Vital Annex: International Journal of Novel Research in Advanced Sciences
ISSN: 2751-756X
Volume 03 Number 04 (2024)
https://journals.innoscie.com/index.php/ijnras

Article

Green Synthesis, Characterization and Bioactivity Evaluation of Bis (5-((1H-Imidazol)Methyl)-3-Phenylimidazolidin) Derivatives

Adil Hussein Dalaf[1], Mohammed Jwher Saleh[2], Jamil Nadhem Saleh[3]

1. Department of Chemistry, College of Science, Tikrit University, Iraq
* Correspondence: adil.h.dalaf@tu.edu.iq
2,3. Salah al-Din Education Directorate, Iraq

Abstract: This study describes the environmentally friendly synthesis of novel imidazole derivatives by the use of both conventional and microwave techniques to react Schiff bases with histidine in ethanol. Despite their importance in medicinal chemistry, imidazole molecules are still difficult to synthesize efficiently. The research included the preparation of new imidazole derivatives by reacting prepared Schiff bases with the amino acid histidine in the presence of ethanol as a solvent. The reaction was carried out using conventional and microwave methods, and the progress of the reaction was monitored and described by determining the melting point and purity. The Rf values were determined using thin-layer chromatography (T.L.C.), infrared spectroscopy (FT-IR), proton nuclear magnetic resonance (^{1}H-NMR), and quantitative elemental analysis (C.H.N.). The biological activity of the synthesised compounds was evaluated by examining their effect on the growth of four antibiotic-resistant bacterial isolates: Gram-negative (Escherichia) and Gram-positive (Staphylococcus aureus). The antibiotic *Amoxicillin* was used as a control sample. The prepared compounds showed good inhibitory activity against the tested bacteria. Furthermore, the laser activity of the synthesized composites was measured using a helium-neon laser (visible laser). The composites were exposed to radiation for four different time periods (15, 30, 45, 60) seconds, and their physical properties were re-examined to observe any changes caused by the laser exposure.

Keywords: Green Chemistry, Imidazole, Biological activity, Laser activity

Citation: Dalaf, A. H., Saleh, M. J., Saleh, J. N. Green Synthesis, Characterization and Bioactivity Evaluation of Bis (5-((1H-Imidazol)Methyl)-3-Phenylimidazolidin) Derivatives. Vital Annex: International Journal of Novel Research in Advanced Sciences 2024, 3(4), 118-128.

Received: 17th Sept 2024
Revised: 24th Sept 2024
Accepted: 1st Oct 2024
Published: 8th Oct 2024

1. Introduction

Imidazole rings are widely found in natural products and pharmaceutical molecules and are one of the most essential nitrogen-containing five-membered heterocyclic structures. In addition, imidazole heterocyclic compounds are essential in medicinal chemistry and are vital in treating various diseases. New medicinal derivatives are being vigorously developed worldwide [1]. Due to the unique structural characteristics of imidazole structure and its electron-rich properties, it is advantageous for the imidazole group to bind to various receptors and enzymes in biological systems through various weak interactions, thus exhibiting a variety of biological activities.

At present, many imidazole-containing compounds with high medicinal potential have been widely used as clinical drugs for the treatment of various diseases, such as antibacterial [2], antifungal [3], and anti-inflammatory [4]. Due to the critical pharmacological or biological activities and immense medicinal value of imidazole-based molecules, medicinal chemists, and organic synthesis, researchers have found that they have antiviral [5], antiparasitic [6], and anticancer effects [7]. Researchers have long been

interested in synthesizing small molecules with imidazole structures. However, a simple and efficient method for constructing imidazole heterostructures is still needed.

In recent decades, many classical strategies have emerged for the synthesis of these cyclic compounds in vitro. The basic principle of laser operation is absorption followed by emission. Absorption, spontaneous emission, and stimulated emission are crucial to the physical basis of laser creation [8]. It is understood that atoms, ions, and molecules can be in specific configurations, and each configuration has a specific amount of energy associated with it called an energy level. The lowest energy level is called the ground state, and any level above it is called the excited state. It is important to note that the closer the levels are to the ground, the higher their energy [9].

2. Materials and Methods

2.1. Chemical used

Chemicals prepared by Aldrich, BDH Thomas, Fluka, and Merck were used.

2.2. Preparation of 4-imidazolidinone derivatives by the traditional method (A1-A7)

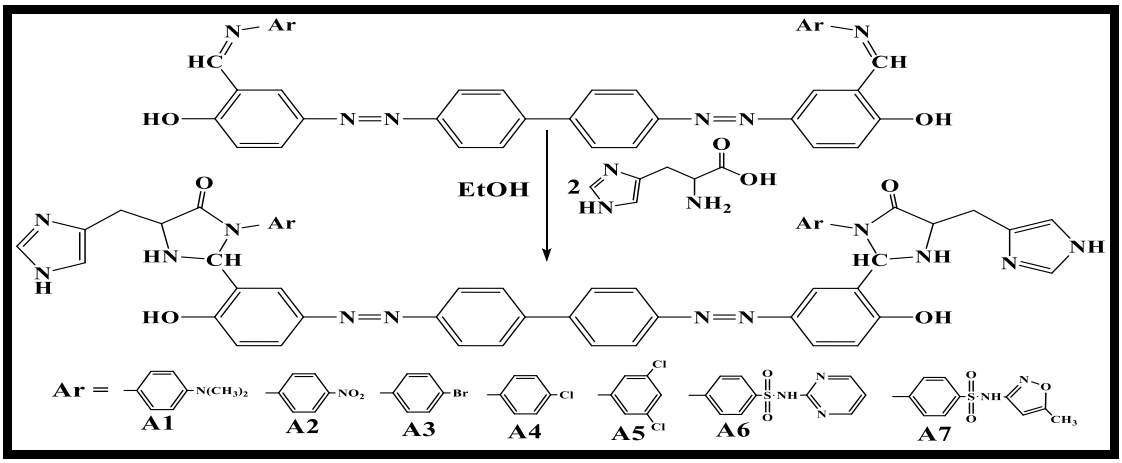
(0.001 mol) of the prepared Schiff bases were mixed in (45 ml) of absolute ethanol with (0.002 mol, 0.31 gm) of histidine dissolved in (10 ml) of absolute ethanol, and the mixture was elevated for (10-7 hours). The completion of the reaction was confirmed using the TLC technique. The mixture was cooled to room temperature and filtered, then washed and recrystallized with ethanol [10, 11]. Table (1) shows some physical properties, percentage, reverse elevation time, and R.f of 4-imidazolidinone derivatives (A1-A7).

2.3. Preparation of 4-imidazolidinone derivatives by microwave method (A1-A7)

Mix (0.001 mol) of the prepared Schiff bases in (10 ml) of absolute ethanol with (0.002 mol, 0.31 gm) of histidine dissolved in (5 ml) of absolute ethanol and put the mixture in the microwave and heated for (5-7) minutes at a temperature of (78 °C) and a power of (400 W). The completion of the reaction was confirmed using the TLC technique. The mixture was cooled to room temperature, filtered, washed with cold water, and recrystallized with ethanol [12, 13]. Table (1) shows some physical properties, percentage, reverse sublimation time, and R.f of 4-imidazolidinone derivatives (A1-A7).

Table 1. Some Physical Properties of the 4-Imidazolidinone derivatives (A1-A7) Prepared by the traditional and microwave methods

Comp.	Traditional method					Microwave method				
No.	Color	Ref. (h.)	M.P. °C	Y. %	R.f	Color	Ref. (h.)	M.P. °C	Y. %	R.f
A 1	Light yellow	9	225-227	74	0.83	Light yellow	7	225-227	74	0.83
A 2	Brown	8	293-295	79	0.75	Brown	7	293-295	79	0.75
A 3	Dark brown	9	280-282	81	0.61	Dark brown	5	280-282	81	0.61
A 4	Dark orange	10	201-203	75	0.69	Dark orange	6	201-203	75	0.69
A 5	Light red	8	261-263	80	0.66	Light red	7	261-263	80	0.66
A 6	Dark brown	9	233-235	85	0.78	Dark brown	6	233-235	85	0.78
A 7	Light orange	10	247-249	70	0.45	Light orange	6	247-249	70	0.45



Scheme 1. Prepared compounds (A1-A7)

2.4. Biological activity study

Mueller-Hinton agar was prepared by dissolving it in 1 liter of distilled water, heating and stirring it with a magnetic stirrer, and then sterilizing it with an autoclave at 121 °C and 1.5 bar pressure [16-19]. For two h, it was cooled to 50 °C, poured into Petri dishes, and frozen at room temperature. Two bacterial isolates were tested: Gram-negative, ***E. coli***, and Gram-positive ***S. aureus***. Two colonies of pure bacterial isolates of both Gram-positive and Gram-negative bacteria were transferred from the solid culture medium to test tubes containing (5 ml) distilled water using heat-sterilized holders [16-23]. The tubes were incubated at 30 °C. (37°C) for (20) hours, then diluted with the physiological solution until the turbidity reaches standard turbidity levels to obtain a cell count of approximately (1.5×10^8) cells/ml [24-27]. Chemical solutions of the prepared compounds were prepared using dimethyl sulfoxide (DMSO) solvent at three concentrations (0.01, 0.001, 0.0001) mg/ml of each substance (for each of these solid derivatives) [28-30].

2.5. Measurement of laser activity of the compounds

The effectiveness of the laser compounds was evaluated using a helium-neon laser (a flammable laser) where the compounds were exposed to four different exposure times (15, 30, 45, and 60) seconds for each compound and the distance between the laser source and the sample was fixed at (10 cm) with a power of (1 milliwatt) and a wavelength of (808 nm) [29]. The measurements were carried out in the laser laboratory of the Department of Physics, College of Science, Tikrit University. After treating the compounds with a radioactive method, their physical properties were re-examined to observe any changes resulting from the laser treatment.

3. Results and Discussion

3.1. Characterization of 4-imidazolidinone derivatives (A1-A7)

The FT-IR spectrum showed an absorption band due to (C=O) at (1670-1654) cm^{-1}, a band usually for (NH) at (3184-3168) cm^{-1}, a band usually for (C-N) at (1287-1264) cm^{-1}, a band due to (C=N) histidine at (1618-1601) cm^{-1}, two bands due to aliphatic (CH) at (2919-2867 & 2974-2919) cm^{-1}, a typical band for aromatic (CH) at (3055-3013) cm^{-1}, two bands due to aromatic (C=C) at (1569-1527 & 1523-1485) cm^{-1} [30-31]. As in Table 2 and Figures 1, 2.

Table 2. FT-IR absorption results for prepared compounds (A9-A15)

Comp.	ν(OH)	ν(NH)	νCH Arom.	ν(CH) Aliph.	ν(C=O)	ν(C=N)	ν(C=C) Arom.	ν(C-N)	Others
A 1	3371	3169	3013	2929, 2867	1655	1608	1545, 1490	1281	--
A 2	3366	3175	3017	2976, 2919	1659	1611	1548, 1523	1276	ν(NO) 1514, 1315
A 3	3332	3170	3055	2974, 2916	1654	1618	1569, 1485	1280	ν(C-Br) 688
A 4	3400	3184	3022	2945, 2866	1681	1618	1527, 1488	1274	ν(C-Cl) 742
A 5	3367	3168	3031	2932, 2867	1663	1606	1539, 1508	1269	ν(C-Cl) 758
A 6	3356	3175	3026	2930, 2903	1660	1615	1561, 1518	1264	--
A 7	3378	3181	3016	2919, 2875	1668	1610	1546, 1505	1287	ν(C-O) 1323

^{1}H-NMR spectrum of A3 shows a signal at (11.7712.46) ppm for (NH) histidine, a signal at (9.61) ppm for (OH), a signal at (9.61) ppm for (NH) imidazole, signals at (77.01-8.29) ppm aromatic rings, a signal at (6.39) ppm for (CH) imidazole, a triplet signal at (3.95-4.00) ppm for (CH) imidazole, and a doublet signal at (3.04, 3.02) ppm for (CH_2) histidine [32, 33]. As in Fig. 3.

^{1}H-NMR spectrum of A5 shows a signal for (NH) histidine at (10.03) ppm, a signal for (OH) at (8.75) ppm, a signal for (NH) imidazole at (8.41) ppm, signals for aromatic rings at (7.01-8.29) ppm, a signal for (CH) imidazole at (5.94) ppm, a triple signal for (CH) imidazole at (3.25-3.32) ppm, a double signal for (CH_2) histidine at (2.76, 2.73) ppm. As in Fig. 4.

3.2. Elemental Analysis (C.H.N.O.) Measurement

Elemental analysis (C.H.N.O) of the manufactured compounds was performed to verify the accuracy and precision of their structural composition, and the obtained elemental ratios were either consistent with the calculated values or very close to them, confirming the validity of the structures of the manufactured compounds [34, 35], as shown in Table (3).

Table 3. Results of elemental analysis (C.H.N.O) of manufactured compounds

Comp No.	Molecular Formula	Calculated				Found			
		C%	H%	N%	O%	C%	H%	N%	O%
A 1	$C_{54}H_{52}N_{14}O_4$	67.31	5.32	20.25	6.46	67.14	5.27	20.19	6.29
A 2	$C_{50}H_{40}N_{14}O_8$	62.16	4.04	20.32	13.16	61.83	3.79	20.01	12.94
A 3	$C_{50}H_{40}Br_2N_{12}O_4$	58.05	3.80	16.18	6.10	57.89	4.02	16.31	6.39
A 4	$C_{50}H_{40}Cl_2N_{12}O_4$	63.43	4.20	17.65	6.54	63.32	4.14	17.42	6.30
A 5	$C_{50}H_{38}Cl_4N_{12}O_4$	59.38	3.71	16.69	6.36	59.76	3.54	16.32	6.16
A 6	$C_{62}H_{52}N_{14}O_8S_2$	62.73	4.32	16.32	10.57	62.65	4.45	16.23	10.45
A 7	$C_{58}H_{50}N_{16}O_{10}S_2$	58.18	4.12	18.71	13.32	47.89	3.97	18.89	13.14

3.3. Green Synthesis and Traditional Synthesis

All compounds were synthesized using conventional and microwave methods, and the two methods were compared in terms of solvent usage, catalyst requirement, reaction time, relative yield, melting point, color, and solubility. The microwave method has the advantages of high yield, low solvent consumption, no catalyst, and short time. It is also easier to separate the compounds prepared using microwave technology. The compounds prepared by the two methods are identical regarding physical properties such as color, melting point, and RF value [36, 37].

3.4. Evaluation of the Biological Activity of Prepared Compounds

Insert a sterile cotton swab into the test tube containing the diluted bacterial growth and remove excess inoculum by pressing the swab against the inner wall of the tube [38,39]. Inoculate Mueller Hinton agar (MHA) with the sterile cotton swab and wipe it over the culture. Leave the Petri dish aside (10-15 days) for a few minutes to absorb the culture and dry the medium [40-43]. The antibacterial activity of the prepared compounds was tested using the agar diffusion method. After inoculating the culture medium with the bacterial isolates, make holes in the Petri dishes using the cylinder measuring method (according to USP 35) [44-47]. Cork drill, put (40 µl) of the three concentrations of the prepared compounds in each well, then incubate the dish at (37°C) for (24) hours, then (24) hours and (48) hours [48-50]. The results are read after 24 hours to indicate the sensitivity of the derivative used, which depends on the inhibitory diameter shown in the culture dish around the well-used, as an increase in the inhibitory diameter means an increase in the bioavailability of the prepared compound [52-53]. Compare the inhibitory diameter with the diameter of the standard antibiotic in solution form, such as amoxicillin, as a control sample [54]. As in Table 4 and Scheme 1, 2.

Table 4. Antibacterial activity of the synthesized compounds (inhibition zone in mm)

Comp. No.	E. Coil Conc. mg/ml			Staph. Aureus Conc. mg/ml		
	0.0001	0.001	0.01	0.0001	0.001	0.01
A 1	7	10	13	9	16	20
A 2	3	8	10	0	8	10
A 3	8	10	12	7	12	18
A 4	5	5	5	10	5	13
A 5	12	12	18	0	6	14
A 6	10	10	12	6	9	12
A 7	4	10	19	10	15	21
Amox.	14	20	30	15	21	30

3.5. Results of Laser Activity Measurement for Synthesized Compounds

In this study, the laser activity of the composites was evaluated by exposing them to a helium-neon laser. Later, the physical properties (color, melting point, and flow rate (Rf)) of the composites were re-examined to evaluate any changes. The investigation revealed that during periods of 15, 30, and 45 seconds, the physical properties of the chemicals remained unchanged. These composites maintained their structural integrity and physical properties and showed no response to the laser during these periods. However, at 60 seconds, significant changes in the physical properties were observed, and these changes were significant in the melting points and Rf values of the thin layer chromatography (TLC) [55]. In addition, small color changes were observed. These changes are likely due to the dissolution of some bonds within the composites, which would lead to the creation of new compounds because of continuous exposure to the high-power laser for 60 seconds [56]. The results of measuring the laser activity of some of the composites are listed in Table (5).

Table 5. Results of Laser Activity Measurement for Synthesized Compounds

Comp.	15 S			30 S			45 S			60 S		
No.	Color	M.P. ℃	R.f	Color	M.P. ℃	R.f	Color	M.P. ℃	R.f	Color	M.P. ℃	R.f
A 1	Light yellow	225-227	0.83	Light yellow	225-227	0.83	Light yellow	225-227	0.83	Yellow	201-203	0.75
A 2	Brown	293-295	0.75	Brown	293-295	0.75	Brown	293-295	0.75	Light brown	274-276	0.66
A 3	Dark brown	280-282	0.61	Dark brown	280-282	0.61	Dark brown	280-282	0.61	Brown	261-263	0.53
A 4	Dark orange	201-203	0.69	Dark orange	201-203	0.69	Dark orange	201-203	0.69	Orange	184-186	0.60
A 5	Light red	261-263	0.66	Light red	261-263	0.66	Light red	261-263	0.66	Orange	243-245	0.53
A 6	Dark brown	233-235	0.78	Dark brown	233-235	0.78	Dark brown	233-235	0.78	Brown	206-208	0.67
A 7	Light orange	247-249	0.45	Light orange	247-249	0.45	Light orange	247-249	0.45	Yellow	221-223	0.54

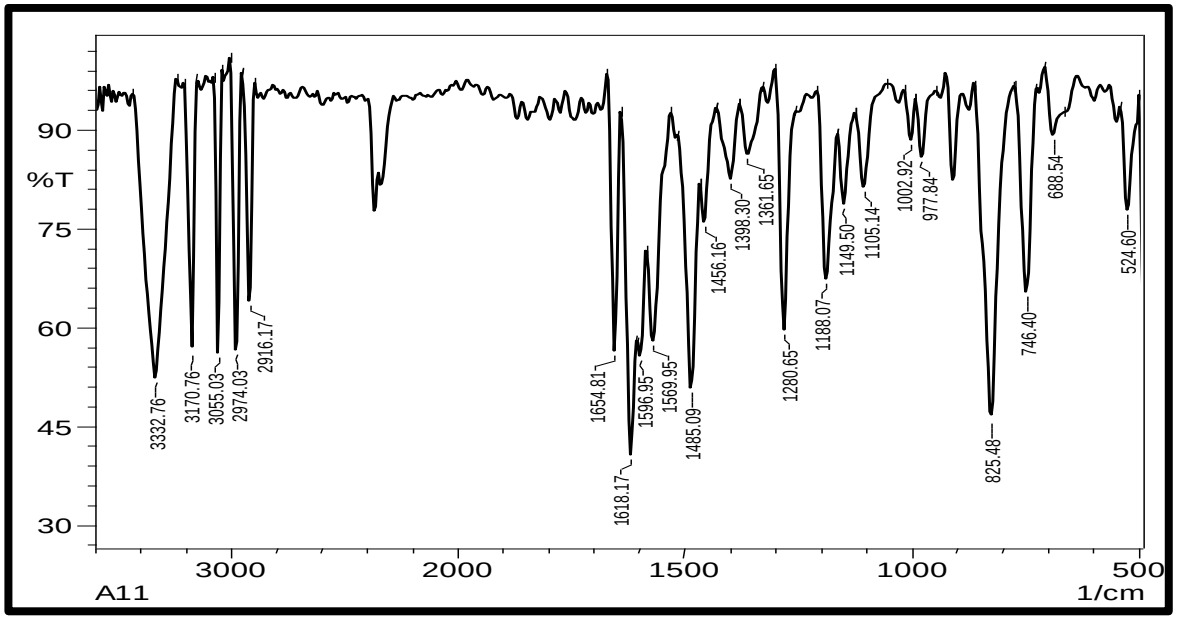


Figure 1. The compound's FT-IR spectra (A3)

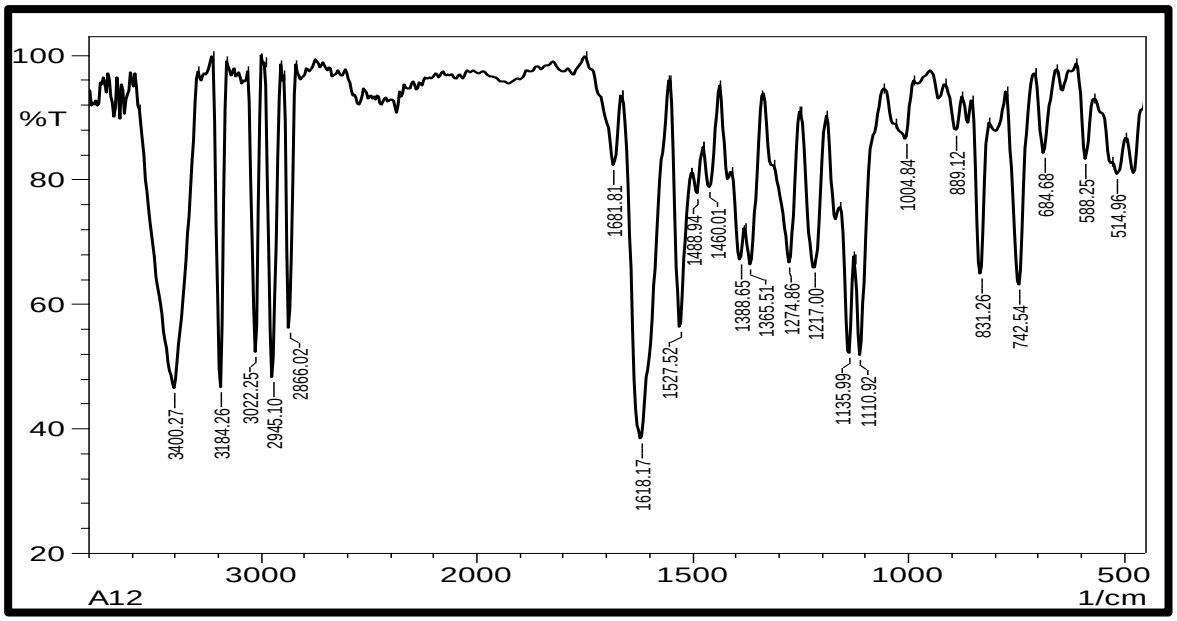


Figure 2. The compound's FT-IR spectra (A4)

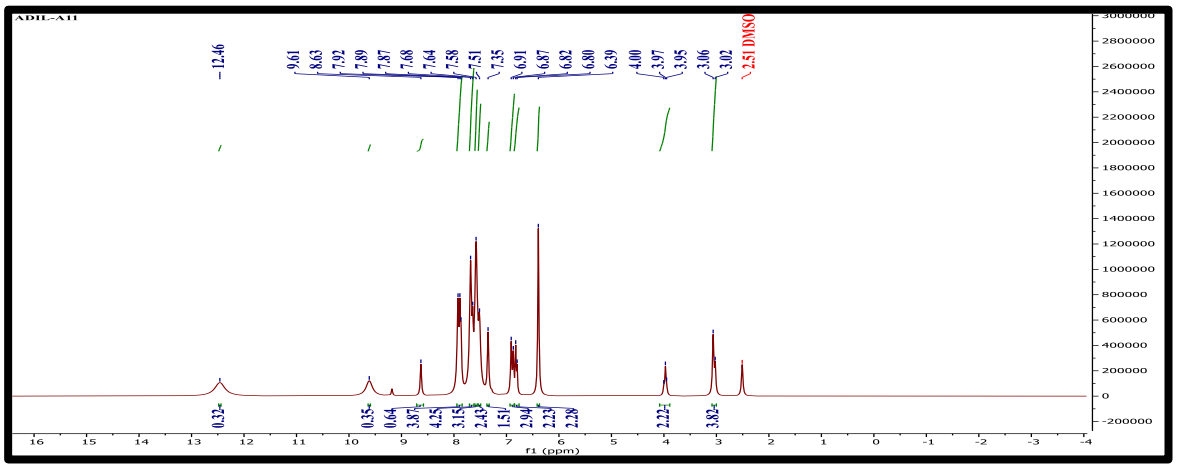


Figure 3. 1-H NMR spectra of the substance (A3)

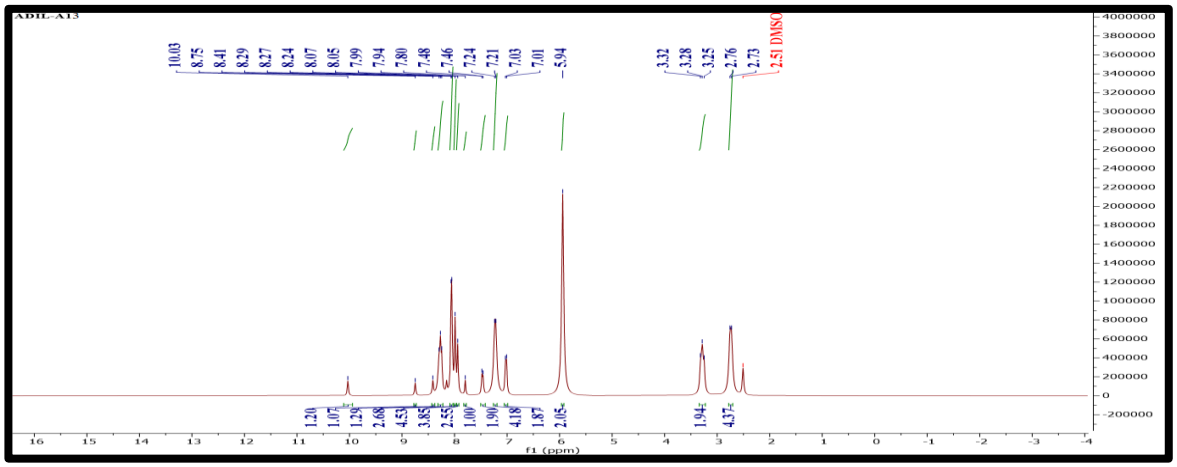
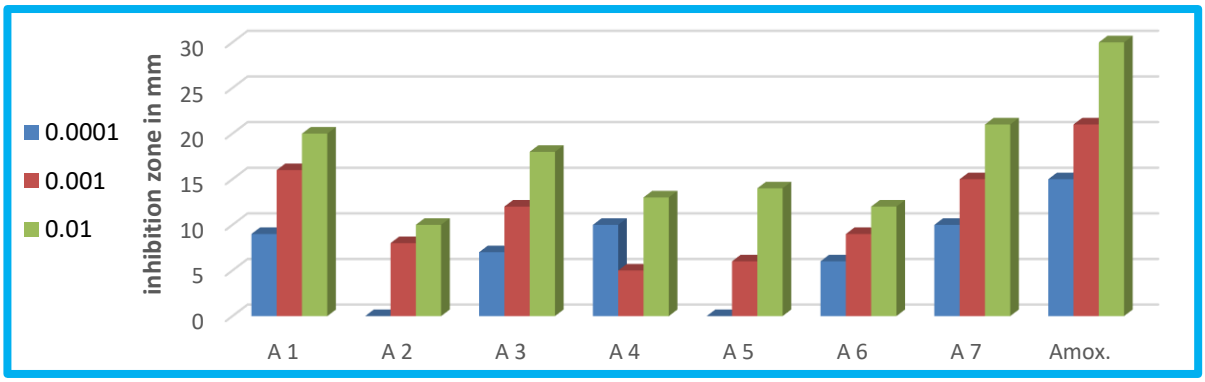
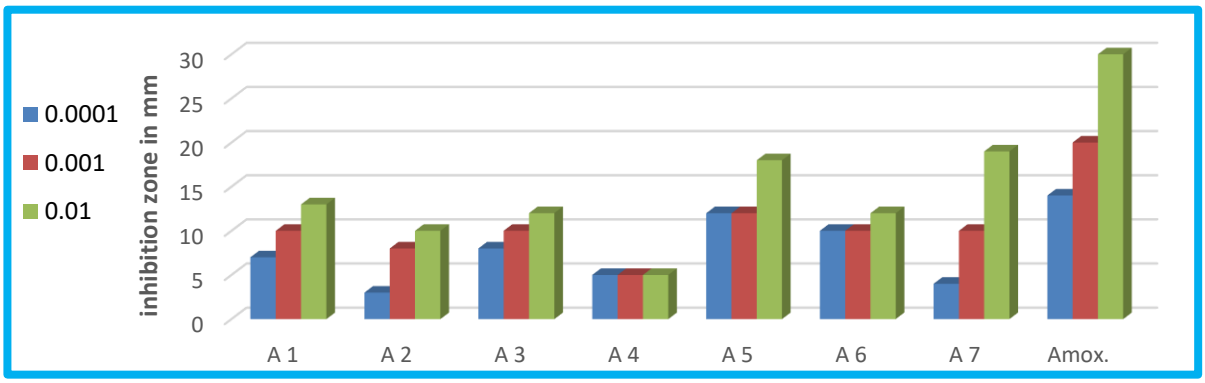


Figure 4. 1-H NMR spectra of the substance (A5)



Scheme 2. Inhibitory activity of (A1-A7) for Staph. aureus



Scheme 3. Inhibitory activity of (A1-A7) for E. coli

4. Conclusion

Compared with conventional methods, microwave methods have achieved better results in obtaining organic compounds. This technology has proven to be economical as it saves time, effort, solvents and catalysts while providing higher product yields. Therefore, it can be concluded that the microwave method is superior, especially for small reactions. In addition, the microwave method uses fewer reactants and causes less pollution to the laboratory environment and the wider ecosystem, making it an environmentally friendly technique. Reactions of Schiff base derivatives with compounds containing suitable functional groups usually produce five-membered heterocycles. Biological studies have shown that the synthesised compounds have antimicrobial activity and can inhibit the growth of bacteria. These compounds exhibit higher biological activity than the parent material, which is important since the starting material is a drug used in the medical field. The synthesized compounds showed high stability when exposed to helium-neon laser irradiation. Physical and spectroscopic measurements confirmed the accuracy and validity of the synthesized nanostructures.

REFERENCES

[1] L. Zhang, X. M. Peng, G. L. Damu, R. X. Geng, and C. H. Zhou, "Comprehensive Review in Current Developments of Imidazole-Based Medicinal Chemistry," *Med. Res. Rev.*, vol. 34, no. 2, pp. 340-437, 2014.

[2] N. S. Khab, Z. Rezaei, M. Eskandari, A. Khalafinezhad, and M. Motazedian, "Synthesis of Metronidazole Derivatives as Antigiardiasis Agents," unpublished, 2007.

[3] H. van den Bossche, "Biochemical Effects of Miconazole on Fungi—I: Effects on the Uptake and/or Utilization of Purines, Pyrimidines, Nucleosides, Amino Acids and Glucose by *Candida albicans*," *Biochem. Pharmacol.*, vol. 23, no. 4, pp. 887-899, 1974.

[4] H. Che, T. N. Tuyen, H. P. Kim, and H. Park, "1, 5-Diarylimidazoles with Strong Inhibitory Activity Against COX-2 Catalyzed PGE2 Production from LPS-Induced RAW 264.7 Cells," *Bioorg. Med. Chem. Lett.*, vol. 20, no. 14, pp. 4035-4037, 2010.

[5] P. Zhan, X. Liu, J. Zhu, Z. Fang, Z. Li, C. Pannecouque, and E. De Clercq, "Synthesis and Biological Evaluation of Imidazole Thioacetanilides as Novel Non-Nucleoside HIV-1 Reverse Transcriptase Inhibitors," *Bioorg. Med. Chem.*, vol. 17, no. 16, pp. 5775-5781, 2009.

[6] V. K. Kapoor, R. Chadha, P. K. Venisetty, and S. Prasanth, "Medicinal Significance of Nitroimidazoles—Some Recent Advances," unpublished.

[7] D. Pectasides, H. Yianniotis, N. Alevizakos, D. Bafaloukos, V. Barbounis, J. Varthalitis, and A. Athanassiou, "Treatment of Metastatic Malignant Melanoma with Dacarbazine, Vindesine and Cisplatin," *Br. J. Cancer*, vol. 60, no. 4, pp. 627-629, 1989.

[8] F. M. Muhammad, B. A. Khairallah, M. J. Saleh, and J. N. Saleh, "Preparation and Characterization of New Rings of Oxazine Derivatives and Studying Their Biological and Laser Effectiveness and Molecular Docking," *Cent. Asian J. Theor. Appl. Sci.*, vol. 5, no. 4, pp. 190-201, 2024.

[9] M. M. Aftan, M. A. Toma, A. H. Dalaf, E. Q. Abdullah, and H. K. Salih, "Synthesis and Characterization of New Azo Dyes Based on Thiazole and Assess the Biological and Laser Efficacy for Them and Study Their Dyeing Application," *Egypt. J. Chem.*, vol. 64, no. 6, pp. 2903-2911, 2021.

[10] A. H. Dalaf, F. H. Jumaa, and H. K. Salih, "Preparation, Characterization, Biological Evaluation and Assess Laser Efficacy for New Derivatives of Imidazolidin-4-One," *Int. Res. J. Multidiscip. Technov.*, vol. 3, no. 4, pp. 41-51, 2021.

[11] H. Dalaf, F. H. Jumaa, and H. K. Salih, "Multidisciplinary Technovation Red," *Int. Res. J. Multidiscip. Technov.*, vol. 15, no. A2, p. C44H36N10O8, 2021.

[12] H. Dalaf, "Synthesis and Characterization of Some Quartet and Quinary Heterocyclic Rings Compounds by Traditional Method and Microwave Routes Method and Evaluation of Their Biological Activity," M.S. thesis, Tikrit Univ., Tikrit, Iraq, 2018.

[13] H. Dalaf and F. H. Jumaa, "Synthesis, Characterization of Some 1,3-Oxazepane-4,7-Dione by Traditional and Microwave Routes Method and Evaluation of Their Biological Activity," *Al-Utroha Pure Sci.*, vol. 8, pp. 93-108, 2018.

[14] H. Dalaf, F. H. Jumaa, and S. A. S. Jabbar, "Synthesis and Characterization of Some 2,3-Dihydroquinozoline and Evaluation of Their Biological Activity," *Tikrit J. Pure Sci.*, vol. 23, no. 8, pp. 66-67, 2018.

[15] S. A. J. Salwa, L. H. Ali, A. H. Adil, and H. S. A. Hossam, "Synthesis and Characterization of Azetidine and Oxazepine Compounds Using Ethyl-4-((4-Bromo Benzylidene) Amino) Benzoate as Precursor and Evaluation of Their Biological Activity," *J. Educ. Sci. Stud.*, vol. 16, no. 5, pp. 39-52, 2020.

[16] Q. Abd, H. I. Ibrahim, H. M. Jirjes, and A. H. Dalaf, "Synthesis and Identification of New Compounds with Antioxidant Activity Beta-Carotene from Natural Auxin Phenyl Acetic Acid," *Res. J. Pharm. Technol.*, vol. 13, no. 1, pp. 40-46, 2020.

[17] A. H. Dalaf and F. H. Jumaa, "Synthesis, Identification and Assess the Biological and Laser Efficacy of New Compounds of Azetidine Derived from Benzidine," *Muthanna J. Pure Sci.*, vol. 7, no. 2, pp. 12-25, 2020.

[18] M. M. Al-Tufah, S. S. Jasim, and K. A. Al-Badrany, "Synthesis and Antibacterial Evaluation of Some New Pyrazole Derivatives," *Prof. Dr. R. K. Sharma*, vol. 20, no. 3, p. 178, 2020.

[19] A. Yass, M. M. Aftan, A. H. Dalaf, and F. H. Jumaa, "Synthesis and Identification of New Derivatives of Bis-1,3-Oxazepene and 1,3-Diazepine and Assess the Biological and Laser Efficacy for Them," *Second Int. & Fourth Sci. Conf. Coll. Sci., Tikrit Univ.*, pp. 77-87, Nov. 2020.

[20] D. Salih, A. H. Dalaf, M. A. Alheety, W. M. Rashed, and I. Q. Abdullah, "Biological Activity and Laser Efficacy of New Co (II), Ni (II), Cu (II), Mn (II) and Zn (II) Complexes with Phthalic Anhydride," *Mater. Today: Proc.*, vol. 43, pp. 869-874, 2021.

[21] M. M. Aftan, M. Q. Jabbar, A. H. Dalaf, and H. K. Salih, "Application of Biological Activity of Oxazepine and 2-Azetidinone Compounds and Study of Their Liquid Crystalline Behavior," *Mater. Today: Proc.*, vol. 43, pp. 2040-2050, 2021.

[22] A. Khairallah, F. M. Muhammad, J. N. Saleh, and M. J. Saleh, "Preparation, Characterization, Biological Activity Evaluation, and Liquid Crystallography Study of New Diazepine Derivatives," *World Med. J. Biomed. Sci.*, vol. 1, no. 7, pp. 65-76, 2024.

[23] M. J. Saleh, J. N. Saleh, K. Al-Badrany, A. H. Dalaf, R. S. Najm, and A. W. A. S. Talluh, "Preparation and Evaluation of the Biological Activity of a 2-Amino Pyran Ring Using a Solid Base Catalyst," *Cent. Asian J. Med. Nat. Sci.*, vol. 5, no. 4, pp. 130-138, 2024.

[24] A. W. A. S. Talluh, M. J. Saleh, and J. N. Saleh, "Preparation, Characterisation and Study of the Molecular Docking of Some Derivatives of the Tetrazole Ring and Evaluation of Their Biological Activity," *World Med. J. Biomed. Sci.*, vol. 1, no. 7, pp. 15-23, 2024.

[25] M. J. Saleh, J. N. Saleh, and K. Al-Badrany, "Preparation, Characterization, and Evaluation of the Biological Activity of Pyrazoline Derivatives Prepared Using a Solid Base Catalyst," *Eur. J. Mod. Med. Pract.*, vol. 4, no. 7, pp. 25-32, 2024.

[26] N. Saleh and A. Khalid, "Synthesis, Characterization and Biological Activity Evaluation of Some New Pyrimidine Derivatives by Solid Base Catalyst Al2O3-OBa," *Cent. Asian J. Med. Nat. Sci.*, vol. 4, no. 4, pp. 231-239, 2023.

[27] A. W. A. S. Talluh, M. J. Saleh, J. N. Saleh, K. Al-Badrany, and H. M. M. Saleh Al-Jubori, "Preparation, Characterization, and Evaluation of the Biological Activity of New 2,3-Dihydroquinazoline-4-One Derivatives," *Eur. J. Mod. Med. Pract.*, vol. 4, no. 4, pp. 326-332, 2024.

[28] W. A. S. Talluh, "Preparation, Characterization, Evaluation of Biological Activity, and Study of Molecular Docking of Azetidine Derivatives," *Cent. Asian J. Med. Nat. Sci.*, vol. 5, no. 1, pp. 608-616, 2024.

[29] H. Dalaf, M. J. Saleh, and J. N. Saleh, "Green Synthesis, Characterization, and Multifaceted Evaluation of Thiazolidinone Derivatives: A Study on Biological and Laser Efficacy," *Eur. J. Mod. Med. Pract.*, vol. 4, no. 7, pp. 155-168, 2024.

[30] W. A. S. Sattar Talluh, J. N. Saleh, M. J. Saleh, and H. M. Saleh Al-Jubori, "Preparation and Characterization of New Imidazole Derivatives Derived from Hydrazones and Study of Their Biological and Laser Efficacy," *Cent. Asian J. Theor. Appl. Sci.*, vol. 5, no. 4, pp. 202-211, 2024.

[31] H. Dalaf, "3-Phenylimidazolidin-4-One: Characterization, Green Synthesis, Evaluation of Biological and Laser Performance," *Eur. J. Mod. Med. Pract.*, vol. 4, no. 7, pp. 417-427, 2024.

[32] W. A. S. Talluh, J. N. Saleh, and M. J. Saleh, "Preparation, Characterization and Evaluation of Biological Activity and Study of Molecular Docking of Some New Thiazolidine Derivatives," unpublished, 2024.

[33] H. Dalaf, F. H. Jumaa, M. M. Aftana, H. K. Salih, and I. Q. Abd, "Synthesis, Characterization, Biological Evaluation, and Assessment Laser Efficacy for New Derivatives of Tetrazole," in *Key Eng. Mater.*, vol. 911, pp. 33-39, Trans Tech Publications Ltd, 2022.

[34] H. Dalaf, F. H. Jumaa, and I. A. Yass, "Synthesis, Characterization, Biological Evaluation, Molecular Docking, Assess Laser Efficacy, Thermal Performance and Optical Stability Study for New Derivatives of Bis-1, 3-Oxazepene and 1, 3-Diazepine," in *AIP Conf. Proc.*, vol. 2394, no. 1, AIP Publishing, Nov. 2022.

[35] M. M. Saleh and F. H. Juma, "Synthesis, Characterization, and Study of Biological Activity of Oxazepine Compounds Derived from 1, 3, 4-Oxadiazole," *Cent. Asian J. Med. Nat. Sci.*, vol. 5, no. 1, pp. 224-232, 2024.

[36] A. I. Owed, A. A. Al-Jubouri, and S. Y. Al-Samarrai, "A Nano-Sensor for Copper Oxide Was Manufactured and Developed Using a New Organic Precipitant via Green Chemistry Methods," *Sensors Mach. Learn. Appl.*, vol. 1, no. 1, 2024.

[37] W. A. S. Talluh, R. S. Najm, M. J. Saleh, and J. N. Saleh, "Synthesis, Characterization, and Evaluation of the Biological Activity of Novel Oxazepine Compounds Derived from Indole-5-Carboxylic Acid," *Am. J. Biosci. Clin. Integrity*, vol. 1, no. 8, pp. 10-19, 2024.

[38] M. M. Saleh, A. L. Al-Nassiry, J. N. Saleh, and M. J. Saleh, "Preparation and Diagnosis of New Complexes for Hg (II) with 4-Amino Acetanilide and (Dppp) as a Ligand and Study of the Bacterial Efficacy and Molecular Docking of the Prepared Complexes," *Cent. Asian J. Theor. Appl. Sci.*, vol. 5, no. 4, pp. 364-373, 2024.

[39] A. W. A. S. Talluh, M. J. Saleh, and J. N. Saleh, "Application of Infrared and Nuclear Magnetic Resonance Spectra in Studying the Bacterial Efficacy of Some Oxazepane Derivatives Derived from Hydrazones," *Sensors Mach. Learn. Appl.*, vol. 3, no. 3, 2024. doi: 10.69534/smla/193913.

[40] M. M. Aftan, A. A. Talloh, A. H. Dalaf, and H. K. Salih, "Impact Para Position on Rho Value and Rate Constant and Study of Liquid Crystalline Behavior of Azo Compounds," *Mater. Today: Proc.*, vol. 45, pp. 5529-5534, 2021.

[41] S. D. Khalaf, N. A. A. S. Ahmed, and A. H. Dalaf, "Synthesis, Characterization and Biological Evaluation (Antifungal and Antibacterial) of New Derivatives of Indole, Benzotriazole and Thioacetyl Chloride," *Mater. Today: Proc.*, vol. 47, no. 17, pp. 6201-6210, 2021.

[42] A. H. Dalaf, F. H. Jumaa, and H. K. Salih, "Preparation, Characterization, Biological Evaluation and Assess Laser Efficacy for New Derivatives of Imidazolidin-4-One," *Int. Res. J. Multidisciplinary Technovation*, vol. 3, no. 4, pp. 41-51, 2021.

[43] H. Dalaf, F. H. Jumaa, and H. K. Salih, "Multidisciplinary Technovation," *Red*, vol. 15, no. A2, p. C44H36N10O8, 2021.

[44] Y. Kh. Alasadi, F. H. Jumaa, A. H. Dalaf, S. M. Shawkat, and M. Gh. Mukhlif, "Synthesis, Characterization, and Molecular Docking of New Tetrazole Derivatives as Promising Anticancer Agents," *J. Pharm. Negative Results*, vol. 13, no. 3, pp. 513-522, 2022.

[45] Y. K. Alasadi, F. H. Jumaa, and A. H. Dalaf, "Synthesis, Identification, Antibacterial Activity and Laser Effect of New Derivatives of Bis-1, 3-Oxazepene-4, 7-Dione and 1, 3-Diazepine-4, 7-Dione," in *AIP Conf. Proc.*, vol. 2394, no. 1, p. 040019, AIP Publishing LLC, Nov. 2022.

[46] M. A. Toma, D. A. Ibrahim, A. H. Dalaf, S. Q. Abdullah, M. M. Aftan, and E. Q. Abdullah, "Study the Adsorption of Cyclopentanone on to Natural Polymers," in *AIP Conf. Proc.*, vol. 2394, no. 1, p. 040007, AIP Publishing LLC, Nov. 2022.

[47] A. M. Hamad, Q. M. Atiyea, D. N. A. Hameed, and A. H. Dalaf, "Green Synthesis of Copper Nanoparticles Using Strawberry Leaves and Study of Properties, Anti-Cancer Action, and Activity Against Bacteria Isolated from Covid-19 Patients," *Karbala Int. J. Mod. Sci.*, vol. 9, no. 1, pp. 12, 2023.

[48] S. Jassim, A. H. Dalaf, and T. F. Abdullah, "Studying the Biological Activity and Properties of Copper Nanoparticles Prepared by Pulsed Laser Ablation in Liquid," *The 3rd Int. and 5th Sci. Conf. for College of Science – Tikrit University*, vol. 1, no. 25, pp. 213-221, 2022.

[49] M. Hamad, Q. M. Atiyea, W. A. Jwair, A. H. Dalaf, A. S. Jasim, S. M. El-Saigher, Z. H. Saad, and L. J. Mohammed, "In Vitro Comparison of the Effect of Zinc Oxide Nanoparticles and Hibiscus sabdariffa Extract on Streptococcus mutans Isolated from Human Dental Caries," *The 3rd Int. and 5th Sci. Conf. for College of Science – Tikrit University*, vol. 2, no. 02, pp. 213-221, 2022.

[50] S. M. Abdulkareem, R. M. Alsaffar, G. H. A. Razzaq, J. H. Mohammed, T. M. Awad, M. A. Alheety, and S. Ghotekar, "Effect of Direct and Indirect In-Situ Sonochemical Synthesis Methods of MWCNTs–CoNiFerrite on the Hydrogen Storage," *J. Sol-Gel Sci. Technol.*, pp. 1-10, 2024.

[51] M. J. Saleh, J. N. Saleh, K. Al-Badrany, A. W. A. S. Talluh, Q. A. Shannak, and A. Z. Abdulmajeed, "Use of Solid Basic Catalysts in the Preparation of Cyclohexenone Derivatives and Evaluation of Their Bacterial Activity," *Vital Annex: Int. J. Novel Res. Adv. Sci.*, vol. 3, no. 3, pp. 104-112, 2024.

[52] M. M. Aftan, H. K. Salih, and A. A. Talloh, "Synthesis of New Mesogenic Schiff Bases Ether with Polar Halogen Substituent and Study Their Liquid Crystalline Properties," *J. Educ. Sci. Stud.*, vol. 5, no. 17, 2021.

[53] A. S. T. Abdul Wahed, "Preparation and Evaluation of Bacterial Activity and Study of the Crystalline Properties of Some 1, 3-Oxazepine-4, 7-Dione Derivatives," *Cent. Asian J. Theor. Appl. Sci.*, vol. 5, no. 2, pp. 15-26, 2024.

[54] H. Dalaf, "3-Phenylimidazolidin-4-One: Characterization, Green Synthesis, Evaluation of Biological and Laser Performance," *Eur. J. Mod. Med. Pract.*, vol. 4, no. 7, pp. 417-427, 2024.

[55] W. A. S. Talluh, M. J. Saleh, J. N. Saleh, and H. M. S. Al-Jubori, "Synthesis and Characterization of Some New Imine Graphene Derivatives and Evaluation of Their Biological Activity," *Cent. Asian J. Med. Nat. Sci.*, vol. 5, no. 4, pp. 272-290, 2024.

[56] R. H. Saleh, W. M. Rashid, A. H. Dalaf, K. A. Al-Badrany, and O. A. Mohammed, "Synthesis of Some New Thiazolidinone Compounds Derived from Schiff Bases Compounds and Evaluation of Their Laser and Biological Efficacy," *Ann. Trop. Public Health*, vol. 23, no. 7, pp. 1012-1031, 2020.