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# Effects the plants on quorum sensing and biofilm by *Acinetobacter baumanii* and *Pseudomonas aeruginosa*

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**Abstract**
In this study, used the ainetobacter and pseudomonas is called nosocomial infection and multidrug-resistant and causes many disease such as bacteremia, pneumonia, meningitis, urinary tract infections and wound infections. This study aimed to evaluate the effects antibiotics at minimum inhibitory concentration and sub-minimum inhibitory concentration on biofilm formation. The plant collection from the market except on collection from tree and worked extract plant and applied on bacteria as inhibition factors for bacteria, the first step to determine that's plants have anti-quorum sensing activity by used over lay assay which is component two layer of nutrient agar first layer is solid nutrient agar with volume 10ml and second layer is semi solid with volume 15ml mixing with serratia marscence worked pore with stable diameter put 100ul from crude extract of plants after 24h appear result to determinant of which of plant have anti-quorum sensing or not. Worked biofilm test and mixing extract of plant with bacteria after 24h show results which of plant can inhibit bacteria or not, add one step to sure that is crude extract not kill bacteria take from each concentration 100ul and culture on nutrient agar.

**Keywords:** Plants, bacteremia, pseudomonas

## Introduction

Antibiotics are one of the most important weapons in fighting bacterial infections. It has greatly benefited the human's health since their introduction. However, over the past few decades, these health benefits are under threat as many commonly used antibiotics have become less and less effective against certain illnesses. This is not only because many of them produce toxic reactions, but also due to emergence of drug-resistant bacteria. It is essential to investigate newer drugs with lesser resistance. Traditional medicine has remained the most affordable and easily accessible source of treatment in the primary health care system of poor communities (Hosseinzadeh S, Jafarikukhdan A, Hosseini A, & Armand R. (2015) [1]. The antimicrobial activity of a plant is highly related to secondary substances that are synthesized and produced by these plants. Secondary metabolites are substances of low molecular weight, which were not the products of the primary metabolic pathway of the producing organism. However, it was first thought to be of no advantage to the plant. Nowadays, it has been believed that they have vital functions (Kant RU, Pratibha, D, & Shoeb, A. (2010) [2]. Olea europaea preparations have been used widely in folk medicine in Mediterranean area. Olive leaf is one of the potent source of plant polyphenols having antioxidant, antimicrobial, and antiviral properties due to its rich phenolic content (Aytul K.K (2010) [3]. The large number of phenolic compounds present in olive leaves aroused the interest of researchers around the world. Also, the studies with animals and humans have reported beneficial health effects such as the capacity of antioxidant, anti-hypertensive, hipo-glicemiant, hypocholesterol, anti-inflammatory, and as co adjuvant in the treatment of obesity (Esmaeili-Mahani S. *et al.* 2010) [4, 26]. The discovery of antibiotics has always been a medical advance that has improved the prognosis of infections. However, resistance to these products has evolved into a major health problem. Some diseases are even resistant to all antibiotics currently available on the market. A reduction in the use of antibiotics must be based on other approaches, namely the use of alternative treatments to antibiotics, such as phytotherapy. In the same objective our study focused on the research of the antibacterial power of Olea Europaea known for its various medicinal properties. "Phytotherapy" is a term that is used in the field of medicine in which, either herbs or their extracts are used as either health promotion agents or to treat diseases (Falzon CC, Balabanova A. Phytotherapy 2017) [5]. Although numerous studies have investigated the bactericidal efficacy of herbal extracts of neem and miswak; other natural products that have been reported to exhibit antibacterial properties include Saussurea costus (S. costus) and Melaleuca alternifolia (M. alternifolia) (Qiu J, Wang J, Luo H, Du X, Li H, Luo M, *et al*. 2011, Graziano TS, Calil CM, *et al*, *2016*) [6, 7]. The S. costus (India costus), is a member of the Asteraceae family and is commonly used in countries such as Saudi Arabia, and India for different medical issues such as asthma, breast and hepatic cancer and thyroid diseases (Byambaragchaa M, de la Cruz J, Yang SH, Hwang SG,2013, Mujammami M. 2020) [8, 9]. It is also known as costus, putchuk, or kuth. Likewise, M. alternifolia, also known as "tea tree oil" exhibits antimicrobial effects against microbes including Staphylococcus aureus, S. mutans and Candida albicans [Lam NS, Long X, Su XZ, Lu F. 2020, Tullio V, Roana J, Scalas D, Mandras N.2019) [10, 11]. And promotes wound healing (Tullio V, Roana J, Scalas D, Mandras N. 2019) [11]. Turmeric extract and the essential oil of Curcuma longa inhibit the growth of a variety of bacteria, parasites, and pathogenic fungi. A study of chicks infected with the caecal parasite Eimera maxima demonstrated that diets supplemented with 1-percent turmeric resulted in a reduction in small intestinal lesion scores and improved

weight gain. Another animal study, in which guinea pigs were infected with either dermatophytes, pathogenic molds, or yeast, found that topically applied turmeric oil inhibited dermatophytes and pathogenic fungi, but neither curcumin nor turmeric oil affected the yeast isolates. Improvements in lesions were observed in the dermatophyte- and fungi-infected guinea pigs, and at seven days post-turmeric application the lesions disappeared. Curcumin has also been found to have moderate activity against Plasmodium falciparum and Leishmania major organisms (Hour T.C., Chen J., Huang C.Y., 2002) [12]. The Capsicum compounds generate metabolic and structural changes that can culminate in the inhibition or inactivation of microorganisms such as bacteria, fungi, and viruses, the mechanisms of action derived from the interactions of the bioactive compounds of CFs and the microorganisms are described. AMPs from CFs are peptides that act as a form of defense against bacterial attacks (Bacon K, Boyer R.*et al*, 2016) [13, 17]. Alteration of cell membrane potential and permeability, as well as membrane pores induction and cell aggregation, are the antibacterial mechanisms by which AMPs can penetrate the cell membrane and once inside, may interact with proteins and nucleic acids, establish a potential cell-killing mechanism (Afroz M, Akter S, Ahmed A, *et al*, 2020) [14]. In Gram-positive bacteria, AMPs seem to pass the cell wall with relative ease, while in Gram-negative bacteria, the AMPs can cross the cell wall by a charge-exchange mechanism, where cationic peptides compete with Ca2+ and Mg2+ ions bound to lipopolysaccharide, once they are attached to the outer membrane proteins (Malanovic N, Lohner K (2016) [15] **.** According to this, it has been proposed membrane models (barrel-stave pore, toroidal pore, and carpet model) associated with cationic AMPs-membrane interactions, membrane disruption, and membrane permeability. By combining both translocation and membrane afnity properties, AMPs can get into bacterial membranes and lead to the disruption of the cell. However, the antibacterial mechanisms of AMPs depend on factors such as peptide structure, the peptide: lipid ratio and the lipid membrane properties (Afroz M, Akter S, Ahmed A, *et al*, 2020) [14]**.** Otherwise, (Baenas N, Belović M, Ilic N, Moreno DA, García-Viguera C, 2019) [16]**.** reported that capsianosides can inhibit the growth and survival of Gram-positive bacteria due to their capacity of chelating calcium, which is used to provide an adequate ionic environment in cationdependent membrane transport system and improves the bioflm architecture development. Conversely, the Gramnegative bacteria such as S. enterica and E. coli lack of cell wall requirement of calcium, which could mean the inefectiveness of capsianosides against the formation of bioflms generated by this type of bacteria (Bacon K, Boyer R, Denbow C, O'Keefe S, Neilson A, Williams R, 2016) [13, 17]**.** Similarly, the antibacterial efect of capsaicin is related to the disruption of peptidoglycan structure due to lipid-lipid interactions providing liquidity in the cell wall (Akyuz L, Kaya M, Mujtaba M, *et al*, 2018) [18]**.** Also, the antibacterial efect of capsaicin depends on its concentration, and its mechanisms of action involve osmotic stress, destroying cell membrane structures, and inhibiting the expressions of the genes responsible for bacterial cell growth (Adaszek Ł, Gadomska D, Mazurek Ł, Łyp P, Madany J, Winiarczyk S, 2019) [19]**.** However, it has been reported that bacteria such as Actinoplanes utahensis NRLL 12,052, Bacillus species isolated from Korean kimchi, and Streptomyces mobaraensis possess capsaicin-degradative enzymes (Adams CA, Zimmerman K, *et al*, 2020) [20] **.** The presence of these types of enzymes could be one of the reasons why some bacteria are not inhibited by capsaicin. Regarding phenolic compounds, it has been reported that ferulic and gallic acids lead to a change in hydrophobicity and a decrease of negative surface charge in cytoplasmic membrane of pathogenic bacteria; causing local rupture and pore formation with leakage of essential intracellular constituents (Bouarab-Chibane L, Forquet V, *et al*, 2019) [21]**.** This supposes the formation of pores in the cell membrane, generating structural damage and subsequent inhibition of microorganisms. Meanwhile, LAB use hydroxycinnamic acids as external electron acceptors, allowing cofactor recovery and gaining additional metabolic energy to tolerate the stressful conditions generated by phenolic compounds. This adaptation is one of the mechanisms by which LAB are not inhibited by these acids, which represents an advantage over other undesirable microorganisms (Filannino P, Di Cagno R, Gobbetti M, 2018) [22]**.** Based on the above, the antibacterial effects of the compounds present in CFs are not always inhibitory and appear to be strain dependent. Suggesting that plants have evolved mechanisms to recognize bacterial AHLs as signature molecules and mount defensive responses. It seems likely that it is common for plants to interfere with the coordinated expression of virulence or other deleterious traits by either blocking or inappropriately stimulating QS (Cui, X., and R. Harling. 2005, Delalande, L., D. Faure, A.*et al*, 2005) [23, 24]. Indeed, transgenic plants that express bacterial AHLs have altered responses to pathogenic bacteria. In most but not all cases such plants apparently prematurely induce the expression of bacterial virulence traits that otherwise would be expressed only when cell densities are high at later stages of the infection process in plants (Fray, R. G. 2002, Ma¨e, A., M. Montesano, V. Koiv, and E. T. Palva. 2001, Toth, I. K. *et al*,2004) [25, 27]. Apparently, most plants mount a defense against bacterial pathogens only after they recognize AHLs directly, or they mount a defense indirectly after they recognize virulence factors that are expressed only upon AHL production in bacteria (Bauer, W. D., and J. B. Robinson. 2002, Savka, M. A., Y. Dessaux, P. Oger, and S. Rossbach. 2002) [28, 29]. It therefore could be expected that plants defend themselves against deleterious bacteria by producing compounds that interfere with the QS system of bacteria. There has been much interest in developing new strategies for plant disease control based on altering the quorum-sensing process in plants (Cui, X., and R. Harling. 2005, Fray, R. G. 2002, Savka, M. A., Y. Dessaux, P. Oger, and S. Rossbach. 2002) [23, 25, 29]. While R. trichocalyx, A. maritimum, Ruta graveolens, B. napus, and P. sativum leaf surface extracts caused slight inhibition of QS. Moringa oleifera leaves, fruits, roots, and seeds are sources of biologically important phytochemicals and may be used as a consummate nutraceutical molecule, because of its innumerable desirable biological properties. There is an extended interest in using natural antioxidant compounds, as the consumer's pressure on food industry augments, to avoid chemical preservatives, due to the increasing evidence implies that synthetic antioxidant produce toxicity. Many gram negative bacteria, including Erwinia carotovora, Enterobacter agglomerans, Chromobacterium violaceum and Pseudomonas aeruginosa use N-acyl homoserine lactones (AHLs) signal molecules to

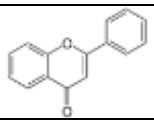
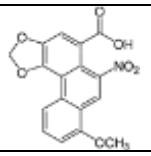
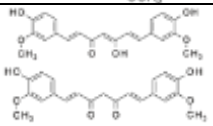
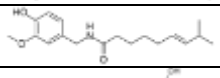
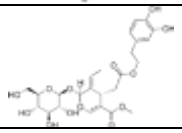
monitor their own population density. At a threshold population density, AHLs interact with cellular receptors and trigger the expression of a set of target genes, including virulence, antibiotic production, biofilm formation, bioluminescence, mobility and swarming, in a process called ‘‘quorum sensing” (QS) (Manefield, M., Rasmussen, T.B, *et al*, 2002) [30]. The discovery of the QS system and its critical role in bacteria virulence and survival has revealed a new target-a novel way to attack and attenuate bacterial pathogenicity. The major advantage of this novel strategy for anti-infective therapy is that it circumvents the problem of antibiotic resistance, which is intimately connected to the use of conventional antibacterial agents, as is specifically interferes with the expression of pathogenic traits rather than to impede growth of the bacteria. To date, the only known QS blockers of non-bacterial origin are halogenated furanones from Delisea pulchra (Manefield, M., Rasmussen, T.B, *et al*, 2002) [30]. Anti-QS activity has also been shown in a number of Florida medicinal plants (Adonizio, A.L., Downum, K., Bennett, B.C., Mathee, K., 2006) [31]**.** And a few other higher plants (Bosgelmez-Tinaz, G., Ulusoy, S., Ugur, A., Ceylan, O., 2007, Rasmussen, T.B., Bjarnsholt, T. et al, 2005) [32, 33]**.** The efficacy and toxicity of previous reported QS blockers (i.e. halogenated furanones) have been important concerns; therefore attention has been focused on identification of such QS blockers from natural and non-toxic sources for the development of novel nonantibiotic drugs for treating bacterial diseases in humans as well as in other animals. Therefore, the present work was done to evaluate oxidative DNA damage protecting activity, antioxidant potential and anti-QS activity of M. oleifera leaf, fruit and seed**.**

## Material and method

### Alcohol extraction preparation:

Ruta or rue, Moringa oleifera, Saussurea costus, Curcuma longa, Capsicum and Olea leaves were collected from the market of Mosul city, where fresh Olea leaves were obtained from the tree, washed with tap water and dried for 24-28 days at room temperature. Follow researcher(grand *et al.*, 1988*)* [38] A modified basic method for research (verpoorte *et al.*, 1982) extraction steps were used for the extraction of the bioactive metabolite compounds. To obtain the plants extract the method of. Was followed briefly, fifty grams from each plant were weighted and with 250 ml ethyl acetateas as solvent (1:5) mixing by electric blender and filtration by medical sterile gauze. Cell-free supernatant was harvested and centrifuged at 4000 rpm for 15 min. The solvent layer was harvested and then evaporated in a rotary evaporator in order to obtain the crude extracts, To this, 100% of dimethyl sulfoxide (DMSO) was added to constitute a 50 mg/mL stock (w/v) from the crude extract and this stock confirmed for their anti-quorum sensing against *Serratia marcescens* by using agar overlay assay and anti-biofilm against A. baumannii isolate 23, P. aeruginosa isolate 12 by using 96 well microtiter plate

**Table: 1**

| NO. | Scientific name of plant | Structural formula | Active component |
|---|---|---|---|
| 1 | Ruta ,rue |  | Flavonoid |
| 2 | Moringa oleifera | R-N=C=S | isothiocyanates |
| 3 | Saussrea costus |  | Aristolochic Acid |
| 4 | Curcuma longa |  | Curcumin |
| 5 | Capsicum |  | capsicism |
| 6 | Olea leaf |  | oleuropein |

### Screening and Evaluation of Quorum Sensing Inhibition (QSI)

### Qualitative Agar Diffusion Assay

Screening for Quorum Sensing Inhibition (QSI) assay was carried out on all prepared extracted plants. Synthesis of red colour pigment (prodigiosin‟2-methyl-3-pentyl-6-methoxyprodigiosin”) is a regulated behavior in quorum sensing in S*erratia marcescens*. Quorum sensing inhibition using S*erratia marcescens* as a reporter strain was performed on the extracted plants (screening for QSI). Five hundred microliters of overnight grown culture of *Serratia marcescens* which was obtained from department of biology/ University of Mosul was inoculated in to 20 mL of nutrient broth medium and incubated for 18 h at 30 °C,. Agar overlay assay was done using nutrient broth soft agar (0.8% agar, 150 mL) and maintained at 45 °C, 10 mL of culture (OD600nm = 0.7) were then added before plating the supernatants on the media. The wells were prepared in the plate by using sterile cork borer (6 mm in diameter) and 30µL of plants extracted were placed in each well. Antibacterial activity was revealed through a zone of clearance at the center, while QSI was observed at the periphery as opaque zone of inhibition with intact bacteria. Fresh nutrient broth medium served as the negative control.

**Assay of biofilm production with crude plants extract**

Overnight culture of *A. baumannii* isolate 23 and *P. aeruginosa* isolate 12, which were grown in BHI broth at 37°C for 18 h , were then diluted using sterile BHI broth to the 0.5 McFarland standard, and 150µL of the diluted isolates was transferred to wells of a sterile 96-well flat-bottomed polystyrene plate. The crude extract of the dried plants was re-dissolved into100% of dimethyl sulfoxide (DMSO) 50 mg/mL stock (w/v) using half fold serial dilution. The concentrations for Ruta, Saussrea costus, Curcuma longa, and Olea leaf used were 0.2, 0.2, 0.2 and 0.15 mg/ml, 50µL of each plant crude extract concentration were added to wells that contained diluted *A. baumannii* isolate 23 and *P. aeruginosa* isolate 12. The seventh well was added with only 50µL of sterile BHI broth with 5% DMSO. The plates were incubated for 24h at 37°C. The intact biofilm remaining in each well was stained with a 1% crystal violet (CV) (Sigma) solution at 37°C for 30 min, and proceed by following the same steps in the section; the test was done in triplicate. Each data point was composed of three independent samples that were averaged.

**Colony Count using Spread Plate Method**

The cultures of *A. baumannii* isolate 23 and *P. aeruginosa* isolate 12 that had been treated with plants crude extract concentrations in crystal violet assay were diluted using serial dilution to 5 folds dilution. 100µL of the fifth fold dilution was spread on Nutrient agar (NA, Oxoid, UK). The spread plates were incubated for 24h at 37°C. The colonies formed were counted and colony forming numbers were determined. The test was done in triplicate. Each data point was composed of three independent samples that were averaged.

**The result**

Appear results that capsicum and moringa oleifera do not have quorum sensing inhibition forward serretia marscence and other plants gives quorum sensing inhibition characteristics as such in figure (1).

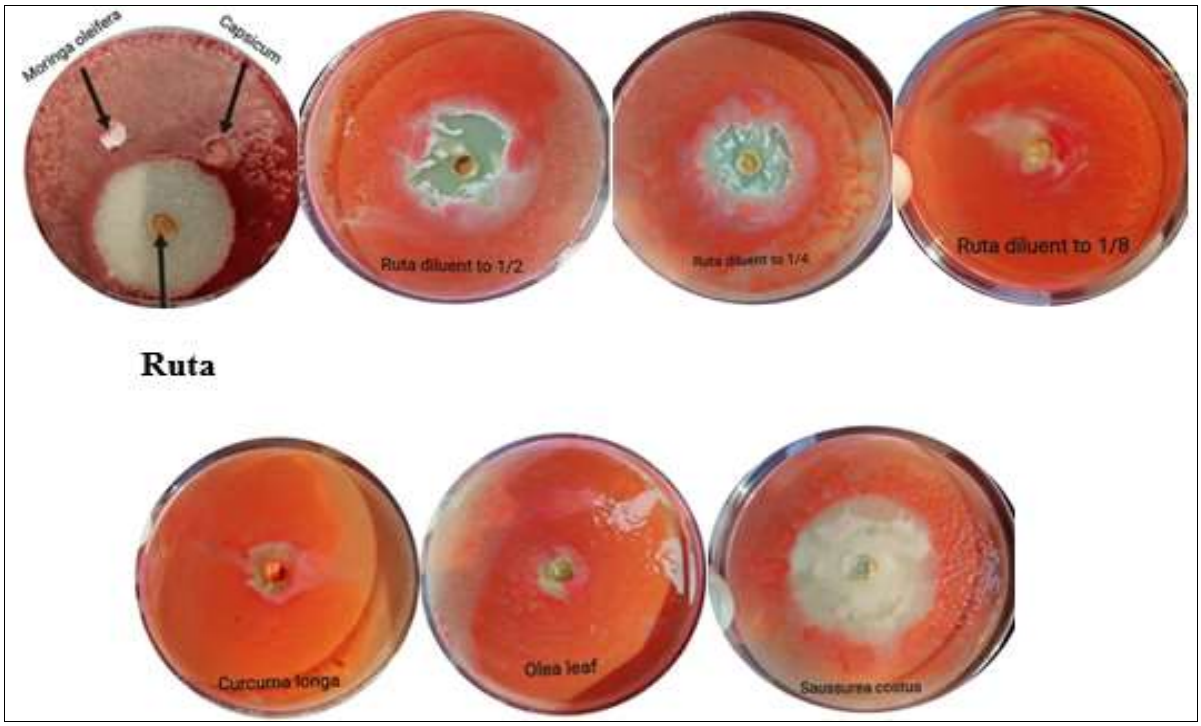
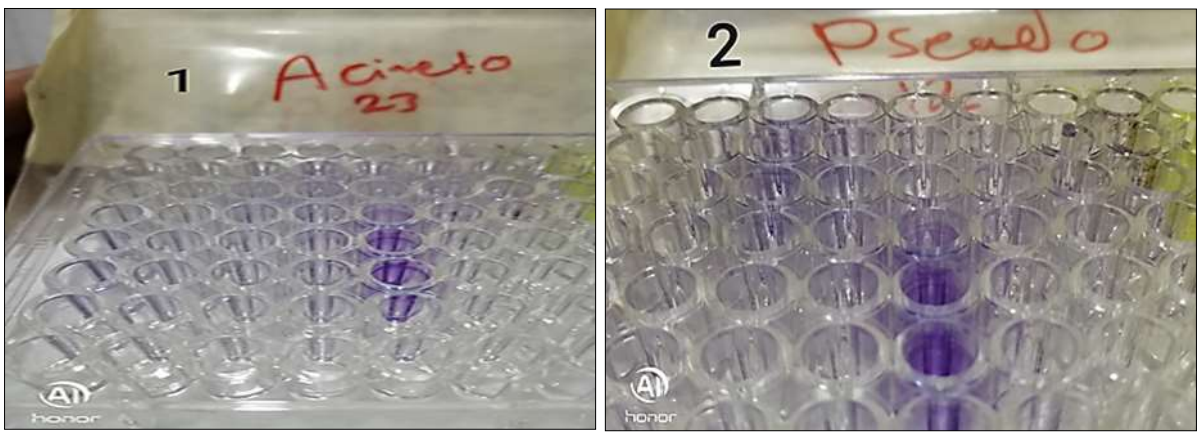



**Fig 1**




1. This picture explain that effect plants on acinetobacter 2. This picture explain that effect plant on pseudomonas

**Fig 2**

The figures explain effects the plant on bacteria used in study.

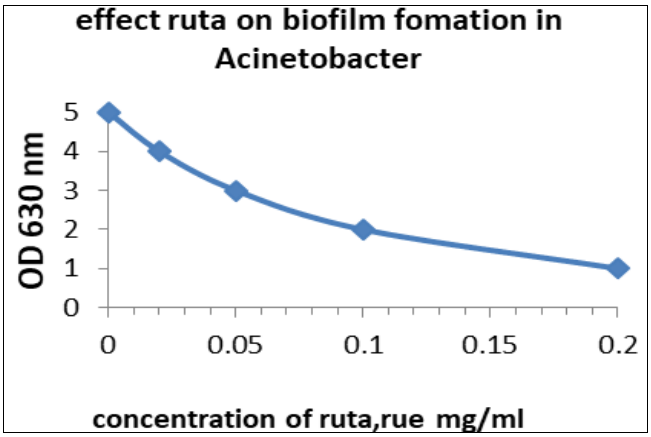



**Fig 3**

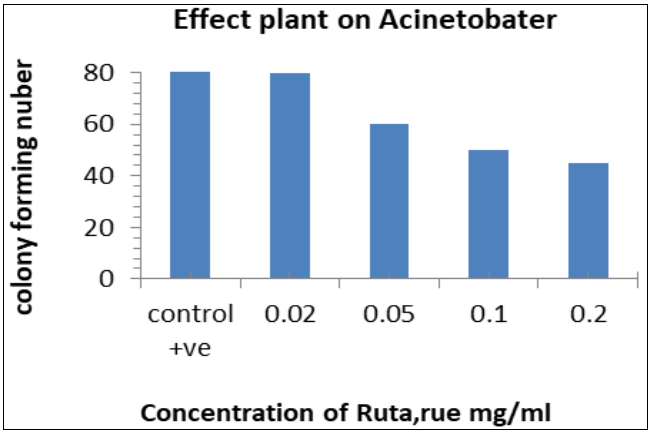



**Fig 4**

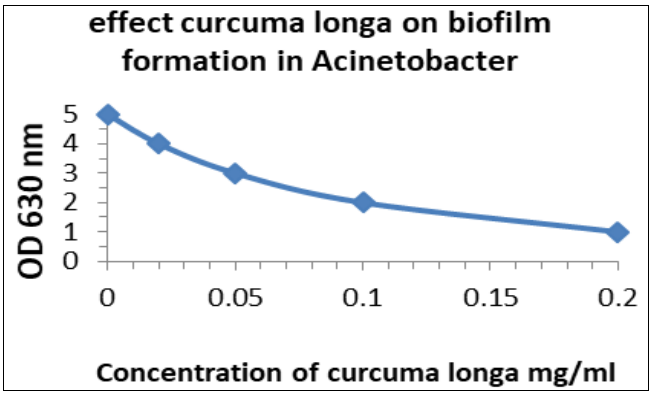



**Fig 5**

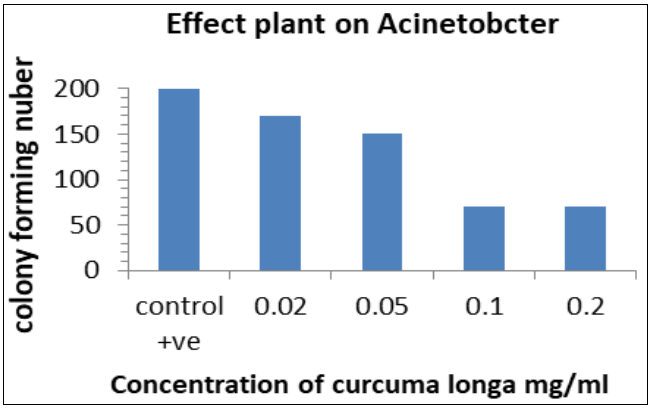



**Fig 6**

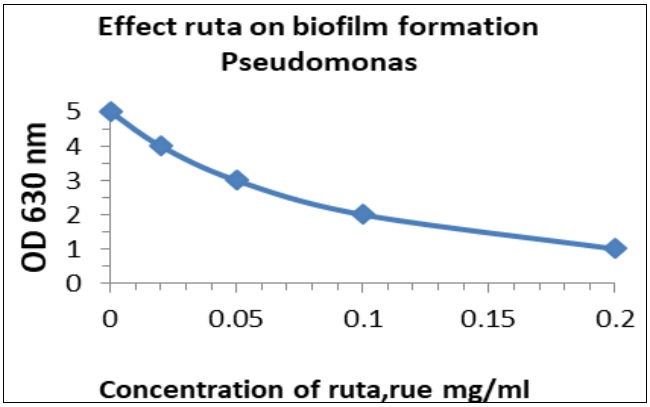



**Fig 7**

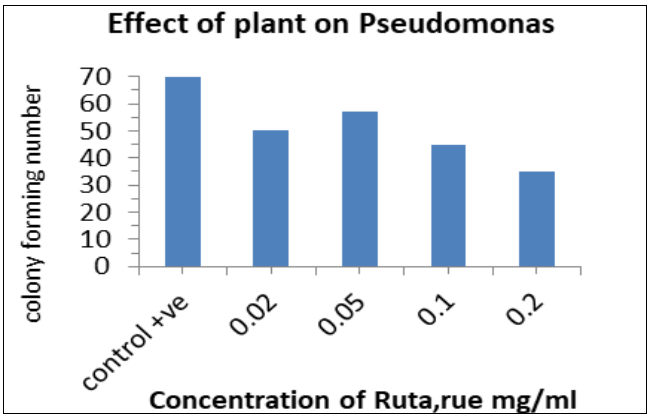



**Fig 8**

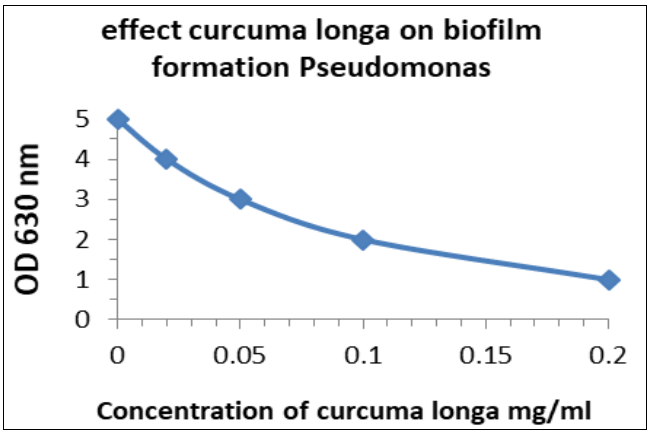



**Fig 9**

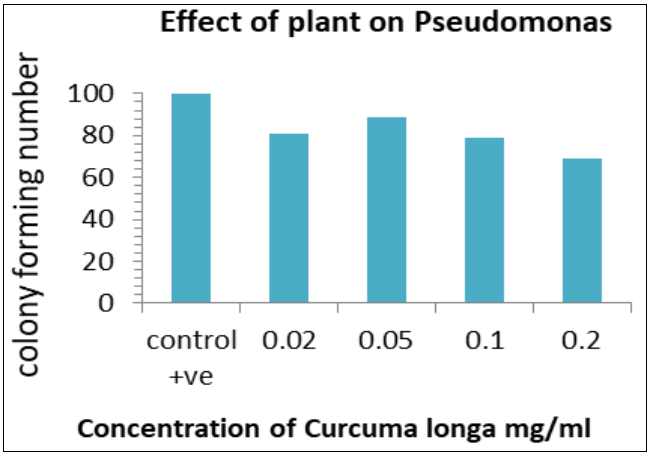



**Fig 10**

**Discussion**

Appear result that olea leaf, ruta, curcuma longa and saussurea cost that have anti quorum sensing activity forward serretia, the capsicum and moringa oleifera not have anti quorum sensing forward serretia hence application crud extract on bacteria pathogen (acinetobacter and pseudomonas). And appear effect on biofilm. Because of emergence multi druge resistant bacteria to antibiotics hence, this study was aimed to investigate the effect of crude of plant on biofilm formation capacity. More previous studies that indicate most natural source as plant that have anti quorum sensing because of this plant contain compound same as AHL-dependent quorum sensing in bacteria opposite chemical compound such as antibiotics that is bacteria have many different ways of antibiotics resistant and because of few used for plants as drug not bacteria plant resistant. The chemical structure and bioactivity mechanisms of plant-derived molecules that act as inhibitors of AHL-dependent QS in bacteria. Characterized of compound as: (i) highly stable compounds that are resistant to degradation by host metabolism, a factor that allows for their transport to the site of action; (ii) low molecular weight molecules that can penetrate bacterial cells and interact with target proteins; and (iii) high-specificity phytochemicals that directly interact with QS activators. Because the whole plant extracts typically contain more than one anti-QS compound and individual constituent phytochemicals are found to be less efficacious than the whole extract (Joshi, C.; Patel, P.; Kothari, V, 2019) [34]. a closer look at natural QS inhibitors bioactivity mechanisms may be helpful not only to reconstruct plant-derived molecular mixtures (Deryabin, D.G.; Tolmacheva, A.A, 2015) [35]. But also for the development of new artificial compositions which exhibit a super-additive effect on quorum sensing. In our opinion, compositions of plant-derived molecules exhibiting a different mode of action are promising, which potentially allow a multiple block on QS-related processes in bacteria. This novel combinatorial approach to QS-disruption will be experimentally verified in our subsequent studies. Fundamentally, the presented data show the phylogenetically developed variety of anti-infectious strategies relevant in plant health and performed by QS inhibition in phytopathogens (Ansari, F.; Ahmad, I, 2018) [36]. That provides new insight into the interactions between plant and bacterial species. In this context, increased understanding of plant-derived molecule modes of action on QS in bacteria should lead to the development of effective QS-disrupting strategies.

**Reference**


1. Hosseinzadeh S, Jafarikukhdan A, Hosseini A, Armand R. The Application of Medicinal Plants in Traditional and Modern Medicine: A Review of Thymus vulgaris. International Journal of Clinical Medicine,2015:6:635-642.
2. Kant RU, Pratibha, D, Shoeb A. Screening of antibacterial activity of six plant essential oils against pathogenic bacterial strains.Asian J. Med. Sci,2010:2(3):152-158.
3. Aytul KK. Antimicrobial and antioxidant activities of olive leaf extract and its food applications. A Thesis Submitted to the Graduate School of Engineering and Sciences of İzmir Institute of Technology, 2010.
4. Esmaeili-Mahani S, Rezaeezadeh-Roukerd M, Esmaeilpour K, Abbasnejad M, Rasoulian B, Sheibani V. *et al*. Olive (*Olea europaea* L.) leaf extract elicits antinociceptive activity, potentiates morphine analgesia and suppresses morphine hyperalgesia in rats. J.Ethnopharmacol,2010:132(1):200-205.
5. Falzon CC, Balabanova A. Phytotherapy: an introduction to herbal medicine. Prim Care,2017:44:217-27. doi: 10.1016/j.pop.2017.02.001
6. Qiu J, Wang J, Luo H, Du X, Li H, Luo M, *et al*. The effects of subinhibitory concentrations of costus oil on virulence factor production in Staphylococcus aureus. J Appl Microbiol,2011:110:333-40. doi: 10.1111/j.1365-2010.04888.x
7. Graziano TS, Calil CM, Sartoratto A, Franco GC, Groppo FC, Cogo-Müller K. *In vitro* effects of Melaleuca alternifolia essential oil on growth and production of volatile Sulphur compounds by oral bacteria. J Appl Oral Sci,2016:24:582-9. doi: 10.1590/1678-775720160044
8. Byambaragchaa M, de la Cruz J, Yang SH, Hwang SG. Anti-metastatic potential of ethanol extract of saussurea involucrata against hepatic cancer in vitro. Asian Pac J Cancer Prev,2013:14:5397-402. doi: 10.7314/APJCP.14.9.5397
9. Mujammami M. Clinical significance of Saussurea costus in thyroid treatment. Saudi Med J,2020:41:1047-53. doi: 10.15537/smj.10.25416
10. Lam NS, Long X, Su XZ, Lu F. Melaleuca alternifolia (tea tree) oil and its monoterpene constituents in treating protozoan and helminthic infections. Biomed Pharmacother,2020:130:110624. doi: 10.1016/j.biopha.2020.110624
11. Tullio V, Roana J, Scalas D, Mandras N. Enhanced killing of Candida krusei by Polymorphonuclear leucocytes in the presence of subinhibitory concentrations of Melaleuca alternifolia and "Mentha of Pancalieri" essential oils. Molecules,2019:24:3824. doi: 10.3390./molecules24213824
12. Hour TC, Chen J, Huang CY. Curcumin enhances cytotoxicity of chemotherapeutic agents in pros-tate cancer cells by inducing p21 (WAF1/CIP1) and C/EBPbeta expressions and suppressing NF-kappa activation. Prostate,2002:51:211-218.
13. Bacon K, Boyer R, Denbow C, O'Keefe S, Neilson A, Williams R. Antibacterial activity of jalapeño pepper (Capsicum annuum var. annuum) extract fractions against select foodborne pathogens. Food Sci Nutr,2016:5(3):730-738. https://doi.org/10.1002/fsn3.453
14. Afroz M, Akter S, Ahmed A, Rouf R, Shilpi J, Tiralongo E, *et al.* Ethnobotany and antimicrobial peptides from plants of the solanaceae family: an update and future prospects. Front Pharmacol,2020:11:565. https://doi.org/10.3389/fphar.2020.00565
15. Malanovic N, Lohner K. Antimicrobial peptides targeting grampositive bacteria. Pharmaceuticals,2016:9(3):59. https://doi.org/10.3390/ph9030059
16. Baenas N, Belović M, Ilic N, Moreno DA, García-Viguera C. Industrial use of pepper (*Capsicum annuum* L.) derived products: technological benefts and

biological advantages. Food Chem,2019:274:872-885. https://doi.org/10.1016/j.foodchem.2018.09.047
17. Bacon K, Boyer R, Denbow C, O'Keefe S, Neilson A, Williams R. Antibacterial activity of jalapeño pepper (Capsicum annuum var. annuum) extract fractions against select foodborne pathogens. Food Sci Nutr,2016:5(3):730-738. https://doi.org/10.1002/ fsn3.453
18. Akyuz L, Kaya M, Mujtaba M, Ilk S, Sargin I, Salaberria AM, *et al.* Supplementing capsaicin with chitosan-based flms enhanced the anti-quorum sensing, antimicrobial, antioxidant, transparency, elasticity and hydrophobicity. Int J Biol Macromol,2018:115:438-446. https://doi.org/10.1016/j.ijbio mac.2018.04.040
19. Adaszek Ł, Gadomska D, Mazurek Ł, Łyp P, Madany J, Winiarczyk S. Properties of capsaicin and its utility in veterinary and human medicine. Res Vet Sci,2019:123:14-19. https://doi.org/10. 1016/j.rvsc.2018.12.002
20. Adams CA, Zimmerman K, Fenstermacher K, Thompson MG, Skyrud W, Behie S, *et al.* Fungal seed pathogen of wild chili peppers possess multiple mechanisms to tolerate capsaicinoids. Appl Environ Microbiol,2020:86(3):01697-1719. https://doi.org/10. 1128/aem.01697-19
21. Bouarab-Chibane L, Forquet V, Lantéri P, Clément Y, Léonard-Akkari L, Oulahal N, *et al.* Antibacterial properties of polyphenols: characterization and QSAR (quantitative structure-activity relationship) models. Front Microbiol,2019:10:829. https://doi.org/10.3389/fmicb.2019.00829
22. Filannino P, Di Cagno R, Gobbetti M. Metabolic and functional paths of lactic acid bacteria in plant foods: get out of the labyrinth. Curr Opin Biotechnol,2018: 49:64-72. https://doi.org/10.1016/j.copbio. 2017.07.016
23. Cui X, R Harling. N-Acyl-homoserine lactone-mediated quorum sensing blockage, a novel strategy for attenuating pathogenicity of gramnegative bacterial plant pathogens. Eur. J. Plant Pathol,2005:111:327-339.
24. Delalande L, Faure D, Raffux A, Uroz S, Angelo-Picard CD, Elasri M, *et al.* N-AcylL-homoserine lactone, a mediator of bacterial quorum-sensing regulation, exhibits plant-dependent stability and may be inactivated by germinating Lotus corniculatus seedlings. FEMS Microbiol. Ecol,2005:52:13-20.
25. Fray RG. Altering plant-microbe interaction through artificially manipulating bacterial quorum sensing. Ann. Bot,2002:89:245-253.
26. Mae A, Montesano M, Koiv V, Palva ET. Transgenic plants producing the bacterial pheromone N-acyl-homoserine lactone exhibit enhanced resistance to the bacterial phytopathogen Erwinia carotovora. Mol. Plant-Microbe Interact,2001:14:1035-1042.
27. Toth IK, Newton JA, Hyman LJ, Lees AK, Daykin M, Ortori C. *et al.* Potato plants genetically modified to produce N-acylhomoserine lactones increase susceptibility to soft rot erwiniae. Mol. Plant-Microbe Interact,2004:17:880-887.
28. Bauer WD, Robinson JB. Disruption of bacterial quorum sensing by other organisms. Curr. Opin. Biotechnol,2002:13:234-237.
29. Savka MA, Dessaux Y, Oger P, Rossbach S. Engineering bacterial competitiveness and persistence in the phyllosphere. Mol. PlantMicrobe Interact,2002:15:866-874.
30. Manefield M, Rasmussen TB, Henzter M, Steinberg P, Kjelleberg S, Givsko M. Halogenated furanones inhibit quorum sensing through accelerated LuxR turnover. Microbiology,2002:148:1119-1127.
31. Adonizio AL, Downum K, Bennett BC, Mathee K. Anti-quorum sensing activity of medicinal plants in southern Florida. J. Ethnopharmacol,2006:105:427-435.
32. Bosgelmez-Tinaz G, Ulusoy S, Ugur A, Ceylan O. Inhibition of quorum sensing–regulated behaviors by Scorzonera sandrasica. Curr. Microbiol,2007:55:114-118.
33. Rasmussen TB, Bjarnsholt T, Skindersoe ME, Hentzer M, Kristoffersen P, *et al.* Screening for quorum-sensing inhibitors (QSI) by use of a novel genetic system, the QSI selector. J. Bacteriol,2005:187:1799-1814.
34. Joshi C, Patel P, Kothari V. Anti-infective potential of hydroalcoholic extract of Punica granatum peel against gram-negative bacterial pathogens. F1000Research,2019:8:70. [CrossRef]
35. Deryabin DG, Tolmacheva AA. Antibacterial and Anti-Quorum Sensing Molecular Composition Derived from Quercus cortex (Oak bark) Extract. Molecules,2015:20:17093-17108. [CrossRef]
36. Ansari F, Ahmad I. Quorum Sensing in Phytopathogenic Bacteria and Its Relevance in Plant Health. In Biotechnological Applications of Quorum Sensing Inhibitors; Springer: Berlin, Germany,2018:351-370. ISBN 978-981-10-9025-7.
37. Verporrte R, Tginastoi A, Vandoorne H, Svendsen AB. Medicinal plant of Surinam, 1-Antimicrobial activity of some medicinal plants. J. Ethanopharmacol.,1982:5:221-226.
38. Grand A, Verpoort R, Wondergem PA, Pousset JL. Anti –infections phytotherapies of the tree – savannah sengal (west – Africa), 11 Antimicrobial activity of 33 species .J. Ethnopharmaco.,1988:22:25-31.