مجلة الدراسات التربوية والعلمية - كلية التربية - الجامعة العراقية
العدد العشرون - المجلد الثاني - الكيمياء - تشرين ثاني 2022 م
doi.org/10.52866/esj.2022.02.20.13

Preparation and Characterization of Some New Compounds of Azo Dyes Derived from Cephalosporins and Some Drugs, the Study of Some Physical Applications, and Evaluation of Their Biological Activity

Anaam Khalif Al-Azzawi ، Nabil Jamal Ayed al-assly
Tikrit University /
College of Education for Pure Sciences - Department of Chemistry

Abstract:

In this research, new azo dyes were prepared from the reaction of cephalosporins with nitrous acid by the sublimation method. Uv-vis., FT-IR, 1H-NMR, 13C-NMR, mass spectrometry, (S.E.M.), (C.H.N.). The electrical conductivity and biological activity of some prepared compounds and four types of pathogenic bacteria were studied, two of them were Gram-positive (G+), and two were Gram-negative(G-). These include (Staphylococcus aureus, Enterococcus faecalis, Klebsiella pneumonia, and Pseudomonas putida) and the Acker Muller-Hinton culture medium. (Molar Huntin Agar) Aqueous solutions of the two compounds [DM74, DM66] with concentrations (0.01,0.001,0.0001,0.00001) mg/mL were also prepared using dimethyl sulfoxide (DMSO) as solvent. The sensitivity test of bacterial isolates used in the study was conducted by diffusion method, and the antibiotics Cefixime, Ceftriaxone, and Ampicillin were used as a control sample. The electrical conductivity and industrial stability of some prepared compounds were also studied.

Keywords: Cephalosporins, Azo Dyes, Enterococcus Faecalis, Staphylococcus Aureus, Klebsiella Pneumonia, Pseudomonas Putida.

تحضير وتوصيف بعض المركبات الجديدة من أصباغ Azo المشتقة من السيفالوسبورينات وبعض الأدوية ، ودراسة بعض التطبيقات الفيزيائية ، وتقييم نشاطها البيولوجي

أنعام خليف عذاب العزاوي ، نبيل جمال عايد الأصلي
جامعة تكريت / كلية التربية للعلوم الصرفة - قسم الكيمياء

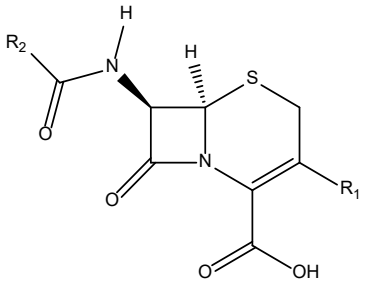
الخلاصة:

في هذا البحث تم تحضير أصباغ آزو جديدة من تفاعل السيفالوسبورينات مع حمض النيتروز بطريقة التسامي. Uv-vis. ، FT-IR ، ^{1}H-NMR ، C-13-NMR ، مطياف الكتلة ، (S.E.M.) ، (CHN). تمت دراسة الموصلية الكهربائية والنشاط البيولوجي لبعض المركبات المحضرة وأربعة أنواع من البكتيريا الممرضة ، اثنان منها موجبة الجرام (G +) واثنتان سالبة الجرام (G-) وتشمل هذه (Staphylococcus aureus ، و Entero-coccus faecalis ، والالتهاب الرئوي Klebsiella ، و Pseudomonas putida) ووسط الثقافة Acker Muller-Hinton. (Molar Huntin Agar) تم أيضًا تحضير المحاليل المائية للمركبين DM74 وDM66 بتركيزات (0.01،0.001،0.0001،0.00001) مجم / مل باستخدام ثنائي ميثيل سلفوكسيد (DMSO) كمذيب. تم إجراء اختبار الحساسية للعزلات البكتيرية المستخدمة في الدراسة بطريقة الانتشار ، واستخدمت المضادات الحيوية Cefixime و Ceftriaxone و Ampicillin كعينة تحكم. كما تم دراسة التوصيل الكهربائي والاستقرار الصناعي لبعض المركبات المحضرة.

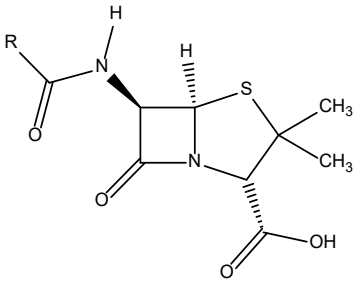
الكلمات الرئيسية: السيفالوسبورينات ، الأصباغ الآزوية ، المكورات المعوية البرازية ، المكورات العنقودية الذهبية ، الالتهاب الرئوي كليبسيلا ، بسيودوموناس بوتيدا.

1. Introduction:

Over the previous years and until the middle of the nineteenth century, the colored materials were natural sources such as organic and inorganic dyes, and organic dyes are aromatic and have an ancient history in dyeing, as they were used in textile dyeing and supplied from a vegetable source [1]. The industrially prepared azo dyes are of the largest varieties, as they can bind to the substance to be dyed and give it distinctive colors [2]. Some of the azo dyes are unaffected by light, oxygen, washing, or acids and bases [3]. Azo dyes are named because they contain the azo group [4]. The azo group consists of two nitrogen atoms linked by a double bond (-N=N-). It has SP^2 hybridization, bonded with aromatic or aliphatic carbon atoms [5]. Azo dyes may contain one azo group called mono azo dyes, or they may be dichotomous may have more than two azo groups called triple azo dyes [6]. According to the IUPAC system, goose dyes are defined as diamide derivatives HN=NH [7], containing two aryl groups and being the most stable, while the -N=N- group is called the Azo group [8]. There is also another classification based on the method of applying these dyes on an industrial scale. The dyes are grouped as dispersed, acidic, basic, or reactive [9]. The main factors that show colors are the presence of unsaturated groups in the molecule, and just as the axochromic groups are essential in increasing the intensity of the color, they give the dye molecule acidic or essential qualities as it expands its ability to contact the substance to be dyed [10]. Cephalosporins are antibiotics similar to penicillins [11] because they contain a beta-lactam ring. Still, the difference between them is that the cephalosporins have a hexagonal ring instead of the five-sided ring that includes the sulfur element next to the beta-lactam ring, as shown in the following structure for them:



cephalosporine



Penicillins

$R_1, R_2 = CH_3, C_2H_5, C_3H_7$

The effect of cephalosporins is similar to the development of penicillin. It impedes the growth of quip escent bacteria and eliminates the highly divided bacteria if given in high concentration [12,13]. Cephalosporins can be divided into the ways of entert ing them: First: given orally. The second: is given through the blood [14]. Cephalosporins are distributed into groups based on the most effective bacteria against them. These groups are called generations, divided into five generations [15]. First-generation: more effective against Gram-positive bacteria and used as prophylactic anc tibiotics for surgery that includes the abdomen and chest [16]. The second generation: targets Gram-positive and Gram-negative bacteria, but it is less effective against Gram-positive bacteria (G+) than the first generation [17]. The third generation is more effective against Gram-negative bacteria (G-) than the first and second generations [18]. Fourth generation: This generah tion is effective against various gram-positive and gram-negative bacteria, as it is intended for more severe ine fections, and examples of the fourth generation (cefepime, cefpiron) [19]. Fifth-generation: The fifth generation of cephalosporins is the advanced geno eration of cephalosporins, and examples of the fifth generation of cephalosporins are ceftaroline and ceftoluzan [20].

2. Experimental:

2.1. Chemicals used: All chemicals used in this work were purchased from BDH, Aldrich and Fluka companies and were used without further purification.

2.2. Devices used: The melting points were measured using Electrothermal Melting Apparatus 9300. The FT-IR spectra were captured using a Shimadzu FT-IR 8400S spectrophotometer with a (4000-400) cm^{-1} by KBr disc. DMSO-d_6 as solvents were used to capture ^{1}H-NMR and ^{13}C-NMR spectra on Bruker instruments running at 400 MHZ.

2.3. Preparation of azo dyes (DM66-DM70)

2.3.1. Preparation of the compound (DM66) [21,22]:

In a (100 mL) round flask (0.01 mol) sodium nitrite was dissolved in (25 mL) distilled water in an ice bath (0-5) ^{0}C. to (0.01 mol) of hydrochloric acid, and in a (100 mL) beaker, (0.01 mol) of one of cefotaxime was dissolved in (25 mL) of distilled water, then added (0.01 mol) of benzene. From the separating funnel, the contents of the baker were filtered on sodium nitrite drop by drop while maintaining the temperature. With the continuation of distillation, we notice the change in the color of the solution from transparent to maroon. After the distillation was completed, stirring continued for a full hour Without heating. The mixture was raised for (3) hours, then filtered and dried the residue, and when exposed to a non-ionic solvent, the color

of the solution changed from red to violet.

The rest of the chemical compounds [DM67, DM68, DM69] were prepared in the same way.

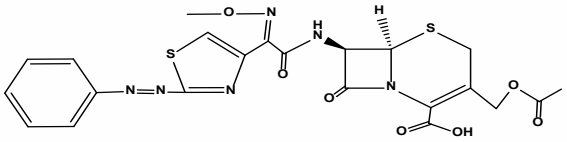
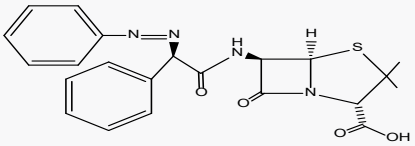
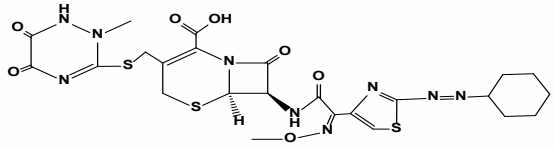
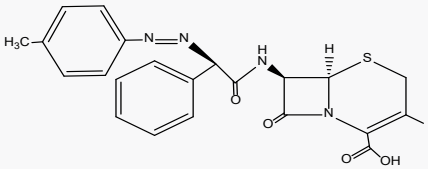
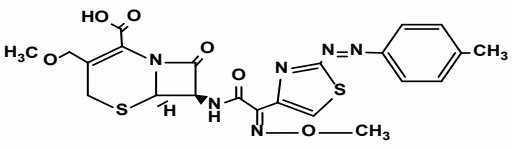
2.3.2. Preparation of the compound (DM70) [23,24]

In a (100 mL) round flask (0.01 mol) sodium nitrite is dissolved in (25 mL) of distilled water in an ice bath (0-5) ^{0}C, and then added (0.01 mol) of hydrochloric acid, and in a (100 mL) beaker, (0.01 mol) of cefpodoxime was dissolved in (25 mL) of distilled water, then (0.01mol) of toluene was added, and from the separating funnel, the contents of the baker were filtered on sodium nitrite drop by drop while maintaining the temperature. With the continuation of distillation, we notice a change in the color of the solution from light yellow to dark orange. After the distillation was completed, stirring continued for an hour Without heating. The mixture was raised for (3) hours, filtered, and dried the precipitate.

Table (1) shows some physical properties of azo dyes.

Comp. No.	Molecular Formula	Color	M.P ^{o}C	Yield %
DM66	$C_{16}H_{17}N_5O_7S_2$	Dark Red	163-165Dec.	87%
DM67	$C_{16}H_{19}N_3O_4S$	Yellow	109-111	92%
DM68	$C_{18}H_{18}N_8O_7S_3$	Red	112-114	89%
DM69	$C_{16}H_{17}N_3O_4S$	Yellow	159-161	84%
DM70	$C_{15}H_{17}N_5O_6S_2$	Dark Red	100-102	85%

Table (2): Shows the prepared azo compounds

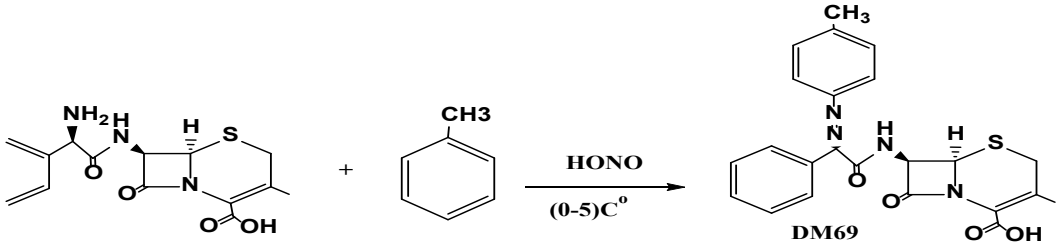
Comp. NO.	Structure & Name
DM66	 (6R,7R)-3-(acetoxymethyl)-7-((2Z)-2-(methoxyimino)-2-(2-(phenyldiazenyl)thiazol-4-yl)acetamido)-8-oxo-5-thia-1-azabicyclo[4.2.0]oct-2-ene-2-carboxylic acid
DM67	 (2S,5R,6R)-3,3-dimethyl-7-oxo-6-((R)-2-phenyl-2-(phenyldiazenyl)acetamido)-4-thia-1-azabicyclo[3.2.0]heptane-2-carboxylic acid
DM68	 (6R,7R)-7-((2Z)-2-(2-(cyclohexyldiazenyl)thiazol-4-yl)-2-(methoxyimino) acetamido)-3-(((2-methyl-5,6-dioxo-1,2,5,6-tetrahydro-1,2,4-triazin-3-yl)thio) methyl)-8-oxo-5-thia-1-azabicyclo[4.2.0]oct-2-ene-2-carboxylic acid
DM69	 (6R,7R)-3-methyl-8-oxo-7-((R)-2-phenyl-2-(p-tolyldiazenyl)acetamido)-5-thia-1-azabicyclo[4.2.0]oct-2-ene-2-carboxylic acid
DM70	 (6R,7R)-7-((2E)-2-(methoxyimino)-2-(2-(p-tolyldiazenyl)thiazol-4-yl)acetamido)-3-(methoxymethyl)-8-oxo-5-thia-1-azabicyclo[4.2.0]oct-2-ene-2-carboxylic acid

2.4. Study of biological activity [25, 26]:

This Study was used on four types of pathogenic bacteria, two of which are gram-positive, two are gram-negative, and they are: Staphylococcus aureus and Enterococcus faecalis, Klebsiella pneumonia, and Pseudomonas putida are essential in the medical field because of their resistance to antibiotics. These bacteria were taken from the laboratories of the College of Education for Pure Sciences, Department of Bio-Sciences, and a Mueller-Hinton-Akar culture medium was used. Molar Huntin Agar) is used to measure the biological activity of antibiotics and chemicals for medical uses and is used to measure and determine the minimum inhibitor (MIC). Aqueous solutions of the two compounds [DM66, DM70] were also prepared. At concentrations of (0.01, 0.001, 0.0001 0.00001, mg/mL) and using a solvent dimethyl sulfoxide (DMSO), a sensitivity test was performed for the bacterial isolates that were used in Study by diffusion method in the nutrient medium of Mueller-Hinton agar, which is a transparent nutrient medium with a dark yellow color. D in the sensitivity test of microorganisms towards antibiotics because it contains an animal infusion extracted from casein and starch.

3. Results and Discussion:

The azo dyes were prepared from the reaction of one mole of cephalosporins or drugs with one mole of nitrous acid.



3.1. Spectroscopic interpretation (U.V-vis., FT-IR .,^{1}H-NMR, ^{13}C-NMR, Mass)

The reaction of the compounds [DM66-DM74] was confirmed by diagnosing the prepared azo dyes by measurements of ultraviolet (Uv-vis.), infrared (FT-IR) , proton nuclear magnetic resonance (^{1}H-NMR), and carbon nuclear magnetic resonance (^{13}C-NMR) spectrum

When studying the ultraviolet (U.V-vis.) spectrum of the prepared azo dyes, we notice the appearance of an absorption band of greater intensity and lower wavelength due to the electronic transitions $\pi \rightarrow \pi^{*}$ and caused by (C=C) bonds, which Pathochromia displacement appears in the prepared azo dyes within a range of (280) nm, as well as a beam of greater wavelength and lower intensity, which is attributed to

the electronic transitions $n \rightarrow \pi^*$, which are caused by the electron pairs. There is no participation in the oxygen and nitrogen atoms. These bands appear pathochromically shifted in the prepared compounds due to oxo groups and succession within the range (380-325) nm [27].

When studying the infrared (FT-IR) spectrum of azo dyes [DM66], it was noticed that the stretching band of the amine group (NH_2) disappeared in the prepared compounds with the appearance of several bands within the range of (3589-3400) cm^{-1} which goes back to (N-H) group ,and the appearance of the stretching band of the hydroxyl group at (3333) cm^{-1}, we also notice the formation of a bar within the range (3223-3120) cm^{-1} Which belongs to the stretching of the olefinic (C-H) group, as well as bundles, appeared within the field (3063) cm^{-1}, which belong to the extension of the aromatic (C-H) group, also appeared a pile with the limits of (2914) cm^{-1}, which belongs to the stretching of the aliphatic (C-H) group., Also, a band seems within the range (1726) cm^{-1}, which belongs to the stretching frequency of the imide carbonyl group. The band is within the content of (1688) cm^{-1} related to the stretching frequency of the carboxylic carbonyl group. A bundle appeared within the range (1626) cm^{-1}, which belongs to the stretch of the (C=C) olefinic group, as well as a pile seemed within the range (1593-1500) cm^{-1}, which belongs to the stretching frequency of the aromatic (C=C) group, and the beam is within the field (1404-1357) cm^{-1} belonging to the frequency of the alkyl (C.H.) group. As for the (C-N) group, curvature beams appeared in the areas (1237-1201) cm^{-1} and group curvature beams. (C-O) appeared in areas (1192-1159) cm^{-1}, and as shown in table (2), these bundles were close to what is found in the literature [28].

Table (3): Results of the ultraviolet (nm) and infrared spectra of azo dyes

Comp. No.	UV,λmax (nm), DMSO	ν (N-H) ν (OH)	νCH alkene νC=C aromatic ν CH aliphatic	νC=N νC=O amide νC=O acid	ν(C=C) olefinic νC=C aromatic δ (C-H) aliphatic	ν(N=N)	ν (C-N) ν (C-O)	δ (C-H) aromatic monosubstituted of plane
DM66	289	3595,3569 3440,3396,3309	3210 3090, 2999	1758 1649	1622 1568, 1409	1568	1271 1188	802
DM67	283	3525 3465	3186,3157 3043,2966,2869	1753 1687	1614, 1583 1483,1456	1515	1282 1251	844,808
DM68	287	3608,3440 3402,3344	3201 3031, 2935	1758 1668	1602,1548,1508 1398,1367	1508	1288 1107	640,707, 748
DM69	236	3593,3531 3448	3253 3043, 2927	1750 1670	1614,1593,1521 1448,1406,1380	1521	1282 1224	748
DM74	288	3577 3446,3404	3253,3164,3128 3088,2970,2933	1753 1660	1616,1570,1537 1398,1321	1537	1253 1197	684,738

When performing the nuclear magnetic resonance analysis of the compound [DM66], shown in Figure (84), we notice two bands at (12.3) ppm belong to the proton of the hydroxyl group. We see two rounds at (8.6-8.4) ppm belongs to the protons of the (NH) group, and we note the protons of the benzene ring appeared as two overlapping beams in the range (7.5-7.4) ppm , as well as the emergence of protons of alkyl groups in the position of (3.6-3.4) ppm , and a signal appeared at (2.2-1.5) ppm belonging to the protons of the solvent (DMSO- d_6).

When studying the ^{1}H-NMR spectrum of carbon for the compound [DM66] shown in Figure (4), it was observed that signals appeared at the position (149.52-110) ppm belonging to the aromatic ring carbons, as well as the appearance of a signal at the site (70.42) ppm attributed to the (CH, aliphatic) group carbon, and the appearance of a signal at the site (62.68) ppm attributed to the group carbon. (CH_2), and the formation of signals at the range 39.98-38.27) ppm attributed to the solvent carbonate (DMSO.d^6) [29].

The mass spectrum of the compound [DM66] showed a peak at m/z=443.1 [$C_{17}H_{11}N_6O_5S_2$], and a second peak at m/z=410.4 [$C_{17}H_{10}N_6O_5S$] A third peak appears m/z = 388.1 [$C_{16}H_{15}N_6O_4S$], the fourth peak appears [$C_{16}H_{15}N_6O_3S$] m/z=371.0 the fourth is overlapping with the peak m/z=367.9, a fifth peak appeared m/z=343.6 [$C_{15}H_{13}N_5O_3S_2$], a sixth peak appeared m/z=324.2 overlapping with m/z=330.1 [$C_{14}H_{12}N_5O_3S$], the seventh peak appeared at m/z=303.1 [$C_{13}H_{13}N_5O_2S$], and the eighth peak appeared at m/z=288.9 [$C_{12}H_{10}N_5O_2S$] Also, the ninth peak m/z=263.0 appeared to overlap with the peak m/z=260.0 [$C_{12}H_{12}N_4OS$], and the tenth peak m/z=236.1 appeared to overlap with the peak m/z=230.0 [$C_{11}H_{10}N_4S$], the eleventh peak appeared at m/z=216.9 [$C_{11}H_{10}N_3S$], and the eleventh peak appeared at [$C_9H_7N_3S$] m/z=189.8, Also, the thirteenth peak m/z=169.9 [$C_7H_{11}N_3S$] appeared, which is the peak of the baseline, and the fourteenth peak m/z=148.8 overlapped with the peak m/z=144.0 [$C_7H_{10}N_2S$], the 15th peak m/z=125.0 appeared overlapping with the peak m/z=129.0 [$C_5H_9N_2S$], and the 16th peak appeared at m/z=103.9 [$C_3H_7N_2S$] the seventeenth peak appeared at [CH_4N_2S] m/z=76.0, and the last peak m/z=55.0 appeared overlapping with the peak m/z=63.0. [CH_5NS] And that the top of the base line proves the validity of the compound, while the rest of the peaks prove the structural shape of the compound [30].

3.2. SEM analysis of the scanning electron microscope:

The effect of laser bombardment by scanning electron microscopy for the two compounds [DM66]. It shows the SEM images of the compound [DM66] at 10µm. We notice the effect of laser bombardment. The surface appears in the form of floating salty rocks interspersed with trenches with deep cavities and voids between

them. At a distance of 1 µm, we notice the effect of laser bombardment. The surface appears in the form of hardened salt rocks interspersed with deep trenches with deep cavities and voids between them. At a distance of (500 µm), we notice the effect of the laser bombardment. The surface appears in the form of a mountain range of varying heights, punctuated by deep trenches and the absence of spaces between them. At a distance of (200 nm), we noticed the effect of the laser bombardment, and the surface appeared as large clouds interspersed with cavities, and the phenomenon of nanoparticles became clear [31,33].

3.3. Dyeing operations:

One of the essential applications of dyes is their use as dyes with better specifications than the specifications of ordinary dyes. The dye is the colored substance that can give its color to another sense, provided that it meets several conditions, namely, that it has a particular ability to the body to be dyed, to be Intense color and stable qualities against the influence of chemical and natural factors such as fastness to light and washing. Azo dyes [DM69, DM68] were used in the dyeing process, where an appropriate amount of azo dye was dissolved in a suitable solvent. The resulting solutions were used to dye equal weight pieces of cotton, wool, cloth, and brocade, where iron was used to fix the dye. When washed with water, it showed apparent stability and had good strength against soap and washing powder [34, 35].

3.4. The electrical conductivity

Electrical conductivity is widely used in coordination chemistry to find possible ionic formulas. It occurs in a compound when it is a solution or a solid, and the degree of conductivity is more significant when the number of ions that it releases in the solution is more. At the same time, the degree of conductivity in the complex is low [36,37].

Table (6): Shows the electrical conductivity values of some compounds prepared using the DMSO solvent.

Test	*Conductivity .us/cm*	*C°*
DM66	4.5	**18.4**
DM74	4.2	**18.3**

3.5. Biological activity of some prepared compounds:

The study of the biological activity of the compounds prepared with certain concentrations showed that most of these compounds have antagonistic activity against the types of bacteria studied, compared to the antibiotic Ceftriaxone, Ampicillin (Cefixime, which are a broad-spectrum antibiotic with an antibacterial activity). It has both positive and negative bacterias (22), and it also has a large inhibitory diameter as it gives a high selectivity when studying the sensitivity of bacteria to the prepared compounds, and since this antibiotic is used to treat many infections and diseases such

as urinary tract infections, especially those that occur as a result of Infection with colon bacteria and Staphylococcus aureus bacteria, as well as simple cystitis in females caused by coliform bacteria, and prostatitis caused by colon bacteria in addition to infections of the lower respiratory tract, sinusitis, arthritis and bones. It is also used to treat diarrhea caused by colon bacteria and is also effective in treating typhoid. Therefore, two compounds of the compounds prepared in this research [DM74, DM66] were studied on different types of chromium-positive and negative bacteria, which recorded a global antagonistic activity against the bacteria studied, and compared with the mentioned antibiotics, it is possible to use these compounds As a treatment for the same infections and pathological conditions above, after investigating the biological path of these compounds, their side effects, and the amount of their accumulation in animal tissues. different compounds (0.01,0.001,0.0001,0.00001 mg/ml), where the diameter of the inhibition ranges between (0 mm minimum diameter of inhibition to 40 mm maximum diameter of inhibition measured) and the table below It shows the inhibitory activity of some of the prepared compounds, and the figures show that the value of the inhibition varies according to the compound, and this is due to the low baseline and because of the presence of resonance [38].

Table (7): The inhibitory activity of the two compounds [DM74, DM66] in the growth of a number of positive and negative bacteria (the diameter of inhibition measured in mm)

Test	*Staph aureus*	*Enterococcus faecalis*	*Pseudomonas putida*	*Klebsiella pneumoniae*	*Antibiotic*
DM3 0.0 1	-	10	18	32	S.a 10
A 0.001	-	6	10	20	E.F 28
B 0.0001	-	-	4	12	P.P 18
C 0.00001	-	-	2	0	K 24
DM7 0. 1	8	30	20	40	E.F 8
A 0.01	-	25	10	30	K 16
B 0.001	-	6	4	-	
C 0.0001	-	8	-	-	

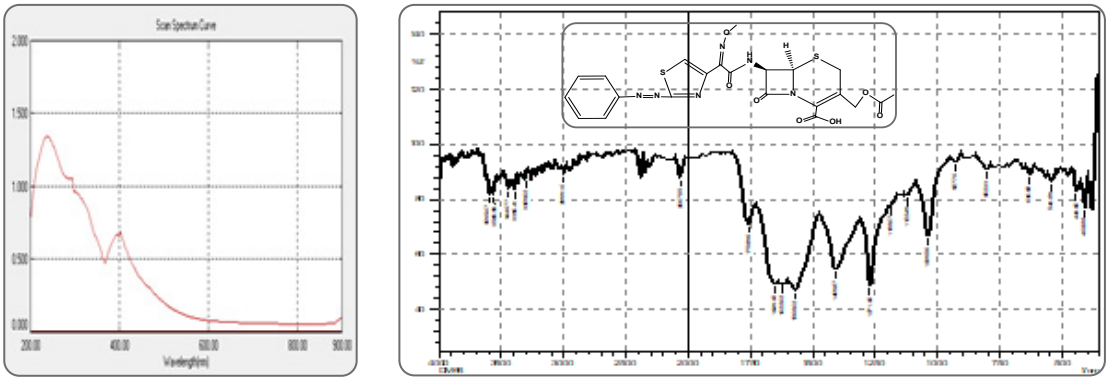


Figure 1: UV and FTIR spectrum of DM66

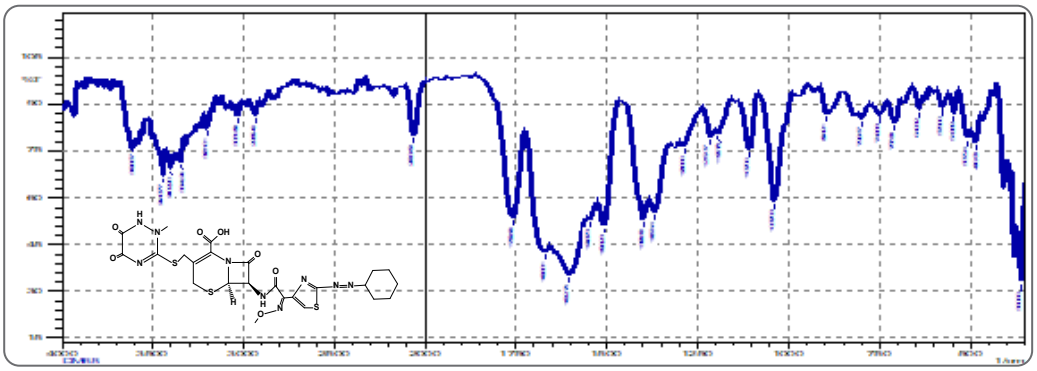


Figure 2: FTIR spectrum of DM68

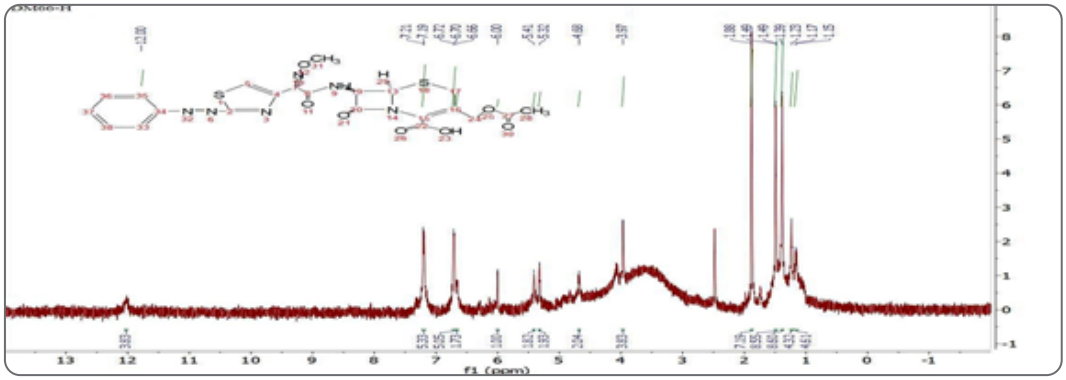


Figure 3: ^{1}H-NMR spectrum of DM66

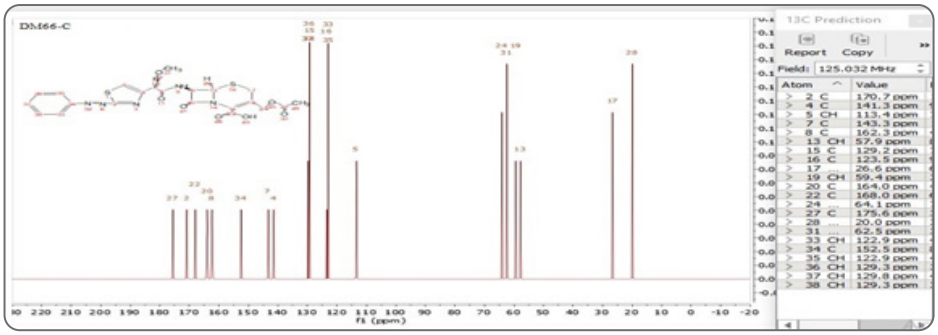


Figure 4: ^{13}C-NMR spectrum of DM66

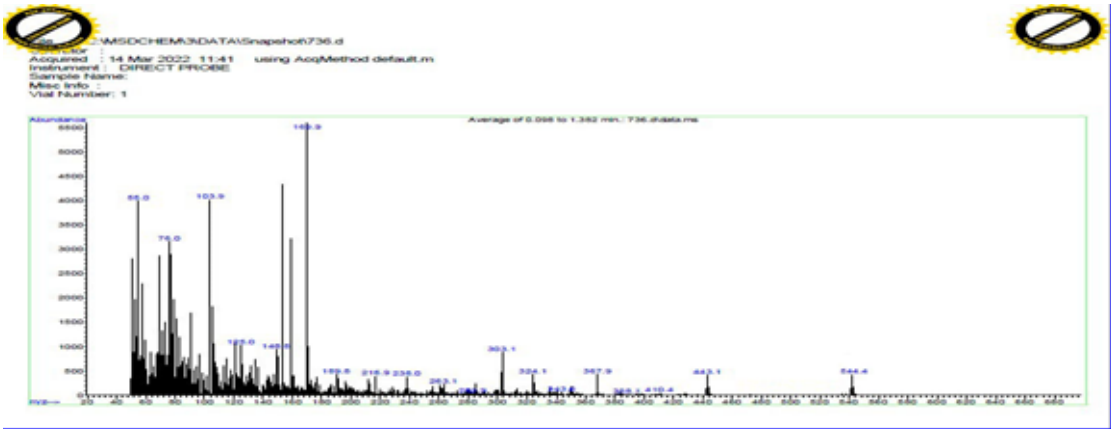


Figure 5: Mass spectrum of DM66

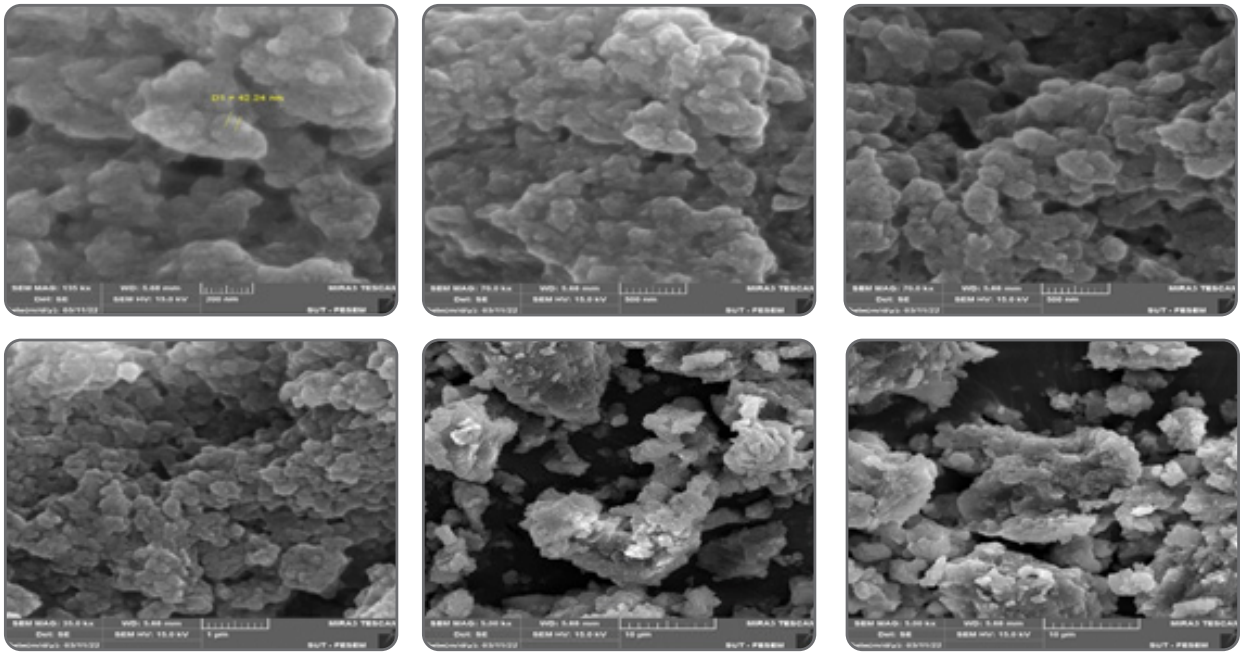


Figure 6: SEM of DM66

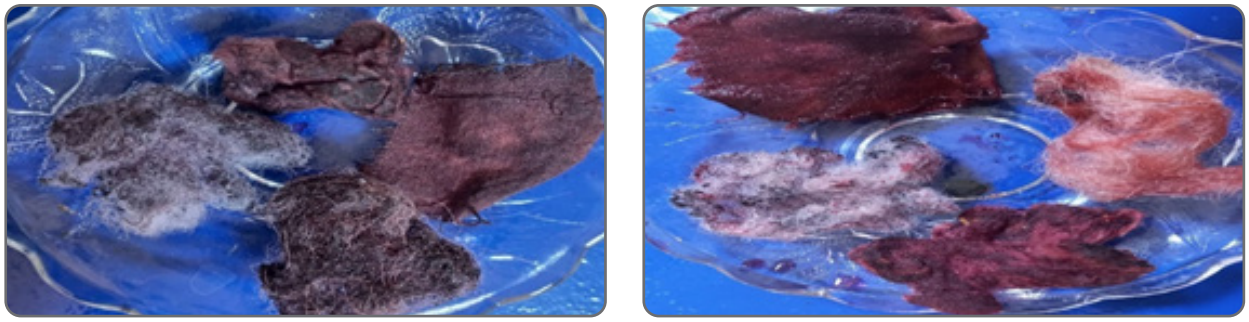


Figure 7: Dyeing process for compound [DM68] before and after washing with water

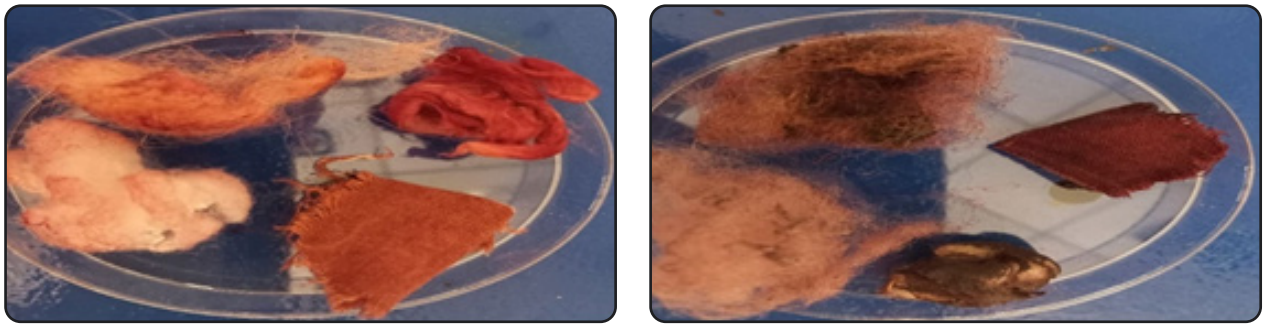


Figure 8: Dyeing process for compound [DM69] before and after washing with water

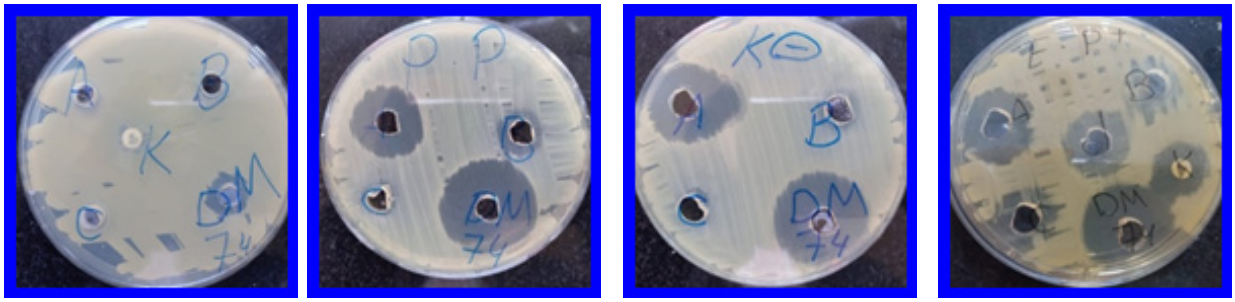


Figure 9: Compound D74 inhibits the growth of all used bacteria

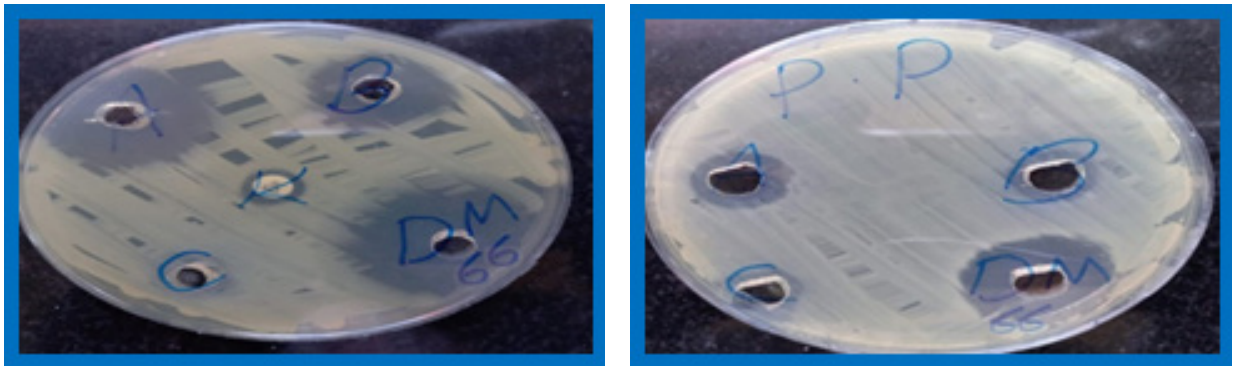


Figure 10: Compound DM66 inhibits the growth of bacteria Pseudomonas putida and Klebsiella pneumoniae

4. Conclusions: Physical and spectroscopic measurements confirmed the accuracy and validity of the prepared compounds. Therefore, the methods used in the preparation were good, successful and low cost. Through SEM analysis, the surface of the prepared compounds appeared as if they were rocky layers interspersed with deep trenches. The values of the precise analysis of the elements for the prepared compounds were identical or close to the calculated percentage. The vehicles were shown to have good electrical conductivity. The prepared compounds also showed good efficacy against

the bacteria used in the study. The prepared azo dyes also showed good industrial stability of their dyes, as it was noticed that the dyes were not removed by washing and maintained their stability.

Reference

Yaneva, Z., Ivanova, D., Nikolova, N., & Toneva, M. (2022). Organic dyes in contemporary medicinal chemistry and biomedicine. I. From the chromophore to the bioimaging/bioassay agent. Biotechnology & Biotechnological Equipment, 36(1), 1-14.

Gordon, P. F., & Gregory, P. (2022). Organic chemistry in colour. In Organic Chemistry in Colour. De Gruyter.

Bafana, A., Khan, F., & Suguna, K. (2021). Purification, characterization, and crystal structure of YhdA-type azoreductase from Bacillus velezensis. Proteins: Structure, Function, and Bioinformatics, 89(5), 483-492.

Bafana, A., Khan, F., & Suguna, K. (2021). Purification, characterization, and crystal structure of YhdA-type azoreductase from Bacillus velezensis. Proteins: Structure, Function, and Bioinformatics, 89(5), 483-492.

Alsantali, R. I., Raja, Q. A., Alzahrani, A. Y., Sadiq, A., Naeem, N., Mughal, E. U., ... & Ahmed, S. A. (2022). Miscellaneous azo dyes: a comprehensive review on recent advancements in biological and industrial applications. Dyes and Pigments, 199, 110050.

Benkhaya, S., M'rabet, S., & El Harfi, A. (2020). A review on classifications, recent synthesis and applications of textile dyes. Inorganic Chemistry Communications, 115, 107891.

Chaudhary, B., & Violet, T. E. (2020). Chemistry of synthetic dyes: a review. J. Interdiscipl. Cycle Res, 12(390), 390-396.

Prajongtat, P., Suramitr, S., Nokbin, S., Nakajima, K., Mitsuke, K., & Hannongbua, S. (2017). Density functional theory study of adsorption geometries and electronic structures of azo-dye-based molecules on anatase TiO2 surface for dye-sensitized solar cell applications. Journal of Molecular Graphics and Modelling, 76, 551-561.

Ince, N. H., & Tezcanli-Güyer, G. (2004). Impacts of pH and molecular structure on ultrasonic degradation of azo dyes. Ultrasonics, 42(1-9), 591-596.

Gürses, A., Açıkyıldız, M., Güneş, K., & Gürses, M. S. (2016). Dyes and pigments: their structure and properties. In Dyes and Pigments (pp. ١٣-٢٩). Springer, Cham.

Serchenya, T. S., Harbachova, I. V., & Sviridov, O. V. (2022). Direct Conjugation of Penicillins and Cephalosporins with Proteins for Receptor Assays of Beta-Lactam Antibiotics. Russian Journal of Bioorganic Chemistry, 48(1), 85-95.

Akhtar, A., Fatima, N., & Khan, H. M. (2022). Beta-Lactamases and Their Classification: An Overview. Beta-Lactam Resistance in Gram-Negative Bacteria, 25-33.

Al-Kaffas, M. (2022). Assessment of in vitro Activities of Ceftaroline, Ceftazidime/avibactam and Colistin against different Gram Negative and Gram Positive Isolates. Egyptian Journal of Medical Microbiology, 31(1), 55-62.

Zhanel, G. G., Pozdirca, M., Golden, A. R., Lawrence, C. K., Zelenitsky, S., Berry, L.,

... & Karlowsky, J. A. (2022). Sulopenem: An Intravenous and Oral Penem for the Treatment of Urinary Tract Infections Due to Multidrug-Resistant Bacteria. Drugs, 1-25.

Beatriz, A., Mondino, M. G., & de Lima, D. P. (2022). Lactams, Azetidines, Penicillins, and Cephalosporins: An Overview on the Synthesis and Their Antibacterial Activity. N-Heterocycles, 97-142.

Kaye, K. S., & Belley, A. (2022). Third-generation cephalosporin-resistant Enterobacterales are critical priority pathogens, too!. Antimicrobial Agents and Chemotherapy, 66(4), e00213-22.

Humbert, M. V., & Christodoulides, M. (2019). Atypical, yet not infrequent, infections with Neisseria species. Pathogens, 9(1), 10.

Li, X., Jia, P., Zhu, Y., Xu, Y., Yu, Y., Lv, Y., ... & Yang, Q. (2021). Establishment of epidemiological cut-off values for cefoselis, a new fourth-generation cephalosporin, against Escherichia coli, Klebsiella pneumoniae, Enterobacter cloacae, Proteus mirabilis and Pseudomonas aeruginosa. Journal of Antimicrobial Chemotherapy, 76(10), 2593-2599.

Lin, X., Lambertz, J., Dahlmann, T. A., Nowaczyk, M. M., König, B., & Kück, U. (2022). A Straightforward Approach to Synthesize 7-Aminocephalosporanic Acid In Vivo in the Cephalosporin C Producer Acremonium chrysogenum. Journal of Fungi, 8(5), 450.

Chaudhry, S. B., Veve, M. P., & Wagner, J. L. (2019). Cephalosporins: a focus on side chains and β-lactam cross-reactivity. Pharmacy, 7(3), 103.

Paterson, D. L., Isler, B., & Harris, P. N. (2021). PRO: Carbapenems should be used for ALL infections caused by ceftriaxone-resistant Enterobacterales. JAC-Antimicrobial Resistance, 3(1), dlab013.

Nel, H., Davis, B., Adler, B., & Gabbay, E. (2021). Case report of osteolytic lesions in a patient with multisystem granulomatous disease. BMJ Case Reports CP, 14(6), e242685.

Jabar, S. A., Hussein, A. L., Dalaf, A. H., & Aboud, H. S. (2020). Synthesis and Characterization of Azetidine and Oxazepine Compounds Using Ethyl-4-((4-Bromo Benzylidene) Amino) Benzoate as Precursor and Evalution of Their Biological Activity. Journal of Education and Scientific Studies, 5(16).

Dalaf, A. H. (2018). Synthesis and Characterization of Some Quartet and Quinary Hetero cyclic Rings Compounds by Traditional Method and Microwave Routes Method and Evaluation of Their Biological Activity. M.Sc. Thesis, Tikrit University, Tikrit, Iraq: 1-94 pp.

Dalaf, A. H., & Jumaa, F. H. (2018). Synthesis, Characterization of some 1,3-Oxazepane-4,7-Dione by Traditional and Microwave routes method and evaluation of their biological activity. Al-utroha for Pure Science. (8): 93-108.

Dalaf, A. H., Jumaa, F. H., & Jabbar, S. A. S. (2018). Synthesis and Characterization of some 2, 3-dihydroquinozoline and evaluation of their biological activity. Tikrit Journal of Pure Science, 23(8): 66-67.

Salwa, A. J., Ali, L. H., Adil, H. D., Hossam, S. A. (2020). Synthesis and Characterization of Azetidine and Oxazepine

Compounds Using Ethyl-4-((4-Bromo Benzylidene) Amino) Benzoate as Precursor and Evalution of Their Biological Activity. Journal of Education and Scientific Studies, ISSN: 24134732. 16(5): 39-52.

Dalaf, A. H., & Jumaa, F. H. (2020). Synthesis, Identification and Assess the Biological and Laser Efficacy of New Compounds of Azetidine Derived from Benzidine. Muthanna Journal of Pure Science (MJPS), 7(2):12-25.

Saleh, R. H., Rashid, W. M., Dalaf, A. H., Al-Badrany, K. A., & Mohammed, O. A. (2020). Synthesis of Some New Thiazolidinone Compounds Derived from Schiff Bases Compounds and Evaluation of Their Laser and Biological Efficacy. Ann Trop & Public Health, 23(7): 1012-1031.

Yass, I. A., Aftan, M. M., Dalaf, A. H., & Jumaa, F. H. (Nov. 2020). Synthesis and Identification of New Derivatives of Bis-1,3-Oxazepene and 1,3-Diazepine and Assess the Biological and Laser Efficacy for Them. The Second International & The Fourth Scientific Conference of College of Science – Tikrit University. (P4): 77-87.

Salih, B. D., Dalaf, A. H., Alheety, M. A., Rashed, W. M., & Abdullah, I. Q. (2021). Biological activity and laser efficacy of new Co (II), Ni (II), Cu (II), Mn (II) and Zn (II) complexes with phthalic anhydride. Materials Today: Proceedings, 43, 869-874.

Aftan, M. M., Jabbar, M. Q., Dalaf, A. H., & Salih, H. K. (2021). Application of biological activity of oxazepine and 2-azetidinone compounds and study of their liquid crystalline behavior. Materials Today: Proceedings, 43, 2040-2050.

Aftan, M. M., Talloh, A. A., Dalaf, A. H., & Salih, H. K. (2021). Impact para position on rho value and rate constant and study of liquid crystalline behavior of azo compounds. Materials Today: Proceedings.

Aftan, M. M., Toma, M. A., Dalaf, A. H., Abdullah, E. Q., & Salih, H. K. (2021). Synthesis and Characterization of New Azo Dyes Based on Thiazole and Assess the Biological and Laser Efficacy for Them and Study their Dyeing Application. Egyptian Journal of Chemistry, 64(6), 2903-2911.

Khalaf, S. D., Ahmed, N. A. A. S., & Dalaf, A. H. (2021). Synthesis, characterization and biological evaluation (antifungal and antibacterial) of new derivatives of indole, benzotriazole and thioacetyl chloride. Materials Today: Proceedings. 6201-6210 ,(17)47.

Dalaf, A. H., Jumaa, F. H., & Salih, H. K. (2021). Preparation, Characterization, Biological Evaluation and Assess Laser Efficacy for New Derivatives of Imidazolidin-4-one. International Research Journal of Multidisciplinary Technovation, 3(4), 41-51.

Dalaf, A. H., Jumaa, F. H., & Salih, H. K. (2021). MULTIDISCIPLINARY TECHNOVATION. Red, 15(A2), C44H36N10O8.

Dalaf, A. H., Jumaa, F. H., Aftana, M. M., Salih, H. K., & Abd, I. Q. (2022). Synthesis, Characterization, Biological Evaluation, and Assessment Laser Efficacy for New Derivatives of Tetrazole. In Key Engineering Materials (Vol. ٩١١, pp. ٣٣-٣٩). Trans Tech Publications Ltd.