INTRODUCTION

Quorum sensing (QS) is a mechanism by which diverse microorganisms can control specific processes in response to population density. For example, many bacteria use quorum sensing to regulate a variety of physiological functions such as biofilm formation, bioluminescence, virulence factors and swarming which has been shown to contribute to bacterial pathogenecity (Li and Tian, 2012; Boban et al., 2023). Also, in Fungi such as *Candida albicans*, a number of molecules have been identified to be quorum sensing molecules which affect the abiliity of *C. albicans* to coordinate functions such as growth and polymorphism; its ability to undergo yeast-to-hyphal shift, morphogenesis and biofilm formation which are important for *C. albicans* virulence (Kruppa, 2009; Kovacs and Majoros, 2020). Such quorum sensing molecules in *Candida albicans* have been identified as farnesol and farneesoic acid, phenylethyl alcohol and tryptophol, morphogenic autoregulatory substance (MARS) (Kovacs and Majoros, 2020; Tian et al., 2021). Similarly, *Saccharomyces cerevisiae*, also uses phenylethanol and tryptophol to regulate morphogenesis during nitrogen starvation (Tian et al., 2021). Apart from microorganisms, other livingorganisms such as social insects (ants and honey bees) use quorum sensing to determine where to nest (Franks et al., 2015). In this review, our interest is in bacterial quorum sensing and its inhibition by medicinal plants; hence we reviwed recent literature on plant-origin inhibition of QS in bacteria to identify the lead bioactive compounds with QS inhibition properties.

What is Bacterial quorum sensing

Bacterial quorum sensing (QS) is a process of cell-cell communication in which bacteria produce, release and detect chemical signal molecules called autoinducers that increase in concentration in response to cell density (Rémy et al., 2018; Mukherjee and Bassler 20 19; Boban et al., 2023). The autoinducers or pheromones are observed to modulate beha vior only above a certain threshold concentration corresponding to a certain cell populati on density, or 'quorum'. QS regulates a variety of bacterial physiological functions such a s biofilm formation, bioluminescence, virulence factors and swarming which has been s hown contribute to bacterial pathogenesis. Quorum sensing is crucial for bacterial com munication and the coordination of group behaviors (Ruan et al., 2025). Gram-negative b acteria commonly use acylated homoserine lactones as signaling molecules (McLean et al., 2004). Gram-positive bacteria use autoinducing peptides (Escobar-Muciño et al., 202 2). When the concentration of these signaling molecules reaches a threshold, bacteria ca n detect them and alter gene expression (Naga et al., 2023).

Basic mechanism of quorum-sensing systems

The fundamental steps involved in detecting and responding to fluctuations in cell numb er are similar in all known quorum-sensing systems. First, low molecular weight molecul es called autoinducers are synthesized intracellularly. Second, these autoinducers are eit her passively released or actively secreted outside of the cells. As the number of bacteria l cells in a population increases, the extracellular concentration of autoinducer likewise in creases. Third, when autoinducers accumulate above the minimal threshold level require d for detection, cognate receptors bind the autoinducers and trigger signal transduction c

ascades that result in population-wide changes in gene expression. Although the steps a re similar, it is important to understand that the mechanism differs between bacteria. In Gram-negative bacteria N-acyl homoserine lactones (AHLs) are produced, which diffuse across the cell membrane (Papenfort and Bassler, 2016). In Gram-positive bacteria, oligo peptides that are actively transported are used, often relying on two-component histidine sensor kinases to detect the signal (Novick and Geisinger 2008). Thus, quorum sensing enables cells in a population to function in tandem and, in so doing; they carry out behav iors as a collective

Classical Quorum Sensing Systems

Three distinct types of quorum sensing have been discovered:

1. Autoinducer -1 (AI-1) Quorum Sensing

AI-1 is synthesized by LuxI and can freely diffuse across the cell membrane. .LuxI/LuxR-t ype QS or N-acyl-homoserine lactone(AHL) signaling (Autoinducer-I), is unique to variou s species of Gram-negative bacteria (McLean et al., 2004; Zhang et al., 2019; Zhou et al., 2020). LuxI-type protein synthesizes an acyl-homoserine lactone autoinducer, and the Lu xR-type protein detects the autoinducer. Upon binding the signal, the LuxR-type protein al ters transcription of downstream target genes. The signal receptor protein, LuxR, resides within the cytoplasm and binds with AI-1 to form a multimer complex that can bind to a '*lux* box' located upstream from the target gene on an operon. In Vibrio fischeri, the biolu minescence gene cluster is comprised of eight Lux genes LuxA-E, LuxG, LuxI and LuxR arrange d in two bidirectionally transcribed operons separated by 218bp. The operon on the right conta

ins genes required for the synthesis of the autoinducers (LuxI) and those for bioluminescence (LuxCDABEG). The LuxI gene is responsible for the production of the autoinducer synthase required for the synthesis of N-(3-oxohexanoyl)-L-homoserine lactone (OHHL). The transcriptional activator LuxR is housed in the leftward operon. At lower cell densities, LuxI undergoes basal transcription gradually accumulating OHHL in the medium until the threshold concentration is reached. As the population density increases achieving the critical concentration of OOHL, the OOHL diffuses back into the cell and binds to LuxR. Binding of the autoinducer to LuxR enhances multimer formation and then activate transcription from both the Lux operons. A blue green light with a maximum intensity at 490nm then marks the bioluminescence phenotype in *Vibrio fischeri.* The LuxCDE encode products that form the multi enzyme complex which synthesizes the aldehyde substrate utilized by luciferase and Lux G gene encodes flavin reductase and is followed by a transcription termination site (McLean et al., 2004, Zhang et al., 2019).

2. Autoinducer-2 (AI-2) Quorum Sensing

This is LuxS-encoded autoinducer-2 (AI-2) system that exist in both Gram-positive and Gram-negative bacteria. It is a major bacterial signaling molecule, often called a universal language for interspecies communication in quorum sensing. AI-2 was first discovered in the QS bacterium *Vibrio harveyi*. LuxS produces AI-2 by cleaving *S*-ribosyl-*L*-homocysteine to generate homocysteine and the AI-2 precursor 4,5-dihydroxy-2,3-pentanedione (DHP). Then, DHP spontaneously cyclises, thus forming AI-2 (Schauder et al., 2001). It is produced and recognised by many species of Gram-negative and Gram-positive bacteria. The LuxS-dependent autoinducer AI-2 is proposed to function in interspecies cell–cell communication in bacteria. In every case, production of AI-2 is dependent on the LuxS autoi

nducer synthase. The LuxS and AI-2 regulate the expression of an operon named lsr (lux S regulated) operon encoding an ATP binding cassette (ABC)-type transporter. A gene en coding a DNA-binding protein that is located adjacent to the Lsr transporter structural op eron is required to link AI-2 detection to operon expression. This gene, named lsrR, encod es a protein that represses lsr operon expression in the absence of AI-2. AI-2 induces tran scription of the *lsrACDBFGE* operon, the first four genes of which encode the Lsr transpo rt apparatus. LsrK is a kinase that phosphorylates AI-2 upon entry into the cell (Erkihun e t al., 2024).

3. **Autoinducing oligopeptide signaling**

Oligopeptide-two-component-type QS in Gram-positive bacteria. Gram-positive bacteria l ack AHL quorum sensing systems, but instead synthesizeautoinducing oligopeptides co nsisting of between 5- 17 amino acids Peptide autoinducers usually result from post tran slational modification of a larger precursor molecule. These oligopeptides are actively tr ansported out of the cell via an ATP-binding cassette (ABC) transporter complex, and are detected extracellularly by a sensor kinase, which phosphorylates a downstream respons e regulator protein[44]. The phosphorylated response regulator binds to DNA to promote th e expression of target genes. Each oligopeptide is unique to a particular species, with so me species producing several different sequences. In *Staphylococcus aureus*, various oli gopeptides modified with thiolactone rings control the production of virulence factors an d surface attachment during late exponential growth, presumably to allow host invasion[4 3]. In *Enterococcus faecalis*, the synthesis of gelatinase, a virulence factor, is activated b

y cyclic peptide containing a lactone ring. Sporulation of numerous Gram-positive species, including *Bacillus subtilis* and *Streptomyces coelicolor*, and the production of bacteriocins (antimicrobial peptides) are also controlled by various autoinducing oligopeptide mediated quorum sensing systems (Escobar-Muciño et al., 2022)

Regulatory Functions of Quorum Sensing in Bacteria

Biofilm Formation

Biofilm is an aggregate of microorganisms in which cells that are frequently embedded within a self-produced matrix of extracellular polymeric substance (EPS) adhere to each other and/or to a surface (Singh et al., 2017). The microbial cells growing in a biofilm are physiologically distinct from planktonic (free-floating single) cells of the same organism. Inerestingly, quorum sensing regulates metabolism in planktonic cells which can induce biofilm formation as well as increase virulence (Erkihun et al., 2024). Biofilm formation is one of the most important mechanism through which microorganisms escape the adverse effects of targeted antibiotics thereby evading the hosts's immune system. Biofilms can form on the inert surfaces of implanted devices such as catheters, prosthetic cardiac valves and intrauterine devices (Singh et al., 2017; Erkihun et al., 2024).

Generalized Model For Biofilm Formation

First, free-floating microorganisms colonize and attach to an abiotic or biotic surface, through intermolecular forces of van der Waals. Second, microorganisms transform from planktonic status to immobilized status, then grows through a combination of cell division and recruitment. Finally, the microcolony is formed and continuous proliferation of mic

roorganisms will build a three dimensional architecture of a biofilm (Erkihun et al., 202 4).

Biofilms and infectious disease

A biofilm is formed by bacteria and is formed by a mass of microbial cells embedded in matrix of extracellular polymeric substances (EPS) produced by the bacteria cluster (Alve s-barroco et al., 2020). Biofilms formation as a function of QS is involved in a wide variet y of microbial infections in the human body. Such infections are difficult to treat by usin g antibiotics due to the accompanying microbial biofilms. Studies have shown that appr oximately 80% of the bacteria producing chronic infections can form biofilms (Preda an d Sandulescu, 2019). Biofilms form on living surfaces as infectious processes leading to heath challenges such as urinary tract infections, catheter asssociated infections,otitis media, periodontitis, chronic bacterial prostatitis, formation of dental plaque, gingivitis, c oating contact lenses.They form on abiotic surfaces as less common but more lethal pro cesses such as endocarditis, infections in cystic fibrosis, and infections of permanent in dwelling devices such as joint prostheses and heart valves (Preda and Sandulescu, 201 9; Hawas et al., 2022; Ali et al., 2024, Erkihun et al., 2024).

Virulence: is the degree of pathogenicity within a group or species of bacteria as indicat ed by case fatality rates and/or the ability of the organism to invade the tissues of the h ost. The ability of bacteria to cause disease is described in terms of the number of infect ing bacteria, the route of entry into the body, the effects of host defense mechanisms, an d intrinsic characteristics of the bacteria called virulence factors.

Virulence factors: are factors that promote establishment and maintenance of an infecti on by colonization and immune evasion mechanisms (Cheung et al., 2021). They are mo lecules expressed and secreted by pathogens that enable them to achieve: colonization of a niche in the host, immunoevasion, evasion of the host's immune response, immuno suppression, inhibition of the host's immune response, entry into and exit out of cells (if t he pathogen is an intracellular one) and uptake of nutrition from the host (Martínez et a l., 2019; Cheung et al., 2021). Such virulence factors include toxins, enzymes and biofilm s (Khan et al., 2023). In bacteria such as *Pseudomonasaeruginosa*, some virulence fact ors reported include: pyoverdin, pyocyanin, and rhamnolipid (Khan et al., 2023). In *Staph ylococcus aureus*, virulence factors identified includes:α-toxin hemolysins, protein A, hya luronidase, protease, coagulase, lipases, deoxyribonucleases and enterotoxins. In *Strept ococcus pyogenes* they include: M protein, lipoteichoic acid, hyaluronic acid capsule, de structive enzymes (including streptokinase, streptodornase, and hyaluronidase), and exot oxins. Bacteria use quorum sensing to synchronise release of the virulence factors. Strat egies to combat certain bacterial infections by targeting these specific virulence factors and mobile genetic elements have been proposed (Preda and Sandulescu, 2019; Hawas et al., 2022; Ali et al., 2024, Erkihun et al., 2024).

Sporulation

Sporulation is the process by which vegetative cells change from one stage to another to form a metabolically inactive and highly resistant endospores (Koopma et al., 2022). Sp orulation is initaed by conditions unfavourable for growth such as depletion of nutrient.

Spores allow organisms to survive in extreme conditions they are not suited to, including very dry, acidic or cold conditions (Huang and Hull 2017). They also allow aerobic bacter ia to grow after a period without oxygen and anaerobic bacteria to do so following expos ure to oxygen. Sporulation occurs in *Bacillus subtilis* when the nutrient supplied to the ba cteria is depleted due to deteriorated environmental conditions. Lower cell densities caus e poor sporulation with starvation of *Bacillus subtilis* cells. At higher cell densities, sporul ation requires extracellular and environmental signals and a part of this phenomenon is controlled through quorum sensing (Windsor 2020).

Swarming motility

Swarming motility is defined operationally as a fast coordinated bacterial surface move ment aided by rotating flagellla (Kearns 2010). Studies show that the pathogenesis and virulence of *P. aeruginosa* are greatly contributed by its different kinds of motilities, inclu ding twitching motility, sliding motility, swimming motility and swarming motility (Yeung et al., 2009).

Inhibition of Quorum Sensing as a Therapeutic Strategy

Interfering with the microbial QS system by quorum inhibition (QI) or quorum quenching (QQ) has been suggested as a potential strategy for disease control (Bouyahya et al., 20 17; Ghosh et al., 2022; Samreen et al., 2022, Khan et al., 2023). This is because QQ aims to shut down the virulence expression in pathogenic bacteria rather than restrict cell gro wth and has shown potential to overcome drug toxicities, complicated super-infection an d antibiotic resistance because it is different from conventional antibiotic therapy, which kills bacteria by interfering with DNA, RNA or protein synthesis, leading to the emergence

of antibiotic-resistant superbugs, QI or QQ is a promising approach that may lead to the development of very effective next generation antibacterial drugs based on interfering wi th bacterial communication to block QS-mediated pathogenic infection. Targeting quoru m sensing has emerged as a promising strategy to combat bacterial infections by disrup ting bacterial communication and reducing virulence without necessarily killing the bact eria (Truchado et al., 2015; Bouyahya et al., 2017; Ghosh et al., 2022; Samreen et al., 202 2, Khan et al., 2023). Some medicinal plants have the ability to interfere with quorum sen sing, suggesting a potential mechanism of action for their therapeutic effects (Martínez et al., 2019; Khan et al., 2023). Natural compounds found in medicinal plants are gaining importance as new strategies for combating pathogens and inhibiting the genes involve d in quorum sensing (Ghosh et al., 2022). Apart from plants, compounds with quorum q uenching or quorum sensing inhibition have been discovered from other natural sources such as food, prokaryotic organisms, fungus, and marine organisms (Qin et al., 2020,). Although we briefly highlighted the later, our interest is in plant origin inhibitors of bacteri al quorum sensing.

Classification of Inhibitors of Bacterial Quorum Sensing

Based on the origin or source, QS inhibitors are classified as: Bacteria-origin antagonists and Non-bacteria-origin antagonists.

Bacteria-Origin QS Antagonists

QS inhibitors from bacteria are mainly pheromone- degrading enzymes- lactonases, acyl ases, oxidoreductases and paraoxonases. They bring about enzymatic degradation of a utoinducers to block quorumsensing-dependent infectionby a process called *quorum qu enching*. A good example of these enzymes is a broad-spectrum AHL-degrading AiiA enz ymes found to be widespread in the *Bacillus* sp. (Boban et al., 2023). AHL-lactonase (Aii A) enzyme has been reported to inactivatebacterial virulence by quorum sensing through hydrolysis of the lactone ring of AHLs. Quorum quenching potential was also detected in species of *Lactobacillus* and acetic acid bacteria (AAB) (Almeida et al., 2020).

Non-Bacteria-Origin Antagonists

These are synthetic agents, compounds from plant and other sources such as fungus, w hich have been found to be capable of altering bacteria group behaviours. They are anal ogs to the naturally occurring AHL signals molecules and inhibit the AHL signal receptor proteins.

Synthetic Antagonists

Analogues of AHL which include N- (trans-2-hydroxycyclopentyl)-3-oxododecanamide an d N-(2-oxocyclohexyl)-3-oxododecanamide. Inhibitors of AI-2 are hydroxylated pyrrolidine s, 5’-(p-nitrophenyl) thioadenosine and 5-nitroindazole. At subinhibitory concentrations, a ntibiotics such as Azithromycin, ceftazidime and ciprofloxacin exhibit QS inhibitory activ ity.

Plant-Origin Antagonists

Plants have long been recognized as reservoirs of bioactive compounds with therapeutic potential, and recent investigations have revealed that a significant number of plant-derived metabolites possess the remarkable ability to interfere with bacterial quorum sensing systems (Hosseinzadeh et al., 2020; Ghosh et al., 2022). These natural compounds, often referred to as quorum sensing inhibitors, can disrupt various stages of the quorum sensing pathway, effectively attenuating bacterial virulence and biofilm formation without exerting direct bactericidal or bacteriostatic effects. Many medicinal plants contain compounds that can inhibit quorum sensing in bacteria. These compounds may act by interfering with the production, detection, or signaling of autoinducers, thereby disrupting quorum sensing-dependent behaviors (Ghosh et al., 2022; Truchado et al., 2015; Bouyahya et al., 2017). By interfering with quorum sensing, medicinal plant extracts can prevent biofilm formation or promote biofilm dispersal, rendering bacteria more susceptible to antimicrobial agents and host immune responses (Hawas et al., 2022).

Extracts from various plants have demonstrated the ability to interfere with quorum sensing in different bacterial species (Truchado et al., 2015; Bouyahya et al., 2017; John and Ramesh, 2020; Hawas et al., 2022). These plants contain a diverse array of phytochemicals, including flavonoids, alkaloids, terpenoids, and phenolic compounds, which may contribute to their quorum sensing inhibitory activity (Samreen et al., 2022). Exploration of alternative anti-infective mechanisms, such as quorum sensing inhibition, holds promise for identifying innovative approaches to drug development that can effectively address the escalating challenge of antibiotic resistance (Khan et al., 2023). The integration of quo

rum sensing inhibitors with conventional antibiotic therapies presents a compelling strat egy to augment treatment efficacy and mitigate the evolutionary pressures that drive the emergence of antibiotic-resistant strains (Almeida et al., 2018, Koshak et al., 2024).

Specific Examples of Plant-Origin Antagonists

Several studies have demontrated that various bioactive compounds found in plants hav e quorum sensing inhibition effects against bacteria at different concentrations Table1.

Zhu et al explored the effects of root exudates of *Sedumalfredii* on quorum sensi ng ability of *Pseudomonas aeruginosa*. Several substancesincluding: leucine, serine, thr eoline, aspartic acid, glycerol, sorbitol, 2-piperidine carboxylic acid, squalene, tropone, m ethyl oleate, monolinolein and thymol were found to have quorum sensing inhibition effe cts. Out of these subsatnces, thymol50µmol/L showed the best quoru. quenching ability by inhibition of protease and elastase synthesis, as weel as suppression of the expressi on of *las*B in QS of *P. aeruginosa*.

Danaraj et al studied the Seagrass *Halodule pinifolia* for anti-quorum sensing aciv ity against *P. aeruginosa*. A total of eight bioactive compounds were identified including protocatacheuic acid, rosmarinic acid, caffeic acid, *P*-coumaric acid, 4-methoxybenzoic a cid , 4-hydroxybenzoic acid, vanillic acid and naringenin. Among these, 4-methoxybenzoi c acid (4-MBA) with MIC of 62.5 µg/ml showed the best antibacterial and anti-quorum se nsing inhibition effects by downregulation of virulence factor production in *P. aeruginos a*.

Shukla et al. studied the impact of gingerol on inhibiting the QS pathways of *P. a eruginosa*. It was observed that its concentration of 30µg/ml was able to suppress multi

ple QS driven production of biomolecules (including biofilm, exoploysaccharides (EPS), pyocyanin, rhamnolipid) without any significant suppression in growth of *P. aeruginosa*. This was achieved by interfering with various QS-receptors (LasR, PhzR and RhlR).

Koshak et al investigated the antimicrobial and anti-virulence effects of *Aframom um melegueta* paradise seeds against Gram-negative bacteria. Specifically, the bioactive compound 4-shogaol at the concentration of 0.4 µg/ml showed anti-virulence effects ag ainst *P. aeruginosa* by reduction of biofilm formation, repression of virulence factor pro duction and down regulation of QS-related genes.

Samreen et al studied the Anti-quorum sensing and biofilm inhibitory effect of*Aca cia nilotica* after screening some medicinal plants. Ethyl acetate fraction of *Acacia niloti ca*showed broad spectrum anti-QS activity against QS-mediated virulence factors (pyocy nin, pyoverine, protease, swarming motility) of *P. aeruginosa* and inhibition of violacein production in *Chromobacteriumviolaceum* at varying subMICs (125, 62.5 and 31.25 µg/ ml) of ethyl acetate fractionof *Acacia nilotica*. Also, at 250-62.5 µg/ml concentration of t he fraction, QS-linked factors of *Serratia marcescens*was effectively interfered with and caused significant reduction in production of prodigiosin, as well as reduction in swarmi ng motility.

Khan et al investigated the antibiofilm and anti-quorum sensing activity of *Psidiu m guajava* L. Leaf extract on *P. aeruginosa* and *Chromobacterium violaceum*. The bioac tive compounds were not identified however, the *Psidium guajava* methanolic leaf extrac t (PGME) at different MICs showed inhibition of biofilm formation and concentration-dep endent inhibition of virulence factor production in *P. aeruginosa*, and significantly, at sub

-minimum inhibitory concentration (MIC) of 250 µg/ml, exhibited QS inhibition by interfering with violacein production in *C. violaceum*.

Al-Rabia et al explored the potential antibiofilm and antivirulence activities of Thymoquinone (TQ) from *Nigella sativa* against PA01 strain of *P. aeruginosa* to ascertain its anti QS effects. Results showed that thymoquinone at concentration of 125µg/ml (1/4 MIC) significantlty reduced biofilm formation, virulence factors production, as well as inhibition of swarming motility and also significantly downregulated the expression of QS genes:*rhlI*, *rhlR*, *lasI*, and *lasR*.

Saha et al investigated the effects of phytomolecules (quercetin and naringenin) on *Vibrocholerae*. Quercetin and naringenin at 50µg/ml showed antibiofilm activity, biofilm dispersal, QS inhibition, two-fold downregulation in the expression of *gbpA,vpsA,* and *mbaA* QS-associated genes, as well as inhibition of QS-dependent production of violacein in *Chromobacterium violaceum* by 70-85%.

Apart from human pathogens, Bektaș et al. investigated the effects of *Laurus nobilis essential oil* (LEO) against fish pathogens *Pseudomonas* species; the results showed that 1,8-cineole or eucalyptol (48.43%) and α-terpinyl acetate (14.78%) were the most active compounds against the tested pathogens out of the 15 components of the essential oil extracted.LEO showed antibiofilm activity against *P. fluorescens* and *P. Putida* but not *P. aeruginosa*.

Also, Guzman et al investigated extracts from *Ikom* (*Piper betle*L.)against quorum sensing in shrimp pathogen *Vibro harveyi.Piper betle* crude extract and alkoid extrcts showedinhibition of QS-dependent biofilm formation and bioluminescence of *Vibro harv*

eyi without growth inhibition; QS genes were affected including: *luxM*, *luxN*, *luxP*, *luxS*, lu

xO, and *luxR*. There was modulation of AI-1 and AI-2 cascades in the *Vibro* spp.

Table 1. Concentration dependent inhibition of bacterial quorum sensing by medicinal plants

Organism	Medicinal plant	Bioactive compound	Concentration	Effects	References
P. aeruginosa	Ginger	Gingerol (Sigma-Aldrich)	30 µg/ml	Interfere with various QS-receptors (LasR, PhzR and RhlR)	Shukla et al 2021
P. aeruginosa	*Psidium guajava*	Not identified (Methanolic leaf extract)	500, 250, 125, and 62.5 µg/ml	Dose-dependent Inhibition of biofilm, concentration-dependent inhibition of pyoverdine, pyocyanin and rhamnolipid production	Khan et al 2023
Chromobacteriumviolaceum			250 µg/ml (sub-MIC)	QS inhibition, Inhibition of violacein formatio	

				n	
P. aeruginosa	*Sedumalfredii* root exudates	Thymol	50 µmol/L	Inhibition of protease and elastase synthesis, suppression of the expression of *las*B in QS	Zhu et al 2021
P. aeruginosa	Seagrass *Halodule pinifolia*	4-methoxybenzoic acid (4-MBA)	62.5 µg/ml	Downregulation of QS-mediated transcript levels, reduction of virulence factor production	Danaraj et al 2020
Vibro cholerae	Plant	Quercetin and naringenin	50µg/ml	Antibiofilm, biofilm dispersal, QS inhibition, two-fold downregulation in the expression of *gbpA,vpsA,* and *mbaA* QS-associated genes	Saha et al 2023
Chromobacterium violaceum				Inhibition of QS-dependent production of violacein Reduction in violacein procuction	
Serratia marcescens MTCC97	*Acacia nilotica*	Ethyl acetate fraction	250, 125, 62.5 µg/ml	Attenuation of QS-linked virulence factor, reduction in production of prodigiosin, reduction in swarming motility and biofilm production.	Samreen et al 2022
Chromobacterium violaceum			125, 62.5 and 31.25 µg/ml	inhibition of vio	

				lacein producti on, reduction in biofilm product ion.	
P. aeruginosa			500, 250 and 125 µg/ml	reduction in bio film production and QS-mediat ed virulence fac tors (pyocynin, pyoverine, prote ase, swarming motility)	
P. aeruginosa	*Aframomu m meleguet a* seeds	4-shagaol	0.4 µg/ml	Reduced biofil m formation, re pression of viru lence factor pro duction, down r egulation of QS -related genes	Koshak et al 2024
P. aeruginosa	*Nigella sativ a*	Thymoquinon e	125 µg/ml	reduced biofilm formation, repr ession of virule nce factor prod uction, inhibitio n of swarming motility downre gulation of expr ession QS gene s: *rhlI*, *rhlR*, *lasI*, and *lasR*.	Al-Rabia e t al 2024
P. fluorescens	*Laurus nobil is*	1,8-cineole or e ucalyptol	48.43%	Antibiofilm	Bektaș et al 2023
P. putida		α-terpinyl acet ate	14.78%	Antibiofilm	
Vibro harveyi	*Piper betle*	Crude extract (CE) and crude alkaloids (CA)	18.12% and 1.45%	Inhibition of QS -dependent biof ilm formation a nd bioluminesc ence. Modulation of autoinducer (A	Guzman e t al 2021

Key: QS- quorum sensing, AI- autorinducer

CONCLUSION

Quorum sensing inhibition (QSI) is different from conventional antibiotic therapy which k ills bacteria by interfering with DNA, RNA or protein synthesis, leading to the emergence of antibiotic resistant superbugs. It is a promising approach that may lead to the develop ment of very effective next generation antibacterial drugs based on interfering with bacte rial communication to block QS-mediated pathogenic infection. Plant-origin inhibitors of bacterial quorum sensing are proven to have therapeutic effect by disrupting the ability o f a pathogen to sense its cell density and diminish the capability of triggering the virulent expression.

Conflict of Interest

The authors declare no conflict of interest regarding this work

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