Journal of Medicinal Herbs and Ethnomedicine 2023, 9: 29-33
doi: 10.25081/jmhe.2023.v9.8523
https://updatepublishing.com/journal/index.php/jmhe

Research Article

ISSN: 2455-0485

Phytochemical screening and antimicrobial activity of plant leaf extract against enteric bacterial pathogens

Uthamalingam Murali[1], N. Pandeeswari[2], Boojhana Elango[3], Karthikeyan Murugesan[4], K. Abirami[5], V. V. Divya[5], T. A. Sathya[5], Kanthesh M. Basalingappa[6], Maghimaa Mathanmohun[3]*

[1]Professor of Surgery, Department of General Surgery, Manipal University College Malaysia, Melaka, Malaysia, [2]Department of Microbiology, Faculty of Agriculture, Annamalai University, Annamalai Nagar-608002, Tamil Nadu, India, [3]Department of Microbiology, Muthayammal College of Arts and Science, Rasipuram, Namakkal-637408, Tamil Nadu, India, [4]Department of Microbiology, Faculty of Medicine and Health Sciences, Centre for Infectious Diseases and Phytochemical Studies, Quest International University, Perak, Malaysia, [5]Deparment of Microbiology, Vivekanandha College of Arts and Science for Women (Autonomous), Tiruchengode, Namakkal-637205, Tamil Nadu, India, [6]Division of Molecular Biology, School of Life Sciences, JSS Academy Of Higher Education & Research, SS Nagar, Mysuru-570015, Karnataka, India

ABSTRACT

Punica granatum, a fruit-bearing shrub belonging to the Lythraceae family, offers various benefits to humans, with both its fibers and seeds being valuable. The seeds contain important oil acids such as palmitic, punica, stearic, and oleic acids. In India, *P. granatum* (pomegranate) leaves have been investigated for their potential antibacterial activity against enteric pathogens. These pathogens are responsible for causing gastrointestinal infections and are often associated with antibiotic resistance. The study aims to explore whether pomegranate leaves possess properties that can combat these enteric pathogens effectively. This research holds promise in identifying a natural and alternative approach to address antibacterial challenges, potentially contributing to the development of novel antimicrobial agents pomegranate is commonly used as a traditional remedy for treating enteric bacterial pathogens. To investigate its antibacterial properties, researchers studied the aqueous extract of *P. granatum* leaf against enteric pathogens, conducting tests like biochemical examinations and microscopy on the isolates. The phytochemical analysis of *P. granatum* (pomegranate) leaf aqueous extract revealed the presence of various bioactive compounds. These compounds include amino acids, carbohydrates, alkaloids, steroids, flavonoids, terpenoids, saponins, tannins, and phenols. To evaluate its antimicrobial activity, the researchers used antibiotic discs, including chloramphenicol, vancomycin, and gentamicin, employing the standard Kirby Bauer method. Results showed that vancomycin had the highest zone of inhibition, followed by chloramphenicol and gentamicin, with respective measurements of 20 mm and 19 mm. Chloramphenicol exhibited sensitivity against *Escherichia coli* (19 mm), while gentamicin showed sensitivity against *Salmonella typhi* (20 mm), *Staphylococcus aureus* (19 mm), and *E. coli* (18 mm). Vancomycin demonstrated sensitivity against *S. aureus* (21 mm). The aqueous leaf extract displayed significant antibacterial activity at concentrations of 20, 40 mcg, and 60 µg, showing effective zones of inhibition ranging from 15 mm to 22 mm against *Pseudomonas aeruginosa*, *E. coli*, *S. aureus*, *Shigella dysentriae*, *Proteus vulgaris*, and *S. typhi*. In conclusion, the study established that *P. granatum* leaf extracts possess remarkable antibacterial properties and contain valuable pharmaceutical bioactive compounds. Due to its efficacy in treating gastrointestinal disorders, it is utilized as a natural remedy in traditional medicine.

KEYWORDS: *Punica granatum* leaf, Phytochemicals constituents, Antimicrobial, Bacterial pathogens

Received: January 25, 2023
Revised: July 17, 2023
Accepted: July 24, 2023
Published: August 08, 2023

***Corresponding Author:**
Maghimaa Mathanmohun
E-mail: maghimaam@gmail.com

INTRODUCTION

Since ancient times, humans have relied on medicinal plants and traditional herbal products for various therapeutic purposes. India, with its rich and diverse flora, has been a hub of such natural remedies (Maghimaa & Palanisamy, 2019; Kabeerdass *et al.*, 2021a; Mathanmohun *et al.*, 2021; Pandeeswari *et al.*, 2021a; Sankareswaran *et al.*, 2021; Maghimaa & Palanisamy,

2016; Nashima & Palanisamy, 2016). Among the noteworthy natural power fruits in India is *P. granatum*, commonly known as Pomegranate, which has been traditionally used for treating various diseases. The fruit is used to prepare juice, as well as other products like jam, jelly, and beverages. Historical records show that ancient Egyptians used extracts from this plant, including its bark and fruits, to cure infections like dysentery and diarrhea. The traditional system of Ayurveda in India has utilized Pomegranate as a medicine for thousands of years (Vakayil *et al.*, 2021a; Kabeerdass *et al.*, 2022a). However, drug resistance has become a significant clinical challenge in treating microbial infections like dysentery and cholera (Kabeerdass *et al.*, 2021b, c; Baburam *et al.*, 2022; Nair *et al.*, 2022; Sharmila *et al.*, 2022; Vakayil *et al.*, 2022a). Despite this, some antibiotics with antibacterial properties remain unexplored in the pharmacological context, supporting their use in traditional anti-diarrheal remedies. Peel and leaf extracts of Pomegranate have shown various pharmacological properties (Fan *et al.*, 2021; Sun *et al.*, 2021; Kabeerdass *et al.*, 2022b, c), and the fruit itself has been reported to possess antiviral properties against influenza, pox, herpes, and HIV-1 virus. Its main components, hydrolyzable pigments like anthocyanins and tannins, offer valuable health benefits to humans, including antibacterial effects. The plant also contains flavonoids like punicalagin, ellagic acid, caffeic acid, and luteolin, among which punicalagin exhibits higher inhibitory effects on the influenza virus. The mature Pomegranate fruit comprises fleshy appendages or seeds covered by a white, membranous, edible layer of the pericarp.

P. granatum juice has been found to possess robust antioxidant activity, surpassing that of fruit juices from oranges and grapes. These natural antioxidants contribute to cell rejuvenation and anti-aging effects in humans. Additionally, Pomegranate shows potent anticancer and anti-inflammatory properties against various human malignancies. This research aims to evaluate the antimicrobial and phytochemical properties of *P. granatum* leaf extract against multidrug-resistant enteric pathogens in vitro. This investigation holds promise for uncovering new potential uses of *P. granatum* as a natural remedy in combating drug-resistant infections.

MATERIALS AND METHODS

Plant Material Collection

The fresh leaf of *Punica granatum* was obtained from the Kolli hills, Rasipuram, Namakkal District, Tamil Nadu, India. The taxonomic identities of the plant were verified (Ansari *et al.*, 2019; Vakayil *et al.*, 2021c; Kabeerdass *et al.*, 2022d; Vakayil *et al.*, 2022b).

Preparation of Plant Extract

The leaves were carefully washed, dried in the shade, ground into a powder, and stored in airtight bottles at 4 ºC. To prepare the leaf extract, 50 g of the powder was soaked in 250 mL of water for 8 hours using a soxhlet apparatus at a temperature of 65 ºC. After 8 hours, the leaf extract was collected, concentrated, and stored in an airtight container at 4 ºC for further use (Abirami & Maghimaa, 2019; Vakayil *et al.*, 2019, 2020, 2021b,e,f; Abirami *et al.*, 2021).

Phytochemical Analysis

The concentrated aqueous extract was subjected to phytochemical analysis to screen for antimicrobial and phytochemical properties (Sivakumar *et al.*, 2018).

Clinical Sample Collection and Culture Preparation

The diarrheal stool samples were collected in sterile containers from hospitals and laboratories in Salem and transported to the laboratory. The samples were inoculated in MacConkey broth, and after 24 hours, pure cultures were obtained on MacConkey agar plates. The pure cultures were then maintained in nutrient agar slants.

Physiological and Biochemical Analysis

The isolates were identified based on their biochemical and physiological profiles.

Antimicrobial Sensitivity Test

The isolates were subjected to an antibiotic sensitivity test using the disc diffusion method, and the plates were incubated for 24 hours. The zone of inhibition was measured using a plate ruler, and the isolates were categorized as Resistant or Sensitive.

Determination of Antibacterial Activity

The aqueous leaf extracts at different concentrations (20, 40, 60 µg) were evaluated against the isolated pathogens using the agar well diffusion method. The plates were incubated at 37ºC overnight, and the zone of inhibition (ZOI) was measured.

RESULTS

Table 1 displays the presence of various compounds, including amino acids, carbohydrates, alkaloids, steroids, flavonoids, terpenoids, saponins, tannins, and phenols in the aqueous leaf extract of *P. granatum*. The pathogenic bacteria were isolated from diarrheal stool samples and subjected to biochemical characterization and microscopy. Microscopic examination revealed the presence of both gram-negative and gram-positive bacteria. Biochemical tests, including IMViC, catalase, oxidase, urease, carbohydrate test, and TSI tests, were conducted. The identified pathogens included *E. coli*, *S. aureus*, *P. aeruginosa*, *S. dysentriae*, *S. typhi*, and *P. vulgaris*. Table 2 presents the results of the antibiotic sensitivity test, indicating that Vancomycin had the highest zone of inhibition (21 mm), followed by Chloramphenicol and Gentamicin (20 mm and 19 mm). Chloramphenicol exhibited sensitivity against *E. coli* (19 mm), while Gentamicin showed sensitivity against *E. coli* (18 mm), *S. aureus* (19 mm), and *S. typhi* (20 mm). Vancomycin was found to be sensitive against *S. aureus* (21 mm).

Table 1: Phytochemical compounds in *P. granatum* leaf extracts

Phytochemical constituents	Acqueous extract
Alkaloids	+
Steroids	+
Flavonoids	+
Tannins	+
Saponins	+
Phenols	+
Terpenoids	+
Amino acids	+
Carbohydrates	+

'+' presence and '-' absence of compound

Table 2: Antibiotic sensitivity towards the isolated pathogens

Isolates	Zone of inhibition (mm)		
	Gentamicin	Vancomycin	Chloramphenicol
P. aeruginosa	15	6	6
S. aureus	19	21	6
S. dysentriae	16	6	6
P. vulgaris	14	6	6
E. coli	18	6	19
S. typhi	20	6	15

Table 3 demonstrates the significant antibacterial activity of the aqueous leaf extract at concentrations of 20, 40, and 60 µg, showing an effective zone of inhibition in the range of 15-22 mm against *P. aeruginosa*, *E. coli*, *S. aureus*, *S. dysentriae*, *P. vulgaris*, and *S. typhi*. These findings highlight the potential of the leaf extract of *P. granatum* as an effective antimicrobial agent against the tested pathogens.

DISCUSSION

There is a growing need for innovative antimicrobial agents derived from plant sources that can offer protection, safety, and cost-effectiveness while addressing antibiotic resistance (Maghimaa & Palanisamy, 2012; Maghimaa *et al.*, 2012; Pandeeswari *et al.*, 2021b; Sivakumar *et al.*, 2021a, b; Sabarinath *et al.*, 2022a, b) and minimizing the adverse side effects associated with synthetic drugs. Pomegranate (*P. granatum*) peel has been widely utilized as an antimicrobial agent (Abirami & Maghimaa, 2019), and its antibacterial properties have been extensively studied in the past. Through phytochemical investigation, active inhibitors present in *P. granatum* leaves have been identified as potent components, making the leaf extract of *P. granatum* a readily available resource of natural antioxidants (Abirami & Maghimaa, 2019). This finding suggests that the peel extract could serve as an effective antibacterial agent. Such a diverse array of phytochemicals suggests that the *P.granatum* leaf extract possesses a wide range of potential health benefits. These bioactive constituents are known for their antioxidant, anti-inflammatory, and antimicrobial properties, which make the pomegranate leaf extract a valuable natural resource with potential therapeutic applications. For the scientific community involved in drug discovery and development, the key focus is on identifying novel active constituents responsible for antibacterial activity (Rajkumar *et al.*, 2023a, b). This

Table 3: Antimicrobial activity of *P. granatum* aqueous extract against the pathogens

Pathogens	Zone of inhibition (mm)		
	20 µg	40 µg	60 µg
P.aeruginosa	17	19	22
S. aureus	15	18	21
S. dysentriae	17	20	22
P.vulgaris	16	18	20
E. coli	15	18	21
S.typhi	16	18	22

requires a multidisciplinary approach to recognize and understand the dynamic compounds that contribute to the antimicrobial properties of *P. granatum* leaf extract. By exploring and harnessing these natural compounds, we may discover valuable solutions to combat bacterial infections in a safer and more sustainable manner.

CONCLUSION

The alarming rise in antibiotic resistance among microorganisms has led to a crucial demand for the development of new antimicrobial compounds. In this context, *P. granatum* emerges as a vital component, valued for its therapeutic properties in traditional medicine.

ACKNOWLEDGMENT

The authors are thankful for the financial support from the Member Secretary, Tamil Nadu State Council for Science and Technology (TNSCST), DOTE Campus, Chennai (S&T Project: TNSCST/STP-PRG/AR/2018-2019) and the DST–FIST Centralized laboratory, Muthayammal College of Arts and science, Rasipuram, Namakkal, Tamil Nadu, India for executing this work.

REFERENCES

Abirami, K., & Maghimaa, M. (2019). Phytochemical screening and bioactivity of *Zingiber officinale* to combat multidrug-resistant bacterial pathogens using foldscope. *Uttar Pradesh Journal of Zoology, 40*(2), 67-74.

Abirami, K., Murugesan, K., & Mathanmohun, M. (2021). Phytochemical screening and antibacterial potential of *Piper nigrum* seed extract against bacterial pathogens. *Research Journal of Agricultural Sciences, 12*(6), 2029-2033.

Ansari, S., Bari, A., Ullah, R., Mathanmohun, M., Veeraraghavan, V. P., & Sun, Z. (2019). Gold nanoparticles synthesized with *Smilax glabra* rhizome modulates the anti-obesity parameters in high-fat diet and streptozotocin-induced obese diabetes rat model. *Journal of Photochemistry and Photobiology B: Biology, 201*, 111643. https://doi.org/10.1016/j.jphotobiol.2019.111643

Baburam, S., Ramasamy, S., Shanmugam, G., & Mathanmohun, M. (2022). Quorum sensing inhibitory potential and molecular docking studies of *Phyllanthus emblica* phytochemicals against *Pseudomonas aeruginosa*. *Applied Biochemistry and Biotechnology, 194*, 434-444. https://doi.org/10.1007/s12010-021-03683-w

Fan, Y., Maghimaa, M., Chinnathambi, A., Alharbi, S. A., Veeraraghavan, V. P., Mohan, S. K., Hussain, S., & Rengarajan, T. (2021). Tomentosin reduces behavior deficits and neuroinflammatory response in MPTP-induced parkinson's disease in mice. *Journal of Environmental Pathology, Toxicology and Oncology, 40*(1), 75-84. https://doi.org/10.1615/JEnvironPatholToxicolOncol.v40.i1.70

Kabeerdass, N., Al Otaibi, A., Rajendran, M., Manikandan, A., Kashmery, H. A., Rahman, M. M., Madhu, P., Khan, A., Asiri, A. M., & Mathanmohun, M. (2021b). *Bacillus*-mediated silver nanoparticle synthesis and its antagonistic activity against bacterial and fungal pathogens. *Antibiotics, 10*(11), 1334. https://doi.org/10.3390/antibiotics10111334

Kabeerdass, N., Kandasamy, S., Albasher, G., Alamri, O., Alsultan, N., Thangaswamy, S., & Mathanmohun, M. (2022d). *Limonia acidissima* leaf mediated gold nanoparticles synthesis and their antimicrobial and wound healing properties. *Materials Letters, 314*, 131893. https://doi.org/10.1016/j.matlet.2022.131893

Kabeerdass, N., Krishnamoorthy, S., Anbazhagan, M., Srinivasan, R., Nachimuthu, S., Rajendran, M., & Mathanmohun, M. (2021c). Screening, detection, and antimicrobial susceptibility of multidrug-resistant pathogens from clinical specimens. *Materials Today: Proceedings, 47*, 461-467. https://doi.org/10.1016/j.matpr.2021.05.018

Kabeerdass, N., Murugesan, K., Arumugam, N., Almansour, A. I., Kumar, R. S., Djearamane, S., Kumaravel, A. K., Velmurugan, P., Mohanavel, V., Kumar, S. S., Vijayanand, S., Padmanabhan, P., Gulyás, B., & Maghimaa, M. (2022c). Biomedical and textile applications of *Alternanthera sessilis* leaf extract mediated synthesis of colloidal silver nanoparticle. *Nanomaterials, 12(*16), 2759. https://doi.org/10.3390/nano12162759

Kabeerdass, N., Murugesan, K., Ramasamy, S., & Mathanmohun, M. (2021a). Phyto mediated silver nanoparticle synthesis coated fabrics towards antibacterial potential. *Research Square*, Preprint. https://doi.org/10.21203/rs.3.rs-703040/v1

Kabeerdass, N., Thangasamy, S., Murugesan, K., Arumugam, N., Almansour, A. I., Kumar, R. S., Velmurugan, P., Vijayanand, S., Nooruddin, T., Mohanavel, V., Sivakumar, S., & Mathanmohun, M. (2022b). Embedding green synthesized zinc oxide nanoparticles in cotton fabrics and assessment of their antibacterial, wound healing, and cytotoxic properties: an eco-friendly approach. *Green Processing and Synthesis, 11*(1), 875-885. https://doi.org/10.1515/gps-2022-0072

Kabeerdass, N., Thangaswamy, S., Mohanasrinivasan, V., Rajasekaran, C., Sundaram, S., Nooruddin, T., & Mathanmohun, M. (2022a). Green synthesis–mediated nanoparticles and their curative character against post COVID-19 skin diseases. *Current Pharmacology Reports, 8*, 409-417. https://doi.org/10.1007/s40495-022-00303-x

Maghimaa, M., & Palanisamy, A. (2012). Biodiesel production by *Chlorella* sp. and *Oscillatoria* sp. *IJPI's Journal of Biotechnology and Biotherapeutics, 2*(10), 2229-6824.

Maghimaa, M., & Palanisamy, A. (2016). Screening, isolation, molecular identification, and hydrocarbon analysis of *Chlamydomonas debaryana*. *International Journal of Current Science, 6*(3), 81-92.

Maghimaa, M., & Palanisamy, A. (2019). Isolation, molecular identification, and hydrocarbon analysis of microalgae from paddy fields of rasipuram, namakkal. *Uttar Pradesh Journal of Zoology, 40*(4), 138-145.

Maghimaa, M., Santhiya, P., & Palanisamy, A. (2012). Production and optimization of lipase from wild and mutant strains of *Bacillus* sp. and *Pseudomonas* sp. *Journal of Academia and Industrial Research, 1*(2), 97-100.

Mathanmohun, M., Ramasamy, S., Krishnamoorthy, S., Palve, A. M., Anbazhagan, M., Nachimuthu, S., & Palanisamy, A. (2021). Screening, molecular detection and hydrocarbon investigation of microalgae from paddy fields of Rasipuram area, Namakkal, tamil nadu. *Materials Today: Proceedings, 47*, 440-445.

Nair, R. V., Manikandan, R., Mathanmohun, M., & Selvakumar, S. (2022). Isolation, screening, and optimization of penicillin-degrading bacterial strains from poultry manure, municipal, and industrial waste. *Research Journal of Agricultural Sciences, 13*(1), 208-210.

Nashima, K., & Palanisamy, A. (2016). Prevalence and distribution of diatoms in the paddy fields of Rasipuram Area, Namakkal Dt, Tamilnadu, India. *International Journal of Current Microbiology and Applied Sciences, 5*(8), 402-413.

Pandeeswari, N., Sivakumar, K., & Maghimaa, M. (2021b). Growth and enhancement of *Rhizobium* under salinity tolerance in groundnut (*Arachis hypogaea* L.). *Journal of the Maharaja Sayajirao University of Baroda, 55*(1), 678-686.

Pandeeswari, N., Sivakumar, K., Mahalakshmi, S., & Maghimaa, M. (2021a). Studies on the physico-chemical analysis of microalgae *Spirulina platensis* on media containing sugar mill effluent. *Journal of the Maharaja Sayajirao University of Baroda, 55*(1), 687-694.

Rajkumar, S., Sathyaprabha, G., & Mathanmohun, M. (2023a). Phytoconstituents profiling and antioxidant potential of *Wrightia tinctoria* R. Br. *Current Botany*, *14*, 32-40. https://doi.org/10.25081/cb.2023.v14.8228

Rajkumar, S., Sathyaprabha, G., & Mathanmohun, M. (2023b). Analysis of Phytochemical constituents and evaluation of *In vitro* antiinflammatory activity of *Wrightia tinctoria* leaf and bark: A traditional medicinal plant of India. *Research Journal of Agricultural Sciences, 14(2),* 375-380.

Sabarinath, B. S., Kumar, K. S., & Maghimaa, M. (2022b). Amalgamation of arbuscular mycorrhizal fungi and phosphate solubilizing bacteria on growth and yield of *Solanum lycopersicum* L. *Journal of Pharmaceutical Negative Results, 13*(S6), 2261-2267. https://doi.org/10.47750/pnr.2022.13.S06.294

Sabarinath, B. S., Kumar, K. S., & Mathanmohun, M. (2022a). Effect of AM Fungi and phosphobacteria on the growth and yield of tomato crop (*Lycopersicon esculentum*). *Research Journal of Agricultural Sciences, 13*(5), 1506-1511.

Sankareswaran, M., Sivaranjani, S., Kanmani, K., Gopi, V., Revathi, S., Sivakumar, K., Maghimaa, M., & Prabhavathi, P. (2021). A review on Anti-HIV and antagonist therapeutics of selected Indian medicinal plant flora. *Journal of Advanced Scientific Research, 12*(2 S2), 35-43.

Sharmila, B., Gnanendra, S., & Maghimaa, M. (2022). Isolation and Determination of Multidrug-resistant Pseudomonas aeruginosa from Clinical Samples. *Research Journal of Agricultural Sciences, 13*(1), 167-172.

Sivakumar, K., Ananda Kumar, D., Nivedhitha, K., & Maghimaa, M. (2018). Effect of AM Fungi and PSB inoculation on the percent root colonization, AM fungal spore number, and psb population in the rhizosphere soils of brinjal (*Solanum melongena* L.). *MCAS Journal of Research, 4*, 53-58.

Sivakumar, K., Pandeeswari, N., & Maghimaa, M. (2021a). Study of biocontrol and other beneficial activities of *Pseudomonas* fluorescens isolated from farmyard manure microflora. *Journal of the Maharaja Sayajirao University of Baroda, 55*(1), 665-677.

Sivakumar, K., Pandeeswari, N., Abarna, S., & Maghimaa, M. (2021b). Interaction of arbuscular mycorrhizal fungi and phosphate-solubilizing bacteria on *Zea mays* (L.) growth under saline condition. *Journal of the Maharaja Sayajirao University of Baroda, 55*(1), 1435-1451.

Sun, X., Veeraraghavan, V. P., Surapaneni, K. M., Hussain, S., Mathanmohun, M., Alharbi, S. A., Aladresi, A. A., & Chinnathambi, A. (2021). Eugenol–piperine loaded polyhydroxy butyrate/polyethylene glycol nanocomposite-induced apoptosis and cell death in nasopharyngeal cancer (C666-1) cells through the inhibition of the PI3K/AKT/mTOR signaling pathway. *Journal of Biochemical and Molecular Toxicology, 35*(4), e22700. https://doi.org/10.1002/jbt.22700

Vakayil, R., Anbazhagan, M., Shanmugam, G., Ramasamy, S., & Mathanmohun, M. (2021a). Molecular docking and *in vitro* analysis of phytoextracts from *Boswellia serrata* for antibacterial activities. *Bioinformation, 17*(7), 667-672. https://doi.org/10.6026/97320630017667

Vakayil, R., Kabeerdass, N., Kuppusamy, A., & Mathanmohun, M. (2019). Phytochemical screening and antibacterial properties of *Punica granatum* extracts against gastrointestinal infections: an *in vitro* study. *Uttar Pradesh Journal of Zoology, 29*, 25-32.

Vakayil, R., Kabeerdass, N., Murugesan, K., Shanmugam, G., Ramasamy, S., & Mathanmohun, M. (2022). Antibacterial activity and molecular characteristics of Indian Olibanum (*Boswellia Serrata*) Phytochemicals: An *in silico* approach. *Applied Ecology & Environmental Research*, *20*(2), 919-929. https://doi.org/10.15666/aeer/2002_919929

Vakayil, R., Kabeerdass, N., Srinivasan, R., Shanmugam, G., Ramasamy, S., & Mathanmohun, M. (2021c). *In vitro* and *in silico* studies on antibacterial potentials of phytochemical extracts. *Materials Today: Proceedings*, *47*, 453-460. https://doi.org/10.1016/j.matpr.2021.05.017

Vakayil, R., Krishnamoorthy, S., Anbazhagan, M., Kumar, N. S., & Mathanmohun, M. (2021e). Antibacterial potential of *Acorus calamus* extracts against multidrug-resistant nosocomial pathogens. *Uttar Pradesh Journal of Zoology, 31*, 144-150.

Vakayil, R., Krishnamoorthy, S., Shanmugam, G., Nachimuthu, S. K., Ramasamy, S., & Mathanmohun, M. (2020). Screening and

Identification of multidrug resistance nosocomial infection isolates from clinical specimens: A cross-sectional study. *Plant Archives, 20*(2), 7247-7251.

Vakayil, R., Muruganantham, S., Kabeerdass, N., Rajendran, M., Mahadeo palve, A., Ramasamy, S., Alahmadi, T. A., Almoallim, H. S., Manikandan, V., & Maghimaa, M. (2021b). *Acorus calamus* - zinc oxide nanoparticle coated cotton fabrics show antimicrobial and cytotoxic activities against skin cancer cells. *Process Biochemistry, 111*, 1-8. https://doi.org/10.1016/j.procbio.2021.08.024

Vakayil, R., Nazeer, T. A., & Mathanmohun, M. (2021d). Evaluation of the antimicrobial activity of extracts from *Acorus calamus* rhizome against multidrug-resistant nosocomial pathogens. *Research Journal of Agricultural Sciences, 12*(5), 1613-1617.

Vakayil, R., Ramasamy, S., Alahmadi, T. A., Almoallim, H. S., Natarajan, N., & Mathanmohun, M. (2022b). *Boswellia serrata*-mediated zinc oxide nanoparticles-coated cotton fabrics for wound healing and antibacterial applications against nosocomial pathogens. *Applied Nanoscience, 12*, 2873-2887. https://doi.org/10.1007/s13204-022-02573-9