Journal of Coastal Life Medicine

journal homepage: www.jclmm.com

Original article doi: 10.12980/JCLM.3.201514J57



# Anti-enteric bacterial activity of the traditional medicinal plants of Kanyakumari coast, Tamilnadu, India

Suyambu Rajan[1], Parameshwaran Suvetha[2], Thiyagarajan Thirunalasundari[3], Solomon Jeeva[4*]

[1]*Department of Microbiology, M. R. Government Arts College, Mannargudi-614 001, Thiruvarur District, Tamilnadu, India*

[2]*Department of Microbiology, Srimad Andavan Arts and Science College, Thiruvanai Koil, Tiruchirappalli-620 005, Tamilnadu, India*

[3]*Department of Biotechnology, Bharathidasan University, Tiruchirappalli-620 024, Tamilnadu, India*

[4]*Department of Botany, Scott Christian College, Nagercoil-629 003, Kanyakumari, Tamilnadu, India*

ARTICLE INFO

*Article history:*
Received 31 Jul 2014
Received in revised form 20 Apr 2015
Accepted 10 Jun 2015
Available online 14 Jul 2015

*Keywords:*
Antibacterial activity
Disc diffusion assay
Enteric bacteria
Plant extracts

ABSTRACT

**Objective:** To evaluate the antimicrobial potentials of 6 traditionally used medicinal plants to treat gastrointestinal infection against pathogenic bacteria, as most of the pathogens develop drug resistance against commonly used antibiotics.

**Methods:** Crude extracts from different parts of different plants were tested against bacterial strains of clinical significance. Extraction of bioactive principles was done with water and ethanol. Evaluation of antibacterial activity was done by disc diffusion assay against selected bacterial stains.

**Results:** Of the 6 different plant materials tested, extracts prepared from *Psidium guajava* leaves showed significantly higher efficacy. Extracts prepared using alcohol exhibited higher antibacterial activity when compared to their corresponding aqueous extracts.

**Conclusions:** The findings of the present study suggested that phytochemical extracts of the presently studied plant materials possess significant anti-enteric bacterial activity, and thus lend pharmacological credibility to the suggested traditional use of the plant as a natural remedy for the treatment, management and/or control of gastrointestinal diseases in the coastal tracts of Kanyakumari district, Tamilnadu, India.

## 1. Introduction

Development and spread of drug-resistant pathogenic microorganisms create a challenge to public healthcare services. In particular, emergence of resistance to antibiotics has hampered the pace by which newer antibiotics are being introduced into the public domain[1]. This drives the discovery of novel antimicrobial therapeutic agents from the biological resources[2]. Global attention has been shifted towards hunting novel bio-molecules of biological origin for the development of new drugs. Despite ever increasing advancement in the field of medicine and molecular diagnosis, it is estimated that 80% of the world population is still dependent on the plant derived pharmaceuticals. World Health Organization report depicted that plant based products or its derivatives account for nearly 28% of drugs available in the market[3]. A large proportion of plant-based compounds are used as lead molecules in drug discovery to produce synthetic molecular analogs that have similar skeletons yet intricate structures. This implicates that phytochemicals play a critical role in diversity-oriented synthesis of natural product-like pharma compounds[4]. Human beings have exploited the plants for curing ailments since antiquity. Tribal people acquire knowledge of medicine from their parents in non-coded form and practice it effectively. Ethnobotanical and ubiquitous plants serve as a rich resource of natural drugs for research and development[5-9]. Medicinal plant-based drugs owe the advantage of being simple, effective and exhibit broad spectrum activity[10-15]. Indigenous systems of medicine that use plant-based drugs could provide both concepts of therapy as well as therapeutic agents to complement modern medicine in management of diseases[16-21]. Considering the medicinal value of medicinal plants, present study evaluated the antibacterial potentials of aqueous and alcoholic extracts of *Psidium guajava* (*P. guajava*) leaves, *Punica granatum* (*P. granatum*) fruit rind, *Aegle marmelos* (*A. marmelos*) fruit pulp, *Hemidesmus indicus* (*H. indicus*) root, *Mangifera indica* (*M. indica*) seed kernel and *Saraca asoca* (*S. asoca*) stem bark against selected clinical bacterial strains. These plants were selected after repeated discussions and consultations with people and healers of Puthalam village, situated in the southwest coast of Kanyakumari district, Tamilnadu, India.

## 2. Materials and methods

### 2.1. Plant material

*P. guajava* leaves, *P. granatum* fruit rind, *A. marmelos* fruit pulp, *H. indicus* root, *M. indica* seed kernel and *S. asoca* stem bark

*Corresponding author: Solomon Jeeva, Research Centre in Botany, Scott Christian College, Nagercoil-629 003, Kanyakumari, Tamilnadu, India.
Tel: +91-9952202112
E-mail: solomonjeeva@gmail.com

were collected from the fields in Puthalam village [N 08˚06.086' and E 077˚28.372'; altitude 17 m (mean sea level)], Kanyakumari district, Tamilnadu, India, and taken to the laboratory. Flora of the Presidency of Madras[22] and The flora of Tamilnadu Carnatic[23] were used for identification and authentication of the plants. Plant materials were washed separately under running tap water, followed by rinse using sterile distilled water. Excess of water was removed from the plant material using filter paper before they were used for powdering. Shade dried plant materials were powdered by making use of mechanical blender (Smith, India). Dried powder was stored in an airtight container and was used for extraction.

### 2.2. Preparation of extracts

The powdered plant material (150 g) was extracted with water and alcohol using cold maceration method. Both the extracts were filtered with a muslin cloth and the filtrate was concentrated in vacuum evaporator. Dried extracts were used for further studies.

### 2.3. Bacterial strains

A total of fourteen clinically isolated bacterial strains including both Gram-negative and Gram-positive bacteria like *Escherichia coli* (*E. coli* ), *Shigella* sp., *Salmonella typhi* (*S. typhi*), *Lactobacillus* sp., *Streptococcus pyogenes* (*S. pyogenes*), *Pseudomonas fluorescence* (*P. fluorescence* ), *Enterobacter* sp, *Citrobacter* sp., *Xanthomonas campestris* (*X. campestris*), *Xanthomonas citri* (*X. citri*), *Pseudomonas aeruginosa* (*P. aeruginosa*), *Klebsiella* sp., *Streptococcus faecalis* (*S. faecalis*) and *Staphylococcus aureus* (*S. aureus*) were selected to assess susceptibility patterns. The bacterial cultures were maintained in nutrient agar slants at 37 ˚C. Each of the microorganisms were freshly cultured prior to susceptibility testing by transferring them into a separate test tube containing nutrient broth and incubated overnight at 37 ˚C.

### 2.4. Antibacterial sensitivity assay of extracts

#### 2.4.1. Preparation of disc

Known quantity of the extract was dissolved in dimethylsulfoxide:poly butylenes succinate in the ratio of 1:1. It was then filtered by making use of syringe filter of pore size (0.42 µm). Sterile discs of 6 mm diameter were loaded with various concentrations of extracts and were dried. Dried discs were stored in sterile containers till use. Solvent loaded discs were also prepared and were used as negative control and tetracycline loaded discs were used as positive control.

#### 2.4.2. Antibacterial assay

Petri plates containing 20 mL of nutrient agar were seeded with a 24 h old culture of the bacterial strain. Different concentrations (100 µg, 200 µg, 400 µg and 800 µg) of plant extracts were impregnated into the sterile 6 mm diameter discs. Discs were dried and dispensed on the solidified nutrient agar medium previously inoculated with test microorganisms. Tetracycline and vehicle loaded (dimethylsulfoxide:poly butylenes succinate) discs were used as positive and negative control respectively. Then it was incubated at 37 ˚C for 24 h. The assessment of antibacterial activity was based on the measurement of zone of inhibition formed around the discs. Antibiotic zone scale was used to measure zone of inhibition (HiMedia, Mumbai).

#### 2.4.3. Determination of minimum inhibitory concentration (MIC)

Agar dilution method was used to find out the MIC. MIC was recorded based on the growth of the test organism at the particular concentration.

### 2.5. Statistical analysis

All data were expressed as mean ± SD. Statistical analysis was performed by using origin version 6.0 software.

## 3. Results

Tribal and country people acquire incredible knowledge of herbal medicine from their parents in non-coded form. With the repeated discussions and consultation with people of East Puthalam village, Kanyakumari District, Tamilnadu, India 6 plant parts were selected to screen antibacterial activity. All these 6 plants have been traditionally used to treat gastrointestinal infections.

Antibacterial activity of aqueous and alcoholic extracts of 6 different plants were assessed by disc diffusion and drug dilution method. Aqueous extract of *P. guajava* exhibited best antibacterial activity against *Klebsiella* sp. and the zone of inhibition ranged from 20–23 mm. Similarly aqueous extracts of other plants also showed antibacterial activity and the zone of inhibition ranged from 12–15 mm for *H. indicus*, 15–21 mm for *M. indica*, 11–26 mm for *P. granatum*, 15–20 mm for *S. asoca* and 12–15 mm for *A. marmelos* (Table 1).

Table 2 reveals antibacterial potentials of alcoholic extracts of different plant materials. Among the microorganisms used, *S. faecalis* was susceptible to alcoholic extracts of all plants and the average zone of inhibition was 19.16 mm followed by *S. aureus* and *E. coli*

**Table 1**
Antibacterial nature of aqueous extracts of different plants.

| Test organisms | Aqueous extract zone of inhibition (mm ± SD) | | | | | |
|---|---|---|---|---|---|---|
| | *A. marmelos* | *H. indicus* | *M. indica* | *P. granatum* | *P. guajava* | *S. asoca* |
| *E. coli* | 13.33 ± 1.15 | 14.66 ± 1.15 | 20.00 ± 2.00 | 21.66 ± 1.15 | 24.60 ± 1.52 | 18.00 ± 1.00 |
| *Shigella* sp. | 12.66 ± 1.52 | 12.00 ± 2.00 | 21.00 ± 1.00 | 20.33 ± 2.08 | 21.33 ± 2.08 | 16.00 ± 1.73 |
| *S. typhi* | 11.60 ± 0.57 | 13.60 ± 0.57 | 20.60 ± 0.57 | 20.60 ± 0.57 | 21.30 ± 0.57 | 15.30 ± 0.57 |
| *Lactobacillus* | 11.60 ± 1.52 | 11.60 ± 1.15 | 16.00 ± 2.00 | 16.00 ± 3.60 | 13.00 ± 3.00 | 13.60 ± 3.05 |
| *S. pyogenes* | 11.50 ± 2.12 | 13.30 ± 2.30 | 13.30 ± 2.80 | 20.00 ± 1.00 | 14.30 ± 1.15 | 16.00 ± 3.00 |
| *P. fluorescence* | 14.00 ± 1.00 | 13.00 ± 3.00 | 15.00 ± 2.64 | 18.60 ± 1.52 | 20.30 ± 0.57 | 15.30 ± 2.08 |
| *Enterobacter* sp. | 11.50 ± 2.12 | 13.00 ± 0.00 | 16.30 ± 1.52 | 16.30 ± 3.05 | 10.50 ± 0.70 | 14.60 ± 3.21 |
| *Citrobacter* sp. | 11.60 ± 2.08 | 12.30 ± 0.57 | 14.30 ± 1.52 | 18.30 ± 0.57 | 12.30 ± 2.08 | 19.00 ± 1.70 |
| *X. campestris* | 12.50 ± 0.70 | 13.30 ± 1.52 | 19.00 ±1.73 | 17.30 ± 1.15 | 16.00 ± 2.64 | 17.60 ± 0.57 |
| *X. citri* | 11.30 ± 1.52 | 12.00 ± 0.00 | 15.00 ± 2.00 | 15.30 ± 0.57 | 15.60 ± 3.21 | 19.30 ± 2.51 |
| *P. aeruginosa* | 12.60 ± 2.30 | 11.30 ± 1.52 | 13.00 ± 1.00 | 13.60 ± 4.61 | 17.00 ± 1.73 | 15.30 ± 2.08 |
| *Klebsiella* sp. | 12.60 ± 2.08 | 11.30 ± 1.15 | 12.30 ± 2.30 | 20.00 ± 1.00 | 23.60 ± 2.08 | 20.60 ± 0.57 |
| *S. faecalis* | 13.00 ± 1.00 | 13.60 ± 1.15 | 16.60 ± 1.15 | 20.30 ± 0.57 | 19.60 ± 1.15 | 16.00 ± 1.00 |
| *S. aureus* | 12.60 ± 0.57 | 15.00 ± 0.00 | 14.30 ± 1.15 | 21.00 ± 2.64 | 18.60 ± 2.30 | 17.00 ± 2.00 |

(18.66 mm each). The antibiotic tetracycline showed minimum zone of inhibition than that of plant extracts (average zone of inhibition 0–18 mm) and the difference was statistically significant. *P. guajava* extract produced (24.60 ± 3.21) mm inhibition zone against *E. coli*, whereas alcoholic extract of *P. granatum* exhibited best activity against *Shigella* sp. [(23.30 ± 1.52) mm].

MIC was used to confirm the antimicrobial nature of plant extracts. It also represented minimum quantity of antimicrobial compound required to kill or arrest multiplication of all microorganisms present in the medium or body fluid. Aqueous extract of *H. indicus* showed least MIC value [(841.66 ± 38.18) µg/mL] against *Citrobacter*, whereas *P. granatum* showed a MIC of (808.33 ± 38.18) µg/mL against *Citrobacter* sp. (Table 3). *P. granatum* extract also showed best MIC against *Klebsiella* sp. and *S. aureus* [(50.00 ± 25.00) µg/

**Table 2**
Antibacterial nature of alcoholic extracts of different plants.

| Test organisms | Zone of inhibition | | | | | |
|---|---|---|---|---|---|---|
| | *A. marmelos* | *H. indicus* | *M. indica* | *P. granatum* | *P. guajava* | *S. asoca* |
| *E. coli* | 12.30 ± 2.08 | 13.30 ± 2.30 | 17.60 ± 1.52 | 22.00 ± 1.33 | 24.60 ± 3.21 | 19.60 ± 1.52 |
| *Shigella* sp. | 15.30 ± 2.08 | 12.30 ± 1.52 | 21.30 ± 1.15 | 23.30 ± 1.52 | 14.30 ± 1.52 | 20.30 ± 0.33 |
| *S. typhi* | 15.60 ± 0.57 | 14.30 ± 1.52 | 18.60 ± 2.30 | 20.60 ± 1.52 | 14.60 ± 2.30 | 19.00 ± 2.60 |
| *Lactobacillus* | 11.60 ± 1.52 | 12.60 ± 1.15 | 16.00 ± 1.00 | 20.00 ± 1.00 | 17.60 ± 1.15 | 16.00 ± 2.60 |
| *S. pyogenes* | 13.60 ± 1.52 | 12.60 ± 1.15 | 16.30 ± 0.57 | 15.30 ± 4.70 | 22.00 ± 3.46 | 17.00 ± 1.00 |
| *P. fluorescence* | 14.00 ± 2.00 | 15.60 ± 1.15 | 19.00 ± 2.64 | 19.30 ± 3.05 | 19.60 ± 3.21 | 16.00 ± 1.00 |
| *Enterobacter* sp. | 13.00 ± 1.41 | 16.00 ± 1.00 | 16.60 ± 1.15 | 14.30 ± 3.21 | 12.60 ± 2.08 | 13.60 ± 1.52 |
| *Citrobacter* sp. | 12.50 ± 0.70 | 14.00 ± 2.64 | 14.00 ± 2.00 | 16.60 ± 2.08 | 14.30 ± 1.52 | 15.60 ± 1.15 |
| *X. campestris* | 12.60 ± 1.52 | 14.60 ± 2.51 | 18.30 ± 6.02 | 20.30 ± 1.52 | 18.30 ± 0.57 | 18.60 ± 1.52 |
| *X. citri* | 16.00 ± 1.00 | 12.60 ± 0.57 | 16.60 ± 2.08 | 17.00 ± 0.00 | 17.60 ± 1.52 | 22.00 ± 1.00 |
| *P. aeruginosa* | 16.00 ± 1.00 | 12.60 ± 0.57 | 14.30 ± 1.52 | 20.00 ± 1.73 | 17.30 ± 2.51 | 15.60 ± 1.15 |
| *Klebsiella* sp. | 12.00 ± 2.82 | 12.50 ± 0.70 | 17.60 ± 1.15 | 16.00 ± 3.00 | 19.60 ± 0.57 | 16.30 ± 1.52 |
| *S. faecalis* | 16.30 ± 3.05 | 13.00 ± 1.73 | 19.60 ± 2.08 | 21.60 ± 1.15 | 23.00 ± 2.64 | 22.00 ± 1.73 |
| *S. aureus* | 11.50 ± 0.70 | 15.60 ± 0.57 | 17.60 ± 4.04 | 21.00 ± 2.00 | 21.00 ± 3.60 | 18.30 ± 1.52 |

Data were expressed as mean ± SD.

**Table 3**
MIC of aqueous extracts of different plants (µg/mL).

| Test organisms | MIC value of aqueous extracts of the plant material | | | | | |
|---|---|---|---|---|---|---|
| | *A. marmelos* | *H. indicus* | *M. indica* | *P. granatum* | *P. guajava* | *S. asoca* |
| *E. coli* | 766.66 ± 76.37 | 758.33 ± 76.37 | 350.00 ± 50.00 | 108.33 ± 38.18 | 41.66 ± 14.43 | 125.00 ± 25.00 |
| *Shigella* sp. | 658.33 ± 62.91 | 783.33 ± 115.47 | 75.00 ± 25.00 | 58.33 ± 14.43 | 75.00 ± 25.00 | 208.00 ± 62.91 |
| *S. typhi* | 83.33 ± 14.43 | 625.00 ± 66.14 | 91.66 ± 38.18 | 91.66 ± 28.86 | 133.33 ± 76.37 | 183.33 ± 28.86 |
| *Lactobacilli* | 577.33 ± 38.18 | 725.00 ± 25.00 | 133.33 ± 14.43 | 533.33 ± 38.18 | 58.33 ± 14.14 | 266.66 ± 14.43 |
| *S. pyogenes* | 575.00 ± 25.00 | 825.00 ± 25.00 | 325.00 ± 25.00 | 333.33 ± 38.18 | 91.66 ± 52.04 | 125.00 ± 66.14 |
| *P. fluorescens* | 675.00 ± 25.00 | 716.66 ± 14.43 | 266.66 ± 28.86 | 58.33 ± 38.18 | 91.66 ± 38.18 | 241.66 ± 38.18 |
| *Enterobacter* sp. | 533.33 ± 28.66 | 733.33 ± 38.18 | 225.00 ± 25.00 | 633.33 ± 33.19 | 191.66 ± 14.43 | 166.66 ± 38.18 |
| *Citrobacter* sp. | 425.00 ± 25.00 | 841.66 ± 38.18 | 550.00 ± 25.00 | 808.33 ± 38.18 | 133.33 ± 38.18 | 291.66 ± 38.18 |
| *X. campestris* | 758.33 ± 38.18 | 608.33 ± 38.10 | 175.00 ± 25.00 | 91.66 ± 144.00 | 116.00 ± 14.43 | 275.00 ± 25.00 |
| *X. citri* | 541.16 ± 52.04 | 793.33 ± 27.53 | 200.00 ± 25.00 | 191.66 ± 14.43 | 383.33 ± 14.43 | 183.33 ± 14.43 |
| *P. aeruginosa* | 525.00 ± 25.00 | 741.66 ± 14.43 | 758.33 ± 52.04 | 75.00 ± 25.00 | 95.66 ± 14.43 | 33.33 ± 14.43 |
| *Klebsiella* sp. | 508.33 ± 14.43 | 79.66 ± 38.18 | 516.66 ± 52.04 | 50.00 ± 25.00 | 41.66 ± 28.88 | 258.33 ± 14.43 |
| *S. faecalis* | 725.00 ± 25.00 | 800.00 ± 25.00 | 408.33 ± 14.43 | 66.66 ± 28.86 | 41.66 ± 14.43 | 58.33 ± 28.86 |
| *S. aureus* | 508.33 ± 14.43 | 341.66 ± 38.18 | 525.00 ± 25.00 | 50.00 ± 25.00 | 41.66 ± 14.43 | 50.00 ± 25.00 |

**Table 4**
MIC of alcoholic extracts of different plants (µg/mL).

| Test organisms | MIC value | | | | | |
|---|---|---|---|---|---|---|
| | *A. marmelos* | *H. indicus* | *M. indica* | *P. granatum* | *P. guajava* | *S. asoca* |
| *E. coli* | 608.33 ± 38.18 | 825.00 ± 25.00 | 108.33 ± 14.43 | 91.66 ± 28.86 | 41.66 ± 14.43 | 50.00 ± 25.00 |
| *Shigella* sp. | 575.00 ± 25.00 | 458.33 ± 80.36 | 41.66 ± 28.86 | 175.00 ± 25.00 | 83.33 ± 52.04 | 100.00 ± 25.00 |
| *S. typhi* | 666.66 ± 28.86 | 350.00 ± 25.00 | 325.00 ± 25.00 | 50.00 ± 0.00 | 66.66 ± 38.18 | 83.33 ± 28.18 |
| *Lactobacillus* | 591.66 ± 38.18 | 633.33 ± 14.43 | 50.00 ± 0.00 | 58.33 ± 14.43 | 83.33 ± 52.04 | 150.00 ± 50.00 |
| *S. pyogenes* | 641.66 ± 14.40 | 425.00 ± 0.00 | 233.33 ± 14.43 | 25.00 ± 0.00 | 83.33 ± 28.86 | 100.00 ± 25.00 |
| *P. fluorescens* | 675.00 ± 25.00 | 133.33 ± 14.43 | 58.33 ± 14.43 | 41.66 ± 14.43 | 91.66 ± 14.43 | 266.66 ± 28.86 |
| *Enterobacter* sp. | 475.00 ± 25.00 | 316.66 ± 14.43 | 75.00 ± 0.00 | 708.33 ± 87.79 | 75.00 ± 25.00 | 325.00 ± 43.30 |
| *Citrobacter* sp. | 633.33 ± 28.86 | 758.33 ± 72.60 | 441.66 ± 28.86 | 591.66 ± 38.18 | 83.33 ± 14.43 | 91.66 ± 14.43 |
| *X. campestris* | 466.66 ± 14.43 | 408.33 ± 14.43 | 41.66 ± 0.00 | 50.00 ± 25.00 | 91.66 ± 28.86 | 33.33 ± 14.43 |
| *X. citri* | 350.00 ± 0.00 | 800.00 ± 25.00 | 116.66 ± 14.43 | 50.00 ± 25.00 | 216.66 ± 28.86 | 141.66 ± 14.43 |
| *P. aeruginosa* | 658.33 ± 14.43 | 616.66 ± 38.18 | 158.33 ± 52.04 | 341.66 ± 52.04 | 58.33 ± 28.86 | 141.66 ± 28.86 |
| *Klebsiella* sp. | 466.66 ± 14.43 | 625.00 ± 25.00 | 141.66 ± 14.43 | 83.33 ± 28.86 | 100.00 ± 25.00 | 108.33 ± 14.43 |
| *S. faecalis* | 91.66 ± 14.43 | 341.66 ± 14.43 | 66.66 ± 14.43 | 66.66 ± 14.43 | 50.00 ± 25.00 | 33.33 ± 14.43 |
| *S. aureus* | 766.66 ± 28.88 | 216.66 ± 14.43 | 411.66 ± 14.43 | 75.00 ± 43.30 | 41.60 ± 14.43 | 191.66 ± 14.43 |

mL each)] followed by *Shigella* sp., [(58.33 ± 14.43) µg/mL].

MIC of aqueous extract of *P. guajava* was (41.66 ± 14.43) µg/mL for *E. coli*, *S. faecalis* and *S. aureus*. It was evident that the growth of invasive bacteria like *Shigella* and *Salmonella* were effectively controlled by the aqueous extract obtained from *M. indica* seed kernel, *P. granatum* fruit rind, *P. guajava* leaves and *S. asoca* stem bark. Among the 6 plant parts tested *P. guajava* and *P. granatum* were the best for intestinal and invasive bacterium (Table 3).

Alcoholic extract of 6 different plants also showed good MIC value against all the microorganisms tested, than the aqueous extracts. *P. granatum* arrested the growth of *S. pyogenes* completely at a concentration of (25.00 ± 0.00) µg/mL. Least MIC value was exhibited by *H. indicus* against *E. coli* [(825.00 ± 25.00) µg/mL MIC value]. Among all the plants tested, *H. indicus* and *P. guajava* leaf alcoholic extract showed best activity (Table 4).

## 4. Discussion

All 6 plants used in the study were tested for various infections especially gastrointestinal infections. The results of present antibacterial study support the use of medicinal plants as anti-diarrhoeal, astringent and anti-inflammatory. Microorganisms like *E. coli*, *Salmonella* and *Shigella* are the primary agents responsible for most of the gastrointestinal infections. *S. pyogenes* and *S. aureus* were mainly involved in invasive inflammatory diseases[24]. The growth of *E. coli*, *Salmonella*, *Shigella*, *Streptococcus* and *Pseudomonas* were effectively inhibited by the extracts of all plants tested (Tables 1-4).

Few other reports from India and abroad also described antibacterial potentials of mango seed kernel. Aqueous extract of *M. indica* inhibited the growth of *S. aureus* and *Proteus vulgaris*[25]. Gallotannins were extracted from *M. indica* kernels with aqueous acetone and purified using analytical high-performance liquid chromatography and mass spectrometry confirmed the presence of hydrolyzable tannins with a degree of galloylation ranging from 4 to 9 and additionally revealed the presence of deca-, undeca-, and dodeca-O-galloylglucose with antibacterial activity, as evidenced from the agar spot and critical dilution assays[26-28].

Ethanolic extract of *M. indica* seed kernel showed good and effective activity against both Gram-positive and Gram-negative bacteria especially against pathogenic serogroups such as *E. coli*, *Salmonella enteritis*, *Shigella flexneri* (*S. flexneri*), *Klebsiella*, *Yersinia enterocolitica*, *Vibrio* sp., *Campylobacter* sp., *S. aureus etc*. [29]. Seed kernel also possesses good antibacterial and antifungal activity against *Agrobacterium* sp., *Proteus* sp., *Pseudomonas* sp., *S. flexneri*, *E. coli*, *S. typhi*, *S. enteritidis*, *S. dysenteriae*, antifungal *Trichophyton mentagrophytes*, *Candida lutea*, *Candida albicans*[30]. Hexane, benzene, chloroform, methanol and water extracts of mango seed kernel showed excellent antibacterial activity against enteropathogenic *E. coli*[31]. Growth of urinary isolates like *E. coli*, *S. pyogenes* and *S. aureus* were also inhibited by aqueous and alcoholic extracts of seed kernel[32]. Kaur *et al*.[33] also reported that single and mixed seed kernel methanol extract inhibited methicillin resistant *S. aureus*, *E. coli* and *Vibrio vulnificus* at 100 mg/mL concentration. Kabuki *et al*.[29], Masibo and He[34], Ribeiro *et al*.[35] and Khammuang and Sarnthima[36] described that phenolic contents like tannins, flavonoids found in seed kernel may be responsible for antibacterial activity. These compounds precipitate surface proteins of microorganisms thereby inhibiting/arresting the growth of microorganisms.

Reports of Reddy *et al*.[37], Opara *et al*.[38], Mathabe *et al*.[39], Duman *et al*.[40], Duraipandiyan *et al*.[41] and Naz *et al*.[42] also support antimicrobial potentials of *P. granatum* fruit rind extracts. They stated that extracts and fractions inhibited the growth of *E. coli*, *S. aureus*, multidrug resistant *S. typhi* and *S. flexneri*. Enteropathogenic *E. coli* growth was also inhibited by the extracts and fraction of *P. granatum* fruit rind[43]. *S. asoca* bark extracts also inhibited the growth of pathogenic strains of *E. coli*, *Salmonella enteritis*, *Shigella sonnei*[44] and also non-pathogenic strains[45]. Antibacterial effect of *A. marmelos* fruit pulp extracts were also supported by Rajan and Jeevagangai[46]. They confirmed that *A. marmelos* fruit pulp extracts exhibited great antibacterial activity against multidrug resistant *S. typhi*, *E. coli*, *Salmonell*a, *Shigella etc*. Austin[47], Das and Devaraj[48], Gayathri and Kannabiran[49] and Rajan and Vayutha[50] reported antibacterial activities of *H. indicus* root extracts against pathogenic *E. coli*, *Salmonella*, *S. aureus*, *Streptococcus mutans*, *Pseudomonas*, *Enterobacter* and *Salmonella typhimurium*.

Results of the present study indicated that antibacterial activity of the extracts varied significantly depending upon the plant used. Data indicated that extracts prepared from *P. guajava* leaves exhibited better antibacterial activities than those extracts prepared from other plants. All the 6 plant extracts showed significant antibacterial activity. The alcoholic extract of *P. guajava* exhibited maximum inhibition, followed by *P. granatum* fruit rind, *M. indica* seed kernel, *S. asoca* stem bark, *H. indicus* root and *A. marmelos* fruit pulp extracts. Gram-negative bacteria were found more susceptible as compared to Gram-positive species. The efficacies of plant extracts were higher than the standard. Herbal medicines are a valuable and readily available resource for primary healthcare and complementary healthcare systems. Unfortunately, many species of plants containing substances of medicinal value have yet to be discovered, though large numbers of plants are constantly being screened for their antimicrobial effects. It has been suggested that phytochemical extracts from plants hold promise to be used in allopathic medicine as they are potential sources of antiviral, antitumoral and antimicrobial agents.

## Conflict of interest statement

We declare that we have no conflict of interest.

## Acknowledgments

The authors thank profusely the management of Bharathidasan University and Srimad Andavan Arts and Science College, Trichy for providing the laboratory facilities.

## References

[1] Asha Devi NK, Rajendran R, Sundaram SK. Isolation and characterization of bioactive compounds from marine bacteria. *Indian J Nat Prod Resour* 2011; **2**(1): 59-64.

[2] Malwal M, Sarin R. Antimicrobial efficacy of *Murraya koenigii* (Linn.) Spreng. root extracts. *Indian J Nat Prod Resour* 2011; **2**(1): 48-51.

[3] Dev S. Impact of natural products in modern drug development. *Indian J Exp Biol* 2010; **48**: 191-8.

[4] Gunasekaran S, Anita B. Analysis of phytochemical variability in Neem formulations. *Indian J Nat Prod Resour* 2010; **1**(3): 291-5.

[5] Balakumar S, Rajan S, Thirunalasundari T, Jeeva S. Antifungal activity of *Aegle marmelos* (L.) Correa (Rutaceae) leaf extract on dermatophytes. *Asian Pac J Trop Biomed* 2011; **1**(4): 309-12.

[6] Paul RK, Irudayaraj V, Johnson M, Patric RD. Phytochemical and anti-bacterial activity of epidermal glands extract of *Christella parasitica* (L.) H. Lev. *Asian Pac J Trop Biomed* 2011; **1**(1): 8-11.

[7] Jeeva S, Sawian JT, Lyndem FG, Laloo RC, Venugopal N. Medicinal plants in Northeast India: past, present and future scenario. In: Prabha AL, editor. *National seminar on past, present and future scenario in medicinal plants and phytochemistry*. Tiruchirappalli: Bharathidasan University; 2007.

[8] Laloo RC, Kharlukhi L, Jeeva S, Mishra BP. Status of medicinal plants in the disturbed and the undisturbed sacred forests of Meghalaya, northeast

India: population structure and regeneration efficacy of some important species. *Curr Sci* 2006; **90**(2): 225-32.

[9] Premkumar G, Sankaranarayanan R, Jeeva S, Rajarathinam K. Cytokinin induced shoot regeneration and flowering of *Scoparia dulcis* L. (Scrophulariaceae)-an ethnomedicinal herb. *Asian Pac J Trop Biomed* 2011; **1**(3): 169-72.

[10] Pugazharasi G, Meenakshi SA, Ramesh KN, Bastin CM, Natarajan E. Screening of antimicrobial activity of *Phyllanthus maderaspatensis* L. *J Basic Appl Biol* 2009; **3**(3&4): 43-9.

[11] Sadheeshna KS, Huxley AJ, Sasikala. *In vitro* propagation of medicinally important plant *Mimosa invisa*. *J Basic Appl Biol* 2009; **3**(3&4): 27-32.

[12] Ponni V, Thenmozhi S, Rajan S. Screening of bioactive potentials and phytochemical nature of *Solanum trilobatum* extracts. *J Basic Appl Biol* 2009; **3**(3&4): 134-39.

[13] Suresh KP. Anti-fungal activity of *Leptadenia reticulate* in rat animal model *in vivo*. *J Basic Appl Biol* 2008; **2**(1): 9-13.

[14] Hasan MF, Das R, Khan A, Hossain MS, Rahman M. The determination of antibacterial and antifungal activities of *Polygonum hydropepper* L. root extract. *Adv Biol Res 3* 2009; **3**(1-2): 53-6.

[15] Jeeshna MV, Manorama S, Paulsamy S. Antimicrobial property of the medicinal shrub, *Glycosmis pentaphylla*. *J Basic Appl Biol* 2009; **3**(1&2): 25-7.

[16] Jeeva S, Kingston C, Kiruba S, Kannan D. Sacred forests-treasure trove of medicinal plants: a case study from South Travancore. In: Trivedi PC, editor. *Indigenous medicinal plants*. Jaipur: Pointer Publishers; 2007, p. 262-74.

[17] Anpin Raja RD, Prakash JW, Jeeva S. Medicinal plants used by Kanis in Aarukani hills of southern Western Ghats. In: Trivedi PC, editor. *Indigenous medicinal plants*. Jaipur: Pointer Publishers; 2009, p. 1-48.

[18] Anpin Raja RD, Prakash JW, Jeeva S. Antibacterial activity of some medicinal plants used by Kani tribe, southern Western Ghats, Tamilnadu, India. In: Trivedi PC, editor. *Ethnic tribes and medicinal plans*. Jaipur: Pointer Publishers; 2010, p. 28-45.

[19] Anpin Raja RD, Prakash JW. Plants used as anti-venom by Kani tribes of Kilamalai reserver forest, Kanyakumari district. *J Basic Appl Biol* 2007; **1**(1): 27-32.

[20] Kala CP, Farooquee NA, Majila BS. Indigenous knowledge and medicinal plants used by vaidyas in Uttaranchal, India. *Nat Prod Rad* 2005; **4**(3): 195-206.

[21] Kala S, Johnson M, Raj I, Bosco D, Jeeva S, Janakiraman N. Preliminary phytochemical analysis of some selected medicinal plants of south India. *J Nat Conscientia* 2011; **2**(5): 478-81.

[22] Gamble JS. *Flora of the Presidency of Madras. Vol I-III*. Dehra Dun: Bishen Singh Mahendra Pal Singh; 1993.

[23] Mathew KW. *The flora of Tamilnadu Carnatic*. Tiruchirapalli: The Rapinat Herbarium; 1983.

[24] Rajan S. *Medical microbiology*. Tamilnadu: MJP Publishers; 2007.

[25] Sairam K, Hemalatha S, Kumar A, Srinivasan T, Ganesh J, Shankar M, et al. Evaluation of anti-diarrhoeal activity in seed extracts of *Mangifera indica*. *J Ethnopharmacol* 2003; **84**: 11-5.

[26] Engels C, Knödler M, Zhao YY, Carle R, Gänzle MG, Schieber A. Antimicrobial activity of gallotannins isolated from mango (*Mangifera indica* L.) kernels. *J Agric Food Chem* 2009; **57**(17): 7712-8.

[27] Engels C, Gänzle MG, Schieber A. Fractionation of gallotannins from mango (*Mangifera indica* L.) kernels by high-speed counter-current chromatography and determination of their antibacterial activity. *J Agric Food Chem* 2010; **58**(2): 775-80.

[28] Engels C, Schieber A, Gänzle MG. Inhibitory spectra and modes of antimicrobial action of gallotannins from mango seed kernels (*Mangifera indica* L.). *Appl Environ Microbiol* 2011; **77**(7): 2215-23.

[29] Kabuki T, Nakajima H, Arai M, Ueda S, Kuwabara Y, Dosako S. Characterization of novel antimicrobial compounds from mango (*Mangifera indica* L.) kernel seeds. *Food Chem* 2000; **71**: 61-6.

[30] Das PC, Das A, Mandal S, Islam CN, Dutta MK, Patra BB, et al. Anti-inflammatory and antimicrobial activities of the seed kernel of *Mangifera indica*. *Fitoterapia* 1989; **60**: 235-40.

[31] Rajan S, Balakumar S, Thirunalasundari T. Antibacterial activity of *Mangifera indica* seed kernel on enteropathogenic *Escherichia coli*. *Biomedicine* 2006; **26**: 25-8.

[32] Sowmiya S, Soundarapandiyan P, Rajan S. Bioactive studies of *Mangifera indica* against bacteria isolated from urine samples. *Curr Res J Biol Sci* 2009; **1**: 139-43.

[33] Kaur J, Rathinam X, Kasi M, Leng KM, Ayyalu R, Kathiresan S, et al. Preliminary investigation on the antibacterial activity of mango (*Mangifera indica* L: Anacardiaceae) seed kernel. *Asian Pac J Trop Med* 2010; **3**: 707-10.

[34] Masibo M, He Q. Major mango polyphenols and their potential significance to human health. *Compr Rev Food Sci Food Saf* 2008; **7**: 309-19.

[35] Ribeiro SMR, Barbosa LCA, Queiroz JH, Knödler M, Schieber A. Phenolic compounds and antioxidant capacity of Brazilian mango (*Mangifera indica* L.) varieties. *Food Chem* 2008; **110**(3): 620-6.

[36] Khammuang S, Sarnthima R. Antioxidant and antibacterial activities of selected varieties of Thai mango seed extract. *Pak J Pharm Sci* 2011; **24**(1): 37-42.

[37] Reddy MK, Gupta SK, Jacob MR, Khan SI, Ferreira D. Antioxidant, antimalarial and antimicrobial activities of tannin-rich fractions, ellagitannins and phenolic acids from *Punica granatum* L. *Planta Med* 2007; **73**(5): 461-7.

[38] Opara LU, Al-Ani MR, Al-Shuaibi YS. Physico-chemical properties, vitamin C content, and antimicrobial properties of pomegranate fruit (*Punica granatum* L.). *Food Bioprocess Technol* 2009; **2**(3): 315-21.

[39] Mathabe MC, Nikolova RV, Lall N, Nyazema NZ. Antibacterial activities of medicinal plants used for the treatment of diarrhoea in Limpopo Province, South Africa. *J Ethnopharmacol* 2006; **105**(1-2): 286-93.

[40] Duman AD, Ozgen M, Dayisoylu KS, Erbil N, Durgac C. Antimicrobial activity of six pomegranate (*Punica granatum* L.) varieties and their relation to some of their pomological and phytonutrient characteristics. *Molecules* 2009; **14**(5): 1808-17.

[41] Duraipandiyan V, Ayyanar M, Ignacimuthu S. Antimicrobial activity of some ethnomedicinal plants used by Paliyar tribe from Tamil Nadu, India. *BMC Complement Altern Med* 2006; **6**: 35.

[42] Naz S, Siddiqi R, Ahmad S, Rasool SA, Sayeed SA. Antibacterial activity directed isolation of compounds from *Punica granatum*. *J Food Sci* 2007; **72**(9): M341-5.

[43] Rajan S, Balakumar S, Thirunalasundari T. Antibacterial activity of *Punica granatum* Linn. fruit rind extracts and fractions on enteropathogenic *E. coli*. *Asian J Microbiol Biotechnol Environ Sci* 2008; **10**: 625-7.

[44] Rajan S, Johnson J, Selvichristy J. Antibacterial activity and preliminary phytochemical screening of the extracts of the bark of *Saraca asoca* (Roxb.) Wild. (Caesalpiniaceae). *J Sci Trans Environ Technov* 2008; **1**(3): 149-51.

[45] Nandagopal B, Sankar S, Ramamurthy M, Sathish S, Sridharan G. Could the products of Indian medicinal plants be the next alternative for the treatment of infections? *Indian J Med Microbiol* 2011; **29**(2): 93-101.

[46] Rajan S, Jeevagangai TJ. Studies on the antibacterial activity of *Aegle marmelos* fruit pulp and its preliminary phytocemistry. *J Basic Appl Biol* 2009; **3**: 76-81.

[47] Austin A. A review on Indian sarsaparilla, *Hemidesmus indicus* (L.) R. Br. *J Biol Sci* 2008; **8**(1): 1-12.

[48] Das S, Devaraj SN. Antienterobacterial activity of *Hemidesmus indicus* R. Br. root extract. *Phytother Res* 2006; **20**(5): 416-21.

[49] Gayathri M, Kannabiran K. Antimicrobial activity of *Hemidesmus indicus*, *Ficus bengalensis* and *Pterocarpus marsupium* roxb. *Indian J Pharm Sci* 2009; **71**(5): 578-81.

[50] Rajan S, Vayutha P. Antibacterial activity, antioxidant activity and phytochemical studies of *Hemidesmus indicus* root. *Res J Biol Sci* 2010; **4**: 46-54.