Journal of Chemistry and Nutritional Biochemistry
https://jcnb.sabapub.com
E ISSN: 2709-5932

2022 Volume 3, Issue 2 : 44 – 57
DOI : 10.48185/jcnb.v3i2.671

Short Review on Metal Complexes of Schiff Bases containing Antibiotic, and Bioactivity Applications

Abdulmajeed A.M. Alezzy [1,*], Hanan A.M. Alnahari[1], Sultan A.H. Al-horibi[2]

[1] Department of Chemistry, Faculty of Applied Science, Thamar University, Dhamar, Yemen
[2] Department of Chemistry, Albaydha University, Albaydha, Yemen

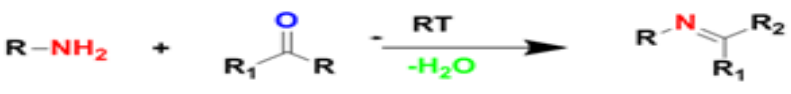
Received: 01.12.2022 • Accepted: 25.12.2022 • Published: 30.12.2022 • Final Version: 30.12.2022

Abstract: In the fields of medicine and pharmaceuticals, a family of compounds known as Schiff bases (SB) plays an important part. Schiff base metal complexes are known to display a broad range of biological activities, each of which is unique in comparison to the others. Anticonvulsants, antibacterial agents, antifungal agents, anticancer agents, antiviral agents, and HIV-fighting medicines are all included in this area of pharmaceuticals. It is general information that the search for new medications and the creation of new medicines is a constant endeavor for scientists and researchers. This is true both in terms of the hunt for new medicines and the manufacturing of new medicines. Antibiotics are losing their effectiveness as microorganisms develop resistance to the drugs that treat them, thus there is a pressing need to discover new substances that might combat this problem. Because of this, the focus of this study was on Schiff bases that had just recently been identified, as well as the metal complexes of those bases that had these qualities.

Keywords: Schiff base, Metal complex, Drug discovery, Bioactivity.

1. Introduction

Hugo Schiff is the naming of Schiff bases. In most cases, the formation of Schiff-base ligands is accomplished by the condensation of aldehydes/ ketones using primary amines (Figure. 1) [1]. Numerous research has documented the usage of medications that are based on aldehyde and drugs that are based on amine in order to manufacture pharmaceuticals that are dependent imine [2, 3]. Schiff bases have been demonstrated to display a wide variety of biological actions, such as antipyretic, antibacterial, antifungal, antimalarial, antiproliferative, and antiviral qualities [4, 5]. There is a diverse assortment of natural, natural-derived, and non-natural chemicals that include amine or azomethine groups, (For some instances, refer to Figure. 2) It has been demonstrated that the presence of an azomethine group in these kinds of compounds is essential to the biological activities that they exhibit [4–6].



R-Aliphatic,aromatic compounds; R_1 -H,CH_3

* Corresponding Author: abdulmajeed.alezzy@tu.edu.ye

Figure 1. Establishing Schiff bases.

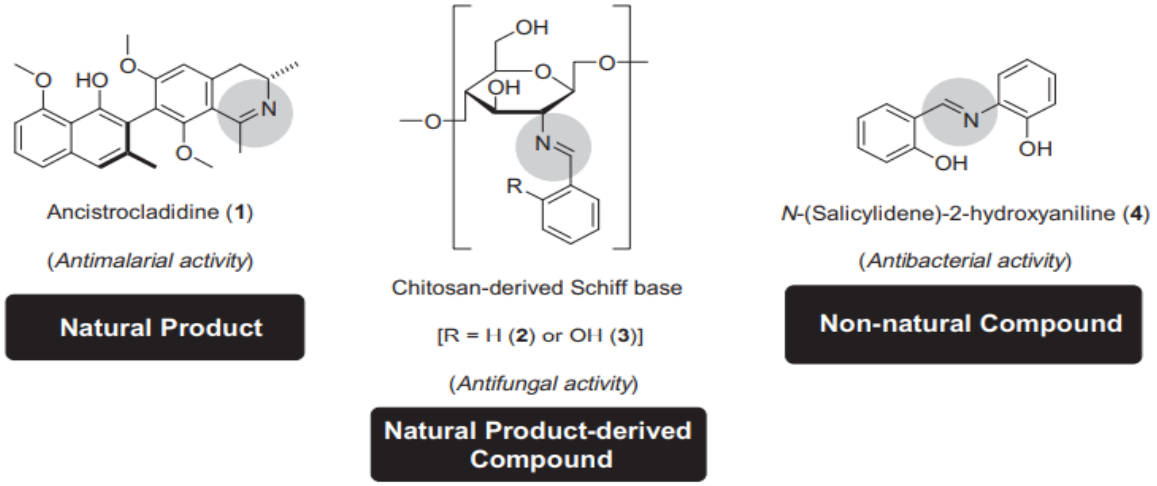


Figure 2. Illustrations of bioactive Schiff bases.

We outline the standard procedures for synthesizing Schiff bases in this review. We additionally highlight the most noteworthy instances of this class's pharmaceuticals that have been reported in the literature to have antimalarial, antibacterial, antifungal, and/or antiviral properties. This review does not address the connection between Schiff bases and other pharmacological effects, such as those that are anti-proliferative.

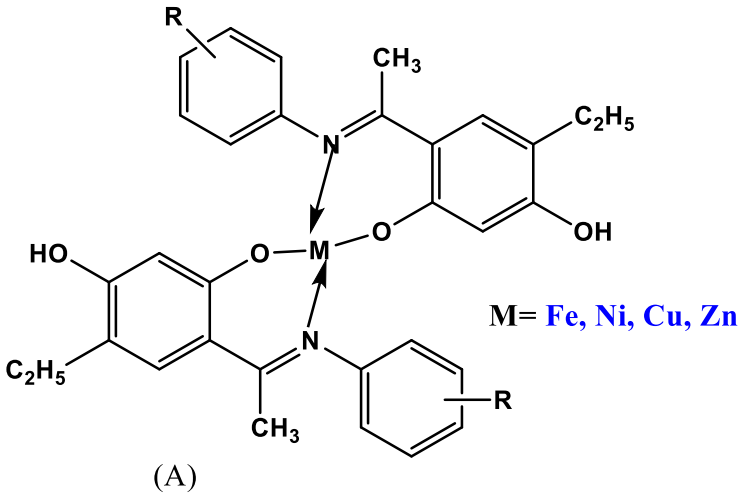
In a variety of processes, several Schiff base complexes have outstanding catalytic activity. Numerous studies on their use both heterogeneous and homogeneous catalyzed have been published during the last several years. Numerous Schiff base complexes' strong heat and moisture stabilities provided advantageous properties for their usage as catalysts in high-temperature processes. Understanding the characteristics both the ligands and the metals may help in the synthesis of significantly active compounds since the activity is often boosted by complexation. The research of these compounds' coordination has increased significantly as a result of the impact that particular metals have on the biological activity of these compounds as well as their inherent chemical interest as polydentate ligands. Medical chemists are currently interested in developing novel chemotherapeutic Schiff bases and their metal complexes.

Implementing Schiff base complexes with transition metals was shown to increase biological activity. Research is now being carried out all around the world on the synthesis, characterization, and structural property relationship (SAR) of Schiff bases. Numerous investigations have shown the significant chemical and biological significance of a lone pair of electrons in the sp2 hybridized orbital of the nitrogen atom of the imine group [7]. By forming a hydrogen connection between the active centers of cell components and the sp2 hybridized of the nitrogen atom of the imine group, they disrupt normal cell functions [8]. Therefore, it will be intriguing to research Schiff base's antimicrobial activity.

Schiff bases of Complexes of copper, nickel, iron, and zinc (Figure 3) were created. It was determined whether the metal complexes have any antibacterial action by testing them against certain clinically significant pathogens, including Klebsiella pneumoniae, Staphylococcus aureus, Proteus vulgaris, and Proteus mirabilis. DMF and 1, 4-dioxane were used as solvents while the Agar Ditch method was used to measure antibacterial activity. More activity was seen in the Schiff bases than in the metal complexes. Due the metal complexes had varying effects on the different bacterial

strains and solvents that were examined, it likely that the molecular structure of the drug, the solvent, and the bacterial strain that was being investigated each have their own unique influence on the antibacterial activity. In 1, 4-dioxane, the zinc complex outperformed the other three metals in terms of antibacterial activity. In DMF, iron complex had the strongest bactericidal action [9].

NK Chaudhary et al. [10] "generated four new metal complexes of Co (II), Ni (II), Cu (II), and Zn (II) using Schiff base produced from amoxicillin and picolinaldehyde. When the ligand and metal complexes were put to the test against four human pathogenic clinical strains of bacteria, the results indicated that the complexes had the potential to be effective antibacterial agents (Figure. 3). In order to create Schiff bases of type (Figure. 4), 2-(hydroxyl naphthaldehyde) and sulfonamides were condensed (sulfa-guanidine, sulfa pyridine, sulfadiazine, sulfamerazine and sulfathiazole). These Schiff bases have been tested for their potential antibacterial effects on Gram-positive and Gram-negative bacteria, as well as certified and resistant strains of Staphylococcus aureus, Enterococcus facelis, Salmonella typhi, Shigelladysenteriae, Shigellaflexneri, and Klebsiella pneumonia". These Schiff bases perform better than traditional stains against resistant bacteria, and their MIC (Minimum Inhibitory Concentration) values range from 32-128 g/ml, in contrast to the parent sulfonamides, which essentially inert (MIC >512 g/ml) [11].



(A)

Figure 3. Fe (II), Ni (II), Cu (II), and Zn (II) Complexes

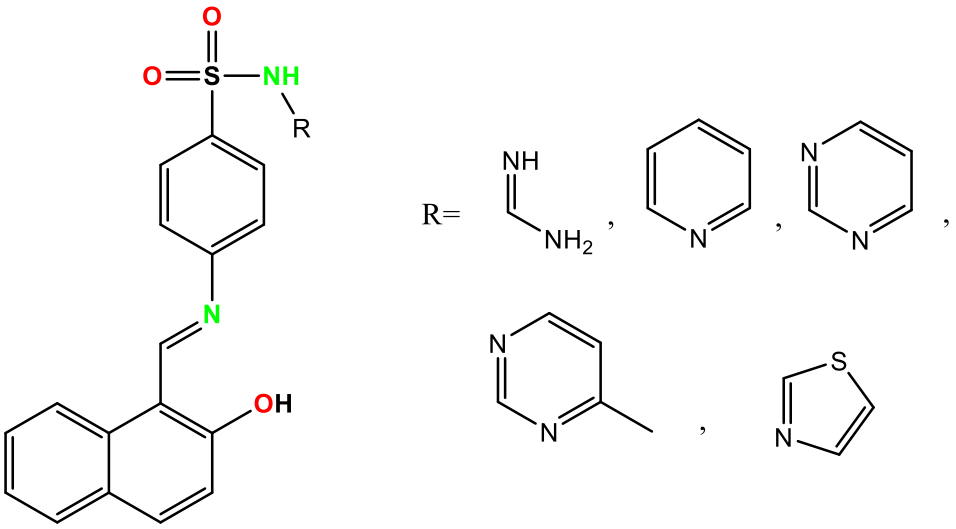


Figure 4. Schiff base of sulfonamides derivatives

Samina et al. [12] have succeeded in creating complexes of the Schiff base including the elements Mn, Co, and Ni. All of the synthetic compounds were put through tests to determine whether or not they have antibacterial or DNA-cleaving properties.

Mohamed et al. [13] were successful in synthesizing complexes of sulfametrole derived Schiff bases including Fe (III), Co (II), and Ni (II) which can be seen in figure 5. Metal complexes have an antibacterial action that is active against a wide variety of bacteria Escherichia coli, Pseudomonas aeruginosa, and Staphylococcus pyogones. Escherichia coli's growth was slowed down due of the complexes. The truth that these complexes have the potential to be employed in a reasonable manner for the treatment of common a variety of ailments that are often caused by Escherichia coli is the primary reason why this is significant. It was discovered that the complexes might prevent the growth of Gram-positive strains of bacteria.

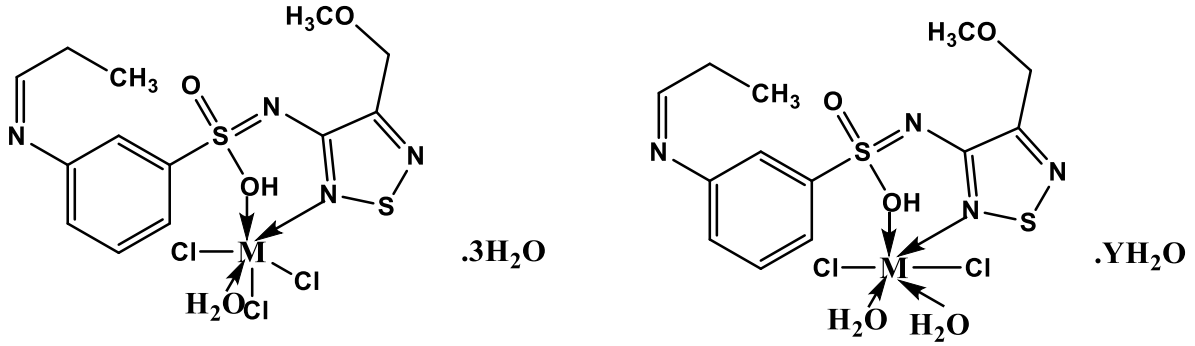


Figure 5. complexes of Fe (III), Co (II), and Ni (II) of sulfametrole derived Schiff bases.

A novel Schiff base known as 3-(((4-chlorophenyl)imino)methyl) benzene-1,2-diol and another Schiff base known as 3-(((4-bromophenyl)imino) methyl)benzene-1,2-diol were successfully synthesized. The two Schiff bases share a structural similarity. Both Schiff bases were used in the synthesis of their Zn (II) and Co (II) complexes. These substances were examined to see whether or whether they inhibited enzyme activity, fought bacteria, were cytotoxic, or fought diabetes in living organisms. According to the findings, zinc complex is an effective inhibitor of the alkaline phosphates enzyme and has the greatest potential to fight diabetes, high blood cholesterol, and cancer cells [14]. 5-chloro-2-hydroxy benzaldehyde and primary amines (1-amino-4-phenoxybenzene, 4-(4-aminophenyloxy) biphenyl, 1-(4-aminophenoxy) naphthalene, and 2-(4-aminophenoxy) naphthalene) were used in the synthesis of new ether-based Schiff bases. As the starting material, these Schiff bases were used in the production of Co (II) complexes. The Schiff bases that were created and the Co (II) complexes that they formed were subjected to additional testing for a wide range of biological investigations. In the DNA protection assay, simple ligand molecules showed considerable protective activity, whereas Co (II) complexes demonstrated neutral behavior [15].

A Schiff base known as 1-((3-nitrophenylimino) methyl) naphthalen-2-olate was successfully synthesized, along with its metal complexes containing Zn (II) and Co (II). All these synthesized compounds were tested for enzyme inhibition, antibacterial characteristics, cytotoxic capabilities, and in vivo anti-diabetic effects. and at least one of these actions was stopped or prevented by the active compounds that were created, [16]. A novel Schiff base known as 2, 4-diiodo-6-((2-phenylaminoethylimino) methyl) phenol has been synthesized, along with its metal complexes including the elements Cu (II), Ni (II), Co (II), Mn (II), and Zn(II). The antibacterial activities of metal complexes were quite impressive by Elham S Aazam et al. [17]. The Schiff base compound 2, 3-bis[(3-ethoxy-2-hydroxybenzylidene) amino] but-2-enedinitrile was synthesized, along with its

associated copper and nickel complexes. Copper complexes were tested for their ability to inhibit the growth of Escherichia coli, and the results showed that they had both a Minimum Inhibitory Concentration and Minimum Effective Concentration. Values of bactericidal concentration that are lower than those values of the complexes that have been commercially manufactured [18]. The respective metal salts were treated with Schiff bases (Trimethylsilyl-propyl-p-aminobenzoate with salicylaldehyde) and ortho-Vanillin, which resulted in the synthesis of three mononuclear complexes. One of the complexes was a Cu (II) complex, while the other two were Zn (II) complexes. The anti-microbial (antibacterial and antifungal) activation of compounds that were synthesized were tested against a variety of microorganisms, including Aspergillus fumigatus ATCC66567, "Penicillium chrysogenum ATCC 20044, Fusarium ATCC 20327, Bacillus sp. ATCC 31073, and Pseudomonas sp. ATCC 15780". In comparison to the conventional drugs Caspofungin and Kanamyci, Schiff bases and metal complexes have been shown to have significantly higher antibacterial activity [19].

Mostafa et al. [20], the produced triazole Schiff bases are reacted by refluxing with either CoCl2.6H2O or NiCl2.6H2O allowed for the synthesis of the "Copper (II) and Nickel (II)-triazole Schiff base complexes. The anti-microbial (antibacterial and antifungal) properties of the produced Copper (II) and Nickel (II) complexes were investigated by testing them on Candida albicans and Aspergillus flavus, respectively. Escherichia coli and Staphylococcus aureus were also tested. Condensation processes were used to produce novel hydrazone compounds, including Schiff bases (2-(1-hydrazonoethyl) phenol, (2, 4-dibromo 6-(hydrazonomethyl) phenol, and 2-(hydrazonomethyl) phenol". In order to evaluate the antibacterial potential of their biological activities, in vitro tests were conducted using bacteria such as Escherichia coli, Proteus vulgaris, Bacillus subtilis, and Staphylococcus aurous [21, 22]. In addition to that, the matching Cu (II) complexes were manufactured. Research has been conducted on DNA interactions, as well as antibacterial and cytotoxic properties, in an effort to acquire a deeper understanding of the complexes' role in the living world and the biological information they impart.

Jaganathan et al. [23] have investigated benzaldehyde was used as the starting material for the synthesis of two new types of sulfonamide Schiff bases 4-(benzylidene amino) benzene sulfonamide and 4-((4-methylbenzylidene)amino) benzene sulfonamide. The antibacterial activity of the Schiff bases was quite impressive. Using modified agar diffusion procedures, it was demonstrated that the material has antibacterial capabilities against both Gram-positive and Gram-negative bacteria. A well-defined Schiff base as the starting point to synthesis of the new Zinc (II) binary complex. Encapsulation regulates the release of the zinc, which attenuates the nanoparticles' antibacterial activity [24]. This resulted in all zinc-loaded nanoparticles having a lower antimicrobial activity compared to zinc compounds on their own. New base on the Schiff condensation of ortho-phthalaldehyde with 2-aminobenzoic acid in a ratio of 1:2 yielded the ligand, which was produced. The biological activity of metal complexes was investigated after they were produced. According to the results of the biological study, the metal complexes proved to be an antibacterial agent that more efficient than the parent Schiff base ligand against one or more species of bacteria [25]. The newly synthesized Schiff base 2-((2-(2-(allylthio)-1-carboxyethylidene) amino)-4-(methylthio) butanoic acid has a good antioxidant activity, It was shown by a decrease in oxidative stress as well as an improvement in the functions of the body's endogenous antioxidants in response to CCl4 intoxication. In addition to this, it safeguards the operational activities of the numerous enzymes involved in the oxidative phosphorylation and tricarboxylic acid cycle of the mitochondria [26]. The following Schiff base compounds of "N′-substituted benzohydrazide and sulfonohydrazide derivatives were successfully synthesized by using N′-(2-hydroxy-3-methoxybenzylidene)-4-tert-

butyl-benzohydrazide, N′-(5-bromo-2 hydroxybenzylidene)- 4-tert-butylbenzohydrazide". The biological activities of the compounds, anti-microbial (antibacterial, antifungal), cytotoxic, and enzymatic activities, have been investigated through the use of screening procedures. It was discovered that the chemicals that were produced were also efficient against the alkaline phosphatase enzyme. In addition to this, their antibacterial efficacy against seven different bacterial and five different fungus strains ranges from substantial too good. The minimum concentration needed to inhibit bacterial growth, known as the MIC (Minimum Inhibitory Concentration), can range anywhere from 1.95 to 500 g/mL [27].

Mariangela et al. [28] "have synthesized new Schiff bases by starting with "sulfanilamide, 3-fluorosulfanilamide, or 4-(2-aminoethyl)-benzene sulfonamide. Their activity against the pathogenic fungus Cryptococcus neoformans, the bacterial pathogen Brucellasuis, and the protozoan parasite Leishmania donovani chagasi", which is responsible for leishmaniasis, has been determined to be antifungal, antibacterial, and anti-protozoan, respectively. The findings of this research on enzyme inhibition reveal that sulfonamide Schiff bases is an effective means of inhibiting all three of the investigated enzymes.

Omyma et al. [29] have used that Schiff bases, "2-[(pyridin-2-ylmethylidene) amino]-6-aminopyridine, and 2-[(pyridin-2-ylmethylidene) amino] phenol" that were successfully synthesized. These Schiff bases were used to make complexes of the elements Cr, Mo, and W. The catalytic activity of the complexes was examined with regard to the hydrogen peroxide decomposition reaction. It has been determined whether or not the ligands and their complexes possess any antibacterial properties. The condensation of benzyl and triethylene tetraamine resulted in the production of a novel Schiff base ligand. Salts of Mn (II), Co (II), Ni (II), Cu (II), Zn (II), and Cd (II) are used in the preparation of the complexes. Screening was done on the metal complexes to determine their action against various microorganisms According to the activity data; the metal complexes have antibacterial activity that is greater than that of the parent Schiff base ligand [30]. The reaction of "m-hydroxy benzoic acid with 1, 5-dimethyl-3-[2-(5-methyl-1H-indol-3-yl)-ethylimino resulted in the synthesis of new Azo Schiff base compounds. -2-phenyl-2, 3-dihydro-1H-pyrazol-4-ylamine and with 3-[2-(1H-indol-3-yl)-ethylimino]-1,5-dimethyl-2-phenyl-2,3-dihydro-1H-pyrazol-4-ylamine". Bacillus subtilis and Staphylococcus aureus were the two Gram-positive bacteria that were tested, while Escherichia coli & Pseudomonas aeruginosa were the two Gram-negative bacteria that were tested [31]. Both the free ligands and their complexes were tested for their biological activity against the bacteria.

The Schiff base "N, N′-bis(5-sulfosalicyliden)-3,4-diaminobenzophenone was used to create some new water-soluble complexes, with M = Zn, Cu, Ni, and Mn". These complexes were synthesized. The synthesized Schiff base and its metal complexes were tested to determine whether or not they possessed antibacterial activity. It was determined whether or not the complexes had an inhibiting effect on the proliferation of the cancer cell line [32]. By using microwave irradiation as the technique of synthesis, a new acyclic Schiff base and its complexes with chromium (III) were produced. The antibacterial activity of the complexes was tested, and the results showed that they had an inhibiting impact on both Gram-positive and Gram-negative bacteria [33].

Nadia et al. [34] have synthesized Schiff base via the condensation of "5-methyl-1H-pyrazole-3-carbohydrazide with various aromatic aldehydes-pyridoxal, salicylaldehyde, 3-methoxy-2-hydroxybenzaldehyde, 3-ethoxy-2- hydroxybenzaldehyde and 2 hydroxynaphthene -1-carbaldehyde". The Copper complexes that corresponded to the reactions were produced. Studies on the antibacterial activity of metal complexes and Schiff bases were conducted. We investigated

whether or whether the complexes had an influence on the cancer cell line's ability to grow and proliferate.

Deepak et al. [35] have synthesized “benzyl-[3-(benzylamino-methyl)-cyclohexylmethyl] –amine” derivatives that had a distinct pattern of substitution on the aromatic ring were tested to determine whether or not they had any antibacterial action against Gram-positive and Gram-negative bacterial strains. The majority of the compounds have minimum inhibitory concentration values that range from 0.002 to 0.016 g/mL, which indicates that they are highly active against the bacteria Pseudomonas aeruginosa and Staphylococcus epidermidis. The condensation of "3, 4-(methylenedioxy) aniline with 5-bromosalicylaldehyde" resulted in the production of a new Schiff base ligand. Complexes of zinc (II), cadmium (II), nickel (II), copper (II), iron (III), cobalt (II), manganese (II), mercury (II), and silver (I) were produced. By using the well diffusion method, the in vitro antibacterial properties of the compounds that were produced were evaluated against six different species of bacteria and three different types of fungi. Metal studies have shown that complexes exhibit higher levels of biological activity than Schiff bases [36].

Rabiul et al. [37] have synthesized of Ni (II) complexes of the dibasic tridentate Schiff bases in order to evaluate the antibacterial capability of the complexes that have been created, In vitro tested of the efficacy of these complexes in inhibiting the development of bacteria and fungus has shown that they are efficient.

Gehad et al. [38] have synthesized of “2, 6-pyridinedicarboxaldehydebis (p-hydroxyphenylimine) and 2, 6-pyridinedicarboxaldehydebis were used in the synthesis of metal complexes (o-hydroxyphenylimine). Additionally, complexes of the ligands with the metal ions Fe (II), Co (II), Ni (II), Cu (II), and Zn (II) were formed. The antibacterial activity of the synthesized ligands and their metal complexes was tested against various bacterial species, including Escherichia coli, Pseudomonas aeruginosa, and Staphylococcus aureus, as well as fungi "Candida". The activity results indicate that the metal complexes are more effective antibacterial agents than the parent organic ligands against one or more bacterial species”. This is the case when compared to the metal complexes.

Mehmet et al. [39] have successfully synthesized "trans-N, N′-bis [(2,4-dichlorophenyl) methylidene] cyclohexane-1,2-diamine" as well as its metal complexes with Co(II), Ni(II), and Pd(II). The ligand and its metal complexes were tested for their ability to inhibit the growth of a variety of bacteria and fungi as part of the antimicrobial activity tests. The activity findings indicate that the metal complexes are more effective at inhibiting the growth of one or more bacterial species than the parent Shciff base ligand [40].

Kalanithi et al. [41] have used chalcone-based ligands were used in the synthesis of tridentate complexes of “the metal ions Cobalt (II), Nickel (II), Copper (II), and Zinc (II). 2-[1-(3-(1H-imidazol-1-yl)propylimino)-3-(phenylallyl)]phenol, 2-[1-(3-(1H-imidazol-1-yl) propylimino)-3-p-tolylallyl]phenol, and 2-[1-(3-(1H-imidazol-1-yl)propylimino)-3-4-nitrophenylallyl]phenol (Figure. 6). The antibacterial activity of the ligands and the metal complexes has been tested and compared against the species Pseudomonas, Escherichia, Staphylococcus, Bacillus, Candida, and Aspergillus”.

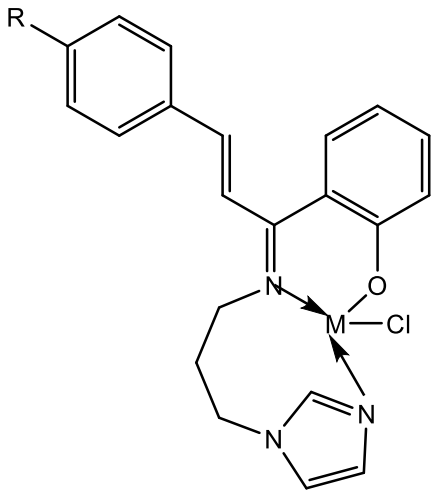


Figure 6. Tridentate complexes of the metal ions Co (II), Ni (II), Cu (II), and Zn (II).

2. Biological Activities

Cinnamaldehyde is a type of aromatic aldehyde that is the primary constituent of the extract of cinnamon bark [42]. The absence of a requirement for direct touch as a prerequisite for cinnamaldehyde's antibacterial activity is the primary benefit of using this compound. Cinnamaldehyde has been demonstrated to be effective against a wide variety of bacteria that are considered to be airborne pathogens [43]. It has been found that cinnamaldehyde and chlorocinnamaldehyde potentiated the cell-inactivating effect when used simultaneously with cis-Diamminodichloroplatinum (II), without increasing the amount of cell-associated platinum [44]. Previous research has shown that nontoxic doses of cinnamaldehyde and derivatives of cinnamaldehyde can increase the cell-inactiv in today's world, a rising number of microbes have developed resistance to the antibiotics that are now in use. This has made it necessary to look for novel chemicals that have the potential to have an effect on harmful bacteria. The heterocyclic compounds were found to play a significant part in the regulation of biological processes, Amir et al, made some of the most astounding strides in the field of medicinal chemistry. There are many Schiff bases that have been identified as having potential use in medicine and are employed in the formulation of therapeutic molecules [45-47]. There is evidence that nitro and halo derivatives of Schiff bases possess antibacterial and anticancer properties.

Gawad et al. [48] reported that several Schiff bases possessed very significant antibacterial activity. There are many Schiff bases that have been identified as having potential use in medicine and are employed in the design of therapeutic molecules [14]. Cinnamaldehyde is a natural chemical that has been shown to have antibacterial properties. In a genuine food system, it is possible for cinnamaldehyde to have a reaction with amino acid, resulting in the formation of Schiff bases adduct. The absence of a requirement for direct touch as a prerequisite for cinnamaldehyde's antibacterial activity is the primary benefit of using this compound. Cinnamaldehyde has been demonstrated to be effective against a wide variety of bacteria that cause food borne illness.

Wei et al. [49], have used adducts that were created by through the direct interaction of amino acids with cinnamaldehyde that took place at room temperature. Benzoic acid served as the standard for determining how effective their antibacterial properties were. Cinnamaldehyde and adducts were more effective against three different microbial strains when the pH of the environment was lower. They demonstrated greater activity than benzoic acid under the same experimental circumstances. Schiff bases produced from 4-aminobenzoic acid and cinnamaldehyde have been successfully

synthesized by Parekh and his fellow researchers. They were tested for their effectiveness as antibacterial agents against a variety of bacterial types that are significant from a medical standpoint. They came to the conclusion that the changes in the synthesized Schiff bases' responses are due to the structural differences between the molecules and are also reliant on the solvent [50]. Chitosan and a Schiff base that was generated from chitosan and cinnamaldehyde were both tested for their ability to inhibit the growth of bacteria by Xioa and his colleagues [51]. Based on the findings, it appears that the bioactivity of the Schiff base is significantly more potent than that of chitosan. It was discovered that the concentration of Schiff base has a direct correlation to the antibacterial activity of the compound. For the formation of the necessary Schiff base, Srikar et al. [52]. made use of p-dimethyl amino cinnamaldehyde. This Schiff base was then utilized for quantitative determination of sparfloxacin in bulk and pharmaceutical dosage forms.

Bharti et al. [53], "have prevented that metal complexes were more effective than the Schiff base when they created Cu (II) and Hg (II) complexes using Schiff's base of sulfamethoxazole [4-amino-N-(5-methyl-3-isoxazolyl) benzene sulfonamide] (Figure 7 and Figure 8A & 8B)".

Bukhari et al. [54], have found that the reactions of "sulphamethoxazole and salicylaldehyde with transition metals, such as Mn (ll), Co (ll), Ni (ll), and Cu (ll)", are successful. In these compounds, initially a Schiff base was created by condensing salicylaldehyde and sulfamethoxazole, and then that base reacted with transition metals to produce octahedral complexes. Octahedral complexes are characterized by their eight-sided structure. There have been reports that the Schiff base ligand and the complexes that are now under investigation are more effective than the parent medication against Klebsiella, Escherichia, and Staphylococcus. It has also been discovered that the complexes of sulphamethoxazole with transition metals are more active and less toxic than the drug's parent compound.

Siraj et al. [55] have Co (II) and Ni(II) complexes with a Schiff base produced from sulfamethoxazole and furfural have been synthesized (Figure. 9) and described using physical features, analytical data, FT-IR spectrum analyses, and elemental analysis. The Schiff base was derived from sulfamethoxazole and furfural. Infrared spectrum data of the Schiff base and that of the complexes, The Schiff base and the complexes have been evaluated for their antibacterial activity against four pathogenic microorganisms. These microbes include Staphylococcus, Escherichia, Aspergillus flavus, and Candida albicans. The ligand demonstrated a low level of antibacterial activity, with an inhibition zone ranging from 8 to 14 mm, but the metal complexes shown a higher level of antimicrobial activity, with an inhibition zone ranging from 8 to 15 mm, against the microorganisms that were tested.

Sumrra et al. [56] have synthesized of sulfonamide-derived Schiff bases were synthesized by the condensation reaction of "4-aminobenzene-1-sulfonamide and 4-amino-N-(3-methyl-2,3-dihydro-1,2-oxazol-5-yl)benzene-1-sulfonamide with 2-hydroxy-3-methoxybenzaldehyde in an equimolar ratio as well as their transition metal complexes. The synthesized compounds were screened for antimicrobial activities against bacterial Streptococcus aureus, Bacillus subtilis, Eshcheria coli, and Klebsiella pneomoniae species and fungal Aspergillus niger and Aspergillus flavous strains. A further assay was devised to screen the antioxidant activities of the samples (including 2,2-diphenyl-1-picrylhydrazine radical scavenging activity, total phenolic contents, and total iron reduction power), as well as the enzyme inhibition characteristics of the samples (amylase, protease, acetylcholinesterase, and butyrylcholinesterase)". The considerable findings obtained from these activities provided evidence that both the ligands and the transition metal complexes containing them bioactive in their nature.

Yusuf et al. [57], have synthesized of “Schiff-base derived from N-(2-hydroxybenzylidene)-3-(benzylidene amino) benzene sulfonamide, and its metal complexes of Cu (II), Fe (II) and Mn (II). Antibacterial efficacy against Gram-positive Staphylococcus aureus and Gram-negative Escherichia coli" bacterial strains, as well as antifungal activity against Mucor inducus and Aspergillus fumigatus” were tested for the synthesized ligand and its metal complexes. The results of these investigations demonstrated that Schiff base and its metal complexes exhibited substantial antibacterial and antifungal action at high concentrations.

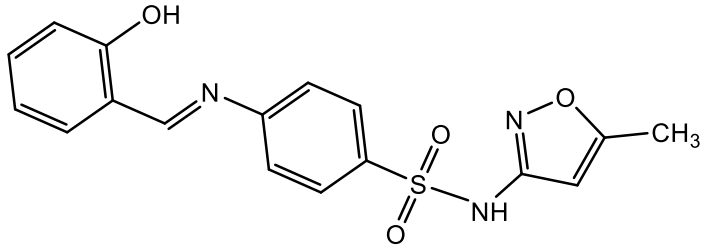


Figure 7. Schiff base

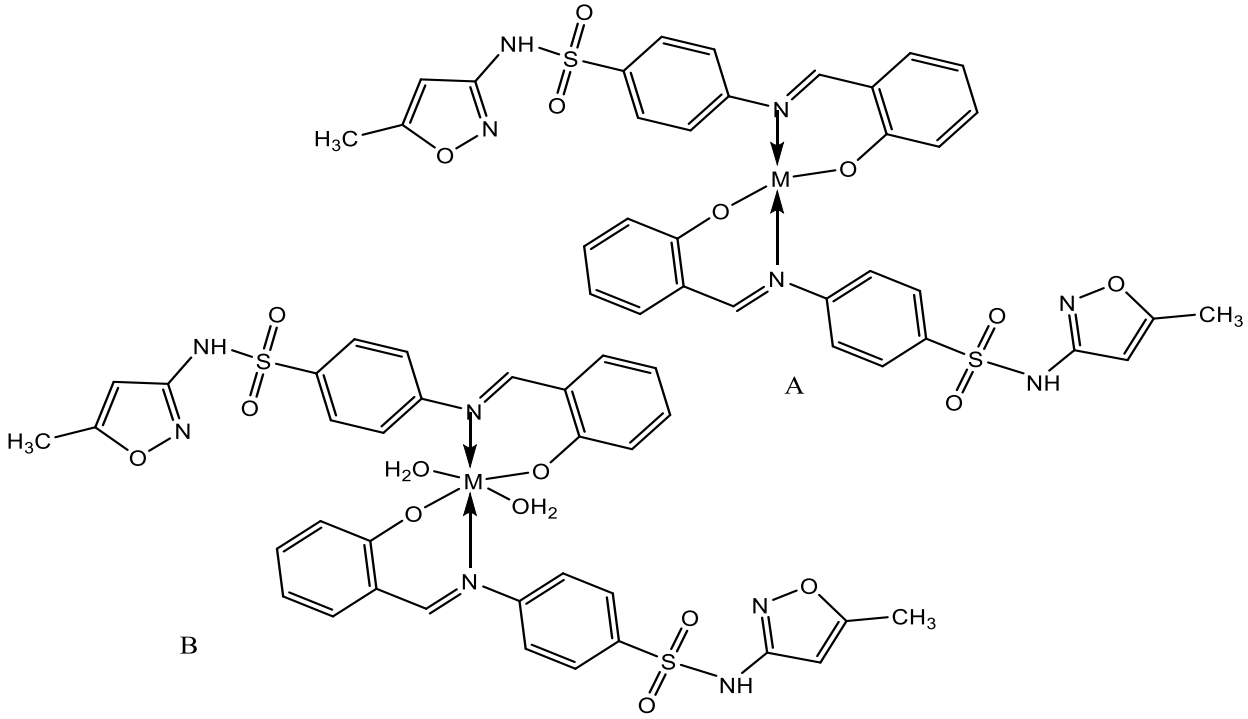


Figure 8. (A, B): Metal complex (A) Hg (B) Cu

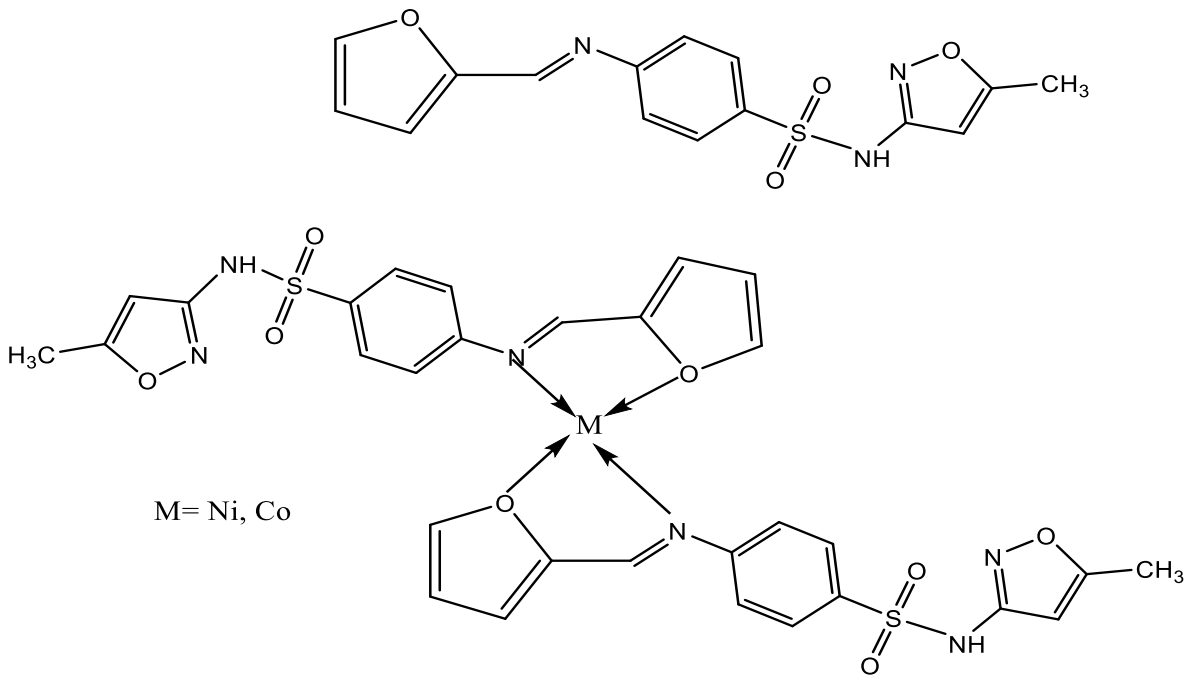


Figure 9. Schiff base and its complexes include Co (II) and Ni (II).

Conclusion

The aim of this study in this review paper is to describe the recently reported Schiff bases and their metal complexes that have therapeutic and biological effects. The bulk of the Schiff bases that were discussed can be easily made and have a variety of biological uses. Still, there is potential for creating novel Schiff bases and metal complexes with a wide range of applications. It is well known that scientists and researchers are constantly working to discover new treatments and develop new ones. This holds true for both the search for new medications and the creation of those medicines. There is a great need to find novel compounds that could perhaps address this issue because antibiotics are losing their efficacy as germs develop resistance to the medications that treat them. Therefore, the recently discovered Schiff bases and their metal complexes that possessed these characteristics were the main subjects of this investigation.

References

[1] Schiff, H. (1864). Mittheilungen aus dem Universitätslaboratorium in Pisa: eine neue Reihe organischer Basen. Justus Liebigs Annalen der Chemie, 131(1), 118-119.

[2] Dhar, D. N., & Taploo, C. L. (1982). Schiff-bases and their applications. Journal of Scientific & Industrial Research, 41(8), 501-506.

[3] Przybylski, P., Huczynski, A., Pyta, K., Brzezinski, B., & Bartl, F. (2009). Biological properties of Schiff bases and azo derivatives of phenols. Current Organic Chemistry, 13(2), 124-148.

[4] Bhise, N. A., Al-horaibi, S. A., Gaikwad, S. T., & Rajbhoj, A. S. (2019). Synthesis, spectral characterization, antimicrobial, anti-inflammatory, antioxidant, and cyclic voltammetric studies of β-diketone and its metal complexes. Rasayan J Chem, 12(1), 101-13.

[5] Souza, A. O. D., Galetti, F., Silva, C. L., Bicalho, B., Parma, M. M., Fonseca, S. F., ... & De Oliveira, M. C. (2007). Antimycobacterial and cytotoxicity activity of synthetic and natural compounds. Química Nova, 30, 1563-1566.

[6] Guo, Z., Xing, R., Liu, S., Zhong, Z., Ji, X., Wang, L., & Li, P. (2007). Antifungal properties of Schiff bases of chitosan, N-substituted chitosan and quaternized chitosan. Carbohydrate research, 342(10), 1329-1332.

[7] Arshad, N., Channar, P. A., Saeed, A., Farooqi, S. I., Javeed, A., Larik, F. A., ... & Flörke, U. (2018). Structure elucidation, DNA binding, DFT, molecular docking and cytotoxic activity studies on novel single crystal (E)-1-(2-fluorobenzylidene) thiosemicarbazide. Journal of Saudi Chemical Society, 22(8), 1003-1013.

[8] Vashi K., Naik HB. (2004) Synthesis of carboxamides of 2'-amino 4'-(6-bromo-3-coumarinyl) thiazole as analgesic and anti-inflammatory agents. Indian J Heterocyclic Chem 12(3): 307-310.

[9] Nair, R., Shah, A., Baluja, S., & Chanda, S. (2006). Synthesis and antibacterial activity of some Schiff base complexes. Journal of the Serbian Chemical Society, 71(7), 733-744.

[10] Chaudhary, N. K., & Mishra, P. (2018). Bioactivity of some divalent M (II) complexes of penicillin based Schiff base ligand: Synthesis, spectroscopic characterization, and thermal study. Journal of Saudi Chemical Society, 22(5), 601-613.

[11] Mondal, S., Mandal, S. M., Mondal, T. K., & Sinha, C. (2017). Spectroscopic characterization, antimicrobial activity, DFT computation and docking studies of sulfonamide Schiff bases. Journal of Molecular Structure, 1127, 557-567.

[12] Tadavi, S. K., Yadav, A. A., & Bendre, R. S. (2018). Synthesis and characterization of a novel schiff base of 1, 2-diaminopropane with substituted salicyaldehyde and its transition metal complexes: Single crystal structures and biological activities. Journal of Molecular Structure, 1152, 223-231.

[13] Abu-Dief, A. M., & Mohamed, I. M. (2015). A review on versatile applications of transition metal complexes incorporating Schiff bases. Beni-suef university journal of basic and applied sciences, 4(2), 119-133.

[14] Abd El-Halim, H. F., Mohamed, G. G., & Khalil, E. A. (2017). Synthesis, spectral, thermal and biological studies of mixed ligand complexes with newly prepared Schiff base and 1, 10-phenanthroline ligands. Journal of Molecular Structure, 1146, 153-163.

[15] Shabbir, M., Akhter, Z., Ismail, H., & Mirza, B. (2017). Synthetic bioactive novel ether based Schiff bases and their copper (II) complexes. Journal of Molecular Structure, 1146, 57-61.

[16] Sakthi, M., & Ramu, A. (2017). Synthesis, structure, DNA/BSA binding and antibacterial studies of NNO tridentate Schiff base metal complexes. Journal of Molecular Structure, 1149, 727-735.

[17] Aazam, E. S., & El-Said, W. A. (2014). Synthesis of copper/nickel nanoparticles using newly synthesized Schiff-base metals complexes and their cytotoxicity/catalytic activities. Bioorganic Chemistry, 57, 5-12.

[18] Matar, S. A., Talib, W. H., Mustafa, M. S., Mubarak, M. S., & AlDamen, M. A. (2015). Synthesis, characterization, and antimicrobial activity of Schiff bases derived from benzaldehydes and 3, 3′-diaminodipropylamine. Arabian Journal of Chemistry, 8(6), 850-857.

[19] Zaltariov, M. F., Cazacu, M., Avadanei, M., Shova, S., Balan, M., Vornicu, N., ... & Varganici, C. D. (2015). Synthesis, characterization and antimicrobial activity of new Cu (II) and Zn (II) complexes with Schiff bases derived from trimethylsilyl-propyl-p-aminobenzoate. Polyhedron, 100, 121-131.

[20] Nassar, M. Y., Aly, H. M., Abdelrahman, E. A., & Moustafa, M. E. (2017). Synthesis, characterization, and biological activity of some novel Schiff bases and their Co (II) and Ni (II) complexes: a new route for Co3O4 and NiO nanoparticles for photocatalytic degradation of methylene blue dye. Journal of Molecular Structure, 1143, 462-471.

[21] Belal, A. A., Zayed, M. A., El-Desawy, M., & Rakha, S. M. (2015). Structure investigation of three hydrazones Schiff's bases by spectroscopic, thermal and molecular orbital calculations and their biological activities. Spectrochimica Acta Part A: Molecular and Biomolecular Spectroscopy, 138, 49-57.

[22] Lodyga-Chruscinska, E., Symonowicz, M., Sykula, A., Bujacz, A., Garribba, E., Rowinska-Zyrek, M., ... & Chruscinski, L. (2015). Chelating ability and biological activity of hesperetin Schiff base. Journal of inorganic biochemistry, 143, 34-47.

[23] Venkatesan, J., Sekar, M., Thanikachalam, V., & Manikandan, G. (2017). Thermal decomposition and kinetic analyses of sulfonamide Schiff's bases in oxygen atmosphere-A comparative study. Chemical Data Collections, 9, 229-243.

[24] Halevas, E., Nday, C. M., Kaprara, E., Psycharis, V., Raptopoulou, C. P., Jackson, G. E., ... & Salifoglou, A. (2015). Sol–gel encapsulation of binary Zn (II) compounds in silica nanoparticles. Structure–activity

correlations in hybrid materials targeting Zn (II) antibacterial use. Journal of Inorganic Biochemistry, 151, 150-163.

[25] Abdallah, S. M., Zayed, M. A., & Mohamed, G. G. (2010). Synthesis and spectroscopic characterization of new tetradentate Schiff base and its coordination compounds of NOON donor atoms and their antibacterial and antifungal activity. Arabian Journal of Chemistry, 3(2), 103-113.

[26] Ratha, P., Chitra, L., Ancy, I., Kumaradhas, P., & Palvannan, T. (2017). New amino acid-Schiff base derived from s-allyl cysteine and methionine alleviates carbon tetrachloride-induced liver dysfunction. Biochimie, 138, 70-81.

[27] Sirajuddin, M., Uddin, N., Ali, S., & Tahir, M. N. (2013). Potential bioactive Schiff base compounds: synthesis, characterization, X-ray structures, biological screenings and interaction with Salmon sperm DNA. Spectrochimica Acta Part A: Molecular and Biomolecular Spectroscopy, 116, 111-121.

[28] Ceruso, M., Carta, F., Osman, S. M., Alothman, Z., Monti, S. M., & Supuran, C. T. (2015). Inhibition studies of bacterial, fungal and protozoan β-class carbonic anhydrases with Schiff bases incorporating sulfonamide moieties. Bioorganic & Medicinal Chemistry, 23(15), 4181-4187.

[29] Ali, O. A., El-Medani, S. M., Ahmed, D. A., & Nassar, D. A. (2014). Metal carbonyl complexes with Schiff bases derived from 2-pyridinecarboxaldehyde: Syntheses, spectral, catalytic activity and antimicrobial activity studies. Journal of Molecular Structure, 1074, 713-722.

[30] Mohamed, G. G., Omar, M. M., & Ibrahim, A. A. (2010). Preparation, characterization and biological activity of novel metal-NNNN donor Schiff base complexes. Spectrochimica Acta Part A: Molecular and Biomolecular Spectroscopy, 75(2), 678-685.

[31] Al-Hamdani, A. A. S., Balkhi, A. M., Falah, A., & Shaker, S. A. (2016). Synthesis and investigation of thermal properties of vanadyl complexes with azo-containing Schiff-base dyes. Journal of Saudi Chemical Society, 20(5), 487-501.

[32] Asadi, M., Asadi, Z., Sadi, S. B., Zarei, L., Baigi, F. M., & Amirghofran, Z. (2014). Synthesis, characterization and the interaction of some new water-soluble metal Schiff base complexes with human serum albumin. Spectrochimica Acta Part A: Molecular and Biomolecular Spectroscopy, 122, 118-129.

[33] Kumar, S. P., Suresh, R., Giribabu, K., Manigandan, R., Munusamy, S., Muthamizh, S., & Narayanan, V. (2015). Synthesis and characterization of chromium (III) Schiff base complexes: Antimicrobial activity and its electrocatalytic sensing ability of catechol. Spectrochimica Acta Part A: Molecular and Biomolecular Spectroscopy, 139, 431-441.

[34] Xie, J. Q., Li, C. H., Dong, J. X., Qu, W., Pan, L., Peng, M. L., ... & Li, Q. G. (2014). The standard molar enthalpy of formation of a new copper (II) Schiff-base complex and its interaction with bovine serum albumin. Thermochimica Acta, 598, 7-15.

[35] Kumar, D., Joshi, S., Rohilla, R. K., Roy, N., & Rawat, D. S. (2010). Synthesis and antibacterial activity of benzyl-[3-(benzylamino-methyl)-cyclohexylmethyl]-amine derivatives. Bioorganic & medicinal chemistry letters, 20(3), 893-895.

[36] Sundararajan, M. L., Jeyakumar, T., Anandakumaran, J., & Selvan, B. K. (2014). Synthesis of metal complexes involving Schiff base ligand with methylenedioxy moiety: Spectral, thermal, XRD and antimicrobial studies. Spectrochimica acta part A: molecular and biomolecular spectroscopy, 131, 82-93.

[37] Hasan, M. R., Hossain, M. A., Salam, M. A., & Uddin, M. N. (2016). Nickel complexes of Schiff bases derived from mono/diketone with anthranilic acid: Synthesis, characterization and microbial evaluation. Journal of Taibah University for Science, 10(5), 766-773.

[38] Mohamed, G. G., & Abd El-Wahab, Z. H. (2005). Mixed ligand complexes of bis (phenylimine) Schiff base ligands incorporating pyridinium moiety: Synthesis, characterization and antibacterial activity. Spectrochimica Acta Part A: Molecular and Biomolecular Spectroscopy, 61(6), 1059-1068.

[39] Aslantaş, M., Kendi, E., Demir, N., Şabik, A. E., Tümer, M., & Kertmen, M. (2009). Synthesis, spectroscopic, structural characterization, electrochemical and antimicrobial activity studies of the Schiff base ligand and its transition metal complexes. Spectrochimica Acta Part A: Molecular and Biomolecular Spectroscopy, 74(3), 617-624.

[40] Raman, N., Kulandaisamy, A., & Jeyasubramanian, K. (2001). Synthesis, spectroscopic characterization, redox, and biological screening studies of some Schiff base transition metal (II) complexes derived from salicylidene-4-aminoantipyrine and 2-aminophenol/2-aminothiophenol. Synthesis and Reactivity in Inorganic and Metal-Organic Chemistry, 31(7), 1249-1270.

[41] Kalanithi, M., Rajarajan, M., Tharmaraj, P., & Sheela, C. D. (2012). Spectral, biological screening of metal chelates of chalcone based Schiff bases of N-(3-aminopropyl) imidazole. Spectrochimica Acta Part A: Molecular and Biomolecular Spectroscopy, 87, 155-162.

[42] Sashidhar, N. S. (2002). Studies on bioactive natural compounds for their antimicrobial and antioxidant properties. Ph. D. thesis.

[43] Adabiardakani, A., Mohammad, H. H. K., & Kargar, H. (2012). Cinnamaldehyde schiff base derivatives: a short review. World Appl Program, 2(11), 472-476.

[44] Dornish, J. M., Pettersen, E. O., & Oftebro, R. (1989). Modifying effect of cinnamaldehyde and cinnamaldehyde derivatives on cell inactivation and cellular uptake of cis-diamminedichloroplatinum (II) in human NHIK 3025 cells. Cancer research, 49(14), 3917-3921.

[45] Adabiardakani, A., Mohammad, H. H. K., & Kargar, H. (2012). Cinnamaldehyde schiff base derivatives: a short review. World Appl Program, 2(11), 472-476.

[46] Guillier, L., Nazer, A. I., & Dubois-Brissonnet, F. (2007). Growth response of Salmonella typhimurium in the presence of natural and synthetic antimicrobials: estimation of MICs from three different models. Journal of food protection, 70(10), 2243-2250.

[47] Sahu K., Behera R.K., Pathaik R. C., Nayak A., Behera G.B. (1979) Indian J. Chem, 18B: 557.

[48] Abdel Gawad, F. M. (1993). Spectrophotometric and potentiometric studies of some salicylidene-Sulphan derivatives. Egyptian Journal of Pharmaceutical Sciences, 34(3-Jan), 219-232.

[49] Wei, Q. Y., Xiong, J. J., Jiang, H., Zhang, C., & Ye, W. (2011). The antimicrobial activities of the cinnamaldehyde adducts with amino acids. International journal of food microbiology, 150(2-3), 164-170.

[50] Parekh, J., Inamdhar, P., Nair, R., Baluja, S., & Chanda, S. (2005). Synthesis and antibacterial activity of some Schiff bases derived from 4-aminobenzoic acid. Journal of the Serbian Chemical Society, 70(10), 1155-1162.

[51] Xiao X., Jiang-tao W., Jie B. (2010) Journal of Chemical Engineering of Chinese Universities 04.

[52] Srikar, A., Channabasavaraj, K. P., Dharmamoorty, G., Valmiki, N., Chinnappa, C., & Babu, T. V. (2009). Spectrophotometric Methods for Quantitative Estimation of Sparfloxacin in Bulk and Pharmaceutical Dosage Forms. Journal of Pharmaceutical Sciences and Research, 1(2), 13.

[53] Pervaiz, M., Riaz, A., Munir, A., Saeed, Z., Hussain, S., Rashid, A., ... & Adnan, A. (2020). Synthesis and characterization of sulfonamide metal complexes as antimicrobial agents. Journal of Molecular Structure, 1202, 127284.

[54] Bukhari I. H., Haleem A., Jabbar A., Bhatti H. N., (2005). Bioscience Research Biosci. Res. 2 (3) 142-146.

[55] Siraj, I. T., & Sanusi, S. (2021). Synthesis, Characterization and Antimicrobial Studies of Co (II) and Ni (II) Schiff Base Complexes Derived Furfuraldehyde and Sulfamethoxazole. International Journal of Scientific Research in Chemistry (IJSRCH), 6(4), 01-09.

[56] Sumrra, S. H., Hassan, A. U., Imran, M., Khalid, M., Mughal, E. U., Zafar, M. N., ... & Braga, A. A. (2020). Synthesis, characterization, and biological screening of metal complexes of novel sulfonamide derivatives: Experimental and theoretical analysis of sulfonamide crystal. Applied Organometallic Chemistry, 34(7), e5623.

[57] Yusuf, B. A., Ibrahim, A. K., & Hamisu, A. (2018). Sythesis, Physico-Chemical and Antimicrobial Evaluation of Cu (II), Fe (II), Mn (II) Complexes with Schiff Base Derived from N-(2-hydroxybenzylidene)-3-(benzylideneamino) benzenesulfonamide. ChemSearch Journal, 9(1), 1-8.