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Synthesis, Characterization and Antimicrobial Properties of Metal-based Tosylamides

[1]Nna, P.J., [1]Baride, N., & *[1]Orie, K.J.
[1]Department of Chemistry, Ignatius Ajuru University of Education, Port Harcourt, Rivers State, Nigeria

***Corresponding author email**: oriekingsley81@gmail.com

Abstract
As a group of pharmaceuticals, the metal complex of heterocyclic tosylamide derivatives is one of the most extensive classes in medicinal chemistry; its members are employed in the treatment of infections, diabetes, inflammation, and neurological diseases. This work explored the synthesis, characterisation, and antibacterial activity of tosylamide metal complexes. Further steps involved synthesising and recrystallising the ligand's Co (II) and Ni (II) complexes in suitable solvents. Melting point and thin layer chromatography were employed to ascertain the purity levels. To better understand the complexes and ligands, we used ESI-MS, FTIR, and NMR to get structural details. The fact that specific absorption bands in the infrared spectra of tosylamide derivatives moved to higher or lower wave numbers in the complexes proved that there was azomethine nitrogen coordinating with the metal ion. The produced ligand and its metal complexes were evaluated for their antimicrobial properties against several species of E. coli, Bacillus, Salmonella, Penicillium, and Candida. Some coordinated ligands shown even higher efficiency against these diseases, yet the ligand and its complexes were effective against the selected bacterial and fungal strains. In comparison to common antibacterial drugs like tetracycline and nystatin, the produced chemicals showed reduced sensitivity.

Keywords: Bioactivity, Metal Complexes, Tosylamide, Synthesis, Antimicrobial Properties

Introduction

Public health concerns related to the emergence of bacterial and fungal resistance to commonly used antimicrobial treatments have grown in recent years in clinical settings. Lack of effective preventative strategies and a dearth of effective medications are contributing factors to this worldwide health crisis. As suggested by Fernández et al. (2016) and Hashempour-Baltork et al. (2019), the overuse and improper administration of conventional antimicrobial medications may contribute to the emergence of multi-drug resistant bacteria and fungi. Notable pharmacological features of heterocyclic nucleases include their ability to kill insects, as well as fungi and bacteria (Chebout et al., 2022; Priya et al., 2023). Piroxicam, tenoxicam, and sulphasalazine are a few pills that contain aminopyridines that have anti-inflammatory properties. Another product and its uses include the anti-HIV drug delavirdine, the antibacterial chemical sulphapyridine, and the antihistamine tripelennamine (Lakrout et al., 2014; Patil et al., 2014; Chebout et al., 2022). According to Mfuh and Larionov (2015), aminopyridines play an essential role in medicinal chemistry because of the wide variety of biological responses they can elicit in different species. Medicinal applications of aminopyridine compounds, which were among the earliest effective antibiotics, are still relevant today (Clayden et al., 2012). Many human ailments, including as infections, diabetes, inflammatory disorders, and neurological difficulties, are being treated with metal complexes. Pharmaceuticals based on metal complexes are a hot topic in medical organic chemistry, with researchers exploring many research, therapeutic, and diagnostic opportunities in this area (Fernández et al., 2016; Ndagi et al., 2017). Metal complexes of aminopyridine derivatives have numerous biological applications, such as their ability to inhibit the growth of bacteria and fungi. Among the many applications of these complexes are corrosion prevention and catalysis, in addition to their usage in the medical, analytical, and industrial fields (Orie et al., 2019; Ebosie et al., 2021). Conversely, diagnostic and therapeutic applications exist for a wide variety of organic medications due to their modified pharmacological and toxicological features. In several biochemical reactions aiming at the creation and development of molecular systems relevant to biology and medicine, tosylamides—pyridine-based ligands that combine sulphonamide nuclei and a tosyl group—have been recorded (Samper et al., 2017; Heravi et al., 2021). Because of their therapeutic importance, sulfa drugs have attracted a lot of attention. These medicines are used to

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treat cancer, malaria, leprosy, tuberculosis, and a variety of bacterial diseases (Zhang & Muñiz, 2017; Orie et al., 2021). Multiple tosylamides and their derivatives have been found to suppress proteases, hypoglycemia, carbonic anhydrase, bacteria, cancer, and kidney function (Chohan, 2008). The bio-inorganic and metal-based medicinal chemistry communities have taken an interest in these compounds due to their large pharmacological applications and widespread medical usage. The emergence of drug-resistant bacteria and fungi is a growing concern in the field of pharmacotherapy; tosylamides and metal-based derivatives of these compounds have shown promise in this regard.

Materials and Methods

Materials Used in this Study

These and other chemicals were employed unpurified because they were of analytical grade: 2-aminopyridine, tosyl chloride ethanol, acetic acid, acetone, sodium trioxocarbonate (IV), and others. A Merck pre-coated silica gel plate (10x10 cm) was used for thin-layer chromatography (TLC), and the Rf value was calculated using a solvent mixture of acetic acid and ethanol in a 1:2 ratio. A 256 nm UV light was used to see the chromatogram. The data was collected using a Digital Melting Point Electrothermal IA9300X1. The Fourier Transform Infrared spectrophotometer at NARICT Zaria, equipped with an ATR disc, was used to acquire the IR spectra. At the University of Strathclyde in the UK, a JEOLA-LA-400 MHz-NMR Spectrophotometer was used to record proton nuclear magnetic resonance (1HNMR) and carbon-13 nuclear magnetic resonance (13CNMR), while a liquid chromatography/mass spectrometer was used for molecular formula/mass identification.

Synthesis of Tosylamide Derivative of Aminopyridine

A slightly modified version of the procedure described by Abdul-Qadir et al. (2015) and Chen et al. (2016) was used to create the heterocyclic sulphonamide 2-aminopyridine derivative. In a 250 mL round-bottom flask, 5-grams of 2-aminopyridine and 1 millilitre of sodium tricarbonate were mixed with 25 millilitres of distilled water. The mixture was then vigorously agitated for 15 minutes in a fume chamber. After that, 10 grammes of tosyl chloride (0.053 mol) was added to the mixture and agitated constantly for four hours at room temperature. A shift from an alkaline to an acidic pH range and a TLC examination signalled the completion of the reaction. The product precipitated after being adjusted to an acidic pH with a few drops of strong hydrochloric acid; further washes with distilled water ensured that the product was free of acid; and finally, recrystallisation was accomplished using a solvent system consisting of ethanol and water in a ratio of 1:5. The final crystal was obtained by filtering, washing it with distilled water, and then drying it [C12H12N2O2S]

Complexation of Tosylamide

With minor adjustments, Orie et al. (2021) provided the methodology that was used for the complexation of monotosylated 2-aminopyridine. In separate 250 mL round-bottom flasks, a sulphonylated aminopyridine solution (C12H12N2O2S) containing 2.0g and 806mmol was added to a boiled ethanolic solution containing 1.19g and 404mmol of Co(NO3)2•6H2O, as well as 1.16g and 403mmol of Ni(NO3)2•6H2O. Two hours were spent stirring the concoction, and another two hours were spent letting it stand. After precipitation, the mixture was filtered and rinsed with ethanol many times. Recrystallisation was performed using a solvent mixture of DMSO and ethanol (1:6), and the resulting products were left to dry at room temperature.

Antimicrobial Test Agent Preparation

Various sterile test tubes were filled with 50% v/v DMSO to create antimicrobial test agents (both ligands and complexes) at concentrations of 100 µg/ml, 10 µg/ml, and 1.0 µg/ml, respectively. The tubes were marked correctly.

Bacteria Sensitivity Test

The Mueller-Hinton Agar test, which involves diffusion in agar, was adopted in accordance with the method described by Nna et al. (2020). The manufacturer's specifications were followed in the formulation of the medium. The test organism was given a second chance by being streaked on newly made nutrient agar for 24 hours at 37°C. Then, it was suspended in nutrient broth and left to acclimatise in nutrient broth overnight at 37°C. The next day, it was diluted with sterile water to make a 0.5 standard McFarland solution. Finally, it was inoculated onto Mueller Hinton Agar. To produce wells in the media, a cork borer was sterilised by immersing it in ethanol, then passing it through a Bunsen flame. Each well was filled with a different dilution of the bioactive compounds, which were prepared using 50% dimethyl sulfoxide (DMSO). They incubated the Petri dishes at 37°C for 18–24 hours. We measured the diameter of the inhibitory zone surrounding the well in millimetres (mm) after examining the plates.

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Fungal Sensitivity Test

This experiment used the Agar diffusion method, specifically Dextrose Agar. All ingredients were carefully combined according to the manufacturer's instructions. After being transferred to a fresh medium, the fungal isolates were grown at room temperature for 120 hours in order to revive them. After a well-sporulated colony was harvested, the spores were transferred to a tube of sterile distilled water. Then, they were added to the molten medium and gently stirred until homogenised. Finally, the mixture was transferred to sterile Petri dishes, and the spores were allowed to solidify. The bioactive chemicals were prepared using dimethyl sulfoxide (DMSO) and placed into wells created in the media using a cork borer. We left all of the contaminated plates to incubate at room temperature for around five to seven days. Then the inhibition zone around the wells was checked by looking at the plates.

Results

Physicochemical Properties of the Ligands and Complexes and its complexes

The physicochemical properties of tosylamide and it complexes are showed in Table 1.

Table 1: The Physicochemical Properties of the Ligands and Complexes

Compound	Formula	Molecular Weight	Colour/ Nature	Melting point(C^0)	% yield	R_F Value	Solvent mixture
LA	$C_{12}H_{12}N_2O_2S$	248.10	offwhite	180-182	68	0.69	EtOH:H_2O (1:1)
L-Co	$[Co(C_{12}H_{12}N_2O_2S)_2]$	555.13	yellow	184-186	75	0.74	DMF:ACE (2:1)
L-Ni	$[NI(C_{12}H_{12}N_2O_2S)_2]$	556.70	Green	200-202	70	0.70	DMF:ACE (2:1)

EtOH=ethanol, DMF=Dimethylformaide, Ace=acetone

NMR Analysis Tosylamide

The NMR study of tosylamide is presented in Table 2, the table contains the eexperimental, and Literature (ref),

Table 2: NMR Data for 4-Methyl-*N*-(pyridin-2-yl)benzene sulphonamide

Categories	Frequency of Operation	Chemical Shift, Proton and Coupling Constand
Experimental	^{1}HNMR(500 MHz, DMSO), (δ ppm)	J11.03 (br, s, one H, NH), G8.05 (dd, J=5.63 Hz, 1.88 Hz, one H), F7.76 (m, J=8.41 Hz, one H), D7.15 (d, J=7.85.11 Hz, one H), C7.19 (d, J=8.8.68 Hz, one H), B 7.33 (d, J=8.03 Hz one H), A7.52 (m, one H), E6.91 (ddd, J=6.83 Hz, 5.63 Hz, 1.88 Hz, one H), 2.32-I,2.29 (s, three H)
	^{13}CNMR(126 MHz, DMSO), (δ ppm)	21.33, 114.32, 116.60, 125.94, 126.50, 126-129.65, 139.13, 141.31, 143.13, 145.14,152.89
	Chem NMR C13-Estimation	20.9, 125.4, 125.4, 136.3, 140.9, 148.9, I61.1, 113.0, 108.9, 138.9
Literature	^{1}HNMR(500MHz, MeOD), ^{1}H (δ ppm)	11.43 (br,s, 1H, NH), 7.97 (d, *J* = 8.11 Hz, 1H, CH), 7.61 (d, *J* = 8.31 Hz,1H, CH), 7.25 (t, *J* = 7.21Hz, 1H, CH), 7.20 (s, 1H, CH), 7.11(t, *J* = 8.41Hz, 1H, CH), 7.15 (d, *J* = 8.39 Hz, 1H, CH), 2.48 (s, 3H, CH3)
	^{13}CNMR (125MHz,MeOD) ppm	22, 22, 113, 117, 138, 148, 150

J=Coupling constant, s=Singlet, d=Doublet, t=Triplet, br=Broad, m=medium, dd= Double of doublet, ddd= Double of doublet of doublet

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FTIR data of Tosylamide and its Coordination Compounds

The FTIR data of tosylamide and its coordination compounds is presented in Table 3

Table 3: FTIR data of Tosylamide and its Coordination Compounds

S/No	Ligand/Complex	Vibration Frequency (cm^{-1})/ Possible Functional Group
1.	$C_{12}H_{12}N_2O_2S$	3286.81, 3610.86 NH, 2918.47CH, 1689.70 C=N, 1519.96 C=C, 1134.18 C-N, 1003.03 S=O, 933.58, 846.71 aromatic C=C
2.	$[Co(C_{12}H_{12}N_2O_2S)_2]$	3294.53, 3610.55 NH, 2931.90 CH, 1674.27 C=N, 1134.18 C – N S=O, 1010.73, 848.71 Aromatic C=C, 1519.95 C=C
3.	$[Ni(C_{12}H_{12}N_2O_2S)_2]$	3286.81, 3603.15 NH, 2931.90 CH, 1615.12 C=N, 1519.99 C=C, 1134.18 C – N, 1010.73 S=O, 925.86, 840.99 aromatic C=C

Antibacterial activity of Tosylamide

Table 4 shows the results of the antibacterial activity test between tosylamide oil and four clinical pathogen species: E. coli, Bacillus sp., Salmonella sp., Penicillium sp., and Candida sp. The test was conducted using Tetracycline, an antibacterial standard drug, and Nystatin, a standard drug, as positive controls..

Table 4: Antimicrobial l activity of tosylamide and its complexes

Concentrations	**Concentrations µg/ml**	***E. coli***	***Bacillus sp***	***Salmonella sp.***	***Candida sp.***	***Penicillium sp.***
$C_{12}H_{12}N_2O_2S$	100	4mm	5mm	6mm	7mm	6mm
	10	-	-	-	-	-
	1.0	-	-	-	-	-
$[Co(C_{12}H_{12}N_2O_2S)_2]$	100	14mm	13mm	10mm	12mm	8mm
	10	3mm	6mm	5mm	7mm	4mm
	1.0	-	-	-	-	
$[Ni(C_{12}H_{12}N_2O_2S)_2]$	100	13 mm	12 mm	10 mm	10 mm	8 mm
	10	6mm	7mm	4mm	4mm	5mm
	1.0	-	-	-	-	-
Tetracycline/ Nystatin		25 mm	21mm	26mm	24mm	23mm

Discussion

At room temperature, an aqueous alkaline medium was used to react 2-aminopyridine with tosyl chloride in an equimolar ratio to produce tosylamide. At room temperature, it was used to synthesise Co(II) and Ni(II) complexes after purification. The ligand and complex melting points are within the purity range, as shown in Table 1. Supporting this, the results of the TLC study showed that out of the many solvent systems used as mobile phases, there was just one (Abdul-Qadir et al., 2015). While the cobalt and nickel complexes had melting values of 184–186 and 200–202 °C, respectively, the ligand had a melting point of 180–182 °C. According to research by Lakrou et al. (2014) and Chen et al. (2016), the ligand and its complexes have yield percentages of 68%, 75%, and 70%, respectively. Supporting the aromatic region of both the pyridine and benzene rings are chemical shift values between 6.4 and 8.5 ppm (Al-Shaheen & Al-Bergas, 2020). The proton of the sulphonamide group is associated with the peak at 11.03 ppm, while the proton of the methyl group in tosyl groups is at 2.24 ppm (Deng & Mani, 2006; Orie et al., 2021). Protons with different chemical shifts interact with one other at different coupling constants: one at 8.05 ppm (dd), one at 7.15 ppm (d), and a coupling constant of 1.88 Hz for the proton at 7.52 ppm (m). The coupling constant (3J coupling) between the proton at 7.19 ppm and the proton at 7.52 ppm is 8.68 Hz. The proton whose chemical shift is 6.91 ppm (ddd) interacts with a proton at 8.05 ppm in one pair of electrons, which has a 3J coupling constant of 6.85 Hz; in the second pair of electrons, there is a proton at 7.52 ppm with a 3J coupling constant of 5.46 Hz; and in the third pair of electrons, there is a proton at 7.19 ppm with a 4J coupling constant of 1.00 Hz (Deng & Mani 2006; Orie et al., 2021). There is a methyl group attached to the aromatic ring, as shown by a chemical shift of 21.33 ppm, and an aromatic ring can be confirmed by a range of 114.32 to 152.89 ppm (Lakrou et al., 2014; Al-Shaheen & Al-Bergas, 2020).

A signal at 817.85 cm-1 was detected for the aromatic C=C bond group, a peak at 1681.98 cm-1 for the pyridine ring imine, and a peak at 3587.72 cm-1 for the amine. According to Deng and Mani (2006) and Orie et al. (2021),

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the tosylamide (-N-S=O) peak was observed at 1003.08-1240.91 cm-1. Clues point to 1674.24 cm-1 for the imine nitrogen's coordination to the Co(II) ion and 1615 cm-1 for the Ni(II) ion. Both Al-Shaheen & Al-Bergas (2020) and Downlawson et al. (2020) detected azomethine within the 1643.41–1585.0 cm-1 frequency range, which is consistent with our results (C = N). Tosylamide and related constituents' bioactivities are listed in Table 4. Among the five compounds tested, the results showed that the synthesised ones were susceptible to certain bacteria at doses ranging from 1 to 100 µg/ml. When tested at concentrations between 1.0 and 10.0 µg/ml, the ligand showed no activity against any of the pathogens, but it did show activity at concentrations above 100 µg/ml. Among the microbes examined, Candida sp. and Salmonella sp. exhibited the highest levels of activity in the clinical setting. At concentrations ranging from 10 to 100 µg/ml, the Co(II) and Ni(II) ion complexes showed activity (Table 4), suggesting that the complexes were more effective than the ligand alone. These results support the activity test carried out by Shamle et al. (2020), which showed that the ligands had less bioactivity than the complexes of the 1-methylimidazole derivative. According to studies conducted by Lakrout et al. (2014) and Nna et al. (2020), the bioactivity of tosylamide and its complexes was found to be lower than that of standard medications (Tetracycline/Nystatin).

Conclusion

A variety of physicochemical properties and analytical methods were used to characterise the synthesized tosylamide derivatives from 2-aminopyridine and their complexes. When tested against harmful microbes, these chemicals showed that the tosylamide derivative was ineffective against most of the tested bacterial and fungal strains, but it became much more effective when combined with specific metals. Chemical and medicinal chemists have access to potentially useful synthetic substances and methods. It is suggested that other pathogens be tested against using the synthetic chemical.

Recommendations

Based on the findings of this study, the following recommendations are proposed:

1. Further exploration of different metal ions to enhance the bioactivity of tosylamide complexes.
2. Optimization of synthesis protocols for large-scale production and potential commercial applications.
3. Evaluation of the potential synergistic effects of metal-based tosylamides with existing antimicrobial agents.
4. Further characterization of the metal complexes with XRD and two dimensional NMR

References

Abdul-Qadir, M., Ahmed, M., Aslam, H., Waseem, S., & Shafiq, M. I. (2015). Amidine sulfonamides and benzene sulfonamides: Synthesis and their biological evaluation. *Journal of Chemistry*, *2015*(1), 524056.

Al-Shaheen, A. J., & Al-Bergas, A. F. (2020). Synthesis and identification of some complexes of 4-[N-(2, 4-dihydroxybenzylidene) imino] antipyrinyl with serine (L1) or with theronine (L2) ligands and evaluation of their bacteria activities. *J. Educ. Sci*, *29*(4), 42-61.

Chebout, O., Trifa, C., Bouacida, S., Boudraa, M., Imane, H., Merzougui, M., ... & Merazig, H. (2022). Two new copper (II) complexes with sulfanilamide as ligand: Synthesis, structural, thermal analysis, electrochemical studies and antibacterial activity. *Journal of Molecular Structure*, *1248*, 131446.

Chen, Y. L., Sharma, P., & Liu, R. S. (2016). Sulfonamide-directed gold-catalyzed [2+ 2+ 2]-cycloadditions of nitriles with two discrete ynamides to construct 2, 4-diaminopyridine cores. *Chemical Communications*, *52*(15), 3187-3190.

Chohan, Z. H. (2008). Metal-based sulfonamides: Their preparation, characterization and in-vitro antibacterial, antifungal & cytotoxic properties. X-ray structure of 4-[(2-hydroxybenzylidene) amino] benzenesulfonamide. *Journal of Enzyme Inhibition and Medicinal Chemistry*, *23*(1), 120-130.

Clayden, J., Greeves, N., & Warren, S. (2012). *Organic chemistry*. Oxford University Press, USA.

Deng, X., & Mani, N. S. (2006). An efficient route to 4-aryl-5-pyrimidinylimidazoles via sequential functionalization of 2, 4-dichloropyrimidine. *Organic Letters*, *8*(2), 269-272.

Ebosie, N. P., Ogwuegbu, M. O., Onyedika, G. O., & Onwumere, F. C. (2021). Biological and analytical applications of Schiff base metal complexes derived from salicylidene-4-aminoantipyrine and its derivatives: A review. *Journal of the Iranian Chemical Society*, *18*(12), 3145-3175.

Fernández, J., Bert, F., & Nicolas-Chanoine, M. H. (2016). The challenges of multi-drug-resistance in hepatology. *Journal of hepatology*, *65*(5), 1043-1054.

Hashempour-Baltork, F., Hosseini, H., Shojaee-Aliabadi, S., Torbati, M., Alizadeh, A. M., & Alizadeh, M. (2019). Drug resistance and the prevention strategies in food borne bacteria: an update review. *Advanced pharmaceutical bulletin*, *9*(3), 335.

Cite this article as:
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Heravi, M. M., Amiri, Z., Kafshdarzadeh, K., & Zadsirjan, V. (2021). Synthesis of indole derivatives as prevalent moieties present in selected alkaloids. *RSC advances*, *11*(53), 33540-33612.

Lakrout, S., K'tir, H., Amira, A., Berredjem, M., & Aouf, N. E. (2014). A simple and eco-sustainable method for the sulfonylation of amines under microwave-assisted solvent-free conditions. *RSC Advances*, *4*(31), 16027-16032.

Mfuh, A. M., & Larionov, O. V. (2015). Heterocyclic N-oxides-an emerging class of therapeutic agents. *Current medicinal chemistry*, *22*(24), 2819-2857.

Ndagi, U., Mhlongo, N., & Soliman, M. E. (2017). Metal complexes in cancer therapy–an update from drug design perspective. *Drug design, development and therapy*, 599-616.

Orie, K. J., Ngochindo, R. I., & Abayeh, O. J. (2019). Synthesis of 1, 1-bis (2-carbamoylguanidino) furan-2-ylmethane. *Journal of Chemical Society of Nigeria*, *44*(2).

Orie, K. J., Duru, R. U., & Ngochindo, R. I. (2021). Synthesis and complexation of monotosylated 4-aminopyridine with Nickel (II) and Iron (II) Ions. *Makara Journal of Science*, *25*(3), 6.

Nna, P. J., Legborsi, J. and Orie, K. J. (2020). Comparative Study on the Phytoconstituents and Antimicrobial Analysis of Jatropha curcas Leaf and Stem Bark. Direct Res. J. Chem. Mater. Sci. Vol. 7(3), Pp. 37-43.

Patil, S. A., Halasangi, B. M., Toragalmath, S. S., & Badami, P. S. (2014). Thermal, physico-chemical, in vitro anti-microbial and DNA cleavage investigations of newly synthesized Co (II), Ni (II) and Cu (II) complexes of O, N donor Schiff base. *DER PHARMA CHEMICA*, *6*(3), 261-271.

Priya, B., Utreja, D., Sharma, S., Kaur, G., & Madhvi. (2023). Synthesis and antimicrobial activities of indole-based Schiff bases and their metal complexes: a review. *Current Organic Chemistry*, *27*(11), 941-961.

Samper, K. G., Marker, S. C., Bayón, P., MacMillan, S. N., Keresztes, I., Palacios, Ò., & Wilson, J. J. (2017). Reprint of "Anticancer activity of hydroxy-and sulfonamide-azobenzene platinum (II) complexes in cisplatin-resistant ovarian cancer cells". *Journal of inorganic biochemistry*, *177*, 335-343.

Shamle, N. J., Tella, A. C., Obaleye, J. A., Balogun, F. O., Ashafa, A. O., & Ajibade, P. A. (2020). Synthesis, characterization, antioxidant and antidiabetic studies of Cu (II) and Zn (II) complexes of tolfenamic acid/mefenamic acid with 1-methylimidazole. *Inorganica Chimica Acta*, *513*, 119942.

Zhang, H., & Muñiz, K. (2017). Selective piperidine synthesis exploiting iodine-catalyzed Csp3–H amination under visible light. *ACS Catalysis*, *7*(6), 4122-4125.