Methylquinazoline-4 (3H) from hot ethanolic solution of 3-(2-aminophenyl)-2-methylquinazolin-4(3H)-one by adding in ethanolic solution of 2-hydroxy-1-naphtholdehyde. A general method has been used for the preparation of complexes using the reaction of metal salts and the corresponding Schiff-base. A methanolic solution of ligand and Cu(II), Ni(II) Co(II), Mn(II) and Zn(II) chlorides was mixed gently and refluxed for 3 h. The complex shows good antioxidant, antitubercular and antimicrobial activities [Fig. 13]. The antibacterial and antifungal activities of the ligand and its complexes were tested
against two gram-positive bacteria such as Staphylococcus aureus Bacillus subtilis, one gram-negative Escherichia coli and two fungi Aspergillus niger and Aspergillus flavus & results were found to be positive.

Fig. 13 [Shiff base metal complex of 3-2-(1-(1-Hydroxynaphthalene-2-yl) Methylene amino) Phenyl) -2-Methylquinazoline-4 synthesised by K. Siddappa& co workers in 2013.]
Eddie L. Chang & co workers Synthesized Schiff base of Cobalt Complexes containing a new hybrid amine-imine-oxime ligand derived from the condensation reaction of diacetylmonoxime with benzidine [27], & found to be effective against *Bacillus subtilis* [Fig. 14]. However the same complex showed no activity towards *Staphylococcus aureus* or the Gram-negative bacteria *Escherichia coli* and *Enterobacter fecalis*.

![Schiff base ligand](image)

**Fig. 14** [Cobalt Complexes of Schiff base with amine-imine-oxime ligand prepared by Eddie L. Chang & co workers in 2010]

Mahalakshmi & co workers [28] derived the binuclear Schiff base complexes are formed newly using different transition metals at their stable oxidation state as Cu(II), Ni(II), and VO(II). 3,3′,4,4′-tetraminobiphenyl and 2-aminobenzaldehyde were condensed to form a new Schiff base ligand having an two N4 group responsible for better chelating to the metal centers(Fig. 15). The free ligand and their metal complexes were screened for their antimicrobial activities against the following species: *Klebsiella pneumoniae*, *Escherichia coli* and *Staphylococcus aureus*. A comparative study of minimum inhibitory concentration (MIC) values of the Schiff base and its complexes indicate that the metal complexes exhibit higher antibacterial activity than the free ligand. As the test solution concentration increases, the biological activity also increases. The minimum inhibitory concentration (MIC) values of the investigated compounds are summarized.
The observed MIC values indicate that the complexes have higher antimicrobial activity. The metal complexes Cu(II), Ni(II) and VO(II) have higher antimicrobial activity than the ligand.

Fig. 15 [Cu(II), Ni(II), and VO(II) Schiff base complexes were prepared by condensing 3,3′,4,4′-tetraminobiphenyl and 2-aminobenzaldehyde by Mahalakshmi & co workers in 2014]

Shakir M. Alwan & co workers made an interesting approach of synthesizing a new series of pyridopyrimidine derivatives containing Schiff bases of certain amino acids [29]. The new derivatives were synthesized by reacting 3-formyl-2H-pyrido pyrimidine-2, 4 (3H)-dione with glycine, alanine, glutamic acid, histidine, tryptophan or leucine in methanol under reflux using glacial acetic acid as catalyst. The Schiff bases showed good to moderate antibacterial activity against the test microbes. Compounds showed also antifungal activity [Fig 16]. Compounds showed reasonable activity against \textit{p. aurogenosa} and \textit{C. albicans}, while it showed a good activity against \textit{E. coli} and no activity against G(-) bacteria. Compound showed a moderate activity against \textit{E. coli} and a good activity against \textit{Candida albicans}. However, the Schiff bases of the aromatic amino acids, showed better antimicrobial activities compared with those of aliphatic amino acids.
S.M.S.Shariar co workers [30] synthesized Schiff base Benzophenone Thiosemicarbazone derived from thiosemicarbazide and Benzophenone & the compound was used to study their antibacterial activities against some pathogenic bacteria by disc diffusion method. Benzophenone thiosemicarbazone showed significant antibacterial activity as compared with that of Kanamycin. The compounds was found to possess cytotoxic effect. Minimum inhibitory concentration of this compound was also determined [Fig. 17]. The antibacterial activities of this compound were measured in terms of zone of inhibition. The test compounds showed a good sensitivity against a number of pathogenic bacteria.

D. Nasrin & co workers [31] in view of the antimicrobial activity of a series of nickel, copper and zinc complexes of tridentate Schiff base derived from the condensation reaction of S-benzylidithiocarbazate with 2- hydroxyacetophenone have been synthesized and found to be potential antimicrobial agents. An attempt is also made to correlate the biological activities with geometry of the complexes. The synthesized compounds have been evaluated for their antibacterial and antifungal studies [Fig. 18]. The in-vitro biological screening effects of the investigated compounds were tested against the bacterial species Shigella dysenteriae, Salmonella typhi and Bacillus cereus and fungal species Fusarium equiseti, Macrophomina phaseolina, Botrydiplodia theobromae and Alternaria alternate.

Karim Akbari Dilmaghania & co worker condense 5-(4-aminophenyl)-4-phenyl-1,2,4-triazole-3-thione with 4-methoxy benzaldehyde in methanol which results in production of new Schiff base [32].The synthesized compound were tested for their antimicrobial activity against bacterial (Gram negative and Gram positive) strains in-vitro. The synthetic compound showed different inhibition zones against tested bacterial strains [Fig. 19].The compound showed significant antiproliferative activity against Acinetobacter calcoaceticus. Gajendra Kumari & co workers [33] synthesized and characterized M(III) complexes of Cr, Mn and Fe with a Schiff base derived from 2-amino-4-ethyl-5-hydroxybenzaldehyde and thiocarbohydrazide by several techniques. The Schiff base ligand and the complexes were also tested for their antimicrobial activity (against the bacteria Escherichia coli, Staphylococcus aureus, Pseudomonas aeruginosa and Bacillus megaterium, and the fungi Kluyveromyces fragilis, Rhodotorula rubra, Candida

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*albicans* and *Trichoderma reesei*) to assess their inhibiting potential[Fig 20]. An attempt was also made to correlate the antimicrobial activity with the geometry of the complexes. All complexes were found to be less active against the pathogens *E. coli*, *S. aureus* and *P. aeruginosa*. The Cr(III) complex showed the best antimicrobial activity, but the ligand alone was found to be active against the fungus *T. reesei*.

Fig. 16 [Schiff base ligand prepared by reacting 3-formyl-2H-pyrido pyrimidine-2, 4 (3H)-dione with certain amino acids, Synthesized by Shakir M. Alwan & co workers in 2014]

Fig. 17 [Schiff base Benzophenone Thiosemicarbazone synthesized by S.M.S.Shariar co workers in 2014]
Fig. 18 [Schiff base ligand obtained from condensation reaction of S-benzyldithiocarbazate with 2-hydroxyacetophenone by D. Nasrin & co workers in 2013]

Fig. 19 [Schiff base ligand prepared from 5-(4-aminophenyl)-4-phenyl-1,2,4-triazole-3-thione with 4-methoxy benzaldehyde by Karim Akbari Dilmaghania & co worker in 2009]
Fig. 20 [Schiff base metal M(III) complexes of Cr, Mn and Fe derived from 2-amino-4-ethyl-5-hydroxybenzaldehyde and thiocarbohydrazide by Gajendra Kumari & co workers in]

Azza A.A. Abou-Hussein & co worker [34] synthesized mono- and bi-nuclear acyclic and macrocyclic complexes with hard-soft Schiff base ligand derived from the reaction of 4,6-diacetylresorcinol and thiocarbohydrazide. The Schiff base ligand and its metal complexes were evaluated for their antimicrobial activity against one strain Gram-positive bacteria S. aureus and P. fluorescens as Gram-negative bacteria as well as one pathogenic fungus, as F. Oxysporum. The data were compared with standard antibiotics, chloramphenicol as Gram-negative and Cephalothin as standard reference for Gram-positive bacteria (Fig. 21). Cycloheximide was used as antifungal standard reference. The in vitro antibacterial and antifungal activities demonstrated that the complexes have higher antimicrobial activity in comparison with that of the ligand.

Farukh Arjmand & co -workers [35] has been synthesized the ligand by the condensation reaction of 2-mercaptobenzimidazole and diethyloxalate. The ligand was allowed to react with bis(ethylenediamine)CuII/ NiII complexes to yield complexes [Fig. 22]. The antibacterial and antifungal studies of the synthesized compounds were carried out against S. aureus, E. coli and
A. niger. All the compounds tested, was found to be the most active against bacterial and three fungal pathogens.

Fig. 21 [Schiff base metal (Ru) complex synthesized from 4,6-diacetylresorcinol and thiocabohydrazide by Azza A.A. Abou-Hussein & co worker]

Fig. 22 [Schiff base derived from condensation of 2-mercaptobenzimidazole and diethyloxalate by Farukh Arjmand & co–workers in 2013]
Anju Das Manikpuri & co workers Synthesis Schiff bases of Salicaldehyde and sulfonamides by adding ethanol solution containing few drops of glacial acetic acid in to Salicaldehyde in which sulphonamide was added slowly with constant stirring [35]. The Schiff bases were screened for the biological significance. The antimicrobial screening of duly characterized Schiff bases was performed using paper disc method against some pathogenic strains of *Salmonella enteritidis* and *Staphylococcus aureus* (Fig. 23). Schiff bases showed significant results against *S. enteritidis*. While studying the effects of concentration on zone of inhibition of each compound, the novel Schiff bases gave excellent response against *S. aureus* at all chosen concentration.

![Schiff bases derived from Salicaldehyde and sulfonamides by Anju Das Manikpuri & co workers in 2010](image)

**Fig. 23** [Schiff bases derived from Salicaldehyde and sulfonamides by Anju Das Manikpuri & co workers in 2010]

Elsayed & co worker synthesized, characterized and evaluated biological activity of Co(II) complexe of Schiff base Ligand Derived From Sulphadiazine and its antimicrobial activity was found to be higher against *Escherichia coli*, *Bacillus subtilis* (G+) & *Aspergillus niger* and *Trechodenma viride* [36]. Since, Gram-negative bacteria are considered a quantitative microbiological method testing beneficial drugs in both experimental and clinical tumour
chemistry [Fig. 24]. Therefore it has been claimed that, the synthesis of these complexes might be established a new line for search to new antitumour agents.

Fig. 24 [Metal complexes Schiff bases derived from sulfagundine with Co (II) was synthesized by Badr A. Elsayed & co worker in 2014]

Gomathi Vellaiswami & co workers [37] synthesized a novel Schiff base from 3 ethoxy salicy aldehyde & sulpha pyridine. The orange coloured solid mass formed during refluxing was cooled, filtered, washed and dried in a desiccator. The prepared Schiff base was characterized and it was found that it exhibited promising antibacterial and antifungal activity against various microorganisms [Fig. 25].

Fig. 25 [Schiff base ligand , 4-(3-ethoxy-2-hydroxybenzylideneamino)-N-(pyridin-2-yl)benzenesulfonamide prepaped from sulfapyridine and 3-ethoxysalicyl aldehyde synthesized by Gomathi Vellaiswami & co workers in 2014]
A.V.G.S. Prasad & co-workers synthesized Schiff base from 2-thiophene-carboxy-aldehyde and 2-nitro benzoic acid. Metal complexes of the Schiff base were also prepared from salts of Mn (II) and Co (II) in an alcoholic medium. The chemical structures of the Schiff-base ligand and its metal complexes were confirmed by various spectroscopic studies [Fig. 26]. The free Schiff base and its complexes have been tested for their antibacterial as well as antifungal activity by using disc diffusion method and the results discussed. The experimental results suggested that Schiff base derivatives are more potent in antibacterial and antifungal activities [38].

![Figure 26: Schiff base derived from 2-thiophene-carboxy-aldehyde and 2-nitro benzoic acid by A.V.G.S. Prasad & co-workers in 2014](image)

**Conclusion**

Schiff bases and their derivatives are a class of compounds with vast evidence from literature evidence about pharmacological potential. Schiff base compounds have been shown to be promising leads for the design of more efficient antimicrobial agents. Concisely, Schiff bases are among the molecules which have therapeutic potential for the treatment of various human diseases. Hence there is strong need to explore the molecular aspects of mechanism of actions of various pharmacological mediated affected by Schiff base complexes so that we can use a huge range of antimicrobials.

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Conflict of interest statement

There are no potential conflicts of interest among the authors regarding the publication of this manuscript.

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