

Review Article

Antibiofilm and Quorum-sensing Agents Against *Pseudomonas aeruginosa* and *Staphylococcus aureus*: a Systematic Review of Preclinical Studies, 2022-2026

Sham Ma'aitah^{1*}, Batool AlAmairiyin¹

¹Department of Medical Laboratory Sciences, Faculty of Science, Al-Balqa Applied University, Al-Salt, Jordan.

*Corresponding Author: shamhussam26@gmail.com

HISTORY:

Received: [13/09/2026]
Revised: [24/10/2026]
Published: [31/10/2026]

FUNDING

This research received no external funding.

CONFLICT OF INTEREST

The authors declare no conflict of interest related to the research. Editorial disclosure: Prof. Dr. Haitham Qaralleh, Editor-in-Chief of this journal, has a supervisory relationship with the authors. He was not involved in the editorial handling of this manuscript, the selection of reviewers, or any decision on it. Peer review and the editorial decision were managed independently by another member of the editorial board.

DATA AVAILABILITY

No new primary data were generated. All extracted data, the search strategies and the list of included studies are provided as Supplementary Materials.

ABSTRACT:

Background: Biofilm formation and quorum sensing (QS) make *Pseudomonas aeruginosa* and *Staphylococcus aureus* hard to treat, and many preclinical agents are reported to act against both.

Objective: We mapped preclinical antibiofilm and anti-QS agents against these pathogens and graded how directly each study tested QS.

Methods: PubMed and Scopus were searched without a date limit (3,349 records). Eligible in vitro and in vivo studies were published from 2022 onward, tested an exogenous agent and named either organism in the title. Full-text data were extracted, each study received a QS evidence tier, and risk of bias was appraised with an adapted checklist (in vitro) or SYRCLE's tool (vertebrate studies); two reviewers verified the extraction.

Results: We included 252 studies, led by natural products (115). A QS assay in the target pathogen was present in 140 studies (56%), a surrogate reporter alone in 27 (11%), and 31 (12%) used a vertebrate infection model. In vitro risk of bias was low in 143, moderate in 93 and high in 16. No meta-analysis was done, and title-only organism matching may have missed studies.

Conclusion: Direct QS evidence is common for *P. aeruginosa* but thinner for *S. aureus*, and animal and cytotoxicity data are sparse.

Keywords: Biofilm, Quorum sensing, *Pseudomonas aeruginosa*, *Staphylococcus aureus*, MRSA, Systematic review, Antivirulence

Cite this article as: Ma'aitah, S., AlAmairiyin, B. (2026) Antibiofilm and quorum-sensing agents against *Pseudomonas aeruginosa* and *Staphylococcus aureus*: a systematic review of preclinical studies, 2022-2026. Journal of Basic and Applied Research in Biomedicine, 12(1): 33-50



This work is licensed under a Creative Commons Attribution 4.0 License. You are free to copy, distribute and perform the work. You must attribute the work in the manner specified by the author or licensor.

1. INTRODUCTION

Bacterial biofilms are surface-attached communities embedded in a self-produced matrix, and they tolerate antibiotics and host defences far better than planktonic cells (Flemming *et al.*, 2016). *Pseudomonas aeruginosa* and *Staphylococcus aureus*, including methicillin-resistant *S. aureus* (MRSA), are two of the most important biofilm formers in chronic wounds, cystic fibrosis airways, implanted devices and hospital-acquired infections, and both are on the World Health Organization's priority list of resistant pathogens (WHO Advisory Group, 2025). They are also frequently found together in polymicrobial wound infections (Hotterbeekx *et al.*, 2017).

Quorum sensing (QS) is the cell-density-dependent signalling that coordinates biofilm development and virulence. *P. aeruginosa* uses the Las, Rhl and PQS systems, whereas *S. aureus* relies on the accessory gene regulator (agr) system (Le & Otto, 2015; Lee & Zhang, 2015). QS does not act on biofilm in the same direction in the two organisms: in *S. aureus*, activation of agr drives extracellular proteases and phenol-soluble modulins that can disperse biofilms (Boles & Horswill, 2008). Down-regulating agr lowers the production of agr-regulated toxins but can favour biofilm: agr-negative strains formed biofilm far more often than agr-positive strains, and agr-blocking compounds increased biofilm formation (Vuong *et al.*, 2000). An agr inhibitor would therefore be expected to stabilise, not reduce, an established biofilm. Blocking QS, rather than killing the cell, is a long-standing antivirulence strategy that is expected to exert less selective pressure for resistance (Mühlen & Dersch, 2016).

A large preclinical literature now reports plant extracts, essential oils, nanoparticles, peptides, enzymes, repurposed drugs and

synthetic molecules as antibiofilm or anti-QS agents against these two pathogens. Its quality is uneven. Many papers claim QS inhibition from indirect readouts such as pyocyanin or swarming, concentrations at or above the minimum inhibitory concentration (MIC) confound antibiofilm effects with killing, and docking scores are used as if they were evidence of activity. What a given concentration means also differs between classes (a crude extract is a mixture and a nanoparticle formulation is a delivery system), so the studies cannot be read under one set of pharmacokinetic or pharmacodynamic assumptions. Earlier reviews tend to cover one agent class or one pathogen, and few separate studies that measured QS directly from those that inferred it (Shariati *et al.*, 2024).

We therefore did a systematic review of preclinical studies published from 2022 onward that tested an exogenous antibiofilm or anti-QS agent against *P. aeruginosa* or *S. aureus*/MRSA. Our aims were to (1) describe the agents, models and outcomes, (2) grade each study by how directly it tested QS, and (3) appraise risk of bias in the in vitro and animal evidence.

2. MATERIALS AND METHODS

2.1. Protocol and reporting

The review follows the PRISMA 2020 statement (Page *et al.*, 2021). The databases were last searched in August 2026.

2.2. Eligibility criteria

We included preclinical in vitro and in vivo studies published in English from 2022 onward that tested an exogenous antibiofilm or anti-quorum-sensing agent (natural products, synthetic compounds, nanoparticles, peptides and enzymes, phages, or repurposed drugs) and that named *Pseudomonas aeruginosa* or *Staphylococcus aureus*/MRSA in the title. We required the

organism in the title to keep each study clearly about one of the two organisms. We did not validate this rule against abstracts or indexed keywords; to show its effect, we audited the titles of the records it removed (Section 3.1). We excluded human trials, narrative and systematic reviews, editorials and correction notices, retracted articles, studies of native genes or regulators without an exogenous agent (knockout-only), and purely in silico studies. Because the protocol was not registered, no criteria were fixed in advance in a public record. The restriction to studies published from 2022 onward and naming either organism in the title was decided after the initial search and is therefore a post hoc criterion.

2.3. Information sources and selection

PubMed and Scopus were searched (full strategies in Supplementary Table S1). The PubMed query combined antibiofilm terms, quorum-sensing terms and biofilm terms and excluded clinical trials, randomised controlled trials and records indexed to humans. The Scopus query used the same three concept groups in title, abstract and keywords and excluded clinical-trial terms and the Medicine subject area. Cochrane CENTRAL, which mainly indexes human trials, was also searched at first; its 2 records were not eligible and it was then removed from the review, so they are not counted. Title and abstract screening judged topic only; the restrictions to 2022 onward and to the two target organisms in the title were applied afterwards, when records were assessed for eligibility. The searches had no date limit, which is why records published before 2022 were retrieved and then excluded (Section 3.1). Duplicates were removed across databases before loading (892 records) and within the screening log by DOI, exact-title and fuzzy-title matching (1 record). Records were screened by title and abstract, and the full texts of the remaining records were assessed against the criteria. Records whose full text could not be obtained after searching PubMed Central, Unpaywall and Zotero and attempting retrieval through institutional access were excluded and are counted separately in the flow diagram.

2.4. Data extraction

For each study we extracted the country, study type, agent and class, target pathogen and strain, model system, concentrations, exposure time, biofilm and QS measures and results, in vivo outcomes, cytotoxicity testing and funding. Extraction was done by the authors, and was verified against the full text by two reviewers. Where a paper contradicted itself, we used the value in the Results or the figure and recorded the discrepancy in the workbook.

Each study was assigned one primary agent class, so that the classes are mutually exclusive and sum to the number of included studies. The rule was applied in this order: nanoparticle (including green-synthesised and plant-mediated nanoparticles, and carriers loaded with an antibiotic or plant compound), peptide or enzyme, phage, probiotic or postbiotic, then combination (two or more agents of different classes tested together, or compared, as the study intervention), then repurposed drug, natural product and synthetic or novel compound. The first rule that applied decided the class. Development stage was not used for classification.

2.5. QS evidence tiers

Each study was assigned a QS evidence tier according to what the authors themselves measured. **Direct:** a QS-specific assay in the target pathogen, such as AHL or autoinducer measurement, QS-gene expression, or a *P. aeruginosa* or *S. aureus* reporter strain; AHL degradation counted as Direct only when the pathogen's own AHL or QS read-out was measured, and otherwise as Surrogate reporter. **Surrogate reporter:** the only QS assay was run in a heterologous organism, such as violacein inhibition in *Chromobacterium violaceum* or an *Agrobacterium tumefaciens* AHL biosensor; a study that also had a Direct assay was classed as Direct. **Indirect:** QS-regulated phenotypes only (for example pyocyanin, protease or swarming), or a QS claim without an assay. **In silico only:** docking or simulation with no wet-lab QS data. **Not assessed:** QS was not tested. The

Surrogate reporter tier was added after the first extraction round; 27 studies first coded Direct were moved into it on the basis of the extracted QS fields.

2.6. Risk of bias

In vitro studies were appraised with a nine-item checklist that we built for this review (research question, strain characterisation, controls, standard assay, dose range, statistics, replication, cytotoxicity data, reproducibility). It is not a published or validated instrument and has no validation history; its items follow general preclinical reporting-quality criteria. Each item was scored yes, no or unclear using the operational definitions in Table S3. A study was rated high risk of bias if the control item was scored no or three or more items were scored no, low risk if at least eight items were scored yes, controls were yes and neither statistics nor replication was scored no, and moderate risk otherwise. Vertebrate animal studies (mouse, rat, rabbit or zebrafish) with an infection or efficacy outcome were appraised with SYRCLE's risk-of-bias tool (Hooijmans *et al.*, 2014). SYRCLE was designed for laboratory vertebrates, and items such as random housing do not apply to nematode or insect-larva assays, so studies with invertebrate hosts only (*C. elegans*, *G. mellonella*, *Drosophila*) were not rated with it. Studies that used a vertebrate together with an invertebrate were appraised on the vertebrate component. Toxicity-only animal studies were not appraised. Ratings were not used to exclude studies. The ratings came from a rule-based first pass (Table S3). The scanned was run for the full text for 177 of the 252 in vitro appraisals and for 22 of the 30 SYRCLE appraisals. For the other 75 in vitro appraisals and 8 SYRCLE appraisals, it was run on the extraction row only, before the full texts were retrieved. Their items for statistics, replication and reproducibility were therefore scored unclear (item 5 was scored from the extraction row and item 8 from the coded cytotoxicity flag), and the in vitro studies were rated moderate by the rule. The two reviewers checked all ratings, including these, against the full texts.

2.7. Verification and synthesis

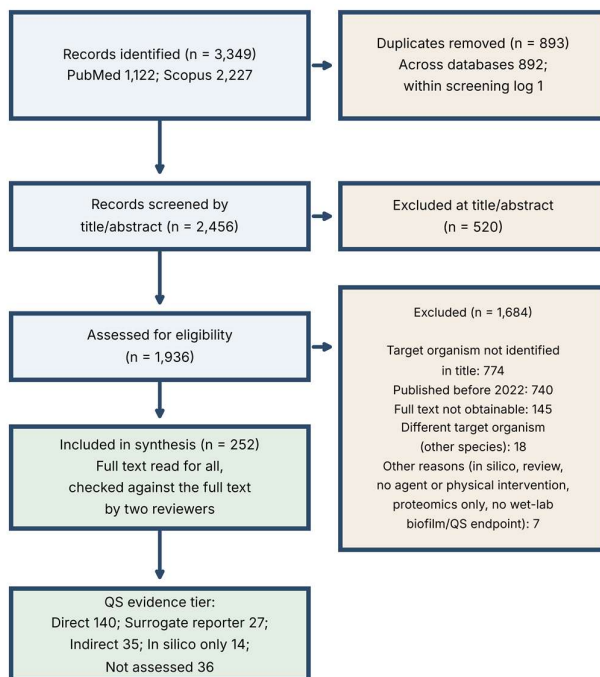
Two reviewers independently checked the extraction, the tiers and the ratings against the full texts, and disagreements were settled by discussion. Because outcomes were reported in different units (percent, fold change, log reduction) and with different designs, no meta-analysis was done; results are summarised descriptively as counts of studies. Docking scores were not compared across studies because the scoring programs differ. We did not model pharmacokinetics or pharmacodynamics, and agents from different classes were not assumed to be comparable at a given concentration; results are therefore described by class. A sensitivity analysis repeated the main summaries for studies with Direct QS evidence.

3. RESULTS

3.1. Study selection

The searches identified 3,349 records. After 893 duplicates were removed, 2,456 records were screened and 520 were excluded on title and abstract. Of 1,936 records assessed for eligibility, 1,684 were excluded: 774 because the target organism was not in the title, 740 because they were published before 2022, 145 because the full text could not be obtained, 18 because the target organism was a different species and 7 for other reasons (including one physical intervention that was not an exogenous agent). Because the searches had no date limit, the pre-2022 records were retrieved and removed at this stage. In total, 252 studies were included (Figure 1). A keyword audit of the 774 titles removed by the organism rule found that about 290 named another organism, 59 used broad terms such as ESKAPE, Gram-negative or drug-resistant bacteria, and the remainder named no organism or one not on our keyword list. Only nine titles contained a target-genus word or abbreviation: five named *S. epidermidis*, three named staphylococci without a species, and one was a peptide name. We did not read the abstracts of the removed records, so the number of eligible studies missed by the title rule is unknown.

PRISMA 2020 flow diagram

**Figure 1.** PRISMA 2020 flow diagram: 3,349 records identified, 893 duplicates removed, 2,456 screened, 1,936 full texts assessed, and 252 studies included.

3.2. Characteristics of the included studies

Publication was steady from 2022 to 2025 (50, 47, 53 and 63 studies) with 39 studies already published in 2026. The studies came from 80 country labels, led by China (40 studies), India (39), Iran (23), Egypt (11) and South Korea (10). Most studies were in vitro only; 92 (37%) added docking or simulation, 50 (20%) used an animal host (32 vertebrate, 18 invertebrate), 13 used a host-cell, tissue or plant infection model and 6 tested a food, device or material application. Mice were the most frequent animal host, followed by *Caenorhabditis elegans*, *Galleria mellonella* larvae and rats. Mammalian-cell cytotoxicity or haemolysis was tested in 66 studies (26%) and not in 186.

P. aeruginosa was the target in 163 studies, *S. aureus*/MRSA in 72 and both species in 17. Natural products were the largest agent class (115 studies), followed by nanoparticles (39), synthetic or novel compounds (37), peptides and enzymes (21), repurposed drugs (18), multi-class combinations (15), probiotics and postbiotics (5) and phages (2).

3.3. QS evidence

A Direct QS assay, that is one run in the target pathogen itself, was present in 140 of 252 studies (56%). A further 27 (11%) used only a surrogate reporter such as violacein inhibition in *Chromobacterium violaceum*, QS-regulated phenotypes only were reported in 35 (14%), docking or simulation only in 14 (6%), and QS was not assessed in 36 (14%). Direct evidence was more common for *P. aeruginosa* (58%) than for *S. aureus*/MRSA (54%) and for studies on both species (35%).

Table 1. QS evidence tier by target organism (number of studies).

Target organism	Direct	Surrogate reporter	Indirect	In silico only	Not assessed	Total
<i>P. aeruginosa</i>	95	22	27	6	13	163
<i>S. aureus</i> /MRSA	39	3	7	6	17	72
Both species	6	2	1	2	6	17

Target organism	Direct	Surrogate reporter	Indirect	In silico only	Not assessed	Total
All studies	140	27	35	14	36	252

Direct: a QS-specific assay in the target pathogen (AHL or autoinducer measurement, QS-gene expression, a *P. aeruginosa* or *S. aureus* reporter strain; AHL degradation counts only when the pathogen's own AHL or QS was measured). **Surrogate reporter:** the only QS assay was run in another organism (for example violacein in *C. violaceum* or an *Agrobacterium* AHL biosensor). **Indirect:** QS-regulated phenotypes only (for example pyocyanin, protease or swarming) or a QS claim without an assay. **In silico only:** docking or simulation with no wet-lab QS data. **Not assessed:** QS was not tested. Tiers reflect what the authors themselves measured (Section 2.5).

By agent class, Direct evidence was highest for repurposed drugs (13 of 18) and lowest for multi-class combinations (6 of 15); natural products had 63 of 115 and the most surrogate-only studies (19).

Table 2. QS evidence tier by primary agent class (number of studies).

Agent class	Direct	Surrogate reporter	Indirect	In silico only	Not assessed	Total
Natural product	63	19	15	7	11	115
Nanoparticle	22	3	9	0	5	39
Synthetic/novel	20	4	4	3	6	37
Combination (multi-class)	6	0	4	1	4	15
Peptide/enzyme	12	0	0	2	7	21
Repurposed	13	1	2	1	1	18
Probiotic/postbiotic	3	0	1	0	1	5
Phage	1	0	0	0	1	2

Each study is counted once, under its primary class, so the rows sum to the 252 included studies. Classes are mutually exclusive and assigned by the rule in Section 2.4; for example, green-synthesised or plant-mediated nanoparticles are classed as Nanoparticle, and only studies that test agents of different classes together or against each other are classed as Combination. **Direct:** a QS-specific assay in the target pathogen (AHL or autoinducer measurement, QS-gene expression, a *P. aeruginosa* or *S. aureus* reporter strain; AHL degradation counts only when the pathogen's own AHL or QS was measured). **Surrogate reporter:** the only QS assay was run in another organism (for example violacein in *C. violaceum* or an *Agrobacterium* AHL biosensor). **Indirect:** QS-regulated phenotypes only (for example pyocyanin, protease or swarming) or a QS claim without an assay. **In silico only:** docking or simulation with no wet-lab QS data. **Not assessed:** QS was not tested. Tiers reflect what the authors themselves measured (Section 2.5).

3.3.1. Agents by class

The included studies are numbered 1–252 in the order of Supplementary Table S2, which gives the agent, model, concentrations, biofilm and QS results for every study; in the text, studies are cited by author and year.

Natural products (n = 115; Supplementary Table S2, nos. 1–115). Plant extracts and fractions were the commonest agents, for example *Torilis japonica* against *S. aureus* (Kim *et al.*, 2022b), *Lavandula dentata* (Aboulwafa *et al.*, 2025) and ginger rhizome (Sagar *et al.*, 2024). Single plant compounds included psoralen (Wen *et al.*, 2024b), thymoquinone (Al-Rabia *et al.*, 2024), piperine (Das *et al.*, 2023), berberine (Wang *et al.*, 2022), baicalin and baicalein (Mao *et al.*, 2023b), and shikonin (Kim *et al.*, 2024). Thirteen studies tested essential oils, among them *Sphagneticola* (Hassan *et al.*, 2025), *Aquilaria* (Wang *et al.*, 2025), *Tagetes* (Khan *et al.*, 2023), *Cupressus* (Al-Mijalli *et al.*, 2023), *Matricaria* (Qaralleh *et al.*, 2024), *Satureja* (Maravić-Vlahović *et al.*, 2025), thyme (Shalmali & Srividya, 2026), *Pelargonium* (Benaissa *et al.*, 2026), *Salvia* (Cinar Koc *et al.*, 2024), *Cistus* (Benaissa *et al.*, 2024) and *Thymus* (Coimbra *et al.*, 2022), and one screened 40 oils (Aziz *et al.*, 2024). Lichen metabolites were studied in (Bharti *et al.*, 2022; Koçöz & Gökalsin, 2026; Le *et al.*, 2024), and microbial products such as rhamnolipids (Khan & Jain, 2025; Saadati *et al.*, 2022), mannorylthritol lipids (Ma *et al.*, 2026), prodigiosin (Liu *et al.*, 2024) and a *Lactiplantibacillus glycolipid* (Patel *et al.*, 2022) were also tested.

Nanoparticles (n = 39; Supplementary Table S2, nos. 116–154). Silver-based nanomaterials were frequent (Abbas *et al.*, 2022; Aflakian & Hashemitabar, 2025; Al-Momani *et al.*, 2023; Azimzadeh *et al.*, 2025; Azimzadeh *et al.*, 2024; Karthikeyan *et al.*, 2025; Khdir & Muhammed, 2025; Owrang & Gholami, 2024; Saleh & Hassan, 2024), together with zinc oxide (Alipour-Khezri *et al.*, 2024; Esnaashari *et al.*, 2026; Karthikeyan *et al.*, 2025; Langarudy *et al.*, 2025; Nath *et al.*, 2025) and chitosan formulations (Bernal-Mercado *et al.*, 2022; Esnaashari *et al.*, 2026; Maršik *et al.*, 2024; Naderi *et al.*, 2025; Ramezani *et al.*, 2026; Saleh & Hassan, 2024). Several carriers delivered a known antibiotic or a plant compound, such as berberine in mesoporous silica (Abd El-Hamid *et al.*, 2024), vancomycin in membrane-derived vesicles (Dou *et al.*, 2025) and curcumin in zein (Badr-Eldin *et al.*, 2024).

Synthetic and novel compounds (n = 37; Supplementary Table S2, nos. 155–191). These were mostly designed against a single QS receptor: LasR inhibitors (Huang *et al.*, 2026; Vetrivel *et al.*, 2023), PqsR antagonists (Chen *et al.*, 2026; Murray *et al.*, 2022) and homoserine lactone analogues (Liu *et al.*, 2025; Wei

et al., 2022); other series included sulfoxide derivatives (Mao *et al.*, 2023a; Ye *et al.*, 2023), N-acylcysteines (Abo-Dya *et al.*, 2022) and halogenated indoles and pyrimidines (Sim *et al.*, 2025; Sim *et al.*, 2024).

Combinations and multi-class studies (n = 15; Supplementary Table S2, nos. 192–206). This group joins agents of different classes, for example citral with triclosan (Chadha *et al.*, 2024), baicalin with cefotaxime (Meng *et al.*, 2026), thymoquinone with nisin (Chen *et al.*, 2023), eugenol with colistin (Kong *et al.*, 2023) naringin with ciprofloxacin (Dey *et al.*, 2024) and vitamin D3 with thymoquinone (Biswas *et al.*, 2025a). It had the lowest share of Direct QS evidence (40%).

Peptides and enzymes (n = 21; Supplementary Table S2, nos. 207–227). Quorum-quenching lactonases (Curcic *et al.*, 2025; Djokic *et al.*, 2022; Porzio *et al.*, 2023; Zhang *et al.*, 2023a; Zhang *et al.*, 2023b) and antimicrobial or designed peptides (Aflakian *et al.*, 2022; Aflakian *et al.*, 2023; Albasri *et al.*, 2026; Dias *et al.*, 2023; Hamid *et al.*, 2025; Leistikow *et al.*, 2024; Masihzadeh *et al.*, 2023; van Gent *et al.*, 2022) predominated, with DNase I (Deng *et al.*, 2022) and recombinant lysostaphin (Yue *et al.*, 2023) as matrix or cell-wall enzymes.

Repurposed drugs (n = 18; Supplementary Table S2, nos. 228–245). Anti-inflammatory drugs (Esnaashari *et al.*, 2023; Mirpour & Zahmatkesh, 2024; Rastgar *et al.*, 2022), the antiretroviral lamivudine (Alyahyawy *et al.*, 2025), the antifungal micafungin (Hijazi *et al.*, 2023), gliptins (Khayat *et al.*, 2022), antihypertensives (Elfaky *et al.*, 2023; Mahfouz *et al.*, 2026) and the gold compound auranofin (Yam *et al.*, 2023) were tested.

Other classes. Probiotic or postbiotic preparations were tested in 5 studies (Aljohani *et al.*, 2023; Azami *et al.*, 2022; Díaz *et al.*, 2024; Liang *et al.*, 2022; Mitsuan *et al.*, 2022), and phages in 2 (Franco *et al.*, 2026; Van Helden *et al.*, 2026).

Figure 2 summarizes the classes. Output rose from 50 studies in 2022 to 63 in 2025 (2026 is a partial year), and natural products were the largest class in every year (panel A). The share of studies with Direct QS evidence was lowest for combinations (40%) and highest for repurposed drugs (72%) (panel B). Most nanoparticle studies (29 of 39) stopped at in vitro testing, whereas 50 of the 252 studies reached an animal host, 32 vertebrate and 18 invertebrate (panel C). Figure 3 maps how the study keywords co-occur.

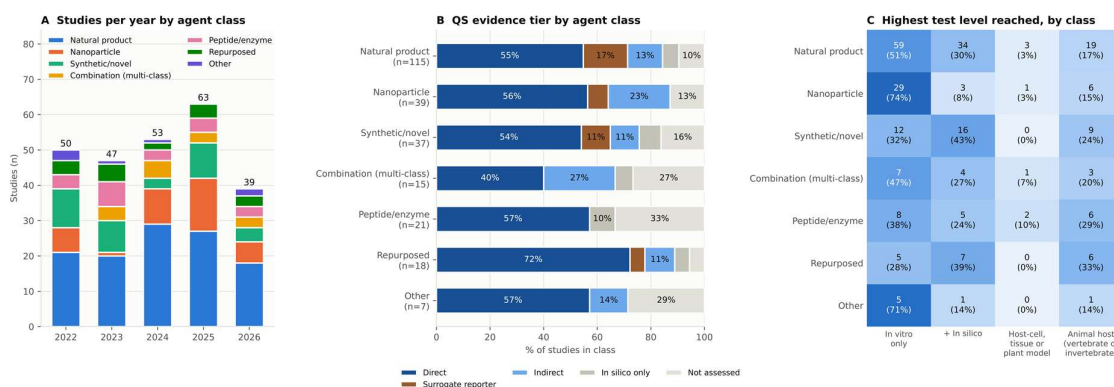


Figure 2. (A) Studies per year by agent class. (B) QS evidence tier within each agent class (probiotic/postbiotic and phage studies are pooled as Other). (C) Highest test level reached per study, by agent class; cells show the number of studies and the percentage of the class.

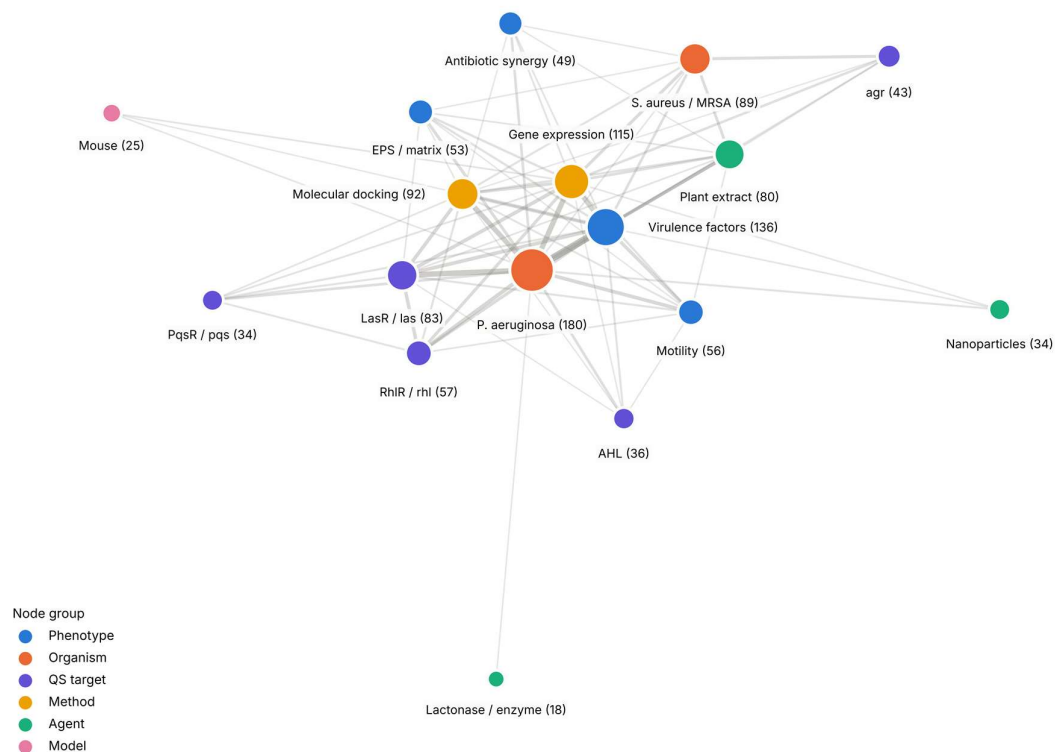


Figure 3. Co-occurrence map of study keywords. A term was assigned to a study if it matched the text of the title, agent, model system, QS-outcome, in vivo organism or mechanism fields, with three exceptions that use the coded fields: the organism nodes (*P. aeruginosa* 163 + 17 on both species = 180; *S. aureus*/MRSA 72 + 17 = 89), the molecular docking node (92 studies coded as in silico) and the mouse node (25 studies with a mouse in the coded in vivo field). A term was drawn as a node if it was assigned to at least 8 studies (the inclusion terms biofilm and quorum sensing were left out) and had at least one edge, and an edge was drawn if two terms occurred together in at least 14 studies. Node size is $60 + 5n$ and line width is $0.4 + 4.5 \times (w / \text{maximum } w)$, where n is the number of studies with the term and w the number of studies with both terms; colour shows the term group. Positions come from a force-directed layout and carry no meaning.

3.4. Animal studies

Of 50 studies with an animal host, 46 measured an infection or efficacy outcome and 4 tested toxicity only. We report vertebrate and invertebrate hosts separately, because invertebrates lack an adaptive immune system, mammalian tissue barriers and mammalian metabolic clearance. Of the 46 efficacy studies, 31 used a vertebrate model (30 mammalian:

mouse, rat or rabbit; and one zebrafish; 27 with Direct QS evidence, 87%) and 15 used an invertebrate host (*C. elegans*, *G. mellonella* or *Drosophila*; 10 with Direct QS evidence, 67%). Of the four toxicity-only studies, three were in invertebrates and one in a vertebrate. No animal study was found for 202 of the 252 studies (80%).

Table 3. Studies using an animal host (n = 50: 27 mammalian, 3 mammalian plus invertebrate, 2 zebrafish, 18 invertebrate). SYRCLE appraised: yes for infection or efficacy studies with a vertebrate host; toxicity-only and invertebrate-only studies were not appraised. Studies are listed in the order of Supplementary Table S2.

Study	Year	Host class	Model	Purpose	SYRCLE appraised	QS tier
Ying et al., 2025	2025	Mammalian	Mouse	Infection/efficacy	Yes	Direct
Al-Rabia et al., 2024	2024	Mammalian	Mouse	Infection/efficacy	Yes	Direct
Zhu et al., 2025	2025	Mammalian	Mouse	Infection/efficacy	Yes	Direct
Turkey et al., 2026	2026	Mammalian	Rat	Infection/efficacy	Yes	Direct
Kamer et al., 2023	2023	Mammalian	Rat	Infection/efficacy	Yes	Direct
Kim et al., 2024	2024	Mammalian	Mouse	Infection/efficacy	Yes	Direct
Abdel Bar et al., 2022	2022	Mammalian	Mouse	Infection/efficacy	Yes	Direct
Al-Monofy et al., 2025	2025	Mammalian	Rat	Infection/efficacy	Yes	Direct
Zhong et al., 2026	2026	Mammalian	Mouse	Infection/efficacy	Yes	Direct
Dehbashi et al., 2024	2024	Mammalian	Mouse	Infection/efficacy	Yes	Direct
Abd El-Hamid et al., 2024	2024	Mammalian	Mouse	Infection/efficacy	Yes	Direct
He et al., 2026	2026	Mammalian	Mouse	Infection/efficacy	Yes	Direct
Jeong et al., 2026	2026	Mammalian	Mouse	Infection/efficacy	Yes	Direct
Badr-Eldin et al., 2024	2024	Mammalian	Mouse	Infection/efficacy	Yes	Indirect
Dou et al., 2025	2025	Mammalian	Mouse	Infection/efficacy	Yes	Not assessed
Abbas et al., 2022	2022	Mammalian	Mouse	Infection/efficacy	Yes	Direct
Huang et al., 2026	2026	Mammalian	Mouse	Infection/efficacy	Yes	Direct
He et al., 2023	2023	Mammalian	Mouse	Infection/efficacy	Yes	Indirect
Lu et al., 2023	2023	Mammalian	Mouse	Infection/efficacy	Yes	Direct
Masihzadeh et al., 2023	2023	Mammalian	Mouse	Infection/efficacy	Yes	Not assessed
Deng et al., 2022	2022	Mammalian	Rabbit	Infection/efficacy	Yes	Direct

Study	Year	Host class	Model	Purpose	SYRCLE appraised	QS tier
Zhang et al., 2023a	2023	Mammalian	Rat	Infection/efficacy	Yes	Direct
Khayat et al., 2022	2022	Mammalian	Mouse	Infection/efficacy	Yes	Direct
Alyahyawy et al., 2025	2025	Mammalian	Mouse	Infection/efficacy	Yes	Direct
Mahfouz et al., 2026	2026	Mammalian	Mouse	Infection/efficacy	Yes	Direct
Elfaky et al., 2023	2023	Mammalian	Mouse	Infection/efficacy	Yes	Direct
Yam et al., 2023	2023	Mammalian	Mouse	Infection/efficacy	No	Direct
Li et al., 2026	2026	Mammalian + invertebrate	Mouse; Tenebrio molitor larvae	Infection/efficacy	Yes	Direct
Chen et al., 2026	2026	Mammalian + invertebrate	Mouse; <i>G. mellonella</i>	Infection/efficacy	Yes	Direct
Yuan et al., 2022	2022	Mammalian + invertebrate	Mouse; <i>C. elegans</i>	Infection/efficacy	Yes	Direct
Pratiwi et al., 2026	2026	Non-mammalian vertebrate	Zebrafish	Toxicity only	No (toxicity only)	Indirect
Djokic et al., 2022	2022	Non-mammalian vertebrate	Zebrafish	Infection/efficacy	Yes	Direct
Matijasević et al., 2025	2025	Invertebrate	<i>C. elegans</i>	Toxicity only	No (toxicity only)	Direct
Wen et al., 2024b	2024	Invertebrate	<i>C. elegans</i>	Infection/efficacy	No (invertebrate host)	Direct
Wen et al., 2024a	2024	Invertebrate	<i>G. mellonella</i>	Infection/efficacy	No (invertebrate host)	Direct
Balkrishna et al., 2026	2026	Invertebrate	<i>C. elegans</i>	Infection/efficacy	No (invertebrate host)	Direct
Balkrishna et al., 2025	2025	Invertebrate	<i>C. elegans</i>	Infection/efficacy	No (invertebrate host)	Direct
Hacioglu et al., 2024	2024	Invertebrate	<i>C. elegans</i>	Infection/efficacy	No (invertebrate host)	Not assessed
Jin et al., 2024	2024	Invertebrate	<i>G. mellonella</i>	Infection/efficacy	No (invertebrate host)	Direct
Yan et al., 2024	2024	Invertebrate	<i>C. elegans</i>	Infection/efficacy	No (invertebrate host)	Indirect
Bernabè et al., 2022	2022	Invertebrate	<i>G. mellonella</i>	Infection/efficacy	No (invertebrate host)	Direct
Wei et al., 2022	2022	Invertebrate	<i>C. elegans</i>	Infection/efficacy	No (invertebrate host)	Direct
Kim et al., 2022a	2022	Invertebrate	<i>C. elegans</i>	Toxicity only	No (toxicity only)	Direct
Bajire et al., 2023	2023	Invertebrate	<i>C. elegans</i>	Infection/efficacy	No (invertebrate host)	Surrogate reporter
Gómez et al., 2022	2022	Invertebrate	<i>G. mellonella</i>	Infection/efficacy	No (invertebrate host)	Not assessed
Samreen & Ahmad, 2025	2025	Invertebrate	<i>C. elegans</i>	Toxicity only	No (toxicity only)	Indirect
Kong et al., 2023	2023	Invertebrate	<i>G. mellonella</i>	Infection/efficacy	No (invertebrate host)	Not assessed
Curcic et al., 2025	2025	Invertebrate	<i>C. elegans</i>	Infection/efficacy	No (invertebrate host)	Direct
Porzio et al., 2023	2023	Invertebrate	Drosophila	Infection/efficacy	No (invertebrate host)	Direct
Aljohani et al., 2023	2023	Invertebrate	<i>G. mellonella</i>	Infection/efficacy	No (invertebrate host)	Direct

Direct: a QS-specific assay in the target pathogen (AHL or autoinducer measurement, QS-gene expression, a *P. aeruginosa* or *S. aureus* reporter strain; AHL degradation counts only when the pathogen's own AHL or QS was measured). **Surrogate reporter:** the only QS assay was run in another organism (for example violacein in *C. violaceum* or an Agrobacterium AHL biosensor). **Indirect:** QS-regulated phenotypes only (for example pyocyanin, protease or swarming) or a QS claim without an assay. **In silico only:** docking or simulation with no wet-lab QS data. **Not assessed:** QS was not tested. **Toxicity only:** no infection or efficacy outcome was measured. Tiers reflect what the authors themselves measured (Section 2.5).

3.5. Risk of bias

Of the 252 in vitro appraisals, 143 were rated low, 93 moderate and 16 high risk of bias. All 75 appraisals made from the extraction row only were moderate by the rule, so these account for 75 of the 93 moderate ratings; among the 177 appraisals scored from the full text, 143 were low, 18 moderate and 16 high. The two reviewers confirmed these ratings against the full texts. The share of studies with Direct QS evidence was similar in the low (57%) and moderate (56%) groups and lower in the high group (7 of 16). Of the 46 animal infection or efficacy studies, 31 included a vertebrate model; 30 were rated with SYRCLE, all with some concerns, and one (Yam et al., 2023) could not be rated because its methods were not available. Allocation concealment was never reported; random housing, caregiver blinding and random outcome assessment were reported in 2 studies each and assessor blinding in 1; sequence generation and baseline similarity were each reported in 11. The other 15 studies used invertebrate hosts without a recorded vertebrate model (*C. elegans*, *G. mellonella* or *Drosophila*) and were not rated with SYRCLE. The 4 toxicity-only studies (Kim et al., 2022a; Matijasević et al., 2025; Pratiwi et al., 2026; Samreen & Ahmad, 2025) were not appraised, so the 50 animal studies divide into 31 with a vertebrate host, 15 invertebrate-only efficacy studies and 4 toxicity-only studies. The 31 vertebrate studies are 30 in mammals (Abbas et al., 2022; Abd

El-Hamid et al., 2024; Abdel Bar et al., 2022; Al-Monofy et al., 2025; Al-Rabia et al., 2024; Alyahyawy et al., 2025; Badr-Eldin et al., 2024; Chen et al., 2026; Dehbashi et al., 2024; Deng et al., 2022; Dou et al., 2025; Elfaky et al., 2023; He et al., 2023; He et al., 2026; Huang et al., 2026; Jeong et al., 2026; Kamer et al., 2023; Khayat et al., 2022; Kim et al., 2024; Li et al., 2026; Lu et al., 2023; Mahfouz et al., 2026; Masihzadeh et al., 2023; Turkey et al., 2026; Yam et al., 2023; Ying et al., 2025; Yuan et al., 2022; Zhang et al., 2023a; Zhong et al., 2026; Zhu et al., 2025) and one in zebrafish (Djokic et al., 2022), and the 15 invertebrate-only studies (Aljohani et al., 2023; Bajire et al., 2023; Balkrishna et al., 2026; Balkrishna et al., 2025; Bernabè et al., 2022; Curcic et al., 2025; Gómez et al., 2022; Hacioglu et al., 2024; Jin et al., 2024; Kong et al., 2023; Porzio et al., 2023; Wei et al., 2022; Wen et al., 2024a; Wen et al., 2024b; Yan et al., 2024). Three of these studies (Chen et al., 2026; Li et al., 2026; Yuan et al., 2022) also used an invertebrate host and were appraised on the mammalian component.

Figure 4 shows the item-level results. In vitro, the weakest items were cytotoxicity data (26% yes), reporting of statistics (63%), replicates (64%) and sufficiently detailed methods (61%). Among the 30 rated vertebrate studies, allocation concealment was not reported in any, and sequence generation, baseline similarity, blinding and random housing were mostly unreported.

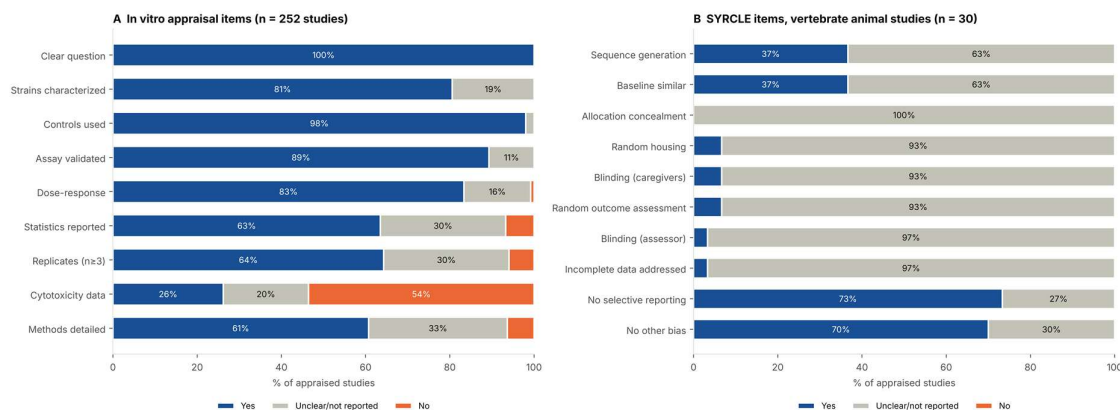


Figure 4. Item-level appraisal. (A) In vitro items for all 252 studies. (B) SYRCL items for the 30 vertebrate studies rated (29 mammalian and one zebrafish; the 31st vertebrate study, Yam *et al.*, 2023, could not be rated; the studies are listed in Section 3.5; the 15 invertebrate-only efficacy studies and 4 toxicity-only studies are not shown). Ratings were a rule-based first pass. All ratings were then checked against the full texts by two reviewers. "Unclear" means the report was insufficient to judge.

3.6. Sensitivity analysis

Among the 140 studies with Direct QS evidence, natural products accounted for 63 (45%, against 46% of all 252 studies) and *P. aeruginosa* for 95 (68%, against 65%), so the Direct subset leans slightly towards *P. aeruginosa*. Of the 145 records excluded because the full text could not be obtained, 18 had first been extracted from an abstract or snippet, which gave 270 extracted studies before exclusion. Had these 18 been kept, the Direct share would have been 54% (145 of 270) instead of 56%.

4. DISCUSSION

4.1. Principal findings

This review mapped 252 preclinical studies from 2022 to 2026. Three features stand out: natural products make up 46% of the evidence (Supplementary Table S2, nos. 1–115), *P. aeruginosa* is studied more than twice as often as *S. aureus*/MRSA, and only 12% of studies tested an agent in a vertebrate infection model (Table 3), with a further 6% in invertebrate hosts. Most studies (56%) ran a QS-specific assay in the target pathogen itself; another 11% used only a surrogate reporter such as violacein in *C. violaceum*, and the remaining 34% inferred QS activity from phenotypes or docking, or did not test it. Earlier reviews have covered natural compounds against *P. aeruginosa* (Shariati *et al.*, 2024) and the *P. aeruginosa* QS systems as drug targets (Soukari *et al.*, 2018); the present review adds *S. aureus*/MRSA and separates studies by what was actually measured.

4.2. How strong is the QS evidence?

The tiering separates what authors measured from what they concluded. A Direct assay was less frequent for *S. aureus*/MRSA (54%) than for *P. aeruginosa* (58%), and lowest for studies on both species (35%) and for multi-class combinations (40%). Surrogate readouts such as violacein inhibition in *C. violaceum* or an *Agrobacterium* AHL biosensor test QS interference in a model organism, not in the target pathogen, and they cannot be assumed to predict activity against the QS systems of *P. aeruginosa* or *S. aureus*. We therefore placed studies whose only QS assay was of this kind in a separate Surrogate reporter tier (27 studies, 11%; for example; Çevikbaş *et al.*, 2024; Hernández-Moreno *et al.*, 2023; Mohan *et al.*, 2024; Tritipmongkol *et al.*, 2022) and did not count them as Direct; counted as Direct, they would have raised that share to 66%. Several other issues recurred during full-text verification and should temper reading of the Direct tier. Some QS-gene expression results were obtained at or above the MIC, where lower expression may reflect reduced growth. Antibiofilm effects at such concentrations likewise cannot be separated from killing, so claims of antivirulence activity are strongest where sub-MIC dosing and growth controls were reported. This follows the pathoblocker principle that an antivirulence agent should disarm the bacteria without killing them (Schütz &

Empting, 2018), and sub-inhibitory concentrations of some agents have been reported to increase motility and biofilm formation in certain strains (Touati *et al.*, 2025).

Growth controls differ in how well they exclude artefacts. A single end-point OD600 reading, or a viable count at one time, shows whether growth differs at that moment but not why. A longer lag phase, a slower growth rate or a lower plateau can each leave a treated culture below its control at the read-out. A treated culture that is still in early exponential phase when the control has reached stationary phase has fewer cells, less autoinducer and lower expression of QS-regulated genes and virulence factors, and this looks like quorum quenching or biofilm inhibition although signalling was not specifically affected. Continuous kinetic profiling, a plate-reader growth curve read at short intervals over the whole assay, separates these cases. It gives the lag time, maximum growth rate and plateau, so authors can show that treated and control cultures were at the same growth stage when sampled, or normalise the QS read-out to cell density. We did not extract whether studies reported a growth curve, only whether an untreated or growth control was mentioned (checklist item 3), so we cannot say how many Direct-tier studies ruled out this artefact. The Direct tier shows that QS was measured in the target pathogen, not that a growth delay was excluded as the explanation. Timing and dose matter as well, because an agent that delays growth at one concentration may leave QS unaffected at a lower one.

Claims of dual antibiofilm and anti-QS activity also need care, because QS does not act on biofilm in the same direction in the two species. In *S. aureus*, agr activation promotes dispersal (Boles & Horswill, 2008) and agr-negative strains or agr-blocking compounds can enhance biofilm (Vuong *et al.*, 2000), so an agent that inhibits agr might be expected to stabilise or even increase biofilm; a fall in biofilm together with an agr readout then needs another explanation, such as killing or effects on adhesion or matrix. Our tiers record whether QS was measured, not whether the direction of the QS effect fits the biofilm result, so a Direct tier in *S. aureus* does not by itself show that the antibiofilm effect is QS-mediated.

4.3. In silico work

Docking appeared in 92 studies (37%). Binding energies depend on the program and scoring function, and docking scores correlate poorly with measured affinity for many target families (Wang *et al.*, 2016), so we did not compare them across studies. In one study the printed energies against PqsA were −176.99 kcal/mol for hypericin and −70.21 kcal/mol for cineole, which cannot be binding free energies (Chakraborty *et al.*, 2024). Typical docking scores for drug-like molecules lie between about −6 and −12 kcal/mol, which at 298 K corresponds to dissociation constants of roughly 40 μM to 2 nM ($\Delta G = RT \ln K_d$). The tightest non-covalent protein–ligand pair usually quoted, biotin–streptavidin, has a ΔG of about −18 to −20

kcal/mol (Kd near 10^{-14} M), and -177 kcal/mol would imply a Kd near 10^{-130} M. Per non-hydrogen atom the values are also implausible: cineole has 11 heavy atoms (-6.4 kcal/mol per atom) and hypericin 38 (-4.7), whereas ligand efficiencies of real binders rarely exceed about 0.5 kcal/mol per heavy atom. The source of these numbers (a different unit or scoring term, or an error) is not clear, so we kept only the claim that hypericin scored better than cineole and excluded the values from any comparison. Fourteen studies supported QS activity by in silico work alone (Alossaimi *et al.*, 2025; Chakraborty *et al.*, 2024; Dey *et al.*, 2024; Ganesh *et al.*, 2022; Hamid *et al.*, 2025; Kim *et al.*, 2025; Kooschlar *et al.*, 2024; Lal *et al.*, 2023; Maldonado-Pérez *et al.*, 2025; Nurfauziah *et al.*, 2026; Omar *et al.*, 2025; Piruthivraj *et al.*, 2024; Shilpi *et al.*, 2026; Trognon *et al.*, 2022). Docking is best read as hypothesis-generating unless it is paired with a wet-lab QS assay.

4.4. Translation

Animal data were sparse. Of the 46 infection studies, 31 used a vertebrate model and 30 of these were rated as having some concerns (Figure 4B; SYRCLE; Hooijmans *et al.*, 2014), because randomisation, blinding and allocation concealment were rarely reported. The 15 studies in invertebrate hosts were not rated, because SYRCLE does not fit them and we did not adapt a separate checklist. These hosts lack an adaptive immune system, mammalian tissue barriers and mammalian metabolic clearance, so they are screening models, and their results should not be read as evidence of mammalian efficacy. Mammalian-cell cytotoxicity or haemolysis was tested in only 26% of studies, and in at least one study embryo toxicity occurred below the active antibiofilm dose (Pratiwi *et al.*, 2026), which questions the therapeutic window. Inhibitor specificity, pharmacokinetics and host-cell toxicity are recognised obstacles to clinical use of QS inhibitors (Schütz & Empting, 2018; Touati *et al.*, 2025). Reporting also varied: several papers gave results only in figures, used units inconsistently, or described their findings more strongly in the abstract than the data supported. We recorded such internal discrepancies in the Notes column of the supplementary workbook.

4.5. Strengths and limitations

The strengths of this review are a recent, bounded search window, tiering of QS evidence by what the studies measured, extraction verified against the full text, and a documented change log.

Several limitations apply. Eligibility required the organism to be named in the title, so studies whose titles name only a general term or a broader group may have been missed. Because the year and title criteria were applied at the eligibility stage, many records (774 for the organism not being in the title and 740 for publication before 2022) were removed only then. In addition, 145 otherwise eligible records could not be retrieved in full text and were excluded, mostly closed-access articles, and 18 of these had first been extracted from an abstract or snippet. Only PubMed and Scopus were searched (137 and 115 included studies came from them); Embase, Web of Science and BIOSIS Previews were not, so coverage of the preclinical literature may be incomplete. Language was limited to English. Studies in invertebrate hosts (15) were not rated with SYRCLE, and no alternative checklist was applied to them. Finally, effect sizes were reported in different units, so we did not do a meta-analysis and cannot rank agents by potency.

4.6. Implications

Future studies should test QS in the target pathogen with a specific reporter or gene-expression assay at sub-MIC doses, report kinetic growth curves at every concentration used and compare QS read-outs at matched cell density, include cytotoxicity and a selectivity index, and move promising agents into randomised, blinded infection models with SYRCLE-aligned reporting (Hooijmans *et al.*, 2014). Reviews and funders should treat docking-only and phenotype-only claims as preliminary.

5. CONCLUSIONS

Preclinical antibiofilm and anti-QS research against *P. aeruginosa* and *S. aureus*/MRSA is abundant and led by natural products, and 56% of the studies tested QS in the target pathogen itself and a further 11% relied on a surrogate reporter alone. The evidence is weakest where it matters for translation: *S. aureus* QS data, animal infection models, cytotoxicity and reporting of randomisation and blinding. Claims of QS inhibition should be read together with the dose relative to the MIC and the type of assay.

SUPPLEMENTARY MATERIALS

Supplementary File 1 (PRISMA 2020 checklist); Supplementary File 2 (Tables S1–S3: search strategies, included studies and in vitro risk-of-bias rubric); the extraction workbook (Screening Log, Data Extraction, QA - In Vitro, QA - In Vivo (SYRCLE), PRISMA Tracker, Synthesis, Sensitivity by verification and Version history); and the list of the 18 records (among the 145 without full text) that had first been extracted from an abstract or snippet and were then excluded, provided in the workbook sheet “Archived - no full text”.

ETHICS APPROVAL

Not applicable. This systematic review used published literature only and involved no human participants or animals.

DECLARATION OF GENERATIVE AI AND AI-ASSISTED TECHNOLOGIES

The authors acknowledge that AI-assisted technologies were partially used in the preparation of this manuscript. Specifically, [Claude Sonnet 5.5 (Anthropic)] was employed to support language refinement and grammar correction. All content was critically reviewed, edited, and approved by the authors to ensure accuracy, originality, and alignment with academic standards. No AI tools were used to generate data, interpret results, or replace the authors' intellectual contribution.

DATA AVAILABILITY

No new primary data were generated. All extracted data, the search strategies and the list of included studies are provided as Supplementary Materials.

CONFLICT OF INTEREST

The authors declare no conflict of interest related to the research. Editorial disclosure: Prof. Dr. Haitham Qaralleh, Editor-in-Chief of this journal, has a supervisory relationship with the authors. He was not involved in the editorial handling of this manuscript, the selection of reviewers, or any decision on it. Peer review and the editorial decision were managed independently by another member of the editorial board.

FUNDING

This research received no external funding.

AUTHORS' CONTRIBUTIONS

Conceptualization, S.M. and B.A.; methodology, S.M. and B.A.; literature search and study selection, S.M. and B.A.; data extraction and curation, S.M. and B.A.; risk-of-bias assessment, S.M. and B.A.; formal analysis, S.M.; visualization, B.A.; writing – original draft preparation, S.M.; writing – review and editing, S.M. and B.A.; supervision and project administration, B.A. All authors have read and approved the final version of the manuscript and agree to be accountable for all aspects of the work.

ACKNOWLEDGMENTS

We thank Waed Al-Tarawneh and Osama Musa for independently verifying the extracted data, quorum-sensing evidence tiers and risk-of-bias ratings against the full texts.

ORCID

Sham Ma'aitah  <https://orcid.org/0009-0007-6282-2906>

Batool AlAmairin  <https://orcid.org/0009-0000-6093-2254>

REFERENCES

- Abbas, H.A., Shaker, G.H., Mosallam, F.M. and Gomaa, S.E., (2022). Novel silver metformin nano-structure to impede virulence of *Staphylococcus aureus*. *AMB Express*, 12(1), 84. <https://doi.org/10.1186/s13568-022-01426-6>
- Abd El-Hamid, M.I., Ibrahim, D., Elazab, S.T., Gad, W.M., Shalaby, M., El-Neshwy, W.M., Alshahrani, M.A., Saif, A., Algendy, R.M., AlHarbi, M., Saleh, F.M., Alharthi, A. and Mohamed, E.A.A., (2024). Tackling strong biofilm and multi-virulent vancomycin-resistant *Staphylococcus aureus* via natural alkaloid-based porous nanoparticles: perspective towards near future eradication. *Front Cell Infect Microbiol*, 13, 1287426. <https://doi.org/10.3389/fcimb.2023.1287426>
- Abdel Bar, F.M., Alossaimi, M.A., Elekhawy, E., Alzeer, M.A.A., Abo Kamer, A., Moglad, E. and ElNaggar, M.H., (2022). Anti-Quorum Sensing and Anti-Biofilm Activity of Pelargonium × hortorum Root Extract against *Pseudomonas aeruginosa*: Combinatorial Effect of Catechin and Gallic Acid. *Molecules*, 27(22), 7841. <https://doi.org/10.3390/molecules27227841>
- Abo-Dya, N.E., Agha, K.A., Abbas, H.A., Abu-Kull, M.E., Alahmadi, M.I. and Osman, N.A., (2022). Hybrid N-Acylcysteines as Dual-Acting Matrix Disruptive and Anti-Quorum Sensing Agents Fighting *Pseudomonas aeruginosa* Biofilms: Design, Synthesis, Molecular Docking Studies, and In Vitro Assays. *ACS Omega*, 7(23), 19879-19891. <https://doi.org/10.1021/acsomega.2c01667>
- Aboulwafa, M.M., Mostafa, N.M., Youssef, F.S., Eldahshan, O.A. and Singab, A.N.B., (2025). *Lavandula dentata* leaves as potential natural antibiofilm agents against *Pseudomonas aeruginosa*. *Sci Rep*, 15(1), 8540. <https://doi.org/10.1038/s41598-025-88824-5>
- Aflakian, F. and Hashemitabar, G., (2025). Biosynthesized silver nanoparticles at subinhibitory concentrations as inhibitors of quorum sensing, pathogenicity, and biofilm formation in *Pseudomonas aeruginosa* PAO1. *Heliyon*, 11(4), e42899. <https://doi.org/10.1016/j.heliyon.2025.e42899>
- Aflakian, F., Rad, M., Hashemitabar, G., Lagzian, M. and Ramezani, M., (2022). Design and assessment of novel synthetic peptides to inhibit quorum sensing-dependent biofilm formation in *Pseudomonas aeruginosa*. *Biofouling*, 38(2), 131-146. <https://doi.org/10.1080/08927014.2022.2028280>
- Aflakian, F., Rad, M., Hashemitabar, G., Lagzian, M. and Ramezani, M., (2023). Antibacterial and antibiofilm activities of novel antimicrobial peptides against *Pseudomonas aeruginosa* isolates from bovine mastitis. *Bulg J Vet Med*, 26(3), 351-360. <https://doi.org/10.15547/bjvm.2021-0064>
- Ahmad, A.A.M., El-Naenaeey, E.Y., Aloufi, A.S., Khalifa, E.K., Khamis, T., Elmowalid, G.A. and El-Hamid, M.I.A., (2025). Thymoquinone/ β -N-acetylglucosaminidase, a novel plant-derived combination, inhibited quorum sensing signaling pathways and disrupted biofilm in *Staphylococcus aureus*. *Front Cell Infect Microbiol*, 15, 1686764. <https://doi.org/10.3389/fcimb.2025.1686764>
- Ahsan, A., Loh, T.C., Barnes, T.J. and Prestidge, C.A., (2026). Liquid crystalline nanoparticles for co-delivery of gentamicin and cinnamaldehyde: enhancing antibiofilm efficacy against *Pseudomonas aeruginosa* via quorum sensing inhibition. *Int J Pharm*, 702, 127218. <https://doi.org/10.1016/j.ijpharm.2026.127218>
- Al-Helo, F.K., El-Banna, N., Qaralleh, H., Al-Limoun, M.O. and Khleifat, K., (2025). Quorum Sensing Inhibition and Virulence Factor Attenuation in *Pseudomonas aeruginosa* by Camphor. *J Pharmacopuncture*, 28(3), 229-239. <https://doi.org/10.3831/KJPI.2025.28.3.229>
- Al-Mijalli, S.H., El Hachlafi, N., Jeddi, M., Abdallah, E.M., Assagaf, H., Qasem, A., Lee, L.H., Law, J.W., Aladhadh, M., Alnasser, S.M., Bouyahya, A. and Mrabti, H.N., (2023). Unveiling the volatile compounds and antibacterial mechanisms of action of *Cupressus sempervirens* L., against *Bacillus subtilis* and *Pseudomonas aeruginosa*. *Biomed Pharmacother*, 167, 115609. <https://doi.org/10.1016/j.biopha.2023.115609>
- Al-Momani, H., Almasri, M., Al Balawi, D.A., Hamed, S., Albiss, B.A., Aldabaibeh, N., Ibrahim, L., Albalawi, H., Al Haj Mahmoud, S., Khasawneh, A.I., Kilani, M., Aldhfeeri, M., Bani-Hani, M., Wilcox, M., Pearson, J. and Ward, C., (2023). The efficacy of biosynthesized silver nanoparticles against *Pseudomonas aeruginosa* isolates from cystic fibrosis patients. *Sci Rep*, 13(1), 8876. <https://doi.org/10.1038/s41598-023-35919-6>
- Al-Monofy, K.B., Abdelaziz, A.A., Abo-Kamar, A.M., Al-Madboly, L.A. and Farghali, M.H., (2025). In vitro and in vivo investigation of the antibacterial, antivirulence, and anti-quorum sensing activities of β -carotene against difficult-to-treat resistant *Pseudomonas aeruginosa*. *BMC Microbiol*, 25(1), 501. <https://doi.org/10.1186/s12866-025-04234-7>
- Al-Rabia, M.W., Asfour, H.Z., Alhakamy, N.A., Abdulaal, W.H., Ibrahim, T.S., Abbas, H.A., Salem, I.M., Hegazy, W.A.H. and Nazeih, S.I., (2024). Thymoquinone is a natural antibiofilm and pathogenicity attenuating agent in *Pseudomonas aeruginosa*. *Front Cell Infect Microbiol*, 14, 1382289. <https://doi.org/10.3389/fcimb.2024.1382289>
- Albasri, H.M., Alfaraj, R., Radwan, A.A., Almaarik, B., Alagamy, M., Eltayb, E.K., Alomar, S., Aleanizy, F.S. and Alqahtani, F.Y., (2026). Anti-virulence activity of peptide C7-3 and its derivatives against *Pseudomonas aeruginosa*. *Microb Pathog*, 219, 108739. <https://doi.org/10.1016/j.micpath.2026.108739>
- Alenazi, N.A., Aleanizy, F.S., Alqahtani, F.Y., Aldossari, A.A., Alanazi, M.M. and Alfaraj, R., (2024). Anti-quorum sensing activity of poly-amidoamine dendrimer generation 5 dendrimer loaded kinase inhibitor peptide against methicillin-resistant *Staphylococcus aureus*. *Saudi Pharm J*, 32(2), 101932. <https://doi.org/10.1016/j.jsps.2023.101932>
- Alfaraj, R., Alkathiri, F.A., Alamri, L.A., Alnassar, N.B., Alanazi, S.H., Algarni, R.A., Alhabdan, N.S. and Abuthnain, R.A., (2025). Exploring the repurposed role of solithromycin as an antivirulence agent against *Staphylococcus aureus* and its resistant variants. *Front Microbiol*, 16, 1540997. <https://doi.org/10.3389/fmicb.2025.1540997>
- Alipour-Khezri, E., Moqadami, A., Barzegar, A., Mahdavi, M., Skurnik, M. and Zarrini, G., (2024). Bacteriophages and Green Synthesized Zinc Oxide Nanoparticles in Combination Are Efficient against Biofilm Formation of *Pseudomonas aeruginosa*. *Viruses*, 16(6), 897. <https://doi.org/10.3390/v16060897>
- Aljohani, A.M., El-Chami, C., Alhubail, M., Ledder, R.G., O'Neill, C.A. and McBain, A.J., (2023). *Escherichia coli* Nissle 1917 inhibits biofilm formation and mitigates virulence in *Pseudomonas aeruginosa*. *Front Microbiol*, 14, 1108273. <https://doi.org/10.3389/fmicb.2023.1108273>
- Alossaimi, M.A., Abdel Bar, F.M., Elekhawy, E. and ElNaggar, M.H., (2025). Antibacterial and antiviral potential of harmalacidine hydrochloride, a β -carboline alkaloid, against respiratory tract pathogens: *Staphylococcus aureus* and H1N1 influenza virus. *PLoS One*, 20(11), e0335014. <https://doi.org/10.1371/journal.pone.0335014>
- Alyahyawy, O.Y., Munshi, R.M., Badr-Eldin, S.M., Aldawsari, H.M., Abualsunun, W., Abbas, H.A., Salem, I.M., Hegazy, W.A.H. and Nazeih, S.I., (2025). Reprofile lamivudine as an antibiofilm and anti-pathogenic agent against *Pseudomonas aeruginosa*. *AMB Express*, 15(1), 33. <https://doi.org/10.1186/s13568-025-01835-3>
- Ammar, Y.A., Ragab, A., Migahed, M.A., Al-Sharbasy, S., Salem, M.A., Riad, O.K.M., Selim, H.M.R.M., Abd-Elmaksoud, G.A. and Abusaif, M.S., (2023). Design, green synthesis, and quorum sensing quenching potential of novel 2-oxo-pyridines containing a thiophene/furan scaffold and targeting a LasR gene on *P. aeruginosa*. *RSC Adv*, 13(39), 27363-27384. <https://doi.org/10.1039/d3ra04230h>
- Arami, N., Tajani, A.S., Hashemi, M., Rezaei, T., Ghodsi, R., Soheili, V. and Bazzaz, B.S.F., (2025). Targeted inhibition of PqsR in *Pseudomonas aeruginosa* PAO1 quorum-sensing network by chalcones as promising antibacterial compounds. *Mol Biol Rep*, 52(1), 175. <https://doi.org/10.1007/s11033-025-10270-3>
- Azami, S., Arefian, E. and Kashef, N., (2022). Postbiotics of *Lactobacillus casei* target virulence and biofilm formation of *Pseudomonas aeruginosa* by modulating quorum sensing. *Arch Microbiol*, 204(2), 157. <https://doi.org/10.1007/s00203-022-02770-8>
- Azimzadeh, M., Greco, G., Farmani, A., Nourian, A., Pourhajabagher, M., Taherkhani, A., Alikhani, M.Y. and Bahador, A., (2025). Biofilm inhibition of multidrug-resistant *Pseudomonas aeruginosa* using green-synthesized silver

- nanoparticles and colistin. *Sci Rep*, 15(1), 14993. <https://doi.org/10.1038/s41598-025-00005-6>
- Azimzadeh, M., Greco, G., Farmani, A., Pourhajibagher, M., Taherkhani, A., Alkhani, M.Y. and Bahador, A., (2024). Synergistic effects of nano curcumin mediated photodynamic inactivation and nano-silver@colistin against *Pseudomonas aeruginosa* biofilms. *Photodiagnosis Photodyn Ther*, 45, 103971. <https://doi.org/10.1016/j.pdpdt.2024.103971>
- Aziz, N., Rollando, Monica, E. and Susanto, F.X.H., (2024). Aromatherapeutic Antibacterials: Comparative Study of 40 Essential Oils and Their Biofilm Inhibition in *Pseudomonas aeruginosa* ATCC9027. *HAYATI J Biosci*, 31(3), 474-485. <https://doi.org/10.4308/hjb.31.3.474-485>
- Badr-Eldin, S.M., Mubarak Aldawsari, H., Ahmed, O.A.A., Kotta, S., Abualsunun, W., Eshmawi, B.A., Khafagy, E.-S., Elbaramawi, S.S., Abbas, H.A., Hegazy, W.A.H. and Seleem, N.M., (2024). Utilization of zein nano-based system for promoting antibiofilm and anti-virulence activities of curcumin against *Pseudomonas aeruginosa*. *Nanotechnol Rev*, 13(1), 20230212. <https://doi.org/10.1515/ntrev-2023-0212>
- Baird, R., Gogoi, D., Forde, L., Ahmed, S.W., Niu, M., Cavanagh, B., Fitzpatrick, F. and Reeves, E.P., (2026). Inhibition of *Pseudomonas aeruginosa* Biofilm Formation by Peptidyl-Arginine Deiminases 2 and 4. *J Innate Immun*, 18(1), 104-119. <https://doi.org/10.1159/000550256>
- Bajire, S.K., Prabhu, A., Bhandary, Y.P., Irfan, K.M. and Shastry, R.P., (2023). 7-Ethoxycoumarin rescued *Caenorhabditis elegans* from infection of COPD derived clinical isolate *Pseudomonas aeruginosa* through virulence and biofilm inhibition via targeting Rhl and Pqs quorum sensing systems. *World J Microbiol Biotechnol*, 39(8), 208. <https://doi.org/10.1007/s11274-023-03655-8>
- Balkrishna, A., Bhatti, S., Ngpoore, N.K., Jangid, H., Varshney, Y., Singh, R., Nain, P., Dev, R., Lochab, S. and Varshney, A., (2026). Disruption in Quorum-Sensing Circuits and Biofilm Matrix in *Pseudomonas aeruginosa* by Super-Critical CO₂ Extracted Oleoresins From *Rauvolfia serpentina* Seeds Rescue *Caenorhabditis elegans* Model of Infection. *FASEB J*, 40(9), e71885. <https://doi.org/10.1096/fj.202600762R>
- Balkrishna, A., Ngpoore, N.K., Bhatti, S., Varshney, Y., Kabdwal, M., Nain, P., Dev, R., Lochab, S. and Varshney, A., (2025). Linolenic acid-enriched supercritical carbon dioxide extract from seeds of *Phyllanthus emblica* L., a functional food with quorum quenching and anti-biofilm action, rescues *Caenorhabditis elegans* infection model from *Pseudomonas aeruginosa*. *Appl Food Res*, 5(2), 101244. <https://doi.org/10.1016/j.afres.2025.101244>
- Ben Soltana, O., Barkallah, M., Rima, M., Bouaziz, T., El Garah, F., Abdelkafi, S. and Fendri, I., (2026). Antibiofilm potential of *Chlorococcum dorsiventrals* extracts against *Pseudomonas aeruginosa*: Biochemical and molecular insights. *Microb Pathog*, 214, 108399. <https://doi.org/10.1016/j.micpath.2026.108399>
- Benaissa, A., Khadir, A., Tamfu, A.N., Kucukaydin, S., Latti, N., Benbelaïd, F., Boudiba, S., Eroglu, B., Bendahou, M. and Ceylan, O., (2024). Biofilm Disruption and Virulence Attenuation Effects of Essential Oil From Endemic Algerian *Cistus munbyi* (Cistaceae) Against Clinical Strains of *Pseudomonas aeruginosa*. *Nat Prod Commun*, 19(4), 1934578X241245234. <https://doi.org/10.1177/1934578X241245234>
- Benaissa, A., Tamfu, A.N., Bouali, W., Bousseham, A., Medjdoub, H., Babali, B., Busra, A.E., Kucukaydin, S., Anouar, E.-H. and Ceylan, O., (2026). Biofilm disruption by citronellol and geraniol against clinical uropathogenic *Pseudomonas aeruginosa*: an integrated in vitro and in silico investigation. *Mol Biol Rep*, 53(1), 1269. <https://doi.org/10.1007/s11033-026-12450-1>
- Bernabè, G., Marzaro, G., Di Pietra, G., Otero, A., Bellato, M., Pauletto, A., Scarpa, M., Sut, S., Chilin, A., Dall'Acqua, S., Brun, P. and Castagliuolo, I., (2022). A novel phenolic derivative inhibits AHL-dependent quorum sensing signaling in *Pseudomonas aeruginosa*. *Front Pharmacol*, 13, 996871. <https://doi.org/10.3389/fphar.2022.996871>
- Bernabè, G., Marzaro, G., Shalata, M.E.M., Iosob, D., Inglima, V., Bellato, M., Castagliuolo, I. and Brun, P., (2025). Repurposing MK-8245 as a Quorum Sensing Inhibitor to Suppress Virulence and Potentiate Antibiotic Activity in *Pseudomonas aeruginosa*. *Antibiotics*, 14(11), 1116. <https://doi.org/10.3390/antibiotics14111116>
- Bernal-Mercado, A.T., Juarez, J., Valdez, M.A., Ayala-Zavala, J.F., Del-Toro-Sánchez, C.L. and Encinas-Basurto, D., (2022). Hydrophobic Chitosan Nanoparticles Loaded with Carvacrol against *Pseudomonas aeruginosa* Biofilms. *Molecules*, 27(3), 699. <https://doi.org/10.3390/molecules27030699>
- Bharti, S., Nayaka, S. and Kumar, R., (2022). Evaluation of some traditional therapeutic properties of *Usnea longissima* (Ascomycota, lichenized fungi): antimicrobial, antitumor and antioxidant. *J Microbiol Biotechnol Food Sci*, 11(4), e3163. <https://doi.org/10.55251/jmbfs.3163>
- Biswas, P., Bose, S. and Chakraborty, S., (2025a). Vitamin D3 potentiates antimicrobial and antibiofilm activities of streptomycin and thymoquinone against *Pseudomonas aeruginosa*. *World J Microbiol Biotechnol*, 41(3), 104. <https://doi.org/10.1007/s11274-025-04304-y>
- Biswas, B.B., Islam, M.N., Dey, A., Bessho, Y. and Biswas, N.N., (2025b). Exploring *Sonneratia caseolaris*: A mangrove plant source for novel antibacterial compounds targeting quorum sensing and biofilm inhibition. *The Microbe*, 8, 100428. <https://doi.org/10.1016/j.microb.2025.100428>
- Boles, B.R. and Horswill, A.R., (2008). Agr-mediated dispersal of *Staphylococcus aureus* biofilms. *PLoS Pathog*, 4, e1000052. <https://doi.org/10.1371/journal.ppat.1000052>
- Boon, D., O'Rourke, B., Camody, M., Woods, D.F., Gloe, A., Platero-Rochart, D., Sánchez-Murcia, P.A., McGlacken, G.P. and Reen, F.J., (2026). Coumarins Disrupt Cell-Cell Communication and Virulence in Priority Pathogens: Targeting the PQS Signalling System in *Pseudomonas aeruginosa*. *Microb Biotechnol*, 19(7), e70404. <https://doi.org/10.1111/1751-7915.70404>
- Bugyna, L., Švantner, L., Bilská, K., Pribus, M. and Budjaková, H., (2025). Impact of Light-Activated Nanocomposite with Erythrosine B on agr Quorum Sensing System in *Staphylococcus aureus*. *Antibiotics*, 14(10), 1010. <https://doi.org/10.3390/antibiotics14101010>
- Çevikbaş, H., Ulusoy, S. and Kaya Kinaytürk, N., (2024). Exploring rose absolute and phenylethyl alcohol as novel quorum sensing inhibitors in *Pseudomonas aeruginosa* and *Chromobacterium violaceum*. *Sci Rep*, 14(1), 15666. <https://doi.org/10.1038/s41598-024-66888-z>
- Chadha, J., Ahuja, P., Mudgil, U., Khullar, L. and Harjai, K., (2024). Citral and triclosan synergistically silence quorum sensing and potentiate antivirulence response in *Pseudomonas aeruginosa*. *Arch Microbiol*, 206(7), 324. <https://doi.org/10.1007/s00203-024-04059-4>
- Chaitanya, K.S., Yu, T.T., Chaudhari, H., Orenkonday, N., Kuthe, P.V., Kumar, N., Dey, R.J., Murugesan, S. and Gowri Chandra Sekhar, K.V., (2026). Discovery of triazole-tethered glycinate and propanoate derivatives bearing a thiolactone moiety as quorum sensing inhibitors of *Pseudomonas aeruginosa*: design, synthesis, biological evaluation, and biofilm inhibition. *RSC Adv*, 16(30), 27977-27993. <https://doi.org/10.1039/d6ra00717a>
- Chakraborty, S., Baidara, P., Sharma, P., Jose, T.A., Manoharan, R. and Mandal, S.M., (2024). Anti-Biofilm Action of Cineole and Hypericum perforatum to Combat Pneumonia-Causing Drug-Resistant *P. aeruginosa*. *Antibiotics*, 13(8), 689. <https://doi.org/10.3390/antibiotics13080689>
- Chen, H., Ji, P.C., Qi, Y.H., Chen, S.J., Wang, C.Y., Yang, Y.J., Zhao, X.Y. and Zhou, J.W., (2023). Inactivation of *Pseudomonas aeruginosa* biofilms by thymoquinone in combination with nisin. *Front Microbiol*, 13, 1029412. <https://doi.org/10.3389/fmicb.2022.1029412>
- Chen, W., Shang, H., Zhang, W., Ma, Y., Guo, T., Ding, H., Jiang, J., Dong, J., Xu, F., Huang, Y. and Ma, S., (2026). Novel dual-targeting biofilm inhibitors for potentiating antibiotic efficacy against multidrug-resistant *Pseudomonas aeruginosa* infections. *J Adv Res*. <https://doi.org/10.1016/j.jare.2026.05.032>
- Chen, H., Wu, L., Su, Y., Huang, Z., Wang, L., Xia, Z., Huang, H., Wang, W., Fang, J., Gu, Z., Sun, P. and Zheng, J., (2022). Inhibitory Effects of Compounds from *Plumula nelumbinis* on Biofilm and Quorum Sensing Against *P. aeruginosa*. *Curr Microbiol*, 79(8), 236. <https://doi.org/10.1007/s00284-022-02914-5>

- Cinar Koc, A.S., Rizvanoglu, S.S., Eryilmaz, M., Demirci, B. and Onder, A., (2024). Chemical composition and bioactivities of essential oil from an endemic *Salvia absconditiflora* Greuter & Burdet. *Ankara Univ Eczacilik Fak Derg*, 48(2), 586-596 <https://doi.org/10.33483/jfpau.1416623>
- Coimbra, A., Miguel, S., Ribeiro, M., Coutinho, P., Silva, L., Duarte, A.P. and Ferreira, S., (2022). Thymus zygis Essential Oil: Phytochemical Characterization, Bioactivity Evaluation and Synergistic Effect with Antibiotics against *Staphylococcus aureus*. *Antibiotics*, 11(2), 146. <https://doi.org/10.3390/antibiotics11020146>
- Curcic, J., Merendino, I., Matijasevic, D., Jovicic, B., Spriano, S. and Malesevic, M., (2025). ST1-YtnP lactonase from extreme environment: A promising antivirulence agent against multidrug-resistant *Pseudomonas aeruginosa*. *Biomed Pharmacother*, 190, 118443. <https://doi.org/10.1016/j.biopha.2025.118443>
- Dahibhate, N.L., Shukla, S.K. and Kumar, K., (2022). A Cyclic Disulfide Diastereomer From Bioactive Fraction of *Bruguiera gymnorhiza* Shows Anti-*Pseudomonas aeruginosa* Activity. *Front Pharmacol*, 13, 890790. <https://doi.org/10.3389/fphar.2022.890790>
- Danaraj, J., Uthirakrishnan, U., Kumaresan, S., Natarajan, P.K., Krishna, J., Perumal, A.S., Selvakumar, K., Karami, Z. and Pugazhendhi, A., (2024). Multifunctional application of seagrass-derived rosmarinic acid in mitigating biofilm and quorum-sensing virulence transcripts of methicillin-resistant *Staphylococcus aureus*. *J Environ Chem Eng*, 12(4), 113086. <https://doi.org/10.1016/j.jece.2024.113086>
- Das, S., Paul, P., Dastidar, D.G., Chakraborty, P., Chatterjee, S., Sarkar, S., Maiti, D. and Tribedi, P., (2023). Piperine Exhibits Potential Antibiofilm Activity Against *Pseudomonas aeruginosa* by Accumulating Reactive Oxygen Species, Affecting Cell Surface Hydrophobicity and Quorum Sensing. *Appl Biochem Biotechnol*, 195(5), 3229-3256. <https://doi.org/10.1007/s12010-022-04280-1>
- Das, H., Samanta, A.K., Kumar, S., Roychoudhury, P., Sarma, K., Akter, F., Subudhi, P.K. and Dutta, T.K., (2024a). Exploration of Antimicrobial, Antibiofilm and Antiquorum Sensing Activity of the Himalayan Yellow Raspberry (*Rubus ellipticus*) against Clinical Isolates of *Escherichia coli* and *Staphylococcus aureus*. *Indian J Anim Res*. <https://doi.org/10.18805/IJAR.B-4514>
- Das, H., Samanta, A.K., Kumar, S., Roychoudhury, P., Sarma, K., Akter, F., Subudhi, P.K. and Dutta, T.K., (2024b). In vitro Antimicrobial, Antibiofilm and Antiquorum Sensing Activity of Indian *Rhododendron* (*Melastoma malabathricum*) against Clinical Isolates of *Escherichia coli* and *Staphylococcus aureus*. *Indian J Anim Res*. <https://doi.org/10.18805/IJAR.B-4415>
- Debnath, G., Roy, R., Dastidar, D.G., Trivedi, S., Paul, P., Das, S., Chakraborty, P. and Tribedi, P., (2026). L-leucine shows promising antibiofilm potential against *Pseudomonas aeruginosa*. *The Microbe*, 11, 100737. <https://doi.org/10.1016/j.micr.2026.100737>
- Dehbashi, S., Tahmasebi, H., Alikhani, M.Y., Vidal, J.E., Seifalian, A. and Arabestani, M.R., (2024). The healing effect of *Pseudomonas* Quinolone Signal (PQS) with co-infection of *Staphylococcus aureus* and *Pseudomonas aeruginosa*: A preclinical animal co-infection model. *J Infect Public Health*, 17(2), 329-338. <https://doi.org/10.1016/j.jiph.2023.12.016>
- Deng, W., Lei, Y., Tang, X., Li, D., Liang, J., Luo, J., Liu, L., Zhang, W., Ye, L., Kong, J., Wang, K. and Chen, Z., (2022). DNase inhibits early biofilm formation in *Pseudomonas aeruginosa*- or *Staphylococcus aureus*-induced empyema models. *Front Cell Infect Microbiol*, 12, 917038. <https://doi.org/10.3389/fcimb.2022.917038>
- Dey, P., De, R., Parai, D., Hossain, S.T. and Mukherjee, S.K., (2024). Enhanced antimicrobial activity of naringin-ciprofloxacin combination against *Pseudomonas aeruginosa* PAO1: Unveiling quorum-sensing mediated molecular mechanisms in biofilm formation and virulence. *The Microbe*, 5, 100171. <https://doi.org/10.1016/j.micr.2024.100171>
- Dias, S.A., Pinto, S.N., Silva-Herdade, A.S., Cavaco, M., Neves, V., Tavares, L., Oliveira, M., Andreu, D., Coutinho, A., Castanho, M.A.R.B. and Veiga, A.S., (2023). Quantitative Imaging of the Action of vCPP2319, an Antimicrobial Peptide from a Viral Scaffold, against *Staphylococcus aureus* Biofilms of a Clinical Isolate. *ACS Infect Dis*, 9(10), 1889-1900. <https://doi.org/10.1021/acsinfdis.3c00195>
- Diaz, M.A., Vega-Hissi, E.G., Blázquez, M.A., Alberto, M.R. and Arena, M.E., (2024). Restraining *Staphylococcus aureus* Virulence Factors and Quorum Sensing through Lactic Acid Bacteria Supernatant Extracts. *Antibiotics (Basel)*, 13(4), 297. <https://doi.org/10.3390/antibiotics13040297>
- Djokic, L., Stankovic, N., Galic, I., Moric, I., Radakovic, N., Šegan, S., Pavic, A. and Senerovic, L., (2022). Novel Quorum Quenching YtnP Lactonase From *Bacillus paralicheniformis* Reduces *Pseudomonas aeruginosa* Virulence and Increases Antibiotic Efficacy in vivo. *Front Microbiol*, 13, 906312. <https://doi.org/10.3389/fmicb.2022.906312>
- Dogheim, G.M., Shehat, M.G., Mahdy, D.M., Barakat, H.S., Abouelfetouh, A. and Ramadan, A.A., (2025). Antibacterial and anti-virulence activity of eco-friendly resveratrol-loaded lipid nanocapsules against methicillin-resistant *Staphylococcus aureus*. *Sci Rep*, 15(1), 14677. <https://doi.org/10.1038/s41598-025-95343-w>
- Dou, J., Peng, H., Li, S., Shang, W., Yang, Y., Hu, X., Tan, L., Hu, Z., Wang, Y., Lin, F., Hu, Q., Xiao, C., Jiang, X., Li, M. and Rao, X., (2025). Homotypic Membrane Vesicle-Formulated VAN@ΔagrMV for Methicillin-Resistant *Staphylococcus aureus* Biofilm Clearance. *Biomat Res*, 29, 0288. <https://doi.org/10.34133/BMR.0288>
- Dündar, Y., Külahci, M.B., Kuyrukcu Öztürk, Ö. and Beyzi, E., (2025). Synthesis of Some Benzothiazolone Derivatives and Their Effects on Quorum Sensing. *Fabad J Pharm Sci*, 50(3), 721-732. <https://doi.org/10.55262/fabadecezacilik.1787503>
- Elfaky, M.A., Elbaramawi, S.S., Eissa, A.G., Ibrahim, T.S., Khafagy, E.-S., Ali, M.A.M. and Hegazy, W.A.H., (2023). Drug repositioning: doxazosin attenuates the virulence factors and biofilm formation in Gram-negative bacteria. *Appl Microbiol Biotechnol*, 107(11), 3763-3778. <https://doi.org/10.1007/s00253-023-12522-3>
- Eltayb, E.K., Alqahtani, F.Y., Alkahtani, H.M., Alsarra, I.A., Alfara, R. and Aleanizy, F.S., (2022). Attenuation of *Pseudomonas aeruginosa* Quorum Sensing Virulence of Biofilm and Pyocyanin by mBTL-Loaded Calcium Alginate Nanoparticles. *Polymers*, 14(17), 3655. <https://doi.org/10.3390/polym14173655>
- Eshboev, F., Karakozova, M., Abdurakhmanov, J., Bobakulov, K., Dolimov, K., Abdurashidov, A., Baymirzaev, A., Makhyrov, A., Terenteva, E., Sasmakov, S., Piyakina, G., Egamberdieva, D., Nazarov, P.A. and Azimova, S., (2023). Antimicrobial and Cytotoxic Activities of the Secondary Metabolites of Endophytic Fungi Isolated from the Medicinal Plant *Hyssopus officinalis*. *Antibiotics*, 12(7), 1201. <https://doi.org/10.3390/antibiotics12071201>
- Esnaashari, F., Alidoust, F.A., Jafari, N., Ghasemi, M., Asadi Rahmani, F., Sedaghat Safsari, S. and Zahmatkesh, H., (2026). Berberine-ZnO loaded chitosan nanoparticles inhibits biofilm formation in *Pseudomonas aeruginosa* PAO1 through targeting extracellular polymeric substances. *BMC Biotechnol*, 26(1), 26. <https://doi.org/10.1186/s12896-026-01103-7>
- Esnaashari, F., Rostamnejad, D., Zahmatkesh, H. and Zamani, H., (2023). In vitro and in silico assessment of anti-quorum sensing activity of Naproxen against *Pseudomonas aeruginosa*. *World J Microbiol Biotechnol*, 39(9), 244. <https://doi.org/10.1007/s11274-023-03690-5>
- Feng, L., Xu, M., Zeng, W., Zhang, X., Wang, S., Yao, Z., Zhou, T., Shi, S., Cao, J. and Chen, L., (2022). Evaluation of the antibacterial, antibiofilm, and anti-virulence effects of acetic acid and the related mechanisms on colistin-resistant *Pseudomonas aeruginosa*. *BMC Microbiol*, 22(1), 306. <https://doi.org/10.1186/s12866-022-02716-6>
- Flemming, H.-C., Wingender, J., Szewzyk, U., Steinberg, P., Rice, S.A. and Kjelleberg, S., (2016). Biofilms: an emergent form of bacterial life. *Nat Rev Microbiol*, 14, 563-575. <https://doi.org/10.1038/nrmicro.2016.94>
- Franco, D., Papasergi, S., Mediat, F., Guglielmino, S.P.P. and De Plano, L.M., (2026). Engineered Phage Modulates Quorum Sensing and Biofilm Formation in *Pseudomonas aeruginosa*. *Microorganisms*, 14(5), 1028. <https://doi.org/10.3390/microorganisms14051028>
- Gaálková-Radochová, B., Kendra, S., Jordao, L., Kursawe, L., Kikhney, J., Moter, A. and Bujdaková, H., (2023). Effect of

- Quorum Sensing Molecule Farnesol on Mixed Biofilms of *Candida albicans* and *Staphylococcus aureus*. *Antibiotics*, 12(3), 441. <https://doi.org/10.3390/antibiotics12030441>
- Ganesh, P.S., Veena, K., Senthil, R., Iswamy, K., Ponmalar, E.M., Mariappan, V., Girija, A.S.S., Vadivelu, J., Nagarajan, S., Challabathula, D. and Shankar, E.M., (2022). Biofilm-Associated Agr and Sar Quorum Sensing Systems of *Staphylococcus aureus* Are Inhibited by 3-Hydroxybenzoic Acid Derived from *Illicium verum*. *ACS Omega*, 7(17), 14653-14665. <https://doi.org/10.1021/acsomega.1c07178>
- Ghosh, C., Das, M.C., Acharjee, S., Bhattacharjee, S., Sandhu, P., Kumari, M., Bhowmik, J., Ghosh, R., Banerjee, B., De, U.C., Akhter, Y. and Bhattacharjee, S., (2023a). Combating *Staphylococcus aureus* biofilm formation: the inhibitory potential of tormentic acid and 23-hydroxycyclohexanecarboxylic acid. *Arch Microbiol*, 206(1), 25. <https://doi.org/10.1007/s00203-023-03762-y>
- Ghosh, S., Lahiri, D., Nag, M., Dey, A., Sarkar, T., Biswas, R., Dutta, B., Mukherjee, D., Pati, S., Pattanaik, S. and Ray, R.R., (2023b). Analysis of Antibiofilm Activities of Bioactive Compounds from Honeyweed (*Leonurus sibiricus*) Against *P. aeruginosa*: an In Vitro and In Silico Approach. *Appl Biochem Biotechnol*, 195(9), 5312-5328. <https://doi.org/10.1007/s12010-021-03797-1>
- Gómez, A.-C., Lyons, T., Mamat, U., Yero, D., Bravo, M., Daura, X., Elshafee, O., Brunke, S., Gahan, C.G.M., O'Driscoll, M., Gibert, I. and O'Sullivan, T.P., (2022). Synthesis and evaluation of novel furanones as biofilm inhibitors in opportunistic human pathogens. *Eur J Med Chem*, 242, 114678. <https://doi.org/10.1016/j.ejmech.2022.114678>
- González-Cruz, J.A., González-Gallardo, G., Pérez-Velázquez, J.R., García-Mejía, C.D., Guevara-Vela, J.M., Oria-Hernández, J.A., Castillo-Villanueva, A., Rinza-Rocha, T. and Hernández-Vázquez, E., (2025). Synthesis of Urea-Containing Derivatives and their Application as Potential Anti-Methicillin-Resistant *Staphylococcus aureus* Agents. *ChemMedChem*, 20(19), e202500521. <https://doi.org/10.1002/cmde.202500521>
- Hacioglu, M., Yilmaz, F.N., Yetke, H.I. and Haciosmanoglu-Aldogan, E., (2024). Synergistic effects of quorum-sensing molecules and antimicrobials against *Candida albicans* and *Pseudomonas aeruginosa* biofilms: In vitro and in vivo studies. *J Antimicrob Chemother*, 79(11), 2828-2836. <https://doi.org/10.1093/jac/dkac293>
- Hamid, S.J., Salih, T.M. and Aziz, T.A., (2025). Rational Design, Computational Analysis and Antibacterial Activities of Synthesized Peptide-Based Molecules Targeting Quorum Sensing-Dependent Biofilm Formation in *Pseudomonas aeruginosa*. *Pharmaceuticals (Basel)*, 18(10), 1572. <https://doi.org/10.3390/ph18101572>
- Hassan, R.K. and Al-Zubaidi, S.J.J., (2025). Synergistic Effect of Ciprofloxacin and Probiotics against Biofilm-Forming *Pseudomonas aeruginosa*. *Bangladesh J Infect Dis*, 12(2), 250-259. <https://doi.org/10.3329/bjid.v12i2.86048>
- Hassan, W.H.B., Ghani, A.E.A., Taema, E.A., Yahya, G., El-Sadek, M.E., Mansour, B., Abdel-Halim, M.S. and Arafa, A.M., (2025). Chemical profile, virtual screening, and virulence-inhibiting properties of *Sphagneticola trilobata* L. essential oils against *Pseudomonas aeruginosa*. *Sci Rep*, 15(1), 11964. <https://doi.org/10.1038/s41598-025-94486-0>
- He, X., Han, B., Wang, R., Guo, Y., Kao, R.Y.T., Li, H., Sun, H. and Xia, W., (2023). Dual-action gallium-flavonoid compounds for combating *Pseudomonas aeruginosa* infection. *RSC Chem Biol*, 4(10), 774-784. <https://doi.org/10.1039/d3cb00033h>
- He, S., Wang, Y., Wang, W., Li, Y. and Zhang, Z., (2026). Synergistic Inhibitory Effect and Mechanism of Action of Cinnamaldehyde-Carvacrol Nanoemulsion on the *Staphylococcus aureus* and *Escherichia coli* Mixed Biofilms Formation. *MicrobiologyOpen*, 15(2), e70258. <https://doi.org/10.1002/mbo3.70258>
- Hernández-Moreno, L.V., Pabón-Baquero, L.C., Prieto-Rodríguez, J.A. and Patiño-Ladino, O.J., (2023). Bioactive Compounds from *P. pertomentellum* That Regulate QS, Biofilm Formation and Virulence Factor Production of *P. aeruginosa*. *Molecules*, 28(17), 6181. <https://doi.org/10.3390/molecules28176181>
- Hijazi, D.M., Dahabiyeh, L.A., Abdelrazig, S., Alqudah, D.A. and Al-Bakri, A.G., (2023). Micafungin effect on *Pseudomonas aeruginosa* metabolome, virulence and biofilm: potential quorum sensing inhibitor. *AMB Express*, 13(1), 20. <https://doi.org/10.1186/s13568-023-01523-0>
- Homaei, S., Ghourchian, H. and Piri-Gharaghie, T., (2025). Antibacterial activity of alginate-casein nanocapsules containing allicin against multidrug-resistant *Pseudomonas aeruginosa*. *Int Microbiol*, 28(8), 2405-2422. <https://doi.org/10.1007/s10123-025-00697-w>
- Hooijmans, C.R., Rovers, M.M., de Vries, R.B., Leenaars, M., Ritskes-Hoitinga, M. and Langendam, M.W., (2014). SYRCLE's risk of bias tool for animal studies. *BMC Med Res Methodol*, 14, 43. <https://doi.org/10.1186/1471-2288-14-43>
- Hotterbeekx, A., Kumar-Singh, S., Goossens, H. and Malhotra-Kumar, S., (2017). In vivo and In vitro Interactions between *Pseudomonas aeruginosa* and *Staphylococcus* spp. *Front Cell Infect Microbiol*, 7, 106. <https://doi.org/10.3389/fcimb.2017.00106>
- Hrynchuk, N., Zelena, L., Bukhtiarova, T., Vrynchanu, N., Ishchenko, L. and Vazhnichaya, E., (2022). Antibiofilm activity of 4-(adamantyl-1-yl)-1-(1-aminobutyl) benzol against methicillin-resistant *Staphylococcus aureus*. *Mikrobiol Zh*, 84(3), 39-50. <https://doi.org/10.15407/mikrobiolzh.84.03.039>
- Huang, Y., Chen, H., Wu, J., Huang, X., Zhang, Y., Ren, A., Wu, X., Huang, C., Xie, W., Zu, D., Shen, C., Xu, F., Chang, Y., Yang, L., Zhou, H., Sun, P., Xu, J., Liu, J., Li, S. and Zheng, J., (2026). Machine learning-driven discovery of aniline phenylacetate derivatives as LasR-targeted biofilm inhibitors against *Pseudomonas aeruginosa* infections. *Acta Pharm Sin B*, 16(10), 6852-6874. <https://doi.org/10.1016/j.apsb.2026.03.048>
- Ilias, F., El Haci, I.A., El Ghali, F., Mrabet, R., Aifa, S. and Mnif, S., (2025). The effect of some Algerian plant essential oils on *Pseudomonas aeruginosa* biofilm formation and quorum sensing: in vitro and in silico studies. *Nat Prod Res*, 1-11. <https://doi.org/10.1080/14786419.2025.2588794>
- Iobbi, V., Parisi, V., Bernabè, G., De Tommasi, N., Bisio, A. and Brun, P., (2023). Anti-Biofilm Activity of Carnosic Acid from *Salvia rosmarinus* against Methicillin-Resistant *Staphylococcus aureus*. *Plants*, 12(21), 3679. <https://doi.org/10.3390/plants12213679>
- Ivanova, K., Ivanova, A., Hoyo, J., Pérez-Rafael, S. and Tzanov, T., (2022). Nano-Formulation Endows Quorum Quenching Enzyme-Antibiotic Hybrids with Improved Antibacterial and Antibiofilm Activities against *Pseudomonas aeruginosa*. *Int J Mol Sci*, 23(14), 7632. <https://doi.org/10.3390/ijms23147632>
- Jaber, N.A. and Ghafil, J.A., (2026). Molecular insights into sub-inhibitory ceftriaxone-mediated modulation of *Pseudomonas aeruginosa* biofilm architecture, quorum sensing networks, and antibiotic-target docking interactions. *Polim Med*, 56(1), 65-74. <https://doi.org/10.17219/pim.224596>
- Jana, D., Manna, T., Guchhait, K.C., Panja, S., Karmakar, A., Ballav, S., Hazra, S., Dey, S., Panda, A.K. and Ghosh, C., (2025). An investigation on anti-biofilm potential of Aegle marmelos fruit extract against multi-drug-resistant *Staphylococcus aureus*. *BMC Complement Med Ther*, 25(1), 334. <https://doi.org/10.1186/s12906-025-05062-y>
- Jeong, G.-J., Park, D.-J., Kang, J.-H., Kim, S.-C., Ahn, Y.-J., Cho, K.-J., Khan, F., Jung, W.-K. and Kim, Y.-M., (2026). Bacterial biosurfactant-reinforced chitoooligosaccharide/polyvinyl alcohol hydrogels accelerate methicillin-resistant *Staphylococcus aureus*-infected wound healing by attenuating its virulence factors. *Asian J Pharm Sci*. <https://doi.org/10.1016/j.ajps.2026.101118>
- Jiang, Y., Tang, X., Wang, A., Yang, H., Jiang, X., Zhang, Y. and Lou, F., (2025). Shikonin-copper coordination nanoparticles for enhanced antibacterial and antibiofilm activity against *Staphylococcus aureus*. *Sci Rep*, 15(1), 39617. <https://doi.org/10.1038/s41598-025-23269-4>
- Jin, Y., Lin, J., Shi, H., Jin, Y., Cao, Q., Chen, Y., Zou, Y., Tang, Y. and Li, Q., (2024). The active ingredients in Chinese peony pods synergize with antibiotics to inhibit MRSA growth and biofilm formation. *Microbiol Res*, 281, 127625. <https://doi.org/10.1016/j.micres.2024.127625>
- Kamer, A.M.A., Abdelaziz, A.A., Al-Monofy, K.B. and Al-Madbolly, L.A., (2023). Antibacterial, antibiofilm, and anti-quorum sensing activities of pyocyanin against methicillin-resistant *Staphylococcus aureus*: in vitro and in vivo study. *BMC Microbiol*, 23(1), 116. <https://doi.org/10.1186/s12866-023-02861-6>

- Karaca, B., Kyalo Kilonzo, N., Korkmaz, Ş., Onar, O., Yıldırım, Ö. and Çöleri Cihan, A., (2025). The Dual Role of the Medicinal Mushroom *Fomitopsis pinicola* in Inhibiting Biofilm and Reducing Antibiotic Resistance of Methicillin-Resistant *Staphylococcus aureus*. *Food Sci Nutr*, 13(6), e70355. <https://doi.org/10.1002/fsn3.70355>
- Karthikeyan, A., Thiruganasambantham, M.K., Khan, F. and Mani, A.K., (2025). Bacteria-Inspired Synthesis of Silver-Doped Zinc Oxide Nanocomposites: A Novel Synergistic Approach in Controlling Biofilm and Quorum-Sensing-Regulated Virulence Factors in *Pseudomonas aeruginosa*. *Antibiotics*, 14(1), 59. <https://doi.org/10.3390/antibiotics14010059>
- Karuppiiah, V. and Seralathan, M., (2022). Quorum sensing inhibitory potential of vaccenic acid against *Chromobacterium violaceum* and methicillin-resistant *Staphylococcus aureus*. *World J Microbiol Biotechnol*, 38(8), 146. <https://doi.org/10.1007/s11274-022-03335-z>
- Kasthuri, T., Barath, S., Nandhakumar, M. and Karutha Pandian, S., (2022). Proteomic profiling spotlights the molecular targets and the impact of the natural antiviral umbelliferone on stress response, virulence factors, and the quorum sensing network of *Pseudomonas aeruginosa*. *Front Cell Infect Microbiol*, 12, 998540. <https://doi.org/10.3389/fcimb.2022.998540>
- Khalid, S.J., Ain, Q., Khan, S.J., Jalil, A., Siddiqui, M.F., Ahmad, T., Badshah, M. and Adnan, F., (2022). Targeting Acyl Homoserine Lactones (AHLs) by the quorum quenching bacterial strains to control biofilm formation in *Pseudomonas aeruginosa*. *Saudi J Biol Sci*, 29(3), 1673-1682. <https://doi.org/10.1016/j.sjbs.2021.10.064>
- Khan, S. and Jain, L., (2025). Inhibition of a Biofilm using Rhamnolipid obtained from a Moderate halophile *Pseudomonas aeruginosa* SH-6. *Res J Pharm Technol*, 12(18), 5640. <https://doi.org/10.52711/0974-360X.2025.00814>
- Khan, P., Waheed, A., Azeem, M., Parveen, A., Yameen, M.A., Iqbal, J., Ali, M., Wang, S., Qayyum, S., Noor, A. and Naqvi, T.A., (2023). Essential Oil from *Tagetes minuta* Has Antiquorum Sensing and Antibiofilm Potential against *Pseudomonas aeruginosa* Strain PAO1. *ACS Omega*, 8(39), 35866-35873. <https://doi.org/10.1021/acsomega.3c03507>
- Khayat, M.T., Abbas, H.A., Ibrahim, T.S., Khayat, A.N., Alharbi, M., Darwish, K.M., Elhady, S.S., Khafagy, E.S., Safo, M.K. and Hegazy, W.A.H., (2022). Anti-Quorum Sensing Activities of Gliptins against *Pseudomonas aeruginosa* and *Staphylococcus aureus*. *Biomedicine*, 10(5), 1169. <https://doi.org/10.3390/biomedicine10051169>
- Khdar, K.A. and Muhammed, S.M., (2025). Eco-friendly nanoparticles from *Fusarium solani* suppress biofilms and quorum sensing in *Pseudomonas aeruginosa*. *Nanoscale Adv*, 8(1), 80-96. <https://doi.org/10.1039/d5na00898k>
- Kim, Y.G., Lee, J.H., Kim, S.H., Park, S.Y., Kim, Y.J., Ryu, C.M., Seo, H.W. and Lee, J.T., (2024). Inhibition of Biofilm Formation in *Cutibacterium acnes*, *Staphylococcus aureus*, and *Candida albicans* by the Phytopigment Shikonin. *Int J Mol Sci*, 25(4), 2426. <https://doi.org/10.3390/ijms25042426>
- Kim, S., Lee, J.-H., Kim, Y.-G., Tan, Y. and Lee, J., (2022a). Hydroquinones Inhibit Biofilm Formation and Virulence Factor Production in *Staphylococcus aureus*. *Int J Mol Sci*, 23(18), 10683. <https://doi.org/10.3390/ijms231810683>
- Kim, G.S., Park, C.R., Kim, J.E., Kim, H.K. and Kim, B.S., (2022b). Anti-Biofilm Effects of *Torilis japonica* Ethanol Extracts against *Staphylococcus aureus*. *J Microbiol Biotechnol*, 32(2), 220-227. <https://doi.org/10.4014/jmb.2107.07053>
- Kim, T., Tabassum, N., Javaid, A. and Khan, F., (2025). Attenuation of *Staphylococcus aureus* Biofilms and Virulence by 3-Fluorocatechol. *Antibiotics*, 14(12), 1240. <https://doi.org/10.3390/antibiotics14121240>
- Kiruthiga, T., Pathoor, N.N., Veeraragavan, G.R. and Ganesh, P.S., (2024). Exploring the Antimicrobial and Antibiofilm Activities of *Luffa cylindrica* against *Pseudomonas aeruginosa* and *Enterococcus faecalis*. *Texila Int J Public Health*, 12(3). <https://doi.org/10.21522/TIJPH.2013.12.03.Art002>
- Knap, K., Kwieciński, K., Ohońska, D., Reczyńska-Kolman, K., Pamuła, E. and Brzywczy-Włoch, M., (2024). Synergistic effect of antibiotics, α -linolenic acid and solvent type against *Staphylococcus aureus* biofilm formation. *Pharmacol Rep*, 76(6), 1456-1469. <https://doi.org/10.1007/s43440-024-00669-3>
- Koçöz, A.N. and Gökalsin, B., (2026). In vitro modulatory effects of lichen secondary metabolite vulpinic acid on pyoverdine production and quorum sensing-regulated traits in *Pseudomonas aeruginosa*. *World J Microbiol Biotechnol*, 42(3), 120. <https://doi.org/10.1007/s11274-026-04886-1>
- Kong, J., Wang, Y., Yao, Z., Lin, Y., Zhang, Y., Han, Y., Zhou, T., Ye, J. and Cao, J., (2023). Eugenol works synergistically with colistin against colistin-resistant *Pseudomonas aeruginosa* and *Klebsiella pneumoniae* isolates by enhancing membrane permeability. *Microbiol Spectr*, 11(5), e03666-22. <https://doi.org/10.1128/spectrum.03666-22>
- Koosehlar, E., Mohabatkari, H. and Behbahani, M., (2024). In Silico and In vitro Evaluations of the Antibacterial Activities of HIV-1 Nef Peptides against *Pseudomonas aeruginosa*. *Int J Mol Cell Med*. <https://doi.org/10.22088/IJMCMBUMS.13.1.46>
- Kumar, S., Paliya, B.S., Singh, B.N. and Agrawal, S., (2025). Biogenic Gold Nanocrystals Knock Down *Pseudomonas aeruginosa* Virulence via Quorum-Sensing and Antibiofilm Potential. *Nanomaterials*, 15(21), 1648. <https://doi.org/10.3390/nano15211648>
- Kunz Coyne, A.J., Stamper, K., Bleick, C., Kebriaei, R., Lehman, S.M. and Rybak, M.J., (2024). Synergistic bactericidal effects of phage-enhanced antibiotic therapy against MRSA biofilms. *Microbiol Spectr*, 12(4), e03212-23. <https://doi.org/10.1128/spectrum.03212-23>
- Lal, A.F., Gupta, P.S. and Yadav, P.K., (2023). In silico Study of Phenol Explorer Database as Potential Inhibitors of Quorum-Sensing Regulated Pathogenicity in *Pseudomonas aeruginosa*. *Biomed Pharmacol J*, 16(3), 1577-1590. <https://doi.org/10.13005/bpj/2736>
- Lall, N., Kok, A.-M., Oosthuizen, C.B., Verma, S., Chassagne, F., Vo, P.H., Ho, K.-V., Lin, C.-H., Quave, C.L. and Twilley, D., (2025). Antibacterial and Antibiofilm Activity of 8-Hydroxyquinoline Derivatives Against *Mycobacterium* and *Staphylococcus* Species. *Chem Biodivers*, 22(12), e01892. <https://doi.org/10.1002/cbdv.202501892>
- Langarudy, S.H.M., Sigarchian, M., Zahmatkesh, H., Esnaashari, F., Ghasemi, M.F., Zamani, H. and Rasti, B., (2025). Baicalin-Coated Zinc Oxide Nanoparticles: An Efficient Formulation to Combat *Staphylococcus aureus* Biofilm Formation and Quorum Sensing. *ChemistrySelect*, 10(41), e00315. <https://doi.org/10.1002/slct.202500315>
- Lashaki, S.B., Moulavi, P., Ashrafi, F., Sharifi, A. and Asadi, S., (2025). Imipenem/cilastatin encapsulation in UIO-66-NH₂ carrier as a new strategy for combating imipenem-resistant *Pseudomonas aeruginosa* isolates. *J Glob Antimicrob Resist*, 42, 15-27. <https://doi.org/10.1016/j.jgar.2025.01.010>
- Lavan, S. and Athiappan, M., (2024). Anti-Quorum Sensing Efficacy of *Mangifera indica* Kernel Extract against Biofilm Formation in *Pseudomonas aeruginosa*. *Res J Biotechnol*, 19(2), 60. <https://doi.org/10.25303/1902rjbt060075>
- Lavan, S., Varsha, M., Kannan, V., Anandan, R. and Athiappan, M., (2024). Synergistic Quorum quenching activity of Cinnamaldehyde against biofilm forming *Pseudomonas aeruginosa*. *Res J Biotechnol*, 19(6), 116. <https://doi.org/10.25303/1906rjbt01160126>
- Le, T.T., Duong, H.T. and Nguyen, C.H., (2024). Characterization of in vitro antimicrobial activity of gyrophoric acid isolated from *Parmotrema indicum* on methicillin-resistant *Staphylococcus aureus*. *J Appl Pharm Sci*, 14(3), 045-054. <https://doi.org/10.7324/JAPS.2024.163764>
- Le, K.Y. and Otto, M., (2015). Quorum-sensing regulation in staphylococci: an overview. *Front Microbiol*, 6, 1174. <https://doi.org/10.3389/fmicb.2015.01174>
- Lee, J.-H., Kim, Y.-G. and Lee, J., (2022). Inhibition of *Staphylococcus aureus* Biofilm Formation and Virulence Factor Production by Petroselinic Acid and Other Unsaturated C18 Fatty Acids. *Microbiol Spectr*, 10(3), e01330-22. <https://doi.org/10.1128/spectrum.01330-22>
- Lee, J. and Zhang, L., (2015). The hierarchy quorum sensing network in *Pseudomonas aeruginosa*. *Protein Cell*, 6, 26-41. <https://doi.org/10.1007/s13238-014-0100-x>
- Leistikow, K.R., May, D.S., Suh, W.S., Asensio, G.V., Schaezner, A.J., Currie, C.R. and Hristova, K.R., (2024). *Bacillus subtilis*-derived peptides disrupt quorum sensing and biofilm assembly

- in multidrug-resistant *Staphylococcus aureus*. *mSystems*, 9(8), e00712-24. <https://doi.org/10.1128/msystems.00712-24>
- Leitão, M.M., Vieira, T.F., Sousa, S.F., Borges, F., Simões, M. and Borges, A., (2024). Dual action of benzaldehydes: Inhibiting quorum sensing and enhancing antibiotic efficacy for controlling *Pseudomonas aeruginosa* biofilms. *Microb Pathog*, 191, 106663. <https://doi.org/10.1016/j.micpath.2024.106663>
- Lencova, S., Stiborova, H., Munzarova, M., Demnerova, K. and Zdenkova, K., (2022). Potential of Polyamide Nanofibers With Natamycin, Rosemary Extract, and Green Tea Extract in Active Food Packaging Development: Interactions With Food Pathogens and Assessment of Microbial Risks Elimination. *Front Microbiol*, 13, 857423. <https://doi.org/10.3389/fmicb.2022.857423>
- Li, D.D., Li, H., Niu, W.X., Li, H. and Lee, J.H., (2026). A quorum sensing antagonist with dual bacterium- and host-directed anti-pathogenic activity against *Pseudomonas aeruginosa*. *Virulence*, 17(1), 2712735. <https://doi.org/10.1080/21505594.2026.2712735>
- Li, D.-D., Wang, Y., Li, H., Niu, W.-X., Hong, J., Jung, J.H. and Lee, J.-H., (2025). Multifaceted Antipathogenic Activity of Two Novel Natural Products, Chermesiterpenoid B and Chermesiterpenoid B Seco Acid Methyl Ester, Against *Pseudomonas aeruginosa*. *Microb Biotechnol*, 18(2), e70101. <https://doi.org/10.1111/1751-7915.70101>
- Liang, Y., Pan, Y., Li, Q., Wu, B. and Hu, M., (2022). RNA-seq-based transcriptomic analysis of AHL-induced biofilm and pyocyanin inhibition in *Pseudomonas aeruginosa* by *Lactobacillus brevis*. *Int Microbiol*, 25(3), 447-456. <https://doi.org/10.1007/s10123-021-00228-3>
- Lima, E.M.F., Almeida, F.A., Sircili, M.P., Bueris, V. and Pinto, U.M., (2023). N-acetylcysteine (NAC) attenuates quorum sensing regulated phenotypes in *Pseudomonas aeruginosa* PAO1. *Heliyon*, 9(3), e14152. <https://doi.org/10.1016/j.heliyon.2023.e14152>
- Lima, E.M.F., de Almeida, F.A. and Pinto, U.M., (2025). Exploring the antivirulence potential of phenolic compounds to inhibit quorum sensing in *Pseudomonas aeruginosa*. *World J Microbiol Biotechnol*, 41(2), 32. <https://doi.org/10.1007/s11274-025-04255-4>
- Liu, J., Deng, Y., Wang, X., Luo, P., Ding, S., Zhang, W., Uddin, S., Li, H. and Li, Y., (2025). Novel PHL derivatives targeting quorum sensing: A strategy to combat *Pseudomonas aeruginosa* infections. *Biofilm*, 10, 100326. <https://doi.org/10.1016/j.biofilm.2025.100326>
- Liu, Y., Su, S., Yu, M., Zhai, D., Hou, Y., Zhao, H., Ma, X., Jia, M., Xue, X. and Li, M., (2022). Pyranocoumarin derivative LP4C targeting of pyrimidine de novo synthesis pathway inhibits MRSA biofilm and virulence. *Front Pharmacol*, 13, 959736. <https://doi.org/10.3389/fphar.2022.959736>
- Liu, X., Wang, Z., You, Z., Wang, W., Wang, Y., Wu, W., Peng, Y., Zhang, S., Yun, Y. and Zhang, J., (2024). Transcriptomic analysis of cell envelope inhibition by prodigiosin in methicillin-resistant *Staphylococcus aureus*. *Front Microbiol*, 15, 1333526. <https://doi.org/10.3389/fmicb.2024.1333526>
- Lu, X., Wang, G., Xie, Y., Tang, W., Liu, B. and Zhang, J., (2023). Efflux pump inhibitor combined with ofloxacin decreases MRSA biofilm formation by regulating the gene expression of NorA and quorum sensing. *RSC Adv*, 13(4), 2707-2717. <https://doi.org/10.1039/d2ra06696c>
- Luo, X., Wang, S., Yang, Y., Gao, R., Yuan, S., Yu, J., Liu, D. and Tan, X., (2026). Engineered *Pseudomonas aeruginosa* phages with quorum-quenching enzyme or depolymerase for inhibition of biofilm formation. *Front Microbiol*, 16, 1752980. <https://doi.org/10.3389/fmicb.2025.1752980>
- Ma, X., Wang, B., Jiang, Y., Shi, Y., Liu, X. and Chen, Q., (2026). The inhibitory effect of mannosylerythritol lipids on *Staphylococcus aureus* biofilm via the Agr quorum-sensing system. *Food Qual Saf*, 10, fyag038. <https://doi.org/10.1093/fqsaf/fyag038>
- Macho, M., Saha, S., Konert, G., Banerjee, A., Ewe, D., Hrouzek, P., Urajová, P. and Saurav, K., (2022). Screening of the Medicines for Malaria Venture Pandemic Response Box for Discovery of Antiviral Drug against *Pseudomonas aeruginosa*. *Microbiol Spectr*, 10(6), e02232-22. <https://doi.org/10.1128/spectrum.02232-22>
- Mahavy, C.E., Mol, A., Andrianarisoa, B., Duez, P., Jaziri, M.E., Baucher, M. and Rasamiravaka, T., (2022). The Xanthophyll Carotenoid Lutein Reduces the Invasive Potential of *Pseudomonas aeruginosa* and Increases Its Susceptibility to Tobramycin. *Int J Mol Sci*, 23(13), 7199. <https://doi.org/10.3390/ijms23137199>
- Mahendrarajan, V., Lazarus, H. and Easwaran, N., (2024). Quorum quenching mediated biofilm impediment in *Chromobacterium violaceum* and *Staphylococcus aureus* by leaf extracts of *Delonix elata*. *Heliyon*, 10(11), e31898. <https://doi.org/10.1016/j.heliyon.2024.e31898>
- Mahfouz, A.A., Abbas, H.A., Yousef, N. and Elgaml, A., (2026). Disarming *Pseudomonas aeruginosa*: repurposing vardenafil, valsartan, and olmesartan as anti-virulence and antibiofilm agents. *Sci Rep*, 16(1), 24455. <https://doi.org/10.1038/s41598-026-64238-9>
- Maldonado-Pérez, H., Pinzón-Esquivel, J.P., Molina-Salinas, G.M., González-Sánchez, A.A., Dzib-Baak, H.E., Dzul-Beh, Á., Quintal-Novelo, C.J. and Uc-Cachón, A.H., (2025). Non- and Medium-Polar Fractions from *Trametes villosa* Inhibit *Staphylococcus aureus* Growth, Virulence, and Biofilm Formation. *Microbiol Res*, 16(12), 263. <https://doi.org/10.3390/microbiolres16120263>
- Mandalari, G., Minuti, A., La Camera, E., Barreca, D., Romeo, O. and Nostro, A., (2023). Antimicrobial Susceptibility of *Staphylococcus aureus* Strains and Effect of Phloretin on Biofilm Formation. *Curr Microbiol*, 80(9), 303. <https://doi.org/10.1007/s00284-023-03400-2>
- Mao, S., Li, Q., Yang, Z., Li, Y., Ye, X. and Wang, H., (2023a). Design, synthesis, and biological evaluation of benzoheterocyclic sulfoxide derivatives as quorum sensing inhibitors in *Pseudomonas aeruginosa*. *J Enzyme Inhib Med Chem*, 38(1), 2175820. <https://doi.org/10.1080/14756366.2023.2175820>
- Mao, Y., Liu, P., Chen, H., Wang, Y., Li, C. and Wang, Q., (2023b). Baicalein Inhibits the *Staphylococcus aureus* Biofilm and the LuxS/AI-2 System in vitro. *Infect Drug Resist*, 16, 2861-2882. <https://doi.org/10.2147/IDR.S406243>
- Maravić-Vlahović, G., Kindl, M., Andrićević, K., Obranić, S. and Vladimir-Knežević, S., (2025). Modulatory Effects of *Satureja montana* L. Essential Oil on Biofilm Formation and Virulence Factors of *Pseudomonas aeruginosa*. *Pharmaceuticals*, 18(9), 1269. <https://doi.org/10.3390/ph18091269>
- Maršik, D., Mařátková, O., Kolková, A. and Masák, J., (2024). Exploring the antimicrobial potential of chitosan nanoparticles: synthesis, characterization and impact on *Pseudomonas aeruginosa* virulence factors. *Nanoscale Adv*, 6(12), 3093-3105. <https://doi.org/10.1039/d4na00064a>
- Martínez-Rodríguez, O.P., García-Contreras, R., Aguayo-Ortiz, R., Yeiverino, I.R., Fajardo-Hernández, C.A., Patiño, A.D., Hernández Pérez, H.A., Hernández-Garnica, M. and Figueroa, M., (2025). Natural Products Inhibit Bacterial Growth and Modulate Quorum-Sensing Systems Las and Rhl in *Pseudomonas aeruginosa* PA14. *Chem Biodivers*, 22(12), e02040. <https://doi.org/10.1002/cbdv.202502040>
- Masizadeh, S., Amin, M. and Farshadzadeh, Z., (2023). In vitro and in vivo antibiofilm activity of the synthetic antimicrobial peptide WLBU2 against multiple drug resistant *Pseudomonas aeruginosa* strains. *BMC Microbiol*, 23(1), 131. <https://doi.org/10.1186/s12866-023-02886-x>
- Matijasević, D., Malešević, M., Čurčić, J., Pavlović, V.B., Milinčić, D.D., Lević, S.M., Stanisavljević, N., Dinić, M., Pešić, M.B. and Pantić, M., (2025). Inhibition of *Pseudomonas aeruginosa* quorum sensing-regulated behaviors by mushroom extracts. *J Ethnopharmacol*, 353, 120466. <https://doi.org/10.1016/j.jep.2025.120466>
- Mazloui Jourkouyeh, E., Taslimi Eshkalak, M., Faezi Ghasemi, M., Zahmatkesh, H., Rasti, B. and Zamani, H., (2024). Diclofenac Sodium and Gentamicin Co-Encapsulated PLGA Nanoparticles: Targeting Extracellular Matrix Components to Combat Biofilm Formation in *Pseudomonas aeruginosa* PAO1. *J Clust Sci*, 35(7), 2475-2488. <https://doi.org/10.1007/s10876-024-02675-0>
- Meng, X., Ning, C., Lu, X., Kang, M., Yang, Y., Yu, Z., Wang, Y., Sun, Y. and Guo, H., (2026). The Effects of Baicalin in Combination with Cefotaxime on the Biofilm and Metabolic Reprogramming of Multidrug-Resistant *Pseudomonas*

- aeruginosa. *Biomolecules*, 16(4), 598. <https://doi.org/10.3390/biom16040598>
- Mensah, C.N., Ampomah, G.B., Mensah, J.O., Gasu, E.N., Aboagye, C.I., Ekuadzi, E., Boadi, N.O. and Borquaye, L.S., (2022). N-alkylimidazole derivatives as potential inhibitors of quorum sensing in *Pseudomonas aeruginosa*. *Heliyon*, 8(12), e12581. <https://doi.org/10.1016/j.heliyon.2022.e12581>
- Mirpour, M. and Zahmatkesh, H., (2024). Ketoprofen attenuates Las/Rhl quorum-sensing (QS) systems of *Pseudomonas aeruginosa*: molecular and docking studies. *Mol Biol Rep*, 51(1), 133. <https://doi.org/10.1007/s11033-023-09071-3>
- Mitsuwan, W., Sornsene, P. and Romyasamit, C., (2022). Lactaseibacillus spp.; Probiotic candidates from Palmyra palm sugar possesses antimicrobial and anti-biofilm activities against methicillin-resistant *Staphylococcus aureus*. *Vet World*, 299-308. <https://doi.org/10.14202/vetworld.2022.299-308>
- Mohan, A., Rajan, P.P., Kumar, P., Jayakumar, D., Mini, M., Asha, S. and Vaikkathillam, P., (2024). Theophylline as a quorum sensing and biofilm inhibitor in *Pseudomonas aeruginosa* and *Chromobacterium violaceum*. *Int Microbiol*, 27(5), 1457-1471. <https://doi.org/10.1007/s10123-024-00487-w>
- Mühlen, S. and Dersch, P., (2016). Anti-virulence Strategies to Target Bacterial Infections. *Curr Top Microbiol Immunol*, 398, 147-183. https://doi.org/10.1007/82_2015_490
- Murray, E.J., Dubern, J.-F., Chan, W.C., Chhabra, S.R. and Williams, P., (2022). A *Pseudomonas aeruginosa* PQS quorum-sensing system inhibitor with anti-staphylococcal activity sensitizes polymicrobial biofilms to tobramycin. *Cell Chem Biol*, 29(7), 1187-1199.e6. <https://doi.org/10.1016/j.chembiol.2022.02.007>
- Naderi, K., Damavandi, M.S., Rezaei, A. and Havaei, S.A., (2025). Synergistic inhibition of agr quorum sensing in methicillin-resistant *Staphylococcus aureus*: a novel approach with natural compound encapsulation. *Microbiol Spectr*, 14(1), e01759-25. <https://doi.org/10.1128/spectrum.01759-25>
- Nafee, N., Gaber, D.M., Abouelfetouh, A., Alsequey, M., Empting, M. and Schneider, M., (2024). Enzyme-Linked Lipid Nanocarriers for Coping Pseudomonas Pulmonary Infection. Would Nanocarriers Complement Biofilm Disruption or Pave Its Road?. *Int J Nanomedicine*, 19, 3861-3890. <https://doi.org/10.2147/IJN.S445955>
- Nahar, S., Mahamud, A.G.M.S.U., Cho, A.J., Ashrafudoulla, M., Yu, J., Park, S.H. and Ha, S.D., (2025). Flavourzyme Suppresses *Pseudomonas aeruginosa* Biofilms by Targeting Motility, Quorum Sensing, and Virulence Genes. *Curr Microbiol*, 82(6), 240. <https://doi.org/10.1007/s00284-025-04200-6>
- Nancy, K., Soumya, N. and Jayanthi, A., (2023). Bioactivity of Natural Polymers against Clinical Pathogens. *Res J Biotechnol*, 18(10), 235. <https://doi.org/10.25303/1810rjbt350240>
- Nath, M.J., Choudhury, S.R., Priyanka, Khan, S., Mandal, M. and Patel, S.K.S., (2026). Biofilm and Quorum-Sensing Inhibition by Novel *Bacillus xiamenensis* MM07 Endophytic Isolate from *Paederia foetida* to Combat *Pseudomonas aeruginosa*. *Microbiol Res*, 17(4), 65. <https://doi.org/10.3390/microbiolres17040065>
- Nath, R., Lahiri, D., Nag, M., Mahapatra, D., Bhattacharya, M., Dutta, K. and Bhattacharya, D., (2025). Antibiofilm activity of exopolysaccharide-mediated ZnO nanoparticle against *Pseudomonas aeruginosa* biofilm. *Naunyn Schmiedeberg Arch Pharmacol*, 398(5), 5823-5834. <https://doi.org/10.1007/s00210-024-03651-1>
- Ni, K.H., Cai, D., Lu, J. and Tian, J., (2022). Eugenol-Mediated Inhibition of Biofilm Formed by *S. aureus*: a Potent Organism for Pediatric Digestive System Diseases. *Appl Biochem Biotechnol*, 194(3), 1340-1358. <https://doi.org/10.1007/s12010-021-03682-x>
- Nikki, Bhopale, A.J., Kharga, K., Yerramsetti, N., Kumar, R., Kumar, L. and Yadav, A.K., (2025). Design, synthesis, biological evaluation and in silico study of N-(Pyrimidin-2-yl)alkyl/arylamide derivatives as quorum sensing inhibitors against *Pseudomonas aeruginosa*. *Mol Divers*, 29(3), 2001-2016. <https://doi.org/10.1007/s11030-024-10955-0>
- Ning, Y., Wang, X., Chen, P., Liu, S., Hu, J., Xiao, R., Li, L. and Lu, F., (2022). Targeted inhibition of methicillin-resistant *Staphylococcus aureus* biofilm formation by a graphene oxide-loaded aptamer/berberine bifunctional complex. *Drug Deliv*, 29(1), 1675-1683. <https://doi.org/10.1080/10717544.2022.2079768>
- Noori, H.G., Tadjrobehkar, O. and Moazamian, E., (2023). Biofilm stimulating activity of solanidine and Solasodine in *Pseudomonas aeruginosa*. *BMC Microbiol*, 23(1), 208. <https://doi.org/10.1186/s12866-023-02957-z>
- Nortje, N.Q., Aribisala, J.O., Pillay, C. and Sabiu, S., (2025). Molecular modelling and experimental validation of mangiferin and its related compounds as quorum sensing modulators of *Pseudomonas aeruginosa*. *Arch Microbiol*, 207(3), 53. <https://doi.org/10.1007/s00203-025-04240-3>
- Nouh, H.S., El-Zawawy, N.A., El-Sapagh, S., Shalamesh, E.M. and Metwally, S.M., (2026). Harnessing the endophytic *Clavospora lusitanae* for the biogenic synthesis of ethylene glycol-capped cerium oxide nanoparticles: a green approach to combat respiratory *Pseudomonas aeruginosa*. *Microb Cell Fact*, 25(1), 177. <https://doi.org/10.1186/s12934-026-03091-x>
- Nurfauziah, P., Sultan, A.R., Helpia, H. and Aswad, M., (2026). Drug Repurposing of Antihistamines as Antibiotic Adjuvants to Inhibit Biofilm Formation in Methicillin-Resistant *Staphylococcus aureus*: An In Silico and In Vitro Approach. *Trends Sci*, 23(10), 13430. <https://doi.org/10.48048/tis.2026.13430>
- Omar, A.M., Mohammad, K.A., Almalki, M., Abuelnaga, K.O. and Ibrahim, S.R.M., (2025). Integrated Experimental and Computational Discovery of Repurposed and Novel Inhibitors Targeting *Staphylococcus aureus* Biofilms. *J Pharm Bioallied Sci*, 17(3), 140-150. https://doi.org/10.4103/jpbs.jpbs_1389_25
- Orababa, O.Q., Furner-Pardoe, J., Gale, A., Anonye, B., Ratcliff, J., Reddy, N., Maset, R.G., Harrington, N.E., Subhaskaran, S., Holden, S., Diggle, S.P., Corre, C. and Harrison, F., (2026). Uncovering the mechanism of action of a historical antimicrobial against *S. aureus* and *A. baumannii*. *mSphere*, 11(9), e00494-26. <https://doi.org/10.1128/msphere.00494-26>
- Orlandi, V.T., Martegani, E., Trivellin, N., Bolognese, F. and Caruso, E., (2023). Photo-Inactivation of *Staphylococcus aureus* by Diaryl-Porphyrins. *Antibiotics*, 12(2), 228. <https://doi.org/10.3390/antibiotics12020228>
- Owring, M. and Gholami, A., (2024). Green-synthesized silver nanoparticles from *Zataria multiflora* as a promising strategy to target quorum sensing and biofilms in *Pseudomonas aeruginosa*. *Heliyon*, 10(19), e38395. <https://doi.org/10.1016/j.heliyon.2024.e38395>
- Page, M.J., McKenzie, J.E., Bossuyt, P.M., et al., (2021). The PRISMA 2020 statement: an updated guideline for reporting systematic reviews. *BMJ*, 372, n71. <https://doi.org/10.1136/bmj.n71>
- Patel, M., Siddiqui, A.J., Ashraf, S.A., Surti, M., Awadelkareem, A.M., Snoussi, M., Hamadou, W.S., Bardakci, F., Jamal, A., Jahan, S., Sachidanandan, M. and Adnan, M., (2022). Lactiplantibacillus plantarum-Derived Biosurfactant Attenuates Quorum Sensing-Mediated Virulence and Biofilm Formation in *Pseudomonas aeruginosa* and *Chromobacterium violaceum*. *Microorganisms*, 10(5), 1026. <https://doi.org/10.3390/microorganisms10051026>
- Paunova-Krasteva, T., Dimitrova, P.D., Damyanova, T., Borisova, D., Leseva, M., Uzunova, I., Dimitrova, P.A., Ivanova, V., Trendafilova, A., Veleva, R. and Topouzova-Hristova, T., (2025). Interference of *Pseudomonas aeruginosa* Virulence Factors by Different Extracts from *Inula* Species. *Pharmaceuticals*, 18(12), 1824. <https://doi.org/10.3390/ph18121824>
- Pei, Z.J., Li, C., Dai, W., Lou, Z., Sun, X., Wang, H., Khan, A.A. and Wan, C., (2023). The Anti-Biofilm Activity and Mechanism of Apigenin-7-O-Glucoside Against *Staphylococcus aureus* and *Escherichia coli*. *Infect Drug Resist*, 16, 2129-2140. <https://doi.org/10.2147/IDR.S387157>
- Peppoloni, S., Colombari, B., Tagliazucchi, D., Odorici, A., Ventrucci, C., Meto, A. and Blasi, E., (2022). Attenuation of *Pseudomonas aeruginosa* Virulence by Pomegranate Peel Extract. *Microorganisms*, 10(12), 2500. <https://doi.org/10.3390/microorganisms10122500>
- Piruthivraj, P., Maha Swetha, B.R., Anita Margret, A., Rosita, A.S., Rengasamy, P., Krishnamoorthy, R., Gatasheh, M.K., Elfaki Ibrahim, K., Ansari, S. and Vijayakumar, N., (2024). In vitro and in silico evaluation of anti-quorum sensing activity of

- marine red seaweeds *Portieria hornemannii* and *Halymenia dilatata*. *J King Saud Univ Sci*, 36(6), 103188. <https://doi.org/10.1016/j.jksus.2024.103188>
- Porzio, E., Andrenacci, D. and Manco, G., (2023). Thermostable Lactonases Inhibit *Pseudomonas aeruginosa* Biofilm: Effect In Vitro and in *Drosophila melanogaster* Model of Chronic Infection. *Int J Mol Sci*, 24(23), 17028. <https://doi.org/10.3390/ijms242317028>
- Pratiwi, S.U.T., Handayani, T.T., Hamzah, H., Sari, R., Damayanti, E., Allimi, H.S. and Nurhidayat, L., (2026). Quorum Quenching Potential of the Indigenous Kalimantan Fern *Stenochlaena palustris* Against *Pseudomonas aeruginosa*. *Pak J Biol Sci*, 29(2), 60-75. <https://doi.org/10.3923/pjbs.2026.60.75>
- Prieto-Rodríguez, J.A., Hernández-Moreno, L.V., Pabón-Baquero, L.C., Patiño-Ladino, O.J. and Cuca-Suárez, L.E., (2026). Inhibition of Quorum Sensing-Controlled Virulence Factors and Biofilm in *Pseudomonas aeruginosa* by Piper Species. *Antibiotics*, 15(6), 627. <https://doi.org/10.3390/antibiotics15060627>
- Proctor, C.R., Taggart, M.G., O'Hagan, B.M.G., McCarron, P.A., McCarthy, R.R. and Ternan, N.G., (2023). Furanone loaded aerogels are effective antibiofilm therapeutics in a model of chronic *Pseudomonas aeruginosa* wound infection. *Biofilm*, 5, 100128. <https://doi.org/10.1016/j.biofilm.2023.100128>
- Qaralleh, H., (2023). Chemical Composition and Quorum Sensing Inhibitory Effect of *Nepeta curviflora* Methanolic Extract against ESKAP *Pseudomonas aeruginosa*. *J Pharmacopuncture*, 26(4), 307-318. <https://doi.org/10.3831/KPI.2023.26.4.307>
- Qaralleh, H., (2025a). Antivirulence potential of morin hydrate against *Pseudomonas aeruginosa*: Inhibition of biofilm formation, quorum sensing, and virulence gene expression. *Microb Biosyst*, 10(4). <https://doi.org/10.21608/mb.2025.383488.1314>
- Qaralleh, H., (2025b). Attenuation of Quorum Sensing, Virulence Factors, and Biofilm Formation in *Pseudomonas aeruginosa* by *Psidium guajava* Leaf Extract. *Jordan J Biol Sci*, 18(2), 301-313. <https://doi.org/10.54319/jjbs/180211>
- Qaralleh, H., Saghir, S.A.M., Al-Limoun, M.O., Dmor, S.M., Khleifat, K., Al-Ahmad, B.E.M., Al-Omari, L., Tabana, Y., Mothana, R.A., Al-Yousef, H.M. and Alqahtani, A.M., (2024). Effect of *Matricaria aurea* Essential Oils on Biofilm Development, Virulence Factors and Quorum Sensing-Dependent Genes of *Pseudomonas aeruginosa*. *Pharmaceuticals*, 17(3), 386. <https://doi.org/10.3390/ph17030386>
- Qin, J., Yu, L., Peng, F., Ye, X., Li, G., Sun, C., Cheng, F., Peng, C. and Xie, X., (2023). Tannin extracted from *Penthorum chinense* Pursh, a potential drug with antimicrobial and antibiofilm effects against methicillin-sensitive *Staphylococcus aureus* and methicillin-resistant *Staphylococcus aureus*. *Front Microbiol*, 14, 1134207. <https://doi.org/10.3389/fmicb.2023.1134207>
- Raghoonandan, A., Dweba, Y., Aruwa, C.E. and Sabiu, S., (2025). Metabolomic fingerprinting, molecular modelling and experimental bioprospection of *Helianthus annuus* seed cultivars as *Pseudomonas aeruginosa* LasR modulators. *Bioorg Chem*, 154, 108046. <https://doi.org/10.1016/j.bioorg.2024.108046>
- Ramesh, A., Kanagaraja, A., Gopinath, S.C.B. and Raman, P., (2026). Influence of nonpolar aliphatic amino acids on *Pseudomonas aeruginosa* for virulence factors production. *Biotechnol Appl Biochem*, 73(4), 1875-1884. <https://doi.org/10.1002/bab.70139>
- Ramezani, H., Sazegar, H. and Rouhi, L., (2026). Rutin-luteolin flavonoid-encapsulated chitosan nanoparticles: a novel strategy to combat multidrug-resistant *Pseudomonas aeruginosa*. *BMC Biotechnol*, 26(1), 15. <https://doi.org/10.1186/s12896-025-01087-w>
- Rasamiravaka, T., Mol, A., Duez, P., El Jaziri, M. and Baucher, M., (2026). Pentacyclic Triterpenoid Acids Inhibit the Expression of Quorum Sensing-Related Virulence Factors and the Formation of Biofilm in *Pseudomonas aeruginosa* PAO1. *Antibiotics*, 15(6), 623. <https://doi.org/10.3390/antibiotics15060623>
- Rastgar, M.G., Rasti, B. and Zamani, H., (2022). Ibuprofen involves with the reduced expression of *pelD* and *pelF* in pathogenic *Pseudomonas aeruginosa* strains. *Arch Microbiol*, 204(6), 329. <https://doi.org/10.1007/s00203-022-02930-w>
- Ray, R.R., (2024). Antibiofilm activities of the floral extract of *Clitoria ternatea* against the biofilm of two nosocomial pathogens, namely *Staphylococcus aureus* and *Pseudomonas aeruginosa*. *Pharm Sci Asia*, 51(2), 133-144. <https://doi.org/10.29090/psa.2024.02.24.1347>
- Riahi, A., Mabudi, H., Tajbakhsh, E., Roomiani, L. and Momtaz, H., (2024). Optimizing chitosan derived from *Metapenaeus affinis*: a novel anti-biofilm agent against *Pseudomonas aeruginosa*. *AMB Express*, 14(1), 77. <https://doi.org/10.1186/s13568-024-01732-1>
- Ricafrete, R.M.L. and Malalay, A.P., (2026). Synergistic Anti-quorum Sensing and Anti-biofilm Activities of Crude *Terminalia catappa* Leaf Extract Combined With Ciprofloxacin Against *Pseudomonas aeruginosa*. *Cureus*, 18(2): e103643. <https://doi.org/10.7759/cureus.103643>
- Rossetto, V., Moore-Machacek, A., Woods, D.F., Galvão, H.M., Shanahan, R.M., Hickey, A., O'Leary, N., O'Gara, F., McGlacken, G.P. and Reen, F.J., (2023). Structural modification of the *Pseudomonas aeruginosa* alkylquinoline cell-cell communication signal, HHQ, leads to benzofuranoquinolines with anti-virulence behaviour in ESKAPE pathogens. *Microbiology*, 169(3), 001303. <https://doi.org/10.1099/mic.0.001303>
- Saadati, F., Shahyari, S., Sani, N.M., Farajzadeh, D., Zahiri, H.S., Vali, H. and Noghabi, K.A., (2022). Effect of MA01 rhamnolipid on cell viability and expression of quorum-sensing (QS) genes involved in biofilm formation by methicillin-resistant *Staphylococcus aureus*. *Sci Rep*, 12(1), 14833. <https://doi.org/10.1038/s41598-022-19103-w>
- Sabir, S., Das, T., Kuppusamy, R., Yu, T.T., Willcox, M.D., Black, D.S. and Kumar, N., (2023). Novel quinazolinone disulfide analogues as pqs quorum sensing inhibitors against *Pseudomonas aeruginosa*. *Bioorg Chem*, 130, 106226. <https://doi.org/10.1016/j.bioorg.2022.106226>
- Sadeva, I.G.K.A., Wulandari, P.A., Prasetyo, A.V., Wahyuntika, L.P.N., Rahadi, P.N.K., Sasmana, I.G.A.P., Putra, I.M.R. and Darwinata, A.E., (2022). Analysis of anti-quorum-sensing and antibiofilm activity by pomelo peel extract (*Citrus maxima*) on multidrug-resistance *Pseudomonas aeruginosa*. *Biomedicine (Taipei)*, 12(4), 20-33. <https://doi.org/10.37796/2211-8039.1364>
- Sagar, P.K., Sharma, P. and Singh, R., (2022). Inhibition of Quorum Sensing Regulated Virulence Factors and Biofilm Formation by *Eucalyptus globulus* against Multidrug-Resistant *Pseudomonas aeruginosa*. *J Pharmacopuncture*, 25(1), 37-45. <https://doi.org/10.3831/KPI.2022.25.1.37>
- Sagar, P.K., Sharma, P. and Singh, R., (2024). Anti-Quorum Sensing and Anti-Biofilm Activity of Ginger (*Zingiber officinale*) Rhizomes against Multidrug-Resistant Clinical Isolates of *Pseudomonas aeruginosa*. *Avicenna J Med Biotechnol*. <https://doi.org/10.18502/ajmb.v16i1.14171>
- Sajeevan, A., Andrew, D.J., Patra, T.N., Solomon, A.P. and Dandela, R., (2025). Novel synthesis and anti-pathogenic properties of ensifentrine and its intermediates against *Pseudomonas aeruginosa*. *RSC Adv*, 15(17), 13053-13063. <https://doi.org/10.1039/d5ra01722j>
- Saleh, R.M. and Hassan, O.M., (2024). Antibacterial, Antibiofilm, and Quorum Quenching Properties of Biogenic Chitosan Silver Nanoparticles Against *Staphylococcus aureus*. *BioNanoScience*, 14(4), 4456-4468. <https://doi.org/10.1007/s12668-024-01573-z>
- Salem, M.H., Azmy, A.F., Dishisha, T. and Dessouky, N., (2025). *Pseudomonas aeruginosa* clinical isolates in Egypt: phenotypic, genotypic, and antibiofilm assessment of Pluronic F-127. *BMC Microbiol*, 25(1), 245. <https://doi.org/10.1186/s12866-025-03946-0>
- Samreen and Ahmad, I., (2025). Anti-infective synergy of *Acacia nilotica* bioactive fraction and methyl gallate with meropenem against pathogenicity of *Pseudomonas aeruginosa*. *3 Biotech*, 15(7), 209. <https://doi.org/10.1007/s13205-025-04372-9>
- Santajit, S., Tunyong, W., Horpet, D., Binnut, A., Kong-Ngoen, T., Wisessaowapak, C., Thavorasak, T., Pumirat, P. and Indrawattana, N., (2024). Unveiling the Antimicrobial, Anti-biofilm, and Anti-Quorum-Sensing Potential of *Paederia foetida* Linn. Leaf Extract against *Staphylococcus aureus*: An

- Integrated In Vitro-In Silico Investigation. *Antibiotics*, 13(7), 613. <https://doi.org/10.3390/antibiotics13070613>
- Schütz, C. and Empting, M., (2018). Targeting the Pseudomonas quinolone signal quorum sensing system for the discovery of novel anti-infective pathoblockers. *Beilstein J Org Chem*, 14, 2627–2645. <https://doi.org/10.3762/bjoc.14.241>
- Setiawati, S., Sholikah, E.N., Nuryastuti, T., Jumina, J., Lisdianti, P. and Mustofa, M., (2024). The potency of Actinomycetes InaCC A758 against dual-species biofilms: Candida albicans and Staphylococcus aureus. *J Appl Pharm Sci*, 14(8), 188-196. <https://doi.org/10.7324/JAPS.2024.144035>
- Shalmali, K. and Srividya, S., (2026). Investigating the anti-biofilm and wound healing capability of thyme essential oil in the context of multidrug-resistant Pseudomonas aeruginosa and pathogens associated with diabetic wounds. *Res J Biotechnol*, 7(21), 17. <https://doi.org/10.25303/217rjbt017025>
- Shariati, A., Noei, M., Askarinia, M., Khoshbayan, A., Farahani, A. and Chegini, Z., (2024). Inhibitory effect of natural compounds on quorum sensing system in Pseudomonas aeruginosa: a helpful promise for managing biofilm community. *Front Pharmacol*, 15, 1350391. <https://doi.org/10.3389/fphar.2024.1350391>
- Shevate, S., Bankar, A. and Patil, N., (2022). Assessment of quorum quenching activity of Serratia spp. isolated from plant rhizosphere against quorum sensing controlled biofilm-forming pathogens. *J Microbiol Biotechnol Food Sci*, 12(3), e5753. <https://doi.org/10.55251/jmbfs.5753>
- Shilpi, J.A., Sarker, D.K., Seidel, V., Ali, M.T., Uddin, S.J., Basak, A., Chakraborty, S., Khairuzzaman, M., Nahar, A.U. and Abdus Salam, F.B., (2026). In vitro Antibiofilm Activity-directed In silico Identification of Natural Products Targeting Bacterial Biofilm Regulators SarA and LasR. *Curr Pharm Biotechnol*, 27(2), 154-167. <https://doi.org/10.2174/0113892010348855241113031323>
- Shiralizadeh, S., Alikhani, M.S., Farmany, A., Azimzadeh, M., Shokoohizadeh, L., Pourhajibagher, M., Bahador, A. and Alikhani, M.Y., (2025). Effect of photodynamic therapy with imipenem and gentamicin-derived carbon dots on the expression of quorum sensing and virulence genes in Pseudomonas aeruginosa. *BMC Microbiol*, 25(1), 358. <https://doi.org/10.1186/s12866-025-04083-4>
- Sierra-Quitian, A.G., Hernandez-Moreno, L.V., Pabon-Baquero, L.C., Prieto-Rodriguez, J.A. and Patiño-Ladino, O.J., (2023). Antiquorum and Antibiofilm Activities of Piper bogotense C. DC. against Pseudomonas aeruginosa and Identification of Bioactive Compounds. *Plants*, 12(9), 1901. <https://doi.org/10.3390/plants12091901>
- Sim, M., Boya, B.R., Kim, Y.-G., Lee, J.-H. and Lee, J., (2025). Multi-Halogenated Indoles as Antimicrobial and Antivirulence Agents Against Drug-Resistant Staphylococcus aureus. *Microb Biotechnol*, 18(12), e70280. <https://doi.org/10.1111/1751-7915.70280>
- Sim, M., Kim, Y.-G., Lee, J.-H. and Lee, J., (2024). Antibiofilm Activities of Multiple Halogenated Pyrimidines Against Staphylococcus aureus. *Int J Mol Sci*, 25(23), 12830. <https://doi.org/10.3390/ijms252312830>
- Soni, M., Pathoor, N.N., Viswanathan, A., Veeraragavan, G.R. and Ganesh, P.S., (2024). Exploring the antimicrobial and antibiofilm activities of Artocarpus heterophyllus Lam. against Pseudomonas aeruginosa PAO1. *World Acad Sci J*, 6(5), 50. <https://doi.org/10.3892/wasj.2024.265>
- Soukari, F., Williams, P., Stocks, M.J. and Cámara, M., (2018). Pseudomonas aeruginosa Quorum Sensing Systems as Drug Discovery Targets: Current Position and Future Perspectives. *J Med Chem*, 61, 10385–10402. <https://doi.org/10.1021/acs.jmedchem.8b00540>
- Tajani, A.S., Amiri Tehranizadeh, Z., Pourmohammad, A., Pourmohammad, A., Iranshahi, M., Farhadi, F., Soheili, V. and Fazly Bazzaz, B.S., (2023). Anti-quorum sensing and antibiofilm activity of coumarin derivatives against Pseudomonas aeruginosa PAO1: Insights from in vitro and in silico studies. *Iran J Basic Med Sci*. <https://doi.org/10.22038/IJBMS.2023.69016.15047>
- Touati, A., Ibrahim, N.A., Tighilt, L. and Idres, T., (2025). Anti-QS Strategies Against Pseudomonas aeruginosa Infections. *Microorganisms*, 13, 1838. <https://doi.org/10.3390/microorganisms13081838>
- Tritipmangkol, P., Sangkanu, S., Boripun, R., Jeekeawpieam, J., Chuprom, J., Nissapatorn, V., Pereira, M.L., Paul, A.K. and Mitsuwan, W., (2022). Robusta coffee extracts inhibit quorum sensing activity in Chromobacterium violaceum and reduce biofilms against Bacillus cereus and Staphylococcus aureus. *Vet World*, 2391-2398. <https://doi.org/10.14202/vetworld.2022.2391-2398>
- Trogon, J., Vera, G., Rima, M., Stigliani, J.L., Amielet, L., El Hage, S., Lajoie, B., Roques, C. and El Garah, F., (2022). Investigation of Direct and Retro Chromone-2-Carboxamides Based Analogs of Pseudomonas aeruginosa Quorum Sensing Signal as New Anti-Biofilm Agents. *Pharmaceuticals*, 15(4), 417. <https://doi.org/10.3390/ph15040417>
- Turkey, M. and Nazeam, J.A., (2025). Chromatographic fingerprinting and antibiofilm effect of Ziziphus jujuba fraction on Pseudomonas aeruginosa. *AMB Express*, 15(1), 79. <https://doi.org/10.1186/s13568-025-01886-6>
- Turkey, M.S., Nazeam, J.A., Sherbiny, F.F., Alnasser, S.M., Abdo, W., Al-Noshokaty, T.M. and Abass, S.A., (2026). Bioactive goldenseal (Hydrastis canadensis) fraction suppresses multidrug-resistant Pseudomonas aeruginosa in a rat burn wound model: oral and topical administration. *Sci Rep*, 16(1), 27506. <https://doi.org/10.1038/s41598-026-60341-z>
- Twomey, E., O'Connor, P.M., Coffey, A., Kiste, M., Guinane, C.M., Hill, C., Field, D. and Begley, M., (2024). Inhibition of Clinical MRSA Isolates by Coagulase Negative Staphylococci of Human Origin. *Antibiotics*, 13(4), 338. <https://doi.org/10.3390/antibiotics13040338>
- van Gent, M.E., van der Reijden, T.J.K., Lennard, P.R., de Visser, A.W., Schonkeren-Ravensbergen, B., Dolezal, N., Cordfunke, R.A., Drijfhout, J.W. and Nibbering, P.H., (2022). Synergism between the Synthetic Antibacterial and Antibiofilm Peptide (SAAP)-148 and Halicin. *Antibiotics*, 11(5), 673. <https://doi.org/10.3390/antibiotics11050673>
- Van Helden, S.R., Bleick, C.R., Holger, D.J., Ghali, A.E., Alexander, J., Kaye, K.S., Marshall, S.H., Rojas, L.J., Bonomo, R.A., Lehman, S.M. and Rybak, M.J., (2026). Impact of Pseudomonas aeruginosa biofilm exopolysaccharide composition on bacteriophage and bacteriophage-antibiotic combination activity. *Antimicrob Agents Chemother*, 70(1), e00925-25. <https://doi.org/10.1128/aac.00925-25>
- Vetrivel, A., Vetrivel, P., Dhandapani, K., Nachimuthu, S., Ramasamy, M., Madheswaran, S. and Murugesan, R., (2023). Inhibition of biofilm formation, quorum sensing and virulence factor production in Pseudomonas aeruginosa PAO1 by selected LasR inhibitors. *Int Microbiol*, 26(4), 851-868. <https://doi.org/10.1007/s10123-023-00338-0>
- Vuong, C., Saenz, H.L., Götz, F. and Otto, M., (2000). Impact of the agr quorum-sensing system on adherence to polystyrene in Staphylococcus aureus. *J Infect Dis*, 182, 1688–1693. <https://doi.org/10.1086/317606>
- Wang, F., Ding, Z.W., Wang, Y.J., Xu, K.Z., Dar, O.I., Wang, M., Sethupathy, S., Liu, Y.Y. and Tang, S., (2025). Aquilaria sinensis essential oil inhibits biofilm formation and virulence of Staphylococcus aureus. *Front Microbiol*, 16, 1697407. <https://doi.org/10.3389/fmicb.2025.1697407>
- Wang, X., Liu, S., Zhao, C., Zhang, X., Ning, Y. and Lu, F., (2022). Inhibition of Berberine on Methicillin-Resistant Staphylococcus aureus Biofilm Formation. *Rev Bras Farmacogn*, 32(3), 455-459. <https://doi.org/10.1007/s43450-022-00242-0>
- Wang, Z., Sun, H., Yao, X., Li, D., Xu, L., Li, Y., Tian, S. and Hou, T., (2016). Comprehensive evaluation of ten docking programs on a diverse set of protein–ligand complexes: the prediction accuracy of sampling power and scoring power. *Phys Chem Phys*, 18, 12964–12975. <https://doi.org/10.1039/c6cp01555g>
- Wang, J., Yang, J.Y., Durairaj, P., Wen, W.H., Sabapathi, N., Yang, L., Wang, B. and Jia, A.Q., (2024). Discovery and evaluation of 3-(2-isocyanobenzyl)-1H-indole derivatives as potential quorum sensing inhibitors for the control of Pseudomonas aeruginosa infections in vitro. *RSC Med Chem*, 15(9), 3256-3271. <https://doi.org/10.1039/d4md00354c>
- Warrier, A., Satyamoorthy, K. and Murali, T.S., (2025). Naringenin as a Potent Natural Biofilm Inhibitor of Pseudomonas aeruginosa in Diabetic Foot Ulcers Through lasR Competitive

- Inhibition. *Curr Microbiol*, 82(7), 305. <https://doi.org/10.1007/s00284-025-04283-1>
- Wei, Z., Li, T., Gu, Y., Zhang, Q., Wang, E., Li, W., Wang, X., Li, Y. and Li, H., (2022). Design, Synthesis, and Biological Evaluation of N-Acyl-Homoserine Lactone Analogs of Quorum Sensing in *Pseudomonas aeruginosa*. *Front Chem*, 10, 948687. <https://doi.org/10.3389/fchem.2022.948687>
- Wen, Z., Chen, C., Shang, Y., Fan, K., Li, P., Li, C., Zheng, J., Deng, Q. and Yu, Z., (2024a). Baohuoside I inhibits virulence of multidrug-resistant *Staphylococcus aureus* by targeting the transcription *Staphylococcus* accessory regulator factor SarZ. *Phytomedicine*, 130, 155590. <https://doi.org/10.1016/j.phymed.2024.155590>
- Wen, F., Wu, Y., Yuan, Y., Yang, X., Ran, Q., Gan, X., Guo, Y., Wang, X., Chu, Y. and Zhao, K., (2024b). Discovery of psoralen as a quorum sensing inhibitor suppresses *Pseudomonas aeruginosa* virulence. *Appl Microbiol Biotechnol*, 108(1), 222. <https://doi.org/10.1007/s00253-024-13067-9>
- WHO Bacterial Priority Pathogens List Advisory Group, Sati, H., Carrara, E., Savoldi, A., et al., (2025). The WHO Bacterial Priority Pathogens List 2024: a prioritisation study to guide research, development, and public health strategies against antimicrobial resistance. *Lancet Infect Dis*, 25, 1033–1043. [https://doi.org/10.1016/S1473-3099\(25\)00118-5](https://doi.org/10.1016/S1473-3099(25)00118-5)
- Xie, J., Huang, Y., Chen, H., Xia, Z., Wang, L., Yu, X., Yang, J., Xu, J., Fan, H. and Zheng, J., (2026). Raphani Semen Extract Targets the las Quorum Sensing System to Suppress *Pseudomonas aeruginosa* Biofilm and Signal Molecule Production. *Food Sci Nutr*, 14(8), e72034. <https://doi.org/10.1002/fsn3.72034>
- Yadav, A., Mahindru, I., Srivastava, N., Kumar, R., Jain, M., Kumar, L. and Yadav, A.K., (2026). Design, Synthesis, Biological Evaluation, and In Silico Study of N-(Pyrazin-2-yl)Alkyl/Aryl Amide Derivatives as Quorum Sensing Inhibitors Against *Pseudomonas aeruginosa*. *Chem Biodivers*, 23(1), e02287. <https://doi.org/10.1002/cbdv.202502287>
- Yam, J.K.H., Tan, L.Z.W., Hong, Z., Salido, M.M.S., Woo, B.Y., Yong, A.M.H., Tan, C.A.Z., Li, S.F.Y., Yang, L., Givskov, M. and Chng, S.-S., (2023). Auranoicin inhibits virulence pathways in *Pseudomonas aeruginosa*. *Bioorg Med Chem*, 79, 117167. <https://doi.org/10.1016/j.bmc.2023.117167>
- Yan, X., Hou, S., Xing, C., Zhang, Y., Chang, J., Xiao, J. and Lin, F., (2024). Design, Synthesis, and Biological Evaluation of the Quorum-Sensing Inhibitors of *Pseudomonas aeruginosa* PAO1. *Molecules*, 29(10), 2211. <https://doi.org/10.3390/molecules29102211>
- Ye, X., Mao, S., Li, Y., Yang, Z., Du, A. and Wang, H., (2023). Design, Synthesis, and Biological Evaluation of Phenyloxadiazole Sulfoxide Derivatives as Potent *Pseudomonas aeruginosa* Biofilm Inhibitors. *Molecules*, 28(9), 3879. <https://doi.org/10.3390/molecules28093879>
- Ying, J., Guo, S., Pan, Y., Li, D., Tai, Y., Li, Y., Lin, Q., Pan, L., Huang, D., Xiao, H., Pan, R., Xu, X., Xie, J., Lou, Z. and Li, P., (2025). The role of cyano-phycocyanin as a quorum sensing inhibitor to attenuate *Pseudomonas aeruginosa* virulence. *Front Cell Infect Microbiol*, 15, 1624927. <https://doi.org/10.3389/fcimb.2025.1624927>
- Yuan, Y., Yang, X., Zeng, Q., Li, H., Fu, R., Du, L., Liu, W., Zhang, Y., Zhou, X., Chu, Y., Zhang, X. and Zhao, K., (2022). Repurposing Dimetridazole and Ribavirin to disarm *Pseudomonas aeruginosa* virulence by targeting the quorum sensing system. *Front Microbiol*, 13, 978502. <https://doi.org/10.3389/fmicb.2022.978502>
- Yue, Y., Chen, K., Sun, C., Ahmed, S. and Ojha, S.C., (2023). Antimicrobial peptidase lysostaphin at subinhibitory concentrations modulates staphylococcal adherence, biofilm formation, and toxin production. *BMC Microbiol*, 23(1), 311. <https://doi.org/10.1186/s12866-023-03052-z>
- Zahmatkesh, H., Mirpour, M., Zamani, H., Rasti, B., Rahmani, F.A. and Padasht, N., (2022). Effect of samarium oxide nanoparticles on virulence factors and motility of multi-drug resistant *Pseudomonas aeruginosa*. *World J Microbiol Biotechnol*, 38(11), 209. <https://doi.org/10.1007/s11274-022-03384-4>
- Zhang, Y., Liu, X., Wen, H., Cheng, Z., Zhang, Y., Zhang, H., Mi, Z. and Fan, X., (2023a). Anti-Biofilm Enzymes-Assisted Antibiotic Therapy against Burn Wound Infection by *Pseudomonas aeruginosa*. *Antimicrob Agents Chemother*, 67(7), e00307-23. <https://doi.org/10.1128/aac.00307-23>
- Zhang, Y., Wei, W., Wen, H., Cheng, Z., Mi, Z., Zhang, J., Liu, X. and Fan, X., (2023b). Targeting Multidrug-Recalcitrant *Pseudomonas aeruginosa* Biofilms: Combined-Enzyme Treatment Enhances Antibiotic Efficacy. *Antimicrob Agents Chemother*, 67(1), e01358-22. <https://doi.org/10.1128/aac.01358-22>
- Zhong, Z., Ma, Z., Zhang, Y., Gong, Y., Ge, Y., Yang, Y., Zhou, T. and Cao, J., (2026). Evaluation of the combined efficacy of carvone and colistin against colistin-resistant *Pseudomonas aeruginosa*: in vitro and in vivo studies. *Microbiol Spectr*, 14(6), e02307-25. <https://doi.org/10.1128/spectrum.02307-25>
- Zhu, Y.Y., Jin, Q., Wang, Z.J., Wei, M.Z., Zu, W.B., Zhou, Z.S., Hu, B.Y., Zhao, Y.L., Qin, X.J. and Luo, X.D., (2025). Tripterhyponoid A from *Tripterium hypoglauca* Inhibiting MRSA by Multiple Mechanisms. *Molecules*, 30(12), 2539. <https://doi.org/10.3390/molecules30122539>