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Schiff bases represent an important class of compounds as they are utilized as starting materials in the synthesis of industrial products

A graduation research project

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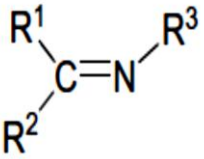
Index

DEDICATION

This Research Paper is lovingly dedicated to our respective parents who have been our constant source of inspiration. They have given us the drive and discipline to tackle any task with enthusiasm and determination. Without their love and support this project would not have been made possible.

Introduction

Schiff bases represent an important class of compounds as they are utilized as starting materials in the synthesis of industrial products [1]. Moreover, Schiff bases are regarded as "privileged ligands" [2] due to their capability to form complexes with different transition metals that can act as catalysts for many different reactions and their relation to synthetic and natural oxygen carriers and biological compounds such as □-lactons. Schiff bases, named after Hugo Schiff [3], are formed when any primary amine reacts with an aldehyde or a ketone under specific conditions. Structurally, a Schiff base (also known as imine or azomethine) (Fig. 1) is a nitrogen analogue of an aldehyde or ketone in which the carbonyl group (C,O) has been replaced by an imine or azomethine group. Schiff bases are some of the most widely used organic compounds. They are used as pigments and dyes, catalysts, intermediates in organic synthesis, and as polymer stabilisers [4]. Schiff bases have also been shown to exhibit a broad range of biological activities, including antifungal, antibacterial, antimalarial, antiproliferative, anti-inflammatory, antiviral, and antipyretic properties [4, 5]. Imine or azomethine groups are present in various natural, natural-derived, and non-natural compounds (see Fig. 2 for some examples). The imine group present in such compounds has been shown to be critical to their biological activities [6]. In view of the importance of Schiff bases, in the present work we report the synthesis of a novel Schiff base ligands (E)-2-((2-phenylhydrazono)methyl)phenol, (Z)-2-(2-hydroxybenzylidene)hydrazine-1-carbothioamide and (E)-N-(4-nitrophenyl)-1-phenylmethanimine and their metal complexes.



R^1, R^2, and/or R^3 = alkyl or aryl

Fig. 1 General structure of a Schiff base.

Review of Literature

The first preparation of imines was reported in the 19th century by Schiff (1864). Since then a variety of methods for the synthesis of imines have been described [7]. The classical synthesis reported by Schiff involves the condensation of a carbonyl compound with an amine under azeotropic distillation. Molecular sieves are then used to completely remove water formed in the system [8]. In the 1990s an in situ method for water elimination was developed, using dehydrating solvents such as tetramethyl orthosilicate or trimethyl orthoformate [9]. In 2004, Chakraborti et al. [10] demonstrated that the efficiency of these methods is dependent on the use of highly electrophilic carbonyl compounds and strongly nucleophilic amines. They proposed as an alternative the use of substances that function as Bronsted-Lowry or Lewis acids to activate the carbonyl group of aldehydes, catalyze the nucleophilic attack by amines, and dehydrate the system, eliminating water as the final step [10]. Examples of Bronsted-Lowry or lewis acids used for the synthesis of Schiff bases include ZnCl2, TiCl4, MgSO4-PPTS, $Ti(OR)_4$, alumina, H_2SO_4, $NaHCO_3$, $MgSO_4$, $Mg(ClO_4)_2$, H_3CCOOH, $Er(OTf)_3$,P_2O_5/Al_2O_3, HCl [10-14]. In the past 12 years a number of innovations and new techniques have been reported, including solvent-free/clay/microwave irradiation, solid-state synthesis, K-10/microwave, water suspension medium, [bmim]BF_4/molecular sieves, infrared irradiation/no solvent, $NaHSO_4$ÆSiO_2/microwave/solventfree, solvent-free/CaO/microwave, and silica/ultrasound irradiation [15-17]. Among these innovations, microwave irradiation has been extensively used due to its operational simplicity, enhanced reaction rates, and great selectivity [16]. The use of microwave irradiation commenced with the independent studies of Rousell and Majetich groups [18, 19]. Microwave irradiation is less environmentally problematic than other methods because it abolishes the excessive use of aromatic solvents and the Dean-Stark apparatus for azeotropic removal of water. Another feature of this technique is that the reactions achieve high efficiency in a shorter period of time. Malaria is a neglected disease that still causes serious public health problems. Every year, approximately 500 million people are afflicted by the disease, of whom around 1–3 million die, 90% of who in sub-Sahara Africa are primarily children [20]. Malaria is currently found in more than 100 countries throughout Africa, Latin America, Asia, and Oceania. Human malaria is mainly caused by four species of Plasmodium (P. falciparum, P. vivax, P. ovale, and P. malariae). The female mosquito of the Anophelesgenus is the vector of Plasmodium [21]. The search for new drugs, vaccines, and insecticides to prevent or treat this disease is clearly a priority. Schiff bases have been shown to be interesting moieties for the design of antimalarial agents. Ancistrocladidine (1; Fig. 2) is a secondary metabolite produced by plants from the families Ancistrocladaceae and Dioncophyllaceae that present an imine group in its molecular scaffold. Compound1has been shown to be active against P. Falciparum K1 and 3D7. The minimum inhibitory concentrations (MIC values) of ancistrocladidine necessary to completely abolish P. falciparum K1 and 3D7 growth were 0.3 and 1.9lg/mL, respectively. Interestingly, compound1was 90- and 10-fold more selective to P. falciparum K1 and 3D7,respectively than to rat skeletal myoblast L-6 cells [22]. Rathelot et al. [38] described the synthesis of Schiff base-functionalized 5-nitroisoquinolines and investigated the in vitro activity of these compounds against an ACC Niger chloroquine resistant P. Falciparum strain. Schiff base 5(Fig. 3) was the most effective antimalarial agent among the synthesized 5-nitroisoquinoline derivatives. The concentration of compound5necessary to inhibit P. Falciparum growth by 50% (IC50) was 0.7lg/mL. Under the same experimental conditions the IC50 value

for chloroquine was 0.1lg/mL [23]. The increase in the mortality rate associated with infectious diseases is directly related to bacteria that exhibit multiple resistance to antibiotics. The lack of effective treatments is the main cause of this problem [24]. The development of new antibacterial agents with novel and more efficient mechanisms of action is definitely an urgent medical need [41]. Schiff bases have been pointed to as promising antibacterial agents. For example, N-(salicylidene)-2-hydroxyaniline (4; Fig. 2) is effective against Mycobacterium tuberculosis H37Rv, exhibiting an MIC value of 8lg/mL [25]. The selectivity of compound 4was checked by performing experiments with J774 macrophages. No cytotoxic effect on J774 macrophages was observed for compound 4, even when it was tested at concentrations as high as 1000lg/mL. More than 80% of macrophage cells were viable at such experimental conditions, demonstrating the high selectivity of compound 4. The synthesis and antimicrobial activity of a series of Schiff bases derived from the condensation of 5-chloro-salicylaldehyde and primary amines has recently been reported [26]. The 5-chloro-salicylaldehyde-Shiff base derivatives 6–15 (Fig. 3) were most active against at least one of the evaluated bacterial species. Pseudomonas fluorescence was the strain most sensitive to compounds 6–11 and 13–15, with MIC values ranging from 2.5 to 5.2lg/mL. The MIC value for the reference drug kanamycin against the same bacterial strain was 3.9lg/mL. The Schiff bases6, 7, 9–11, 14, and 15 presented MIC values in the range of 1.6–5.7lg/mL against Escherichia coli, while the MIC value for kanamycin was 3.9lg/mL. Bacillus subtilis was sensitive to the Schiff base 14 only (MIC = 1.8lg/mL). The MIC values for compounds6and 7 against Staphylococcus aureus were, respectively, 3.1 and 1.6lg/mL [26]. Isatin-derived Schiff bases have also been reported to possess antibacterial activity [27]. Twenty-eight bacteria of clinical interest were used in the studies performed by Pandeya and colleagues. The authors disclosed the isatin-derived Schiff base 16 (Fig. 3) as the most potent compound amongst those synthesized against all the pathogenic bacteria studied. The MIC values for compound 16 against E. Coli NCTC 10418, Vibrio cholerae non-01, Enterococcus faecalis, Proteus shigelloides were 2.4, 0.3, 1.2, and 4.9l g/mL, respectively, while the MIC values for sulfamethoxazole (reference drug) against the same bacterial strains were in the range of 312–5000lg/mL.

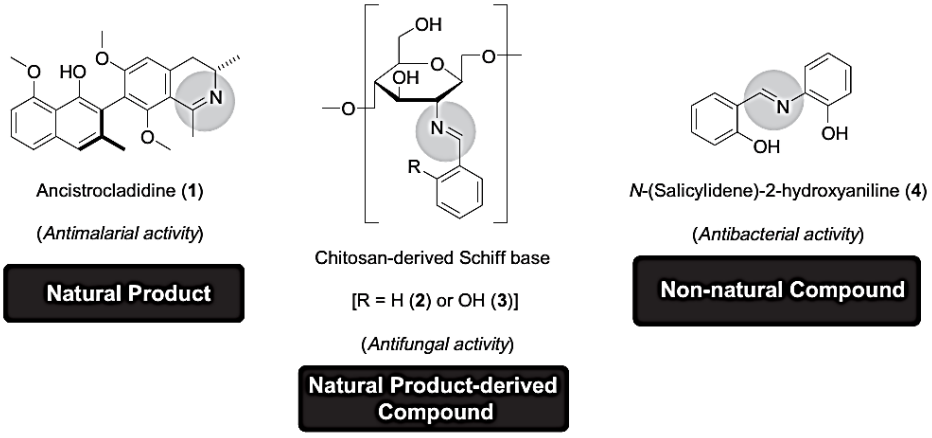


Fig. 2 Examples of bioactive Schiff bases. The imine or azomethine group present in each molecular structure is shaded.

Thus compound 16 was notably 1040-, 1040-, 4160-, and 1020-fold more potent than sulphamethoxazole. Other isatin derived Schiff bases have been described in the literature, but with no expressive antibacterial activities [28, 29]. The isoniazid-derived Schiff base 17 (Fig. 3)

was active against M. tuberculosisH37Rv, exhibiting an MIC value of 0.03 mg/L [30]. In this respect, compound17was slightly more potent than isoniazid, its immediate synthetic precursor. Additionally, the isoniazid-derived Schiff base 17 was not toxic against the cell line VERO (epithelial cells from healthy monkey kidney). The IC50 for compound 17against VERO cells was as high as 1 g/mL, indicating that this isoniazid-derived Schiff base is selective for bacterial cells. The therapeutic safety and effectiveness for compound17is higher than 40,000, making this Schiff base an excellent lead for the development of antitubercular agents [30]. In 2005, Panneerselvam et al [31] described the synthesis and in vitro antibacterial activity of eleven morpholine-derived Schiff bases. Fig. 3 shows the chemical structure of three of them (compounds 18–20). The authors found that S. aureus and Micrococcus luteus were the bacteria most sensitive to the morpholine-derived Schiff base 18 (MIC = 20 and 32l g/mL, respectively).Streptococcus epidermidis was more sensitive to the morpholine-derived Schiff base 19(MIC = 17lg/mL) and Bacillus cereus and E. coli were more sensitive to compound 20 (MIC = 21 and 16lg/mL, respectively). Schiff bases with a 2,4-dichloro-5-fluorophenyl moiety are also effective in the inhibition of bacterial growth. Schiff bases from this class (compounds 21–24 in Fig. 3) completely inhibited the growth of S. aureus, E. coli, Pseudomonas aeruginosa, and Klebsiella pneumonia [32]. MIC values for these compounds varied from 6.3 to 12.5l g/mL, which are comparable to those obtained for the reference drug ciprofloxacin [32]. Madurahydroxylactone Schiff bases are imines derived from natural products. Madurahydroxylactones are secondary metabolites produced by the plant Actinomadura rubra [33]. The imines 25–30 (Fig. 4) are examples of Schiff bases belonging to this class. With the exception of compounds 25 and 30, all madurahydroxylactone-derived compounds were effective in the in vitro inhibition of B. subtilis, Micrococcus flavus, Sarcina lutea, and S. aureus growth, with MIC values varying from 0.2 to 3.1l g/mL [34]. These same compounds (26–29) presented very low activity against Mycobacterium phleior Proteus vulgaris (MIC values higher than > 50.0l g/mL) [34]. Other molecules of natural or non-natural origin that are platforms for the synthesis of Schiff bases for antibacterial activities include amino acids, coumarins, sulfonamides, or resacetophenones, aminothiazolyl bromocoumarins, crown ethers, O-phthaldehyde, or 2-aminophenol and 1,2,4-triazoles [35-38]. The antibacterial property of compounds representative of these classes was examined. However, they did not exhibit any notable activity. Fungal infections are not usually limited to the superficial tissues; indeed, a significant increase in life threatening systemic fungal infections has been reported [39]. The fundamental reason for this is the increasing number of patients at risk, including those with advanced age, major surgery, immunosuppressive therapy, acquired immunodeficiency syndrome (AIDS), cancer treatment, and solid-organ and hematopoietic stem cell transplantation [40]. The search and development of more effective antifungal agents are mandatory [41] and some Schiff bases are known to be promising antifungal agents. Alternaria brassicae and Alternaria brassicicolaare phytopathogenic fungi that severely affect the production of most cruciferous crops (broccoli, cauliflower, mustard, turnip, cabbage, rape, and radish).N-(Salicylidene)-2-hydroxyaniline 4 (Fig. 2) at the concentration of 500 ppm inhibited the growth of these fungi by 67–68% [42]. Compounds 2 and 3 (Fig. 2) are examples of chitosan-derived Schiff bases with antifungal activity. They inhibited the growth of Botrytis cinerea and Colletotrichum lagenarium by 26–33% and 35–38% when used at 1000 ppm, respectively [6]. Overall, studies evaluating the effect of Schiff bases on phytopathogenic fungal growth have been modest and deserve more investigation. Schiff bases with a 2,4-dichloro-5-fluorophenyl moiety, such as compounds 21(Fig. 3) and 31–34 (Fig. 5) have been demonstrated to inhibit the

growth of fungi of clinical interest, such as Aspergillus fumigatus, Aspergillus flavus, Trichophyton mentagrophytes, and Penicillium marneffei. The MIC values for these compounds were in the range of 6.3–12.5lg/mL, indicating that they are as potent as the reference fluconazole [32].

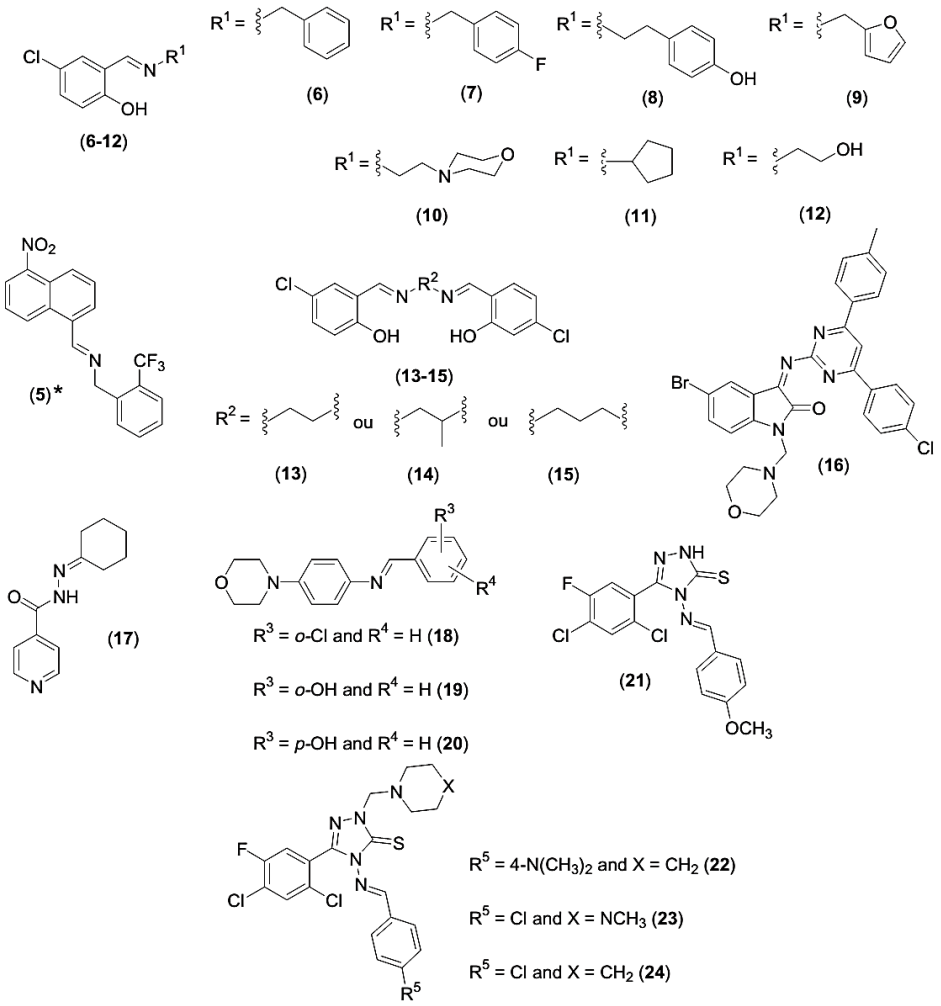


Fig. 3 Chemical structure of some synthetic antibacterial Schiff bases. *Compound **5** is an antimalarial agent.

Piperonyl-derived Schiff bases (35–40, Fig. 5) were active against some fungi at micromolar concentrations. They inhibited the growth of Trichophyton rubrum (MIC = 820–980l M) and Epidermophyton floccosum (MIC = 200–930lM) [43]. The isatin-derived Schiff bases 16 (Fig. 3) and 41–51(Fig. 5) were considerably active against Microsporum audouinii (MIC values ranging from 2.4 to 9.7lg/mL) and Microsporum gypseum (MIC values ranging from 1.2 to 9.7lg/mL) [27]. Compounds16 and 41–51 also inhibited the growth of Candida albicans, Aspergillus niger, Cryptococcus neoformans, T. mentagrophytes, E. floccosum, and Histoplasma capsulatumat MIC values higher than 10lg/mL and lower than 79lg/mL [43]. In another study, Panneerselvam et al. [31] showed that the growth of both C. albicans and A. niger was compromised by treatment with compound 20 (Fig. 3) at 20l g/mL or compound 52 (Fig. 5) at 30l g/mL. As for antibacterial activity, natural product-derived Schiff bases are also promising for the design of new antifungal agents. Domb and colleagues have described an interesting

approach to synthesize a nystatin-dextran-derived Schiff base (53, Fig. 5). This approach dramatically improved nystatin solubility in water [44]. Compound 53completely inhibited the growth of C. albicans and C. neoformans at 20l g/mL, while a concentration of 10lg/mL was required for free nystatin to have a similar effect. Although the nystatin-dextran-derived Schiff base 53 was less active than nystatin itself, the former was shown to be much less toxic to normal cells [63]. The use of vaccines may lead to the eradication of viral pathogens, such as smallpox, polio, and rubella. However, virus-related and hepatitis C human immunodeficiency diseases have been the drawback of vaccine approaches [45]. Viral diseases are life-threatening for immunocompromised patients and a prompt treatment is required to overcome this problem. Although there are many therapeutic options for viral infections, currently available antiviral agents are not yet fully effective, probably due to the high rate of virus mutation. They may also present any of a number of side effects. Salicylaldehyde Schiff bases of 1-amino-3-hydroxyguanidine tosylate are a good platform for the design of new antiviral agents [46]. In fact, from a set of different 1-amino-3-hydroxyguanidine tosylate-derived Schiff bases, compound 54 (Fig. 6) was shown to be very effective against mouse hepatitis virus (MHV), inhibiting its growth by 50% when employed at concentrations as low as 3.2lM [46]. Recently, Sriram and colleagues [46] reported the synthesis and antiviral activity of the abacavir-derived Schiff bases 55–65 (Fig. 6). These compounds are a new series of abacavir prodrugs. Abacavir is a nucleoside analogue capable of inhibiting the activity of reverse transcriptase. It is used to treat human immunodeficiency virus (HIV) and AIDS, and is available under the trade name Ziagen (GlaxoSmithKline). Compounds 55–65were significantly effective against the human immunodeficiency virus-type 1 (HIV-1). The effective concentration (EC50) of these abacavir-derived Schiff bases necessary to achieve 50% protection of human leukemic cells (CEM) against the cytopathic effect of HIV-1 was lower than 6lM [46]. Notably, compound 57 was the most potent Schiff base, being effective at 50 nM. This compound is only toxic to CEM cells at concentrations higher than 100lM, indicating its potential as a lead compound for the design of new anti-HIV-1 [46]. The structure of the thiosemicarbazide moiety confers a good chelating capacity and this property can be increased in thiosemicarbazone by inserting suitable aldehyde or ketone possessing a further donor atom to render the ligand polydentate [47-52].

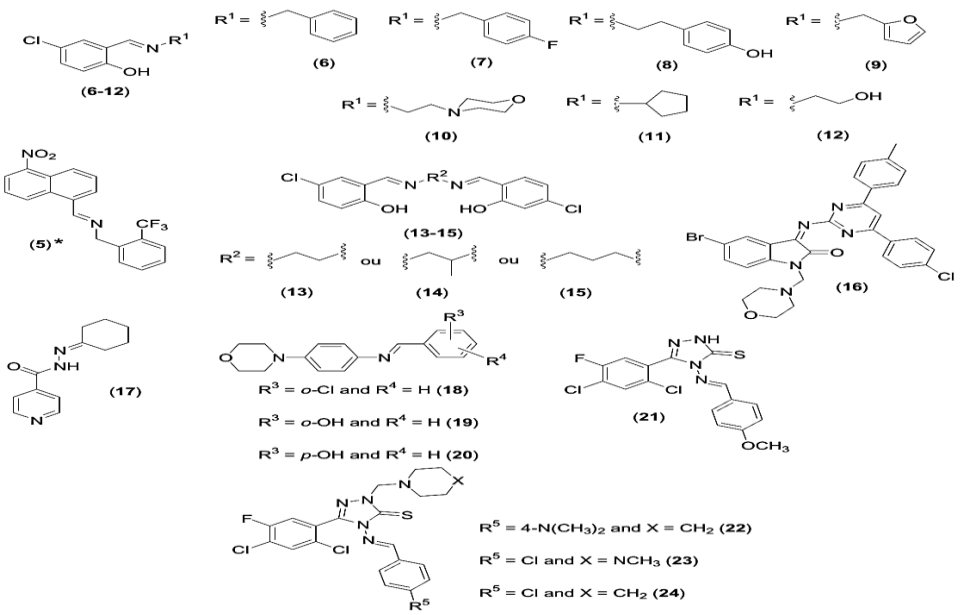


Fig. 3 Chemical structure of some synthetic antibacterial Schiff bases. *Compound **5** is an antimalarial agent.

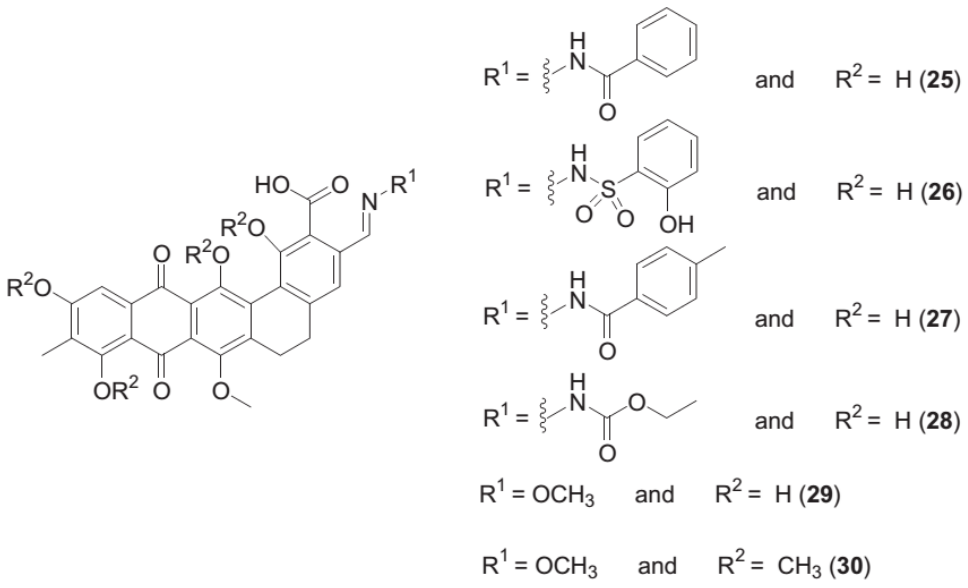


Fig. 4 Examples of antibacterial Schiff bases derived from plant natural products.

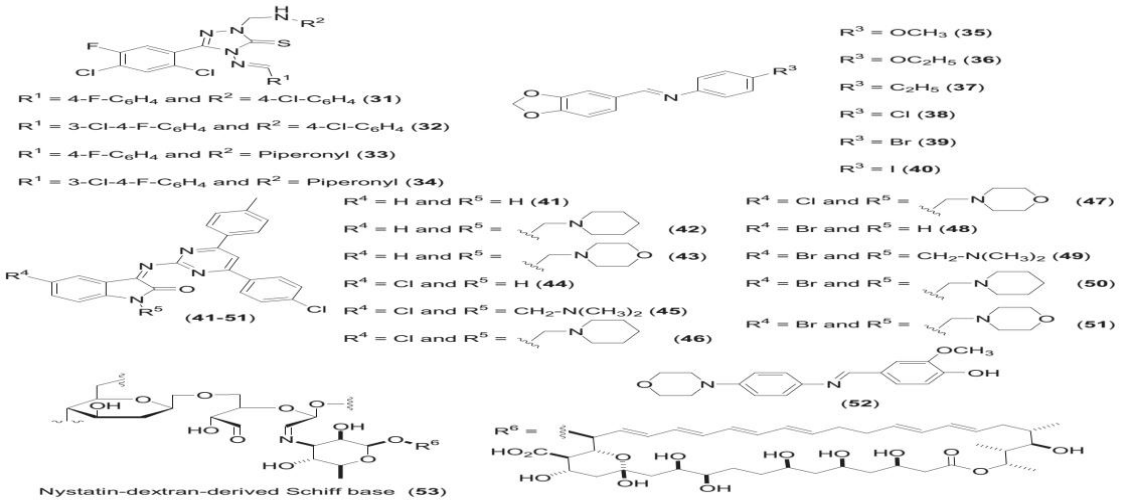


Fig. 5 Chemical structure of some antifungal Schiff bases derived from natural or non-natural compounds.

Experimental Part

In this part the student started to learn by the synthesis of an already prepared ligand and its metal complexes for comparison reasons [53] then a two new ligands and ten metal complexes were prepared.

Materials

All the reagents employed for the preparation of the ligand and its complexes were of the best grade available and used without further purification. Preparation of ligands:

Preparation of ligands

Synthesis of the Schiff base ligand H2L'

Ethanol solution (5 mL) of propane-1,2-diamine (1.1 mmole, 7.9 X 10^{-2} g) was added to a hot 70 ^{o}C ethanol solution (15 mL) of 6-acetyl-7-hydroxy-5-methoxy-2-methyl-4H-chromen-4-one (2.1 mmole, 0.5 g) and reflux for 4h then the solvent was evaporated to 10 mL. After coaling the yellow precipitate was filtered off and dried under vacuum over anhydrous $CaCl_2$

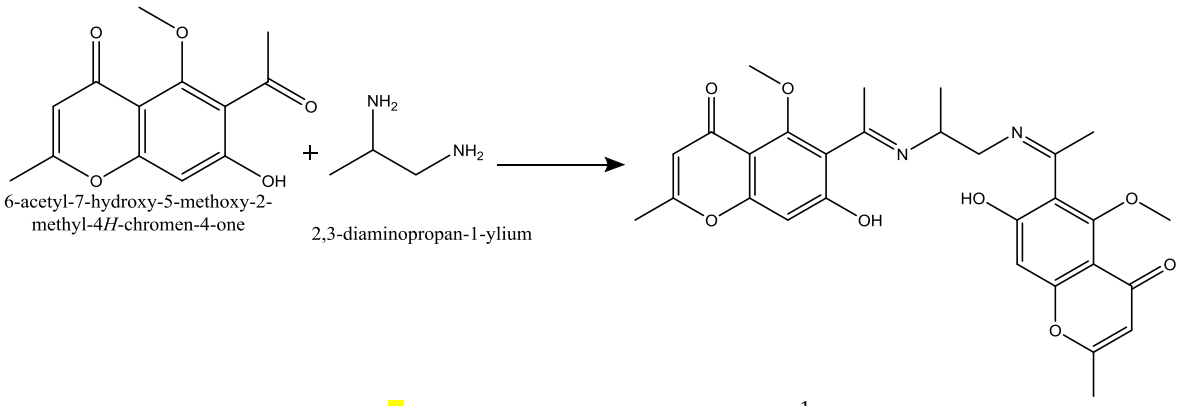


Figure 6: Preparation of the ligand H_2L^1

The Ligand, H_4L^2

Ethanol solution (10 mL) of 2-hydroxybenzaldehyde (1.34 g, 10.97 mmol) was added dropwise to ethanol solution (50 mL) of thiosemicarbazide (1.00 g, 10.97 mmol) with stirring and then 3 drops of sulfuric acid were add and continue refluxing for 2 h. The yellow precipitate (see Figure 37) was then filtered off, washed with methanol, and dried in desiccator over P4O10 (1.23 g, 71% yield).

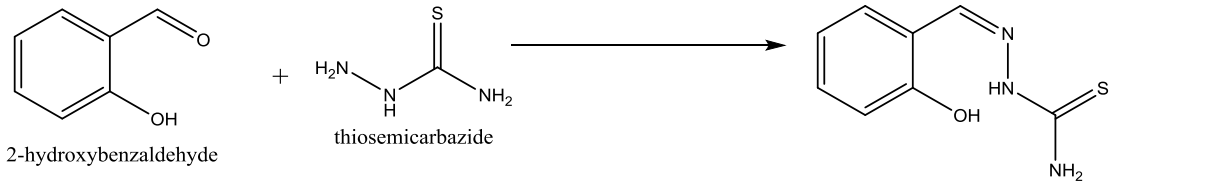


Figure 7: Preparation of the ligand H_4L^2

The Ligand, L^3

Few drops of acetic acid were added to hot (60 ^oC) methanol solution (30 mL) of benzaldehyde (1.00 g, 7.24 mmol) then methanol solution (40 mL) of 4-nitroaniline (0.77 g, 7.24 mmol) was added dropwise. The solvent was evaporated to 50 mL. The yellow solution is left to precipitate in the refrigerator for 24 h. The precipitate (see Figure 38) was then filtered off, washed with methanol, and dried in desiccator over P_4O_{10} (1.23 g, 71% yield).

Figure 8: Preparation of the ligand L^3

Preparation of metal complexes

Preparation of $H2L^{\backslash}$ Complexes:

A hot (60° C) methanol solution of the copper chloride, copper acetate or cobalt acetate was added to a hot (60° C) ethanol solution of the ligand with molecular ratios 1:1 L/M (ligand /metal). The reaction mixture was then refluxed for a 4 h. The precipitates formed were filtered, washed with ethanol, then with diethyl ether and dried under vacuum over anhydrous $CaCl_2$.

Complex 4:

Methanol solution (100 mL) of $Cu(CH_3COO)_2.H_2O$ (2.19 g, 10.97 mmol) was dropwsily added with stirring to ethanol solution (50 mL) of 2-(2-hydroxybenzylidene)hydrazine-1-carbothioamide (2.14 g, 10.97 mmol) and reflux for 4 h. The solution was then evaporated to 80 mL. The precipitate was then filtered off, washed with methanol and dried in desiccator over P_4O_{10} (3.17 g, 70% yield).

Complex 5:

Methanol solution (100 mL) of $FeCl_3.6H_2O$ (1.48 g, 5.49 mmol) was dropwsily added with stirring to ethanol solution (50 mL) of 2-(2-hydroxybenzylidene)hydrazine-1-carbothioamide (1.07 g, 5.49 mmol) and reflux for 4 h. A few drops of trimethyl amine were added to allow precipitation. The solution was then evaporated to 80 mL. The precipitate was then filtered off, washed with methanol and dried in desiccator over P_4O_{10} (1.34 g, 62% yield).

Complex 6:

Methanol solution (100 mL) of $Co(CH_3COO)_2.4H_2O$ (1.37 g, 5.49 mmol) was dropwsily added with stirring to ethanol solution (50 mL) of 2-(2-hydroxybenzylidene)hydrazine-1-carbothioamide (1.07 g, 5.49 mmol) and reflux for 4 h. The solution was then evaporated to 80 mL. The precipitate was then filtered off, washed with methanol and dried in desiccator over P_4O_{10} (1.65 g, 77% yield).

Complex 7:

Methanol solution (100 mL) of $NiCl_2.6H_2O$ (1.30 g, 5.49 mmol) was dropwsily added with stirring to ethanol solution (50 mL) of 2-(2-hydroxybenzylidene)hydrazine-1-carbothioamide (1.07 g, 5.49 mmol) and reflux for 4 h. The solution was then evaporated to 80 mL. The precipitate was then filtered off, washed with methanol and dried in desiccator over P_4O_{10} (1.27 g, 64% yield).

Complex 8:

Methanol solution (100 mL) of $Zn(NO_3)_2.6H_2O$ (1.63 g, 5.49 mmol) was dropwsily added with stirring to ethanol solution (50 mL) of 2-(2-hydroxybenzylidene)hydrazine-1-carbothioamide (1.07 g, 5.49 mmol) and reflux for 4 h. The solution was then evaporated to 80 mL. The precipitate was then filtered off, washed with methanol and dried in desiccator over P_4O_{10} (1.43 g, 62% yield).

Complex 9:

Methanol solution (100 mL) of $Cu(CH_3COO)_2.H_2O$ (1.45 g, 7.24 mmol) was dropwsily added with stirring to ethanol solution (50 mL) of N-(4-nitrophenyl)-1-phenylmethanimine (1.64 g, 7.24 mmol) and reflux for 4 h. The solution was then evaporated to 80 mL. The precipitate was then filtered off, washed with methanol and dried in desiccator over P_4O_{10} (2.44 g, 76% yield).

Complex 10:

Methanol solution (100 mL) of $FeCl_3.6H_2O$ (1.96 g, 7.24 mmol) was dropwsily added with stirring to ethanol solution (50 mL) of N-(4-nitrophenyl)-1-phenylmethanimine (1.64 g, 7.24 mmol) and reflux for 4 h. The solution was then evaporated to 80 mL. The precipitate was then filtered off, washed with methanol and dried in desiccator over P_4O_{10} (٢.٣١ g, ٧٢% yield).

Complex 11:

Methanol solution (100 mL) of $Co(CH_3COO)_2.4H_2O$ (1.80 g, 7.24 mmol) was dropwsily added with stirring to ethanol solution (50 mL) of N-(4-nitrophenyl)-1-phenylmethanimine (1.64 g, 7.24 mmol) and reflux for 4 h. The solution was then evaporated to 80 mL. The precipitate was then filtered off, washed with methanol and dried in desiccator over P_4O_{10} (2.55 g, ٧7% yield).

Complex 12:

Methanol solution (100 mL) of $NiCl_2.6H_2O$ (1.72 g, 7.24 mmol) was dropwsily added with stirring to ethanol solution (50 mL) of N-(4-nitrophenyl)-1-phenylmethanimine (1.64 g, 7.24 mmol) and reflux for 4 h. The solution was then evaporated to 80 mL. The precipitate was then filtered off, washed with methanol and dried in desiccator over P_4O_{10} (2.02 g, 68% yield).

Complex 13:

Methanol solution (100 mL) of $Zn(NO_3)_2.6H_2O$ (2.15 g, 7.24 mmol) was dropwsily added with stirring to ethanol solution (50 mL) of N-(4-nitrophenyl)-1-phenylmethanimine (1.64 g, 7.24 mmol) and reflux for 4 h. The solution was then evaporated to 80 mL. The precipitate was then filtered off, washed with methanol and dried in desiccator over P_4O_{10} (1.70 g, 50% yield).

Results and Discussion

All the synthesized compounds are colored, solid, stable at room temperature, non-hygroscopic, insoluble in water and poorly soluble in common organic solvents such as $CHCl_3$, but soluble in MDF and DMSO. The synthesis of a known ligand and some of its complexes almost gave the same results as published. The IR spectra is used to confirm the structure of the ligands and their metal complexes. The first ligand is already characterized. Ligand 2 behaved as tridentate ligand coordinating through the imine nitrogen, the thioketone and hydroxyl group [54-58]. Ligand 3 is a monodentate ligand coordinating through the imine nitrogen. The broad bands in the 3550-3350 cm^{-1} region are due to coordinated water or water of crystallization. The bands for water of crystallization are different from those of coordinated water. The presence of water molecules within the coordination sphere in the hydrated complexes is supported by the presence of bands in the 3432-3448 , 1600-1610, 940-955 and 620-632 cm-1 regions due to OH stretching, HOH deformation, H_2O rocking and H_2O wagging, respectively [59]. The absence of coordinated water molecules in complexes was confirmed from the absence of the rocking, twisting and wagging vibrational modes which are normally activated in 970-930 cm-1 and 660-600 cm^{-1} regions [60]. The presence of ν(M-Cl) is supported by the presence of a weak intensity ν(M-Cl) band in 347-368 cm^{-1} range indicating a terminal Chloro ligands [53, 61]. Extensive IR spectral studies reported on metal aceto complexes indicate that the acetate ligand may coordinate to a metal center in either a monodentate, bidentate or bridging manner [60]. The νasym.(CO2) and νsym.(CO2) of the free acetate ions are at 1560 cm-1 and 1416 cm-1, respectively [60]. In monodcntate coordination ν(C=O) is found at higher energy than νasym.(CO2) and ν(C-O) is lower than νsym.(CO2). As a result, the separation between the two ν(CO) bands is much larger in monodentate complexes than the free ion [60]. The ESR spectra of polycrystalline samples of copper(II) complexes at room temperatures (298 K) will have axial shape if $g// > g^{\perp}$ characteristic of complexes with $^2B_1(dx2\text{-}y2)$ orbital ground state. [54] The average g values were calculated according to the equation: $gav = 1/3[g// + 2\ g^{\perp}]$. Complexes exhibit $g// < 2.3$, suggests covalent characters around the copper in present complexes. Kivelson and Neiman [56] have reported that a g// value greater than 2.3 indicates ionic character. The g-values were related by the expression, [22, 53] $G = (g//-2)/(g^{\perp}-2)$, if $G > 4.0$ then local tetragonal axes were aligned parallel or only a slightly misaligned, if $G < 4.0$, significant exchange coupling is present. The g///A// is taken as an indication for the stereochemistry of the copper(II) complexes. Addison [58] has suggested that this ratio may be an empirical indication of the tetrahedral distortion of the square planar geometry. The values of g///A// quotient in the range 105–135 cm^{-1} are expected for copper complexes within perfectly square based geometry and those higher than 150 cm^{-1} for tetrahedrally distorted complexes.

Summary and Conclusion

The referenced synthesis of ligand 1 and its metal complexes almost showed identical results. The newly prepared ligands 2 and 3 and their complexes were colored, stable and gave good yield. The prepared compounds is insoluble in water and organic solvents bur soluble in polar solvents such as DMSO.

Recommendations

The prepared compounds may have biological and industrial behavior, which need more work to examine this assumption

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