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In vitro Antimicrobial, Antibiofilm and Antiquorum Sensing Activity of Indian Rhododendron (*Melastoma malabathricum*) against Clinical Isolates of *Escherichia coli* and *Staphylococcus aureus*

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ABSTRACT

Background: Development and persistence of multidrug resistant (MDR) bacteria is considered to be one of the biggest threats to public health worldwide. Development of new antimicrobial agents and alternatives to the conventional antimicrobial agents to control the menace of AMR is the need of the hour. Plants based products can be effectively explored as potential antimicrobial, antibiofilm and antiquorum sensing agents against major bacterial pathogens of human and animals. This present study was conducted to explore the antimicrobial, antibiofilm and antiquorum sensing activity of aqueous and methanol extracts of leaf, flower, fruit and stem of *Melastoma malabathricum* against clinical isolates of *Staphylococcus aureus* and *Escherichia coli*.

Methods: *E. coli* and *S. aureus* were isolated and identified from diarrhoeic pigs and poultry and mastitic milk of cattle of Mizoram, respectively. Leaf, flower, fruit and stem of *M. malabathricum* were collected from Mizoram and extracted by methanol and aqueous solvents. The antimicrobial activity and MIC was determined by using well diffusion method and 96 wells microtiter plate method, respectively. Antibiofilm activity of plant extracts was determined in 96 well tissue culture plate. Antiquorum sensing activity was determined by disc diffusion method.

Result: Methanol leaf extract exhibited antimicrobial activity against *E. coli* but not against *S. aureus* with 18 mm and 6 mm zone of inhibition at 200 mg/mL and 12.5 mg/mL, respectively. Methanol flower extract showed antimicrobial activity against *S. aureus* but not against *E. coli* with 14 mm and 6 mm zone of inhibitions at 200 mg/ml and 12.5 mg/mL, respectively. Similarly, the aqueous leaf extract showed antimicrobial activity against *S. aureus* but not against *E. coli* with 12 mm and 6 mm zone of inhibition at 200 mg/mL and 100 mg/mL, respectively. The MIC of *M. malabathricum* methanol leaf extract against *E. coli* was 3.125 mg/mL, whereas the MIC value of methanol flower and leaf extracts was 6.25 mg/mL against *S. aureus*. Antibiofilm activity of *M. malabathricum* methanol leaf, methanol flower and aqueous leaf extracts was recorded only against *S. aureus* isolates with maximum inhibition at 0.05 mg/mL concentration. Good antiquorum sensing activities was exhibited by the *M. malabathricum* methanol leaf, methanol flower and aqueous leaf extracts against *S. aureus* isolates at 200 mg/mL concentration.

Key words: Antibiofim, Antimicrobial, Antiquorum sensing, *Melastoma malabathricum*.

INTRODUCTION

Escherichia coli and *Staphylococcus aureus* are considered to be the major pathogens of human and animals associated with various disease conditions. Both the organisms are also posing serious threat due to ever growing antimicrobial resistance against existing antimicrobial agents. In addition, the biofilm producing multidrug resistant (MDR) pathogenic bacteria are considered as a major concern to public health. Majority of the antimicrobial drugs available in the arsenal of the medical and veterinary practitioners are becoming inactive (Dutta, 2020). The new generation antimicrobials are costly and limited for routine use for the common man in the middle and low income group of countries (Ghosh *et al*., 2019). With the huge threat posed by the MDR bacterial pathogens there is need to develop safe, dependable and cost effective alternatives to counter the menace of ever increasing threat of AMR.

Plant extracts and bioactive components isolated from ethnomedicinal plants are considered very important resources for novel antibacterial substances with various

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structures and mechanisms of action (Rios and Recio, 2005). There is increasing interest in the search for chemotherapeutic agents from ethnomedicinal plants used in traditional medicine (Sharma *et al*., 2010). *Melastoma malabathricum* (Indian rhododendron), a common shrub, is native to Indomalaya, Japan and Australia. The plant is routinely available in eastern and North eastern region of India. Traditionally, *M. malabathricum* is used as medicinal plant by many local healers for curing of diarrhea, leucorrhoea, puerperal infection, dysentery, wound healing, post-partum treatment and haemorrhoid (Zakaria *et al*., 2011). Several activities have been reported to *M. malabathricum* leaves and flower including antiviral (Nazlina *et al*., 2008), antibacterial (Sunilson *et al*., 2008), antioxidant (Sirat *et al*., 2010), anti-inflammatory and antipyretic (Zakaria *et al*., 2006). The North east region of India is considered as one of the major biodiversity hotspots with various indigenous traditional knowledge (ITK) in usage of natural plant based ethnomedicines by the local healers (Sharma *et al*., 2010).

There is limited information on effect of *M. malabathricum* extracts as antimicrobial, antibiofilm and antiquorum sensing agent against major bacterial pathogens of human and animals. The present study was conducted to explore the efficacy of various extracts of different parts of *M. malabathricum* plant for their antimicrobial, antibiofilm and antiquorum sensing activities against clinical isolates of *E. coli* and *S. aureus*.

MATERIALS AND METHODS

Place and time of the work

The entire work was carried out during June, 2019 to July, 2020 at Department of Veterinary Microbiology, College of Veterinary Sciences and Animal Husbandry, Central Agricultural University, Selesih, Aizawl, Mizoram.

Bacterial culture

E. coli (n=50), isolated from fecal samples of diarrheic pigs and cloacal swabs of chickens and *S. aureus* (n=20), isolated from milk samples of mastitic cows of Aizawl, Mizoram were received from the bacterial repository of the Department of Veterinary Microbiology, College of Veterinary Sciences and Animal Husbandry, Central Agricultural University, Aizawl, Mizoram. All the bacteria were further characterized by standard bacteriological techniques as described by Ewing (1986) and further confirmed by BD Phoenix automated bacterial identification system. *E. coli* (ATCC 25922) and *S. aureus* (ATCC 25923) were used as control organisms under the study. All the pure bacterial isolates were stored at-80°C in glycerol (25% V/V) for further use.

Preparation of plant extract

M. malabathricum plant was identified by Dr. Lalfakzuala, Associate Professor, Department of Botany, Mizoram University, Aizawl, Mizoram. Fresh leaf, flower, fruit and stem/bark of *M. malabathricum* plant were collected from the campus of College of Veterinary Sciences and Animal Husbandry, Central Agricultural University, Selesih, Aizawl, Mizoram. Extraction of all the samples was done as per the method described by Elisha *et al*. (2017). In brief, all the components were washed with running tap water to remove the dust particles or other foreign bodies and air-dried under room temperature for several days until fully dried. The dried plant materials were ground individually to fine powder with a blender machine into coarse powder. All the coarse powder of root, stem, leaf and flowers was soaked independently in water, methanol and hexane solvents (1:10, w/v) for 5-6 h at room temperature. After soaking, the supernatant was collected and filtered through Whatman filter paper No. 1 followed by evaporation at 40°C under vacuum. The filtrate was concentrated in rotary vacuum evaporator (IKA, RV10 digital, Germany) and the concentrated extracts were re-suspended in the same solvents to make the final concentration @ 200 mg/mL All the extracts were again filtered through 0.45 µm syringe filter and the filtrates were stored at -20°C till further use.

Antimicrobial activity of the plant extracts

The antimicrobial activity of the plant extracts was done by agar well diffusion method in Muller Hinton agar (HiMedia, Mumbai) as described by Lahlah *et al.* (2012). All the bacteria were grown on nutrient agar medium (HiMedia, Mumbai) and 2-3 pure colonies were picked up from the culture plate and transferred to the Luria Bertani (LB) broth. The tube was incubated for 4-5 hrs at 37°C and the inoculum density was standardized at 0.5 McFarland. The inoculums were inoculated over the MHA plate using absorbent cotton swab so that a lawn culture may grow. The holes of 6 to 8 mm diameter were made in the plate and were loaded with 20 µL of plant extracts in each well. All the plates were incubated at 37°C for 24 h. Diameters of zone of inhibition were measured by scale. Ciprofloxacin (5 µg) was used as positive control and *E. coli* (ATCC 25922) and *S. aureus* (ATCC 25923) were used as control organisms.

Determination of minimum inhibitory concentration (MIC) of the plant extracts

MIC of the plant extracts were determined in 96 well plate following the method described by Mazzola *et al.* (2009), where 2,3,5 triphenyl tetrazolium chloride (TTC) was used as chromogenic agent. One hundred µL of LB broth was dispensed in each well of the 96 wells plate followed by 100 µL (20 mg) of each extracts added in the first well followed by serial two fold dilution of the plant extracts. Finally 50 µL of bacterial suspension (adjusted to 0.5 McFarland standard) were added to each well. Plates were covered and incubated at 37°C for 24 h. After incubation, 20 µL of 0.1% TTC were added to each well and incubated for 15 minutes. The MIC value was determined based upon the red coloration of the liquid in each wells.

Phenotypic determination of antibiofilm effect of plant extracts

The antibiofilm effect of the plant extracts was determined by tissue culture plate method (Sánchez *et al*., 2016). Overnight grown culture of bacteria (0.4 OD) was centrifuged at 7000 rpm for 10 min at 4°C. The cell pellet was washed twice with phosphate buffered solution (PBS) followed by centrifugation at 7000 rpm for 10 min at 4°C. Finally, the pellet was re-suspended in PBS and OD value was checked at 600 nm (0.4 OD) in spectrophotometer. A serial two fold dilution of the plant extracts was made followed by addition of 10 µL of 0.4 OD bacterial cultures in each wells and incubated at 37°C for 18-24 hours. Additional LB broth was added to make the final volume up to 200 µL in each wells and incubated at 37°C for 24 hrs. After incubation the wells were washed twice with PBS (pH 7.4) to remove free floating planktonic bacteria. Then 200 µL of 0.1% crystal violet solution was added in each well followed by incubation at 37°C for 30 min to stain the adhered cells. The wells were washed twice with 200 µL PBS (pH 7.4) to remove excess stain and the plates were air dried. Then 200 µL methanol was added in each wells to solubilize the bound crystal violet. The untreated wells were used as control (uninoculated broth and bacteria).

The OD value at 570 nm was recorded to check the result using the following formula:

$$\% \text{ Biofilm inhibition} = \frac{\text{OD control-OD test}}{\text{OD control}} \times 100$$

Where:
OD control = Absorbance of untreated control.
OD test = Absorbance of treated.

Phenotypic determination of antiquorum sensing effect of plant extracts

The antiquorum sensing effect of the plant extracts was determined using the method described by Alvarez *et al*. (2012). Commercially available paper discs (6 mm in diameter) were soaked with various concentrations (200 mg/mL, 100 mg/mL, 50 mg/mL, 25 mg/ml and 12.5 mg/mL) of plant extracts and air dried under aseptic condition. All the discs were stored at refrigeration temperature till further use. *Chromobacterium violaceum* (ATCC12472) was used as known positive control bacteria and furanone (Sigma Aldrich) was used as known positive control agent to standardize the quorum sensing inhibition activities. One hundred µL (2.5×10^6 CFU/mL) of freshly prepared bacterial culture was plated over LB agar and allowed to air dry. Discs were placed on the plate (maximum 6 disks on 100 mm plate) at equal distance and incubated at 30°C for 18-24 hours. Disks containing normal saline solution (NSS) and furanone (100 µg) (Sigma) were used as negative and positive control, respectively. Zone of inhibition of pigment formation surrounding the disks was recorded manually by a scale. The result was classified based on the diameter of the zone of inhibition as follows: "not sensitive" for diameter less than 8 mm, "sensitive" between 9 and 14 mm, "very sensitive" between 15 and 19 mm and "extremely sensitive" for larger than 20 mm (Moreira *et al*., 2015).

RESULTS AND DISCUSSION

The *M. malabathricum* methanol leaf extract showed antimicrobial activity against *E. coli* but not against *S. aureus*. Highest and lowest activities were observed at 200 mg/mL and 12.5 mg/mL with 18 mm and 6 mm zone of inhibition, respectively. Conversely, the *M. malabathricum* methanol flower extract showed antimicrobial activity against *S. aureus* but not against *E. coli*. Highest and lowest activity was observed at 200 mg/mL and 12.5 mg/mL with 14 mm and 6 mm zone of inhibitions, respectively. Similarly, the *M. malabathricum* aqueous leaf extract showed antimicrobial activity against *S. aureus* but not against *E. coli*. Highest and lowest activity was observed at 200 mg/mL and 100 mg/mL with 12 mm and 6 mm zone of inhibition, respectively.

In the present study, to determine the antimicrobial activities of medicinal plant extracts, agar well diffusion method and minimum inhibitory concentration (MIC) assays were used. The MIC was selected to test for antimicrobial activities of plant extracts, which provided quantitative results and is considered as the most appropriate and reliable method (Sigei *et al.,* 2015). *M. malabathricum* methanol flower extracts showed effective antimicrobial activity against *S. aureus* with the MIC value of 3.125 mg/mL. Similarly, *M. malabathricum* aqueous leaf extract also exhibited very good antimicrobial activity against *S. aureus* with an MIC value of 6.25 mg/mL. Our results indicated that Gram-positive bacteria were more responsive towards the *M. malabathricum* methanol flower extracts. Our observation is also in corroboration with the reports of Cushnie and Lamb (2005), who also reported that flavonoid compounds showed greater inhibition activities on Gram positive bacteria when compared to Gram-negative bacteria. Wang *et al*. (2008) also reported nearly similar observation against Gram positive bacteria. High sensitivity of that particular extract against Gram positive bacteria may be due to their cell wall and outer membrane structures. Gram negative bacteria carry an outer membrane and a unique periplasmic space, which inhibits either entry of the molecule or trapped (Shan *et al*., 2007). In the present study, the greater inhibition was observed with the flower extract of *M. malabathricum*, which may be due to presence of different active compounds like kaempferol-3-O-*β*-D-glucoside, kaempferol and nar-ingenin (Susanti *et al.,* 2007). In addition, the results of the present study are also in corroboration with the observations of Alnajar *et al*. (2012) of Malaysia. Simanjuntak (2008) also reported the presence of flavonoids, saponins, tannins, glycosides and steroids/ triterpenoids in the leaves of *M. malabathricum* collected from Sumatera, Indonesia.

The minimum inhibitory concentration of *M. malabathricum* methanol leaf extract against *E. coli* was found to be 3.125 mg/mL, whereas the MIC value of methanol flower and leaf extracts of *M. malabathricum* was recorded as 6.25 mg/mL against *S. aureus*. The methanol leaf extract of

M. malabathricum also showed good antimicrobial activity against *E. coli* with MIC value of 3.125 mg/mL. In India, in an earlier study, similar effects were also recorded by Choudhury *et al*. (2011) from Silchar, Assam. The *M. malabathricum* methanolic extract possesses antimicrobial activity due to flavonoids (Zakaria *et al*., 2011). Marzouk *et al*. (2010) also reported that flavonoids are the most known group of polyphenolic compounds for their pharmacological properties including antibacterial activity. Teffo *et al*. (2010) reported that kaempferol and its glycosides are renowned for their pharmacological activities including antibacterial activity. The *M. malabathricum* leaves are found to be rich with glycosides, which might be responsible for their antimicrobial property of *M. malabathricum* may probably due to the presence of glycosides, phytol and tocopherol (Susanti *et al*., 2007).

Most of the extracts obtained from *M. malabathricum* plants have shown encouraging antibiofilm activity against *S. aureus* and *E. coli.* Highest antibiofilm activity (89.60%) was shown by *M. malabathricum* methanol leaf extract. It has been observed that the antibiofilm potential of all the effective extracts were increased with increasing dilution and maximum activity was recorded with 0.05 mg/mL concentration, which might be due to the improved capacity of penetration of the molecules at lower concentration through the biofilm substances. Beyond 0.05 mg/mL concentration, the amount of active molecules was not at the threshold level to inhibit the biofilms. To the finest of our knowledge so far, no reports are available regarding the antibiofilm activity of any extracts from *M. malabathricum*. In related study in Universiti Kebangsaan Malaysia and Universiti Sains Islam Malaysia reported inhibition of biofilm formation against *Streptococcus mutans* by methanolic stem/bark extracts of *M. malabathricum* (Rohazila *et al*., 2014). Few bioactive compounds such as 8-metil-1-undecene, propanenitrile hexanoic acid and 1-decene have been recognized from sub-fraction 18 of the *M. malabathricum* stem bark, which could significantly lessen biofilm formation and adherence activity on *S. mutans* (Rohazila *et al*., 2014). Although the active principle of the crude extracts of *M. malabathricum* is not analyzed, it may be assumed that the antibiofilm activities recorded against *E. coli* and *S. aureus* were due to the similar compounds. The methanol extract of *Carex dimorpholepis* also exhibited antibiofilm properties against *E. coli* up to 78% at 0.10 mg/mL (Lee *et al*., 2013). Similarly, aqueous extracts of *Syzium leggati* could prevent the formation of biofilm by 72% at 0.05 mg/mL (Nostro *et al.,* 2016). In the present study, the antibiofilm activities of various extracts of *M. malabathricum* were more than 85.0% hence, proved to be the best so far. In addition, it is also the first ever report on identification of various solvent extracts of different parts of *M. malabathricum* as potential biofilm inhibitor against *E. coli* and *S. aureus*. A low concentration of the plant extract may be required to prevent biofilm first attachment, while higher concentration of the plant extract is required to disrupt preformed biofilm (Stewart, 2002). Our study indicated that most plant extracts have the antibacterial coupled with antibiofilm activity; therefore, it may prove helpful for developing biofilm inhibitors and increase the effectiveness of infectious diseases treatment.

The *M. malabathricum* methanol leaf, methanol flower and aqueous leaf extracts exhibited good anti Quorum Sensing activities at 200 mg/mL concentration against *E. coli* and *S. aureus* isolates. To the best of our knowledge no reports are available regarding the antiquorum sensing activity of *M. malabathricum* plant extracts and very limited reports are available even for the other plants. Antiquorum sensing activity against *E. coli* and *S. epidermidis* strains was recorded using *L. origanoides*, *Thymus vulgaris* and C*ymbopogon martini* oils (Pappenfort *et al*., 2017). The methanol leaf extract of *P. emblica* and flower extract of *M. indica* also exhibited broad spectrum anti QS activity, which affected the activity of acyl homoserine lactones and autoinducers over a wide range of sub-inhibitory concentrations (Zahin *et al*., 2010). Methanolic root extracts of *Hemidesmus indicus,* bark of *Holarrhena antidysenteri* and aqueous fruit extract of *Punica granatum* and leaf of *Mangifera indica* demonstrated varying level of AHL mediated violacein pigment inhibition in *Chromobacterium violaceium* (Nostro *et al.,* 2016). Simanksi *et al.* (2012) reported that the *Vernonia amygdalina* methanol leaf extract possessed antiquorum sensing activity against *S. aureus*. As an alternative approach to antibiotics, inactivating bacterial quorum sensing (QS) mechanisms is being widely studied. QS is a mechanism through which bacterial cells can communicate with each other with the help of QS molecules, which can control the release of virulence determinants, bioluminescence, plasmid transfer, motility and biofilm formation. With the help of signaling molecules, called autoinducers, this system is controlled that pass through bacterial cell membranes. These signalling molecules are mostly synthesized by N-acyl-homoserine lactones (AHLs) in Gram-negative bacteria. In many studies it showed that plant secondary metabolites are responsible for QS inhibition because it can mimic QS molecules and in QS signalling pathways they inactivate their receptors, which is called quorum quenching (Doğan *et al*., 2019).

The antibiofilm and anti-QS agents are as important as the bacterial inhibition property to fight bacterial pathogenicity and studies enlarged in the last decade on this subject. The rise in antibiotic resistance of important pathogenic bacteria has also advanced these studies. This is the initial study about *M. malabathricum* from North eastern India for its antibacterial, antibiofilm and anti-QS effect against *E. coli* and *S. aurueus*. The methanol and aqueous extracts reduced the expression of biofilm production and QS activities of the target bacteria at very high level. In this regard, our study could contribute to discover new potential biofilm and QS inhibitor molecules against major pathogenic bacterial species. Future analysis on the extracts will possibly reveal novel bioactive compounds.

CONCLUSION

Methanol and aqueous solvent extracts of leaf, roots, stem and flower of *M. malabathricum* exhibited encouraging antimicrobial, antibiofilm and anti QS activities against clinical isolates of *E. coli* and *S. aureus* by *in vitro* techniques. This is the first ever report on antibiofim and anti QS activities of the plant extracts against enteric bacteria. With the observations of the present study, it may be postulated that the extracts in its purified form may be used as topical antimicrobial preparation against biofilm producing bacterial agents.

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Conflict of interest

All authors declare that they have no conflict of interest.

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