



Antibiofilm and Antibacterial Activities of Garlic Extract Against Clinical Isolates of *Pseudomonas Aeruginosa*

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Abstract

Garlic is effective to antibiotic resistant microbes, in garlic there are many natural elements and chemicals, including many enzymes and amino acids. Also the among garlic's highest vital biologically substances is Allicin. Even though allicin is considered the prime antioxidant compound. The antibacterial activity of garlic has been fundamentally attributed to the entity of allicin generated by the enzymatic activity of allinase on allicin. Forty samples of *Pseudomonas aeruginosa* were isolated from burn where all isolates are identified and cultured on nutrient agar medium, MacConkey agar and Cetrimide agar, and diagnosed by microscopic examination, biochemical tests, and the VITEK2 device. Then antibiotic susceptibility testing was completed and biofilm formation for twenty isolate of *pseudomonas aeruginosa* after that tested three concentration of garlic extract (1, 2, 5 mg/ml) as antibiofilm and antibacterial. The results findings showed a reduction in biofilm formation compared to the control group, confirmed by LSD values at a significance level of $P \leq 0.05$ —thereby demonstrating that the reduction in biofilm formation resulted from the effect of the garlic extract. Furthermore, demonstrated antibacterial activity, with efficacy varying according to the extract concentration; higher concentrations proved more effective at inhibiting bacterial growth.

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Keywords: Antibiofilm, Antibacterial, Garlic Extract, *Pseudomonas aeruginosa*

1. Introduction

Plant derived antimicrobials have extremely large therapeutic effects. They are considered as an efficient tool in treating infectious diseases though reducing the complications that connected with synthetic antimicrobials (Saranraj & Sivasakthi, 2014) [23]. The changed pharmacological properties of plant products are generally the result of secondary product combinations resulting from plants. Such plant compounds are often secondary metabolites such as steroids, alkaloids, and fatty acid secretions that have a certain functional influence on the body (Shang *et al.*, 2019 and Josling, 2005) [24, 13]. There are many chemicals and natural elements are found in garlic, in addition to numerous enzymes, sulfur compounds, different vitamins, minerals, and amino acids. Allicin is among garlic's greatest crucial biologically dynamic substances where contain the main antioxidant composite, polar compounds of phenolic and steroidal origin. It is displayed diverse pharmacological countenance without odor and are heat stable (Mohammed *et al.*, 2021) [18]. The antibacterial activity of garlic has been basically attributed to the entity of allicin generated by the enzymatic activity of allinase on allicin (Alam *et al.*, 2018) [1].

Garlic is also effective to antibiotic resistant microbes, and combining garlic extracts with antimicrobial agents results in partial and total synergism (Yadav *et al.*, 2015) [26]. *Pseudomonas aeruginosa* is gram negative, rod shape, a aerobic or facultative anaerobic and monoflagellated bacteria. *P. aeruginosa* is a very invasive microbe that has been discovered in environments, animals, plants, people, and hospital (International Journal of Health & Medical Research, 2025). Furthermore, *P. aeruginosa* is considered as a globally foodborne pathogens due to its great metabolic adaptability, (Fabre *et al.*, 2019) [10] quick reproducibility, and capability to grow at lower temperature. *P. aeruginosa* is capable to cause disease include keratitis, otitis, burn, wound, and

endocarditis, urinary tract infections (Montero *et al.*, 2020 and Hilliam *et al.*, 2020) [19, 11]. The increasing multidrug resistance of *P. aeruginosa* characterizes a main risk to community health and wellbeing. Alteration enzymes can change antibiotics and render them ineffective. For example, this bacterium produces aminoglycoside-modifying enzymes, also carbapenem antibiotics *P. aeruginosa* resistance it by carbapenemases that can break down (Anju *et al.*, 2021) [4]. These genes are often located on mobile genetic elements such as plasmids, transposons. Biofilms are assembly of bacterial cells, a single or mixed species enclosed in a polysaccharide matrix secreted by the bacteria (Rajput & Kumar, 2018) [22] leading to the production and specific secretion of exopolysaccharides, DNA, and protein by the bacterium itself (Anju *et al.*, 2021) [4]. The extracellular polysaccharide matrix EPS matrix provides protection to biofilm cells from several negative environmental stresses, like UV radiation, sudden changes in pH values (Zhou *et al.*, 2013 and Dubois-Brissonnet *et al.*, 2016)) [28, 8]. Biofilm formation is the source of a major problem for the host, as these biofilms are often resistant to antibiotics, phagocytosis, and surfactants, making them difficult to remove once established (Olivares *et al.*, 2019) [20]. Biofilm formation is the source of a major problem for the host, as these biofilms are often resistant to antibiotics, phagocytosis, and surfactants, making them difficult to remove once established (de Sousa *et al.*, 2023). The biofilm formation process in *P. aeruginosa* is regulated by a number of genetic and environmental factors. One of the key systems involved in biofilm formation is the quorum sensing system. Based on cell density, this system is allowed bacteria to communicate with one another and coordinate their behavior, including acyl-homoserine lactones (AHLs) and 2-heptyl-3-hydroxy-4-quinolone (PQS). Another important factor in biofilm formation is production of extracellular polymeric substances (EPS), which are secreted by the bacteria and form a matrix helps them to anchor to surfaces and protect from environmental stresses (de Sousa *et al.*, 2023). This study is aimed to evaluate the antibacterial activity of garlic extract against *P. aeruginosa* and examine its effect on biofilm formation.

2. Methodology

2.1. Collection Bacteria Isolation

Forty samples of *Pseudomonas aeruginosa* were isolated from burn where all isolates are identified and cultured on nutrient agar medium, MacConkey agar and Cetrimide agar, and diagnosed by microscopic examination, biochemical tests, and the VITEK2 device.

2.2. Antibiotic Susceptibility test

Antibiotic susceptibility testing was completed on twenty of the forty bacterial isolates using the VITEK® 2 Compact system conferring to the manufacturer's instructions, and results were interpreted by depending on Clinical and Laboratory Standards Institute (CLSI) (Yang *et al.*, 2009) [25]. The antibiotics test was included Cefixime (CFM), Erythromycin (E), Chloramphenicol (C), Trimethoprim (TR), Piperacillin (PC), Amikacin (AK).

2.3. Detection Biofilm Formation

The biofilm formation of *P. aeruginosa* was determined by spectrophotometric and using microtiter plate assay (Li *et al.*, 2019 and Borlinghaus *et al.*, 2021) [5]. Bacterial colonies were

inoculated into (10 mL) of Trypticase soy broth supplemented with 1% glucose and incubated at 37°C for 24 h. Following incubation, the bacterial cultures were diluted at a ratio of 1:100 using TSB medium. 200 µL of the dilute bacterial suspension was transferred into individual wells of a sterile 96 well flat bottom. Negative control wells containing only sterile broth were included to verify sterility and exclude non-specific binding. After incubation, the contents of the wells were discarded, and the wells were washed 4 times with phosphate buffered saline to remove non-adherent cells (Lee & Zhang, 2021) [15]. Then, the attached biofilms were fixed with acetation of 2% sodium for 30 min. The fixed biofilms were stained with (0.1%) crystal violet for 30 min. Throughout the deionized water, the walls was washed and the excess stain was removed and finally the plates were allowed to air dry at room temperature. By measuring the optical density (OD) of stained adherent cells, biofilm formation was counted by using a microplate ELISA reader at a wavelength of 600 nm. All assesses were performed in triplicate, and the mean OD value was deliberate for each isolate. Based on the obtained OD values, isolates were categorized as, non-weak, moderate, or strong biofilm producers. Table as described in previous studies (Panda *et al.*, 2016) [21].

Table 1: Classification of biofilm formation by tissue culture plate method

Optical densities values	Adherence	Biofilm formation
> 0.240	Strong	Strong
0.120- 0.240	Moderate	Moderate
< 0.120	Non/weak	Non/weak

2.4. Preparation of crude extracts

Garlic extract was performed by using maceration technique. 100-gram sample of fresh garlic cloves was peeled and ground. Then, it is divided to prepare both aqueous and 70% ethanolic extracts (Borlinghaus *et al.*, 2021) [5]. Whilst aqueous extract is prepared with 100 grams of ground garlic by soaking it in 100 mL of hot distilled water for four hours with continuous stirring. Then the mixture was cool and filtered to remove impurities. consequently, by using a freeze dryer, the water was removed, to obtain the dry extract. For ethanolic extract, 100 grams of ground garlic were soaked in 70% ethanol for five days with room temperature and with daily stirring to ensure extraction efficiency (Mohammed *et al.*, 2021) [18]. Yield percentage for both extracts was calculated by using formula underneath:

$$\text{Yield (\%)} = (\text{Weight of dry extract} \div \text{Initial weight of plant material}) \times 100$$

Finally, these extracts were stored in tightly sealed and sterilized glass vials at 4°C until that is used in subsequent experiments (Fadwa *et al.*, 2021) [9].

2.5. Determination of Minimum Inhibitory Concentration (MIC)

Minimum inhibitory concentration firmed by using broth microdilution method in a 96 well microtiter plate. A serial dilution of substance was prepared in Mueller-Hinton Broth (MHB), where 100 µL of each concentration was added to the wells, then followed with 100 µL of a standardized bacterial suspension ($\approx 1.5 \times 10^8$ CFU/mL). The plates were hatched at 37°C for 24 hours, after that the wells were

checked to see bacterial growth (De Marco *et al.*, 2017)

2.6. Effect Garlic Extract on Biofilm Formation

In vitro, biofilm assay was completed using a 96 well microtiter plate as formerly described with some modification (Al-Fridawy *et al.*, 2020)^[29]. Overnight cultures of *P. aeruginosa* were diluted (1:100) into fifteen mL of Tryptic Soy Broth (TSB) added with 2% sucrose, in presence or in absence of different extracts tested at the concentrations shown below. At 37°C for 24h, cultures were incubated under. After incubation, the biofilm developed in each well was washed twice with 200µL of distilled water and then dried for 45min. In each well, 100µL of 0.4% crystal violet was added for 30–45min. After that, four times the wells were washed with distilled water and directly discolored with 200µL of 95% ethanol, after 45 minutes, 100µL of discolored solution was transferred to a well of a new plate and the crystal violet was measured at 570nm in a microplate reader. The amount of biofilm formed was measured comparison the absorbance values of the compounds treated wells against untreated control wells. Biofilm formation bioassays were performed in triplicates in at least three individual experiments for each concentration (Abdel-Moneim *et al.*, 2021)^[2].

2.7. Antibacterial Testing for Garlic Extract

The paper disc diffusion method was being used to evaluate the antimicrobial property of garlic extracts using MHA. The

dilution factor of Bacterial suspension was done with a sterile physiological solution to 108 CFU/ ml (turbidity = McFarland standard 0.5). After that 100 µl of bacterial suspension moistened frequently on MHA and was permitted to dry for 5 minutes. Then filter paper discs (6 mm in diameter) was sterilized in an oven at 80°C for 30 minutes, and placed on MHA and soaked with 20 µl of a solution of each garlic extract with diluted different serial dilution as (1mg/ml, 2mg/ml, 5mg/ml,) respectively, next suspended by methanol for 70% ethanolic extract and the same concentration used after resuspended by sterile distilled water for aqueous extract. Then inoculated plates were incubated at 37°C for 24h (IBM Corp., 2019)^[12].

2.8. Statistical analysis

The Statistical Packages of Social Sciences -SPSS (2019) program was used to detect the effect of difference groups parameters. Least significant difference (LSD) was used to significant compare between means in this study (Khadim & Al Marjani, 2019)^[14].

3. Result and Discussion

3.1. Collection Bacteria Isolation

Pseudomonas aeruginosa isolates were diagnosed based on microscopic characteristics and biochemical tests and their growth on Cetrimide agar, MacConkey agar and nutrient agar medium. The diagnosis was also confirmed by using VITEC device, as shown in figure 1:

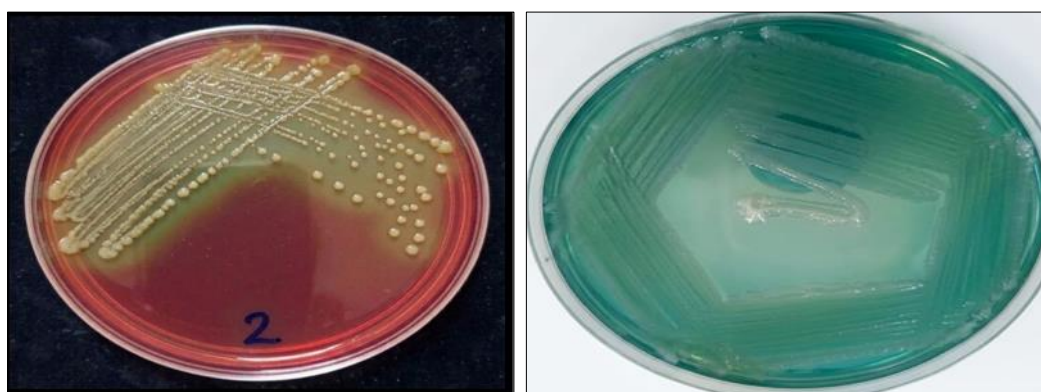


Fig 1: *Pseudomonas aeruginosa* on Cetrimide agar

3.2. Antimicrobial Susceptibility Test

In this study, a total of forty *P. aeruginosa* clinical isolates collected from burn samples. Seven types of antibiotic were

tested against twenty bacterial isolates, as shown in table 2 and figure 2

Table 2: Antimicrobial susceptibility testing in clinical isolates of *Pseudomonas aeruginosa*

Antibiotics	NO. of isolate Resistance (%)	NO. of isolate Intermediate (%)	NO. of isolate Sensitive
Cefixime(CFM)	13(65%)	7(35%)	0(0%)
Erythromycin (E)	20(100%)	0(0%)	0(0%)
Chloramphenicol(C)	17(85%)	3(15%)	0(0%)
Trimethoprim (TR)	20(100%)	0(0%)	0(0%)
Piperacillin (PC)	19(95%)	1(5%)	0(0%)
Amikacin (AK)	0(0%)	10(50%)	10(50%)
Ciprofloxacin (CTR)	14(70%)	6(30%)	0(0%)

All isolates were revealed resistance to Erythromycin and Trimethoprim. 70% of isolates are resisted ciprofloxacin, these results are align with those obtained by Mansouri *et al.*, (2013)^[17] which explain that 55.55% of isolated *P. aeruginosa* were resisted to ciprofloxacin and 87.3 % for

cefotaxime where the isolates of *P. aeruginosa* are taken from different infection sites. This high multi resistance due to the production of hydrolytic enzymes and the acquisition of resistance mechanisms by *P. aeruginosa* strains. In the current study, isolates exhibited resistances for β -lactams in a varied

levels especially for the third-generation cephalosporin, but at the same time several isolates were ESBLs producers. Clinically, antibiotics-resistant bacteria are responsible for

the increased length of hospitalization and mortality (Zhang *et al.*, 2024) ^[27].

bioMérieux Customer:		Microbiology Chart Report		Printed May 14, 2026 12:43:19 AM CST	
Patient Name: J				Patient ID: 202 22 2 7	
Location:				Physician:	
Lab ID: 202 22 2 7				Isolate Number: 1	
Organism Quantity:					
Selected Organism : <i>Pseudomonas aeruginosa</i>					
Source:				Collected:	
Comments:					
Susceptibility Information Analysis Time: 18.02 hours Status: Final					
Antimicrobial	MIC	Interpretation	Antimicrobial	MIC	Interpretation
Ampicillin/Sulbactam	<= 2	S	Meropenem	<= 0.25	S
Piperacillin/Tazobactam	<= 4	S	Amikacin	8	S
Cefotaxime	<= 0.25	S	Gentamicin	<= 1	S
Ceftazidime	8	S	Ciprofloxacin	>= 4	R
Ceftazidime/Avibactam			Tigecycline		
Ceftolozane/Tazobactam			Colistin	<= 0.5	S
Cefepime	<= 0.12	S	Trimethoprim/Sulfamethoxazole	>= 320	R
Imipenem	<= 0.5	S			
AES Findings					
Confidence:		Analysis not performed			

Fig 2: Antimicrobial susceptibility testing of *Pseudomonas aeruginosa*

3.2. Biofilm Formation

Twenty isolate were conferring to biofilm analysis. then they were divided into three categories depend on it production for biofilm, which are : 25 % (n=5) formed strong biofilm, 75 % (n=15) produced moderate biofilm, and 0 % (n=0) of isolates

were considered as weak biofilm producers. Isolates from burns had shown a greater ability to form a strong and moderate biofilm compared with the isolates that obtained from other sources, as illustrated in table 3, 4

Table 3: Optical densities values of biofilm formation in *Pseudomonas aeruginosa*

NO.OF Isolates	Optical densities values	Biofilm formation
Ps1	0.339	Strong
Ps 2	0.232	Moderate
Ps 3	0.207	Moderate
Ps 4	0.196	Moderate
Ps 5	0.212	Moderate
Ps 6	0.156	Moderate
Ps 7	0.259	Strong
Ps 8	0.193	Moderate
Ps 9	0.218	Moderate
Ps 10	0.320	Strong
Ps 11	0.176	Moderate
Ps 12	0.352	Strong
Ps 13	0.329	Strong
Ps 14	0.315	Strong
Ps 15	0.299	Strong
Ps 16	0.319	Strong
Ps 17	0.341	Strong
Ps 18	0.287	Strong
Ps 19	0.303	Strong
Ps 20	0.267	Strong

Table 4: Classification of biofilm formation by tissue culture plate method in *P. aeruginosa*

Biofilm formation	NO. of isolate	(Percentage)
Strong	5	(25 %)
Moderate	15	(75%)
None /Weak	0	(0%)
Total	20	(100%)

The results of the current study showed all isolates had ability to form biofilm. Biofilm formation is an important mechanism in resistance of bacteria. Biofilm formation protects bacterial cells from host immune defenses and decreases the penetration and efficacy of antimicrobial agents, thereby contributing to chronic and recurrent infections. The absence of weak or non-biofilm-forming isolates stresses that biofilm production is a preserved characteristic in these isolates and may play a vital role in their pathogenicity and antimicrobial resistance.

3.3. Determination of Minimum Inhibitory Concentration (MIC)

MIC is defined as lowest concentration, which show no visible bacterial growth was recorded as 2mg/mL, while sub-

inhibitory concentration was determined to be 1m g/mL. In subsequent experiments, the minimum bactericidal concentration is determined by taking samples from wells showing no bacterial growth and cultured on Mueller Hinton Agar (MHA) plates, which were then incubated at 37°C for 24 hours. The lowest concentration of crude garlic extract that produced no bacterial growth on the solid medium was recorded as the MBC, with a value of 5 mg/mL.

3.4. Effect of Garlic Extract on Biofilm Formation

The results show that garlic extract caused a significant decrease ($P \leq 0.05$) in biofilm formation across all clinical isolates (Ps1, Ps10, Ps12, Ps13, and Ps14) of *P. aeruginosa*, as illustrated in table 5 and figure 3:

Table 5: Biofilm formation before and after treatment with garlic extract in difference isolates of pseudomonas aeruginosa

No. of Isolates	Biofilm formation before treatment with garlic extract	Biofilm formation after treatment with garlic extract			L.S.D.
		Sub-MIC =1mg/ml	MIC=2mg/ml	MBC=5mg/ml	
1	0.339 ±0.04 a	0.236 ±0.03 ab	0.137 ±0.03 bc	0.078 ±0.01 c	0.118 *
10	0.320 ±0.03 a	0.272 ±0.03 ab	0.195 ±0.04 bc	0.095 ±0.02 c	0.107 *
12	0.352 ±0.04 a	0.266 ±0.05 ab	0.168 ±0.03 b	0.092 ±0.02 b	0.156 *
13	0.329 ±0.04 a	0.244 ±0.03 ab	0.159 ±0.03 bc	0.079 ±0.01 c	0.115 *
14	0.315 ±0.02 a	0.239 ±0.03 ab	0.133 ±0.02 bc	0.072 ±0.01 c	0.106 *

Means having with the different letters in same row differed significantly. * ($P \leq 0.05$).

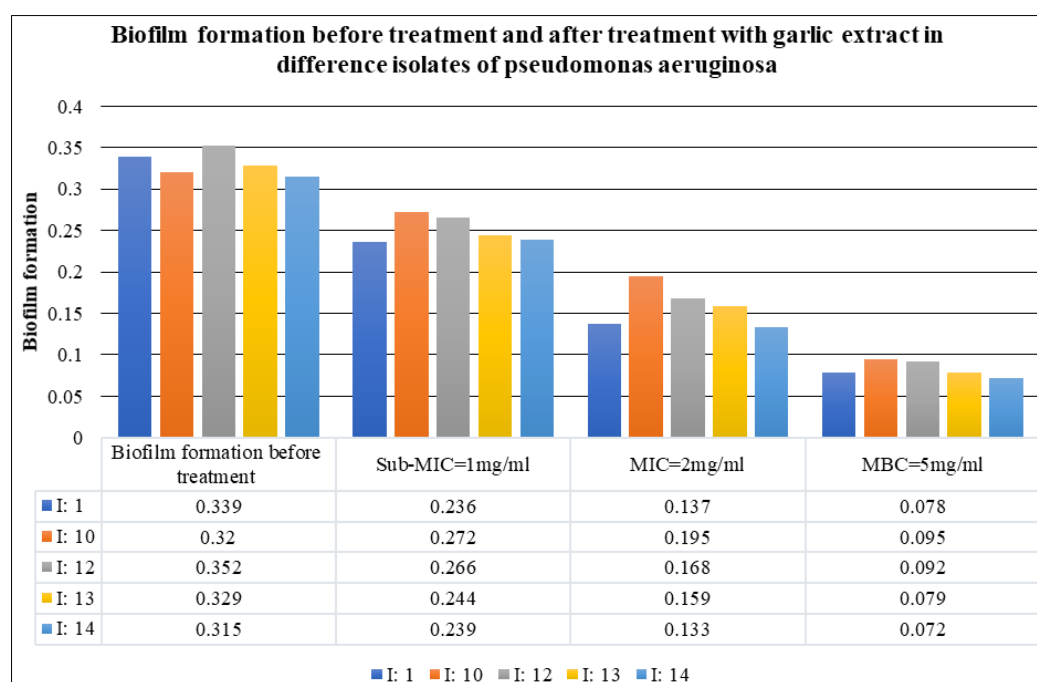


Fig 3: Biofilm formation before and after treatment with garlic extract in difference isolates of pseudomonas aeruginosa

Before treatment, biofilm formation values were high and it was 0.315–0.352. Then they decreased in a concentration dependent. Specifically, values dropped gradually from the initial range of 0.315–0.352 to 0.236–0.272 at the sub-MIC concentration of 1 (mg/ml), then to 0.133–0.195 at the MIC 2 (mg/ml), reaching a minimum of 0.072–0.095 at the MBC 5 (mg/ml). This progressive decline indicates that the efficacy of the garlic extract increases with concentration, demonstrating a clear inhibitory effect on biofilm formation. These results are dealt with the findings of Alvi *et al.*, (2021) [3] which demonstrated that sulfur compounds which derived from garlic such as diallyl disulfide act as inhibitors of the quorum sensing system in *P. aeruginosa*. This inhibition is

reduced biofilm formation and attenuation of bacterial virulence factors. which leads to inhibit the cell communication system and diminishes the bacteria's ability to adhere and produce extracellular polymeric substances (EPS) that is required for biofilm maturation, thereby explaining the markable decreasing in optical absorbance values which observed in the present study.

These findings also support recent studies that are indicating: compounds such as allicin and its sulfur derivatives that that derived from garlic are considered as inhibit the expression of genes regulating the quorum sensing system. This leads to a dose-dependent reduction in the production of virulence factors and biofilm formation, consistent with the progressive

decline observed in this study when transitioning from sub-MIC to MIC and subsequently to MBC levels.

3.5. Antibacterial effects of garlic extract

The antibacterial activity of garlic extract for three isolates of

bacteria *P. aeruginosa* has been tested by using the agar well diffusion (34). At different concentration (1, 2 and 5 mg /ml) of garlic extract, as indicated by the formation of inhibition zones, as shown in table (6) and figure (4):

Table 6: Antibacterial activity of garlic extract against *Pseudomonas aeruginosa* at different concentrations

No. of isolates	MIC=1 mg /ml	Sub-MIC=2 mg /ml	MBC=5 mg /ml
Ps1	9mm	12mm	15mm
Ps2	9mm	11mm	13mm
Ps3	8mm	10mm	9mm

At 1 mg/mL, the inhibition zones ranged from 8 to 9 mm, whereas increasing the concentration to 2 mg/mL resulted in inhibition zones ranging from 10 to 12 mm. At 5 mg/mL, the inhibition zones were 9–15 mm, with the largest inhibition zone observed against isolate Ps1 (15 mm), followed by Ps2

(13 mm) and Ps3 (9 mm). Overall, the inhibitory effect was more pronounced at the higher concentrations, although the response varied among the isolates. Isolate Ps1 showed the greatest susceptibility to the garlic extract, while Ps3 exhibited the lowest response at 5 mg/mL.

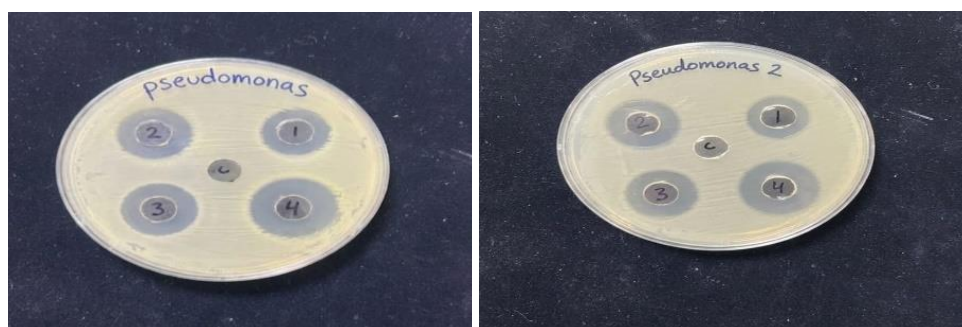


Fig 5: Antibacterial Effects of Garlic Extract

4. Conclusion

This study is determined the ability of *P. aeruginosa* isolates for biofilm formation and pyocyanin production where biofilm formation is associated with the increased resistance to the antibiotic and bacterial colonization within burning infections. The isolates have high levels of biofilm specific resistance despite its moderate or weak biofilms production which means that biofilm formation and pyocyanin could increase the toxicity and pathogenicity of this bacterium. The results is indicated that garlic extract inhibited biofilm formation by *P. aeruginosa* in a dose-dependent manner; mean optical density (OD) values decreased progressively as the extract concentration increased from Sub-MIC to MIC and then to MBC.

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References

1. Alam R, Fawzi EM, Alkhalf MI, Alansari WS, Aleya L, Abdel-Daim MM. Anti-inflammatory, immunomodulatory, and antioxidant activities of allicin, norfloxacin, or their combination against *Pasteurella multocida* infection in male New Zealand rabbits. *Oxid Med Cell Longev*. 2018;2018:1780956. doi:10.1155/2018/1780956.
2. Abdel-Moneim AME, Shehata AM, Alzahrani SO, Shafi ME, Mesalam NM, Taha AE, *et al*. The role of garlic (*Allium sativum*) and its bioactive compounds in improving health and performance: a review. *Animals*. 2021;11(5):1358. doi:10.3390/ani11051358.
3. Alvi GB, Iqbal MS, Ghaith MMS, Haseeb A, Ahmed B, Qadir MI. Biogenic selenium nanoparticles (SeNPs) from citrus fruit have antibacterial activities. *Sci Rep*. 2021;11(1):1-11.
4. Anju VT, Busi S, Ranganathan S, Ampasala DR, Kumar S, Suchiang K, *et al*. Sesamin and sesamol rescues *Caenorhabditis elegans* from *Pseudomonas aeruginosa* infection through the attenuation of quorum sensing regulated virulence factors. *Microb Pathog*. 2021;155:104912. doi:10.1016/j.micpath.2021.104912.
5. Borlinghaus J, Albrecht F, Gruhlke MCH, Nwachukwu ID, Slusarenko AJ. Antibacterial properties of garlic compounds. *Front Microbiol*. 2021;11:613077.
6. De Marco S, Piccioni M, Pagiotti R, Pietrella D. Antibiofilm and antioxidant activity of propolis and bud poplar resins versus *Pseudomonas aeruginosa*. *Evid Based Complement Alternat Med*. 2017;2017:5163575. doi:10.1155/2017/5163575.
7. De Sousa T, Hébraud M, Alves O, Costa E, Maltez L, Pereira JE, *et al*. Study of antimicrobial resistance, biofilm formation, and motility of *Pseudomonas aeruginosa* derived from urine samples. *Microorganisms*. 2023;11(5):1345. doi:10.3390/microorganisms11051345.
8. Dubois-Brissonnet F, Trotier E, Briandet R. The biofilm lifestyle involves an increase in bacterial membrane saturated fatty acids. *Front Microbiol*. 2016;7:1673. doi:10.3389/fmicb.2016.01673.
9. Fadwa AO, Albarag AM, Alkoblan DK, Mateen A. Synergistic effects of antibiotics and ZnO nanoparticles

- against bacterial strains. Saudi J Biol Sci. 2021;28(9):5332-5337. doi:10.1016/j.sjbs.2021.05.070.
10. Fabre V, Sharara SL, Salinas AB, Carroll KC, Desai S, Cosgrove SE. Does this patient have a urinary tract infection? A review of the diagnosis and management of urinary tract infections. JAMA. 2019;322(13):1284-1294. doi:10.1001/jama.2019.13069.
 11. Hilliam Y, Moore MP, Lamont IL, Bilton D, Haworth CS. *Pseudomonas aeruginosa* adaptation and diversification in the cystic fibrosis lung. Microbiology (Reading). 2020;166(8):713-727. doi:10.1099/mic.0.000942.
 12. IBM Corp. IBM SPSS Statistics for Windows [computer software]. Version 26. Armonk (NY): IBM Corp; 2019.
 13. Josling PA. The heart of garlic: nature's aid to healing the human body. HEC Publishing; 2005.
 14. Khadim MM, Al Marjani MF. Pyocyanin and biofilm formation in *Pseudomonas aeruginosa* isolated from burn infections in Baghdad, Iraq. Jordan J Biol Sci. 2019;12(1):31-35.
 15. Lee J, Zhang L. Antimicrobial resistance mechanisms in *Pseudomonas aeruginosa*. Front Cell Infect Microbiol. 2021;11:665759. doi:10.3389/fcimb.2021.665759.
 16. Li WR, Ma YK, *et al.* Diallyl disulfide inhibits quorum sensing in *Pseudomonas aeruginosa*. Front Microbiol. 2019;9:3222.
 17. Mansouri S, Safa A, Najar SG, Najar AG. Inhibitory activity of Iranian plant extracts on growth and biofilm formation by *Pseudomonas aeruginosa*. Malays J Microbiol. 2013;9(2):176-183.
 18. Mohammed A, *et al.* In vitro antibacterial activity of crude garlic (*Allium sativum*) extract against clinical isolates of methicillin-resistant *Staphylococcus aureus*. Biomed Pharmacol J. 2021;14(3):1449-1457.
 19. Montero MM, López Montesinos I, Knobel H, Oliver A. *Pseudomonas aeruginosa* urinary tract infections: epidemiology, diagnosis and management. Curr Opin Infect Dis. 2020;33(1):109-116. doi:10.1097/QCO.0000000000000621.
 20. Olivares E, Badel-Berchoux S, Provot C, Prevost G, Bernardi T, Jehl F. Clinical impact of antibiotics for the treatment of *Pseudomonas aeruginosa* biofilm infections. Front Microbiol. 2019;10:2894. doi:10.3389/fmicb.2019.02894.
 21. Panda PS, Chaudhary U, Dube SK. Comparison of four different methods for detection of biofilm formation by uropathogens. Indian J Pathol Microbiol. 2016;59(2):177-179.
 22. Rajput A, Kumar M. Anti-biofilm peptides: a new class of quorum quenchers and their prospective therapeutic applications. In: Kalia VC, editor. Biotechnological applications of quorum sensing inhibitors. Singapore: Springer; 2018. p. 87-110. doi:10.1007/978-981-10-9026-4_5.
 23. Saranraj P, Sivasakthi S. Medicinal plants and its antimicrobial properties: a review. Glob J Pharmacol. 2014;8(3):316-327.
 24. Shang A, Cao SY, Xu XY, Gan RY, Tang GY, Corke H, *et al.* Bioactive compounds and biological functions of garlic (*Allium sativum* L.). Foods. 2019;8(7):246. doi:10.3390/foods8070246.
 25. Yang L, Rybtke MT, Jakobsen TH, *et al.* Computer-aided identification of drugs as quorum-sensing inhibitors. Antimicrob Agents Chemother. 2009;53(6):2432-2443.
 26. Yadav S, Trivedi NA, Bhatt JD. Antimicrobial activity of fresh garlic juice: an in vitro study. AYU. 2015;36(2):203-207. doi:10.4103/0974-8520.175548.
 27. Zhang ZS, He Z, Shi Y, Guan M, Zhao DS, Zhu D, *et al.* Structure-based discovery of symmetric disulfides from garlic extract as *Pseudomonas aeruginosa* quorum sensing inhibitors. J Agric Food Chem. 2024;72(37):20299-20307. doi:10.1021/acs.jafc.4c04404.
 28. Zhou L, Zheng H, Tang Y, Yu W, Gong Q. Eugenol inhibits quorum sensing at sub-inhibitory concentrations. Biotechnol Lett. 2013;35(4):631-637.
 29. Al-Fridawy RAK, Al-Daraghi WAH, Alkhafaji MH. Isolation and identification of multidrug resistance among clinical and environmental *Pseudomonas aeruginosa* isolates. Iraqi J Biotechnol. 2020.

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