Palanisamy *et al.*
Bulletin of the National Research Centre (2024) 48:11
https://doi.org/10.1186/s42269-024-01166-6

Bulletin of the National Research Centre

RESEARCH

Open Access

Unraveling the antimicrobial efficacy and chemical fingerprinting of medicinal plants against the WHO's prioritized pathogens

Balaji Palanisamy[1], Saravana Kumar Pachaiyappan[1,2*], Mutheeswaran Subramanian[2], Reena Das[1*] and Ignacimuthu Savarimuthu[2]

Abstract

Background The global spread of drug-resistant organisms has necessitated the search for alternative treatments against bacterial and candidal resistant pathogens. Plants have long been used as traditional medicines to ameliorate various diseases, and their antimicrobial properties are still being explored. The aim of the present study is to assess the antimicrobial activity of extracts from *Alstonia scholaris*, *Orthosiphon aristatus*, *Sphaeranthus amaranthoides*, *Crateva magna* and *Garcinia travancorica* against bacteria and *Candida* pathogens.

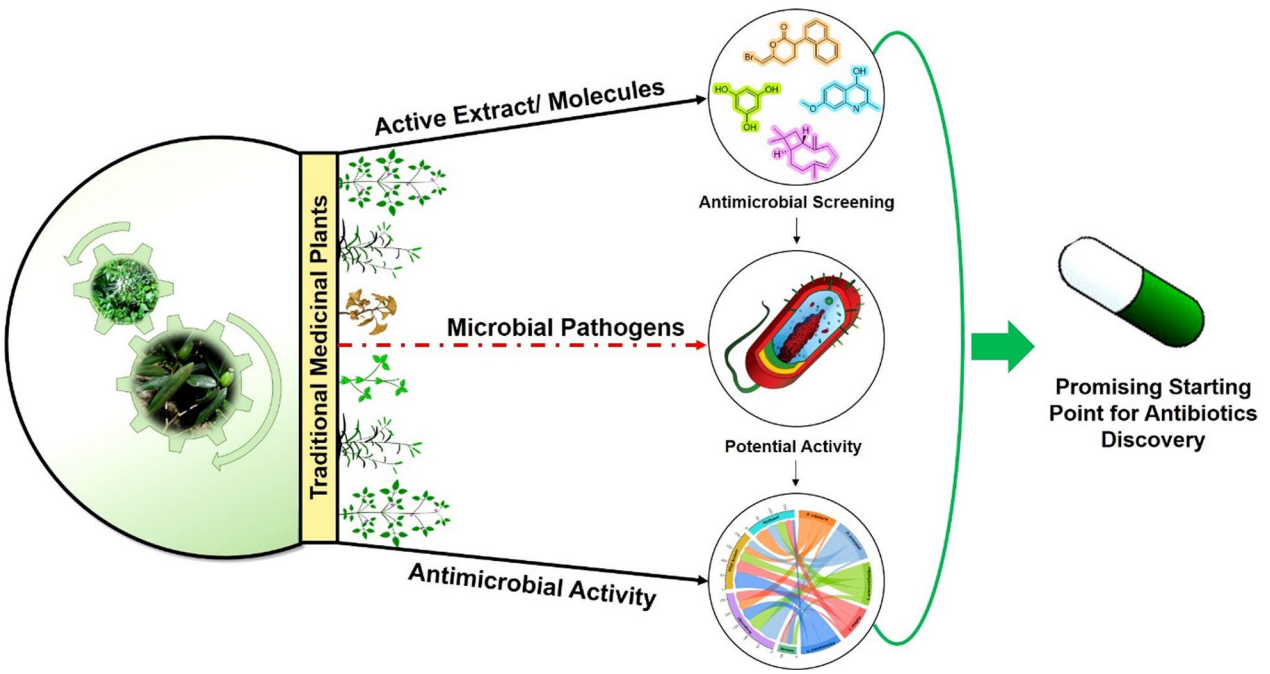
Results Out of 60 different sequential extracts tested, several showed moderate to good antimicrobial activity. Among them, ethyl acetate extract of *G. travancorica* exhibited significant activity against *Lactobacillus acidophilus* (17 mm) followed by *Staphylococcus aureus* (16 mm), *Escherichia coli* (13 mm), *Proteus mirabilis* (12 mm), *Staphylococcus epidermis, Candida krusei* (11 mm), *Candida glabrata* (10 mm) and the chloroform extract from *O. aristatus* showed good activity against *S. epidermis, L. acidophilus* (13 mm), *S. aureus, Escherichia fergusonii*, *C. krusei* (12 mm), *C. glabrata, E. coli* (11 mm) and *Klebsiella pneumoniae* (10 mm), respectively. In addition, GC–MS analysis revealed the presence of nine major compounds in *G. travancorica* and ten compounds in *O. aristatus* which were responsible for the significant antimicrobial activity.

Conclusions These findings highlight the potential of *G. travancorica* and *O. aristatus* as sources for developing new antimicrobial agents against the World Health Organization's (WHO) prioritized pathogens. Further research on these plants could lead to the discovery and synthesis of novel therapeutic agents with enhanced antimicrobial properties.

Keywords Antibiotic potentiating, Herbal extracts, GC–MS, Phytoconstituents, *Orthosiphon aristatus*, *Garcinia travancorica*

*Correspondence:
Saravana Kumar Pachaiyappan
savanah.kumar@gmail.com; saravanakumar12deri01@loyolacollege.edu
Reena Das
reenadas.jrs@drmgrdu.ac.in; reenadas.08@gmail.com
Full list of author information is available at the end of the article

Graphical abstract



Background

The spread of antibiotic resistance has been a dire worriment for humanity and is responsible for over 5.3 million deaths annually across the globe (Ogbole et al. 2018). Antibiotic resistance is emerging as a major threat to humankind, as new resistance mechanisms are being developed periodically by microorganisms (Costa et al. 2016). With the emergence of new drugs, bacteria tend to acquire various mechanisms of resistance to survive. Researchers have put in a lot of efforts on keeping bacterial proteins as drug target; however, mechanisms such as translation control, exploiting trans translational pathway and controlling the regulatory RNAs have emanated to enhance bacteria's resistance towards antibiotics (Aswathanarayan and Vittal et al. 2013). Antibiotic resistance, particularly in microorganisms have occurred in epidemic waves beginning with the emergence of strains that were resistant to penicillin and progressing to the present pandemic of community-associated Methicillin-Resistant *Staphylococcus aureus* (MRSA) (Timpau et al. 2023). Organisms belonging to genera of *Escherichia, Klebsiella*, *Proteus, Salmonella, Staphylococcus*, and *Candida* are the causative agent for infections ranging from bacteremia, pneumonia, meningitis, cellulitis, urinary tract infections, stomach ulcers, candidemia and many more and are infamously known for their expeditious nature to be highly resistant to antibiotics. According to the recent report by the World Health Organization (WHO), traditional medicinal plants are widely utilized as a primary source of healthcare by 70–80% of the global population (Muhammad et al. 2011). These plants have been relied upon for their broad spectrum of biological properties across different cultures, where they hold a prominent place in ethnomedicine (Moglad et al. 2020). The effectiveness of medicinal plants in treating various ailments, including antimicrobial effects against a range of pathogens can be attributed to the presence of active chemical constituents' alkaloids, flavonoids, phenols, and tannins, terpenoids, steroids, resins and other metabolites (Archana and Bose 2022). Globally, researchers have explored the potential of these natural metabolites in combating pathogenic microorganisms due to their promising therapeutic properties and offers a vast repertoire of potential compounds with varying mechanisms of action, which can be harnessed for the development of novel antimicrobial agents (Pratheeshkumar et al. 2015). Therefore, this knowledge contributes to the development of alternative treatments for infectious diseases and addresses the growing concern of antimicrobial resistance. Many natural products derived from medicinal plants, which have been traditionally employed in folk remedies, have been extensively studied

and possess strong scientific evidence supporting their antimicrobial properties. Therefore, investigation of neglected wild plants as potential alternative sources for biomedical applications has gained significant attention in recent times, emphasizing the importance of exploring untapped resources. In line with this context, our study focuses on evaluating the antimicrobial activities of traditional medicinal plant extracts against *Candida* and bacterial pathogens that could serve as alternative therapeutic options for the management of various infections caused by drug-resistant strains. Further, it also offers exciting prospects for the development of novel pharmacological agents and reinforces the importance of traditional medicine in modern healthcare.

Methods

Plant materials

The fresh aerial parts of the selected plants were collected in the summer season from different parts of Tamilnadu (TN), India such as Tirunelveli, Thirukkurungudi and South Veeravanallur between March–April 2023. The plants were identified and authenticated as *Alstonia scholaris* (L.) R.Br., *Orthosiphon aristatus* (Blume) Miq., *Sphaeranthus amaranthoides* Burm.f., *Crateva magna* DC., and *Garcinia travancorica* Bedd., (Fig. 1) by one of the authors Dr S. Mutheeswaran. The ethnobotanical information on the selected plants belonging to five families are depicted in Table 1 (Baliga 2010, 2012; Shang et al. 2010; Khyade et al. 2014; Jagetia and Baliga 2005; Adam et al. 2009; Houghton et al. 2005; Rethinam et al. 2021; Thanigaivel et al. 2019; Othman et al. 2011; Galani et al. 2010; Mostafa et al. 2018; Kiruba et al. 2011; Magalhães et al. 2023; Patel 2023; Espirito Santo et al. 2020). The plants voucher specimens (SM-0017–21) were deposited at Xavier Research Foundation herbarium in St. Xavier's College, Palayamkottai, TN, India for further reference.

Preparation of extracts

The collected plant materials were shade dried at room temperature and then ground into either coarse/fine powder using an electric blender. For each sample, 25 g of powdered plant materials were soaked sequentially in 100 mL of hexane, chloroform, ethyl acetate and methanol. The mixtures were subjected to 30 min of ultrasonication and kept at room temperature for 48 h with intermittent shaking. The extracts were filtered and the solvents were removed under vacuum in a rotavapor at 35 °C. The extracts were further dried at room temperature and kept at 4 °C until they were screened for their antimicrobial activity (Gishen et al. 2020).

Test microbes

Microbial strains used in the present investigation are as follows: Gram-positive bacteria such as *Staphylococcus epidermis* (ATCC 49134), *Staphylococcus aureus* (ATCC11632), *Lactobacillus acidophilus* (MTCC 10307); Gram-negative bacteria such as *Escherichia coli* (ATCC 35218), *Escherichia fergusonii* (ATCC 35469), *Salmonella para-typhi* (MTCC 735), *Proteus mirabilis*

Fig. 1 Photographs of selected plants in their natural habitat, **a** *Alstonia scholaris* (L.) R.Br., **b** *Orthosiphon aristatus* (Blume) Miq., **c** *Crateva magna* Burm.f., **d** *Sphaeranthus amaranthoides* DC., and 1e. *Garcinia travancorica* Bedd.,

Table 1 Ethnobotanical data on plants used in this study

S.no	Plant	Location	Medicinal uses	References
1	*Alstonia scholaris* (L.) R.Br. Apocynaceae (Voucher no. SM-0017)	Range: Valliyur feet -2 Division: RF – Tirunelveli Latitude: N. 08°33´00´´ Longitude: E. 77°30´42´´ Forest type: Thorn Forest	Helps to cure skin diseases and rheumatism, cancer and antineoplastic activity. The root juice is taken with milk to cure leprosy; fresh bark is put in water to draw out the latex, which is taken orally in case of tuberculosis; dried powder is administered orally to cure diarrhea; and bark extract is useful in case of intestinal worms	Baliga (2010), Baliga (2012), Shang et al. (2010), Khyade et al. (2014), Jagetia and Baliga (2005)
2	*Orthosiphon aristatus* (Blume) Miq. Lamiaceae (Voucher no. SM-0018)	Range: Thakkar Sargam Division: RF – Thirukkurungudi Latitude: N. 08°25´00´´21 Longitude: E. 77°30´42´´41 Forest type: Thorn Forest	It has antimicrobial and anti-inflammatory properties. It is highly diuretic and used in the treatment of various kidney conditions, cystitis, urethritis, and gout	Adam et al. (2009), Houghton et al. (2005)
3	*Sphaeranthus amaranthoides* Burm.f. Asteraceae (Voucher no. SM-0019)	Range: Thakkar Sargam Division: RF – Thirukkurungudi Latitude: N. 08°25´00´´21 Longitude: E. 77°30´42´´41 Forest type: Thorn Forest	Prevents the destruction and aging of the soft parts, muscles, nerves, bones, bone marrow, blood cells and antioxidants	Rethinam et al. (2021), Thanigaivel et al. (2019), Othman et al. (2011), Galani et al. (2010), Mostafa et al. (2018)
4	*Crateva magna DC* Capparaceae (Voucher no. SM-0020)	Range: Karungal Sargam Division: RF – South Veeravanallur Latitude: N. 08°33´00´´ Longitude: E. 77°30´42´´ Forest type: Thorn Forest	Helps to cure inflammation, rheumatic fever, gastric irritation, and constipation, for stimulating the appetite or as a digestive, as a laxative against colic and as a febrifuge, urolithiasis, skin irritant against high fever	Kiruba et al. (2011), Magalhães et al. (2023)
5	*Garcinia travancorica* Bedd. Clusiaceae (Voucher no. SM-0021)	Range: Karungal Sargam Division: RF – South Veeravanallur Latitude: N. 08°33´00´´ Longitude: E. 77°30´42´´ Forest type: Thorn Forest	Used as Ointment, Hydragogue-cathartic, Illuminant, varnishes, pigment and water colours	Patel (2023), Espirito Santo et al. (2020)

(MTCC 7002), *Klebsiella pneumoniae* (MTCC 70063) and yeast such as *Candida glabrata* (MTCC 3019), and *Candida krusei* (MTCC 9215). The test ATCC and MTCC strains were procured from HiMedia Laboratories, and the Microbial Type Culture Collection (MTCC), Institute of Microbial Technology (IMTECH) Chandigarh, India, respectively.

Inoculum preparation and antimicrobial susceptibility assay

Candida and bacterial inoculums were first grown in nutrient broth and incubated in a shaker incubator at 37°C overnight. Prior to the experiment, the turbidity of the overnight cultures was adjusted to an optical density equivalent to 0.5 McFarland standard, which corresponds to approximately 10^7 CFU/mL for bacteria and *Candida*. For the antimicrobial assay, 100µL of the adjusted test cultures were evenly spread on sterile Muller-Hinton agar (MHA) plates, ensuring confluent growth of the organisms. The plates were then allowed to dry for 5 min. Followed by 25µL of the plant extracts with concentrations of 1, 2, and 5 mg/disc were loaded onto sterile discs. The discs were dried and then placed on the surface of the pre-inoculated agar MHA plates using sterile forceps. Imipenem 10 µg/disc and cefotaxime/clavulanic acid 30/10 µg/disc were used as positive controls; 5% DMSO was used as a solvent control was included. The antimicrobial potency of the plant extracts was determined after incubation by measuring the zone of growth inhibition (in mm) surrounding the discs on the agar plates against the tested pathogens (Saravana Kumar et al. 2022).

Chemical fingerprinting using GC–MS

The bioactive compounds present in the active crude extract were analysed using GC–MS (Agilent 8890) with an HP-5MS column (30 m x 250 µm × 0.25 µm). The samples were dissolved in methanol, and 20µL of the solution was injected with an anterior column pressure of approximately 11.367 psi. The analysis involved programming the oven temperature to start at 75°C and hold for 3 min, followed by a gradual increase to 350°C at a rate of 5°C per minute. The injection port temperature was set to 330°C, while the transfer and ion source temperatures were maintained at 310°C. Helium was used as the carrier gas, flowing at a rate of 1 mL/min. The instrument was calibrated to scan a mass range of m/z 35–500. To identify the compounds, their mass spectral fragmentation patterns were compared to the NIST98-MS and the Wiley KnowItAll 2020 Mass Spectral Library through spectral analysis.

Results

Antimicrobial efficacy of plant extracts

The antimicrobial activities of 60 different plants' sequential extracts viz., hexane, chloroform, ethyl acetate and methanol from *Alstonia scholaris, Orthosiphon aristatus, Sphaeranthus amaranthoides, Crateva magna* and *Garcinia travancorica* were evaluated against 3 Gram-positive bacteria, 5 Gram-negative bacteria and 2 *Candida* human pathogens. In the line, the antimicrobial activities of the plant extracts showed zones of inhibition varied from good to weak. Specifically, for hexane extract the zones of inhibition ranged from 0–10 mm, 0–11 mm, and 0–13 mm. For the chloroform extract, the range was 0–10 mm, 0–12 mm, and 0–13 mm. The ethyl acetate extract exhibited zones of inhibition ranging from 0–14 mm, 0–15 mm, and 0–17 mm. The methanol extract showed zones of inhibition ranging from 0–10 mm, 0–12 mm, and 0–13 mm at the tested concentrations of 1 mg/disc, 2 mg/disc, and 5 mg/disc, respectively and the detailed results are depicted in Fig. 2 and Additional file 1: Table S1. However, the antibiograms of the extracts were observed to be different depending on the pathogens and their origin. Briefly, 80% of the chloroform extract tested exhibited considerable action against *S. epidermis*, *L. acidophilus*, *C. glabrata*, and *C. krusei*; 70% against *S. aureus*, *E. coli*, *E. fergusonii*, and 20% against *P. mirabilis* and *K. pneumoniae*. Followed by ethyl acetate extract demonstrated 80% activity against *L. acidophilus*, *P. mirabilis*, and *C. krusei*; 70% activity against *E. fergusonii*; 40% activity against *E. coli* and *C. glabrata*; and 20% activity against *S. epidermis*, *S. aureus*, *S. paratyphi*, and *K. pneumoniae*. 80% of the methanol extract inhibited *E. coli*, 70% inhibited *S. para-typhi*, *P. mirabilis*, and *K. pneumoniae*, 40% inhibited *L. acidophilus*, and 20% inhibited *S. epidermis* and *S. aureus*. None of the methanol is active against *Candida* strains. On the other hand, modest activities were observed in hexane extracts, with 80% activity against *C. krusei* and 20% activity against *S. aureus*, *E. fergusonii*, and *C. glabrata* (Fig. 3a, b). These results clearly demonstrated that the chloroform and ethyl acetate crude extracts exhibited higher and broad spectrum of inhibitory effects compared to the methanol extracts. Remarkably, among plant extracts screened, the ethyl acetate extract of *G. travancorica* exhibited significant activity against *L. acidophilus* (17 mm) followed by *S. aureus* (16 mm), *E. coli* (13 mm), *P. mirabilis* (12 mm), *S. epidermis* (11 mm), *C. krusei* (11 mm), *C. glabrata* (10 mm), and no activity were observed against *E. fergusonii*, *S. paratyphi*, *K. pneumoniae*. On the other hand, the chloroform extract from *O. aristatus* showed good activity against *S. epidermis* (13 mm), *L. acidophilus* (13 mm),

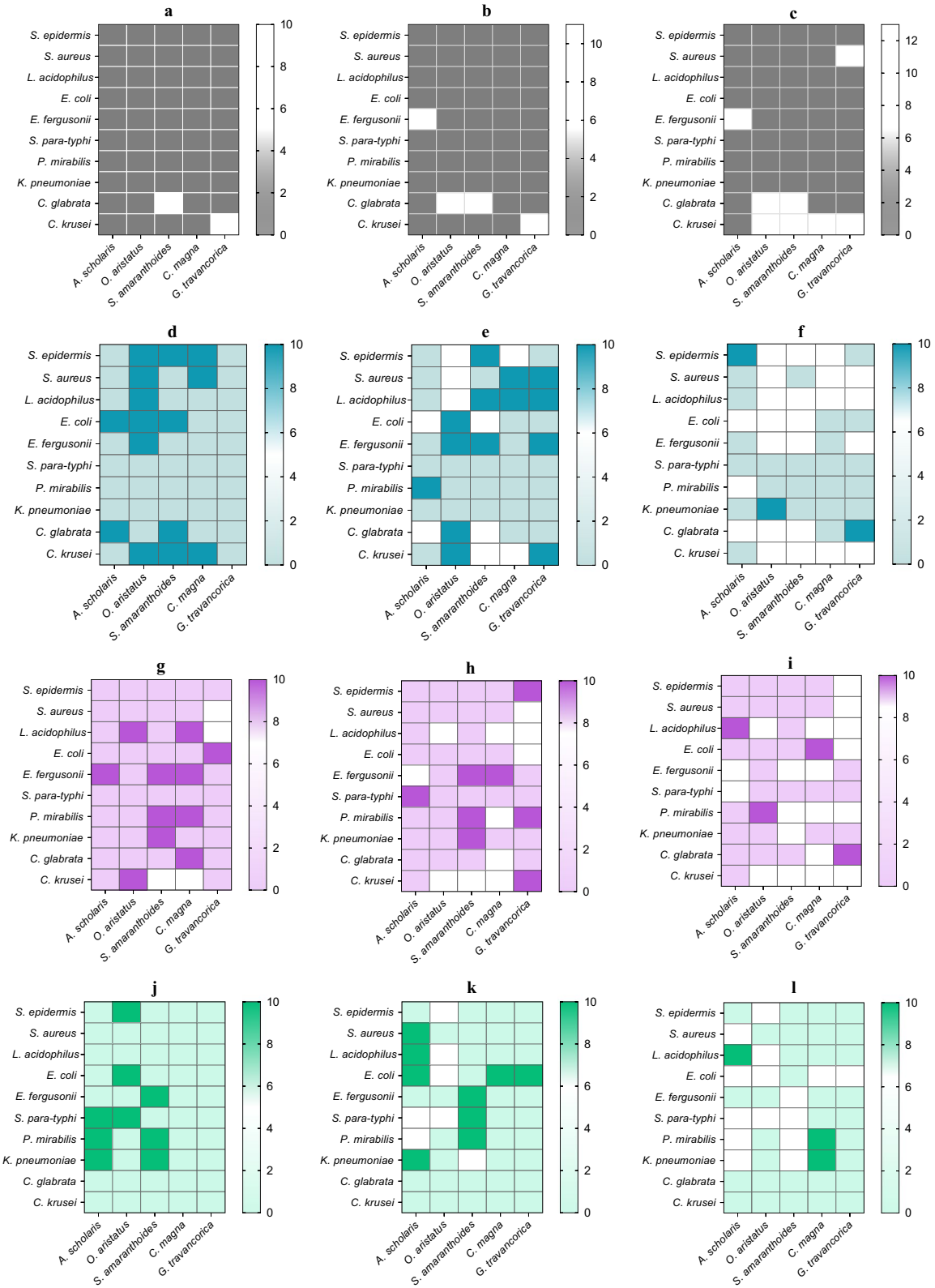


Fig. 2 Heatmap showing the antimicrobial activity of the various plant extracts. 2a-c Antimicrobial activity of hexane extract; 2d-f Antimicrobial activity of chloroform extract; 2 g-i Antimicrobial activity of ethyl acetate extract; 2j-l Antimicrobial activity of methanol extract of *Alstonia scholaris*, *Orthosiphon aristatus*, *Sphaeranthus amaranthoides*, *Crateva magna* and *Garcinia travancorica* (1 mg, 2 mg and 5 mg/disc, respectively)

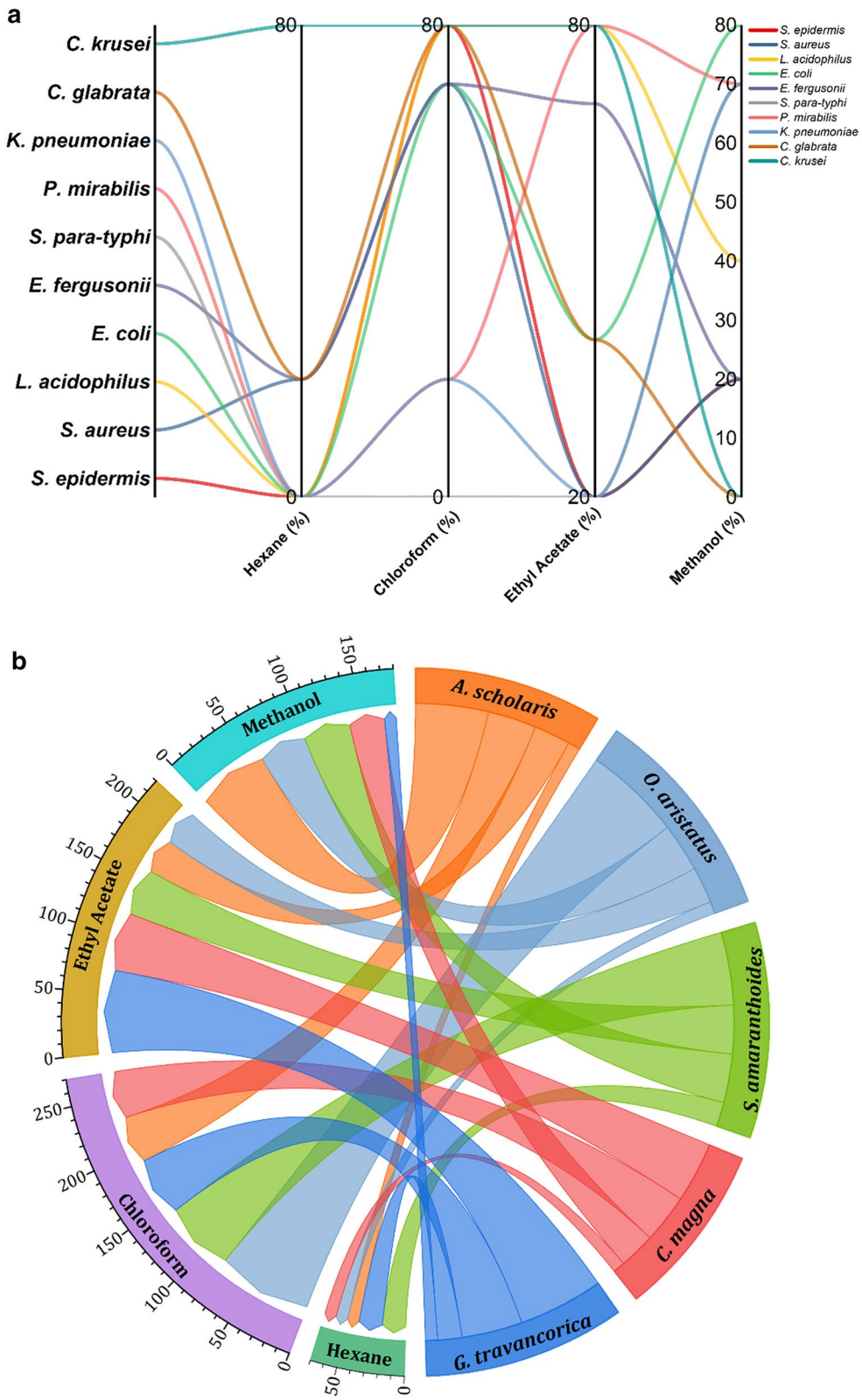


Fig. 3 **a** Parallel plot showing the cumulative percentage of antimicrobial activities of hexane, chloroform, ethyl acetate and methanol extracts (5 mg/disc) of *Alstonia scholaris*, *Orthosiphon aristatus*, *Sphaeranthus amaranthoides*, *Crateva magna* and *Garcinia travancorica* versus bacterial and candidal pathogens, respectively. **b** Chord plot showing the percentage of antimicrobial activity of different extracts of *Alstonia scholaris*, *Orthosiphon aristatus*, *Sphaeranthus amaranthoides*, *Crateva magna* and *Garcinia travancorica* against the tested bacterial and candidal pathogens

S. aureus (12 mm), *E. fergusonii* (12 mm), *C. krusei* (12 mm) *C. glabrata* (11 mm), *E. coli* (11 mm), *K. pneumoniae* (10 mm), and no inhibition was observed for *S. para-typhi*, *P. mirabilis*. Furthermore, based on the broad spectrum of antimicrobial activity, the chemical analyses of the active ethyl acetate extract of *G. travancorica* revealed the presences of 6-methyloctadecane, β-D-glucopyranose, 1,4-dimethoxy-2,3-dimethylbenzene, bromoenol lactone, 1,3,5-benzenetriol, 3,7,11,15-tetramethyl-2-hexadecen-1-ol/ phytol, 2-hexadecen-1-ol,3,7,11,15-tetramethyl-,acetate, [R-[R*,R and trans-Geranylgeraniol (Fig. 4a, Table 2). The chloroform extract of *O. aristatus* indicates the presence of 6-methyloctadecane, 7-methoxy-2-methylquinolin-4-ol, caryophyllene, 2,4-di-tert-butylphenol, 3-trifluoroacetoxydodecane, 2-methyl-7-nonadecene, 9-eicosyne, pentadecanoic acid, 14-methyl, methyl ester, cis,cis,cis-7,10,13-hexadecatrienal and phytol (Fig. 4b, Table 3). These antimicrobial activities may be due to presence of several bioactive compounds in the ethyl acetate and chloroform extracts *G. travancorica* and *O. aristatus*, respectively.

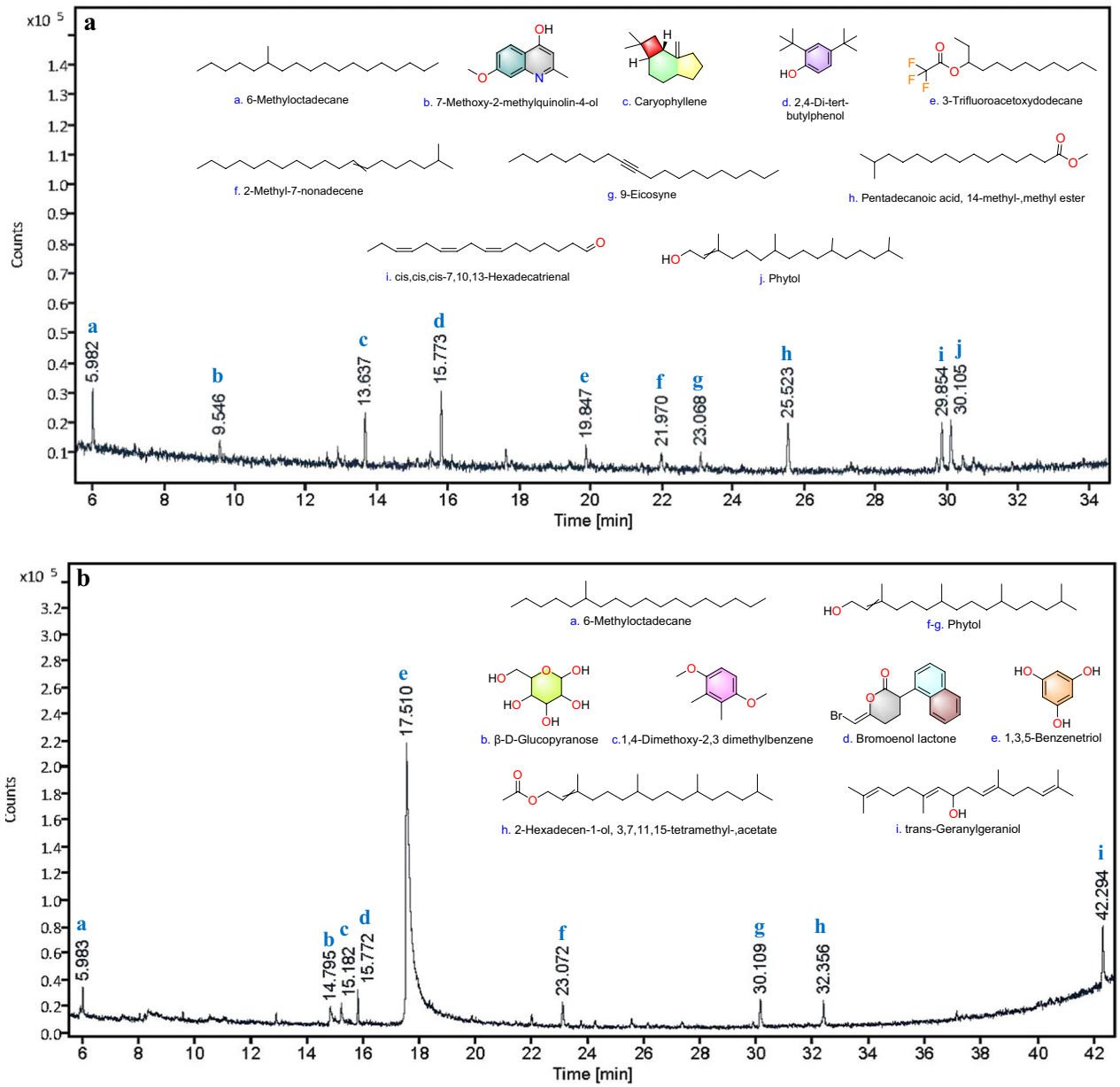


Fig. 4 Chromatogram showing compounds in the active extracts, **a** *Orthosiphon aristatus* and **b** *Garcinia travancorica*

Table 2 GC–MS analysis of chloroform extract from *Orthosiphon aristatus*

Peak	RT (min)	Content (%)	Chemical constituents	Mol. For	Mol. Wt
a	5.982	10.72	6-Methyloctadecane	$C_{19}H_{40}$	268.521
b	9.546	3.28	7-Methoxy-2-methylquinolin-4-ol	$C_{11}H_{11}NO_2$	189.214
c	13.637	12.35	Caryophyllene	$C_{14}H_{21}$•	189.322
d	15.773	17.64	2,4-Di-tert-butylphenol	$C_{14}H_{22}O$	206.329
e	19.847	3.92	3-Trifluoroacetoxydodecane	$C_{14}H_{25}F_3O_2$	282.347
f	21.970	4.23	2-Methyl-7-nonadecene	$C_{20}H_{40}$	280.540
g	23.068	2.78	9-Eicosyne	$C_{20}H_{38}$	278.524
h	25.523	17.02	Pentadecanoic acid, 14-methyl-,methyl ester	$C_{17}H_{34}O_2$	270.457
i	29.854	13.72	cis,cis,cis-7,10,13-Hexadecatrienal	$C_{16}H_{26}O$	234.383
j	30.105	14.34	Phytol	$C_{20}H_{40}O$	296.307

Table 3 GC–MS analysis of ethyl acetate extract from *Garcinia travancorica*

Peak	RT (min)	Content (%)	Chemical constituents	Mol.For	Mol.Wt
a	5.983	2.42	6-Methyloctadecane	$C_{19}H_{40}$	268.521
b	14.795	2.87	β-D-Glucopyranose	$C_6H_{12}O_6$	180.156
c	15.182	2.38	1,4-Dimethoxy-2,3-dimethylbenzene	$C_{10}H_{14}O_2$	166.220
d	15.772	3.12	Bromoenol lactone	$C_{16}H_{13}BrO_2$	317.182
e	17.510	68.30	1,3,5-Benzenetriol	$C_6H_6O_3$	126.031
f	23.072	4.18	3,7,11,15-Tetramethyl-2-hexadecen-1-ol	$C_{20}H_{40}O$	296.307
g	30.109	4.31	Phytol	$C_{20}H_{40}O$	296.307
h	32.356	2.55	2-Hexadecen-1-ol,3,7,11,15-tetramethyl-,acetate, [R-[R*,R	$C_{22}H_{42}O_2$	338.576
i	42.294	9.88	trans-Geranylgeraniol	$C_{20}H_{34}O$	290.491

Discussion

Natural products have been reported to possess significant antimicrobial activities owing to their ability to interact with cell membrane, intercellular organs, enzymes and to inhibit cell cycle progression. However, the evidence on the distribution of microbial pathogens and therapy recommendations in patients remains insufficient for hospitalized and immunocompromised patients. There are also discouraging scenario persists due to poor adherence to the treatments and increased drug resistance among the bacterial and candidal pathogens are associated with nosocomial bloodstream infections, urinary tract infections, candidiasis, diabetic and immunocompromised patients (Teferi et al. 2023; Rossi et al. 2022). Therefore, proper screening and surveillance reports are required to guide antimicrobial stewardship efforts. The present investigation was conducted on sequential hexane, chloroform, ethyl acetate, and methanol extracts of *Alstonia scholaris, Orthosiphon aristatus, Sphaeranthus amaranthoides, Crateva magna*, and *Garcinia travancorica* aimed to delineate the inhibitory effect against a panel of clinically prioritized microbial pathogens. The obtained results revealed that the zones of inhibition varied significantly between extracts and concentrations. Extracts of hexane, chloroform, ethyl acetate, and methanol showed different antimicrobial properties against species of *Candida* implicated in nosocomial infections as well as Gram-positive and Gram-negative bacteria. Among the noteworthy findings were the stronger inhibitory effects of ethyl acetate and chloroform extracts in comparison to methanol which supported findings reported by Odongo et al. (2023) and Komape et al. (2017). In addition, these results are also in accordance with the Perera et al. (2022) indicating that the polar extracts exhibited higher antimicrobial activity compared to the non-polar extracts in treating bacterial and candidal infections. Moreover, it is possible that the methanol crude extracts contain lower concentrations of antimicrobial constituents, which may explain why larger quantities of decoctions are typically consumed over a longer duration to achieve therapeutic efficacy (Al-Tohamy et al. 2018). These observations highlight the importance of extraction methods and solvent choice in obtaining plant extracts with potent

antimicrobial properties. The standout performance of the ethyl acetate extract from *G. travancorica* prompts a closer examination of its chemical composition. The identification of specific compounds, including 6-methyloctadecane, β-D-glucopyranose, 1,4-dimethoxy-2,3-dimethylbenzene, bromoenol lactone, 1,3,5-benzenetriol, 3,7,11,15-tetramethyl-2-hexadecen-1-ol/phytol, 2-hexadecen-1-ol,3,7,11,15-tetramethyl-,acetate, [R-[R*,R, and trans-Geranylgeraniol, sheds light on potential bioactive contributors to the observed antimicrobial effects. Similarly, the antimicrobial activity of essential oil from the leaves of *G. travancorica* has been reported to possess significant activity against Gram-Positive bacteria *Micrococcus mucilaginosus* and Gram-Negative bacteria *Pseudomonas aeruginosa* (Ramasubbu et al. 2020). In addition, the chloroform extract from *O. aristatus* revealed a complex composition featuring compounds such as 6-methyloctadecane, 7-methoxy-2-methylquinolin-4-ol, caryophyllene, 2,4-di-tert-butylphenol, 3-trifluoroacetoxydodecane, 2-methyl-7-nonadecene, 9-eicosyne, pentadecanoic acid, 14-methyl, methyl ester, cis,cis,cis-7,10,13-hexadecatrienal, and phytol. This result is in agreement with the previous report of Widyaningrum et al. (2022) in which the polar extract showed activity against *Propionibacterium acnes* when compared to non-polar ethanol and aqueous extracts. These antimicrobial activities may be due to the presence of several bioactive compounds were previously showed significant activity against microbial pathogens (Shahid et al. 2022; Tung et al. 2022).

Conclusions

Despite the significant advancements in modern medicine, the utilization of plants in healthcare remains crucial in several parts of the world. Plants continue to be a focus of research for drug development due to their accessibility and the ability to select them based on their traditional medicinal uses. In this study, five medicinal plants obtained from ethnobotanical sources demonstrated noteworthy antimicrobial activity. Interestingly, *G. travancorica* demonstrated significant activity against *L. acidophilus*, *S. aureus*, *E. coli*, *P. mirabilis, S. epidermis, C. krusei,* and *C. glabrata*, while the chloroform extract from *O. aristatus* displayed notable activity against *S. epidermis, L. acidophilus, S. aureus, E. fergusonii, C. krusei, C. glabrata, E. coli,* and *K. pneumoniae* with the zones of inhibition ranging from 10-17 mm. Moreover, the identification of major compounds in *G. travancorica* and *O. aristatus* through GC–MS analysis shed light on their significant antimicrobial properties as valuable resources for the development of novel antimicrobial medications. These findings validate the value of ethnomedicine as a reliable source for discovering novel anti-infective agents.

Abbreviations

GC–MS	Gas chromatography–mass spectroscopy
mm	Millimetre
mg	Milligram
CFU	Colony forming units
MHA	Muller-Hinton agar
DMSO	Dimethyl sulphoxide
ATCC	American type culture collection
MTCC	Microbial type culture collection

Supplementary Information

The online version contains supplementary material available at https://doi.org/10.1186/s42269-024-01166-6.

Additional file 1. **Table 1a:** Antimicrobial activity of Alstonia scholaris. **Table 1b:** Antimicrobial activity of Orthosiphon aristatus. **Table 1c:** Antimicrobial activity of Sphaeranthus amaranthoides. **Table 1d:** Antimicrobial activity of Crateva magna. **Table 1e:** Antimicrobial activity of Garcinia travancorica.

Acknowledgments

The authors would like to thank Dr. APJ Abdul Kalam Centre of Excellence of Innovation and Entrepreneurship, and Dr. MGR Educational and Research Institute, Chennai, Tamil Nadu, India, for financial support and laboratory space. The authors would like to extend their thank to Dr. Rama Vaidyanathan, Dr. J. Arun Kumar, Dr. V.S. Priyadharshini, Ms. M. Priyadarshini, Ms. P. Kalishwari and Mr. V. Sathish Kumar are the faculty members of the of Dr. APJ Abdul Kalam Centre of Excellence of Innovation and Entrepreneurship for their constant support. We also thank Dr. M.G.R Educational and Research Institute University's President, Er. A.C.S. Arun Kumar, for providing the extended essential facilities.

Author contributions

SKP contributed to conceptualization; SKP and BP contributed to methodology; SKP contributed to software and validation; SKP, MS and BP contributed to formal analysis, investigation and resources; SKP and RD involved in data curation; SKP and BP involved in writing—original draft preparation and writing—review and editing; SKP and RD involved in visualization; SKP and IS involved in supervision. All authors read and approved the final manuscript.

Funding

Not applicable.

Availability of data and materials

All the data generated or analyzed during this study are included in this article.

Declarations

Ethics approval and consent to participate

Not applicable.

Consent for publication

All authors confirm their consent for the publication of this manuscript and they declare that this manuscript is not published elsewhere or under consideration for publication.

Competing interests

The authors declare that they have no competing interests.

Author details
[1]Dr. APJ Abdul Kalam Centre of Excellence of Innovation and Entrepreneurship, Dr. MGR Educational and Research Institute, Chennai, Tamil Nadu 600095, India. [2]Interdisciplinary Research Centre in Biology, Xavier Research Foundation, St. Xavier's College, Palayamkottai, Tirunelveli, Tamil Nadu 627002, India.

Received: 9 November 2023 Accepted: 1 January 2024
Published online: 10 January 2024

References

Adam Y, Somchit MN, Sulaiman MR, Nasaruddin AA, Zuraini A, Bustamam AA, Zakaria ZA (2009) Diuretic properties of *Orthosiphon stamineus* Benth. J Ethnopharmacol 124(1):154–158. https://doi.org/10.1016/j.jep.2009.04.014

Al-Tohamy R, Ali SS, Saad-Allah K, Fareed M, Ali AA, El-Badry RPF (2018) Phytochemical analysis and assessment of antioxidant and antimicrobial activities of some medicinal plant species from Egyptian flora. J Appl Biomed 16(4):289–300. https://doi.org/10.1016/j.jab.2018.08.001

Archana H, Bose VG (2022) Evaluation of phytoconstituents from selected medicinal plants and its synergistic antimicrobial activity. Chemosphere 287:132276. https://doi.org/10.1016/j.chemosphere.2021.132276

Aswathanarayan JB, Vittal RR (2013) In vitro evaluation of antioxidant and antibacterial activities of *Rotula aquatica* and *Ancistrocladus heyneanus*: Antioxidant and antimicrobial activity of medicinal plants. J Pharm Res 6(2):313–317. https://doi.org/10.1016/j.jopr.2013.02.011

Baliga MS (2010) *Alstonia scholaris* Linn R Br in the treatment and prevention of cancer: Past, present, and future. Integr Cancer Ther 9(3):261–269. https://doi.org/10.1177/1534735410376068

Baliga MS (2012) Review of the phytochemical, pharmacological and toxicological properties of Alstonia scholaris Linn. R. Br (Saptaparna). Chinese J Integr Med. https://doi.org/10.1007/s11655-011-0947-0

Costa S, Lins MO, Hyaric ML, Barros TF, Velozo ES (2016) In vitro antibacterial effects of Zanthoxylum tingoassuiba root bark extracts and two of its alkaloids against multiresistant *Staphylococcus aureus*. Rev Bras Farmacogn 27:195–198. https://doi.org/10.1016/j.bjp.2016.11.001

Espirito Santo BLSD, Santana LF, Kato Junior WH, de Araújo FDO, Bogo D, Freitas KDC, Bastos PRHDO (2020) Medicinal potential of Garcinia species and their compounds. Molecules 25(19):4513. https://doi.org/10.3390/molecules25194513

Galani VJ, Patel BG, Rana DG (2010) Sphaeranthus indicus Linn.: a phytopharmacological review. IJAR 1(4):247. https://doi.org/10.4103/0974-7788.76790

Gishen NZ, Taddese S, Zenebe T, Dires K, Tedla A, Mengiste B, Lulekal E (2020) In vitro antimicrobial activity of six Ethiopian medicinal plants against Staphylococcus aureus, *Escherichia coli* and *Candida albicans*. Eur J Integr Med 36:101121. https://doi.org/10.1016/j.eujim.2020.101121

Houghton PJ, Hylands PJ, Mensah AY, Hensel A, Deters AM (2005) In vitro tests and ethnopharmacological investigations: wound healing as an example. J Ethnopharmacol 100(1–2):100–107. https://doi.org/10.1016/j.jep.2005.07.001

Jagetia GC, Baliga MS (2005) The effect of seasonal variation on the antineoplastic activity of *Alstonia scholaris* R. Br. in HeLa cells. J Ethnopharmacol 96(1–2):37–42. https://doi.org/10.1016/j.jep.2004.07.024

Khyade MS, Kasote DM, Vaikos NP (2014) Alstonia scholaris (L.) R. Br. and Alstonia macrophylla Wall ex. G. Don: a comparative review on traditional uses, phytochemistry and pharmacology. J Ethnopharmacol 153(1):1–18. https://doi.org/10.1016/j.jep.2014.01.025

Kiruba S, Mahesh M, Paul ZM, Jeeva S (2011) Preliminary phytochemical screening of the pericarp of Crataeva magna (Lour.) DC.—a medicinal tree. Asian Pac J Trop Biomed 1(1):S129–S130. https://doi.org/10.1016/S2221-1691(11)60139-1

Komape NPM, Bagla VP, Kabongo-Kayoka P, Masoko P (2017) Anti-mycobacteria potential and synergistic effects of combined crude extracts of selected medicinal plants used by Bapedi traditional healers to treat tuberculosis related symptoms in Limpopo Province. S Afr BMC Complement Altern Med 17(1):1–13. https://doi.org/10.1186/s12906-016-1521-2

Magalhães CDS, da Silva FCL, Randau KP (2023) Morphoanatomy, histochemistry, and phytochemistry of stem and leaves of *Crateva tapia* L. Microsc Microanal 29(2):795–801. https://doi.org/10.1093/micmic/ozac035

Moglad EH, Ska B, Hto A (2020) Various medicinal plants: a promising treatment for multidrug-resistant bacteria isolated from wound infection. Int J Pharm Sci Res 11(2):839–843. https://doi.org/10.13040/IJPSR.0975-8232.11(2).839-43

Mostafa AA, Al-Askar AA, Almaary KS, Dawoud TM, Sholkamy EN, Bakri MM (2018) Antimicrobial activity of some plant extracts against bacterial strains causing food poisoning diseases. Saudi J Biol Sci 25(2):361–366. https://doi.org/10.1016/j.sjbs.2017.02.004

Muhammad H, Carneiro M, Poça KS (2011) Evaluation of the genotoxicity of *Orthosiphon stamineus* aqueous extract. J Ethnopharmacol 133:647–653. https://doi.org/10.1016/j.jep.2010.10.055

Odongo EA, Mutai PC, Amugune BK, Mungai NN, Akinyi MO, Kimondo J (2023) Evaluation of the antibacterial activity of selected Kenyan medicinal plant extract combinations against clinically important bacteria. BMC Complement Altern Med 23(1):100. https://doi.org/10.1186/s12906-023-03939-4

Ogbole OO, Segun PA, Fasinu PS (2018) Antimicrobial and antiprotozoal activities of twenty-four Nigerian medicinal plant extracts. S Afr J Bot 117:240–246. https://doi.org/10.1016/j.sajb.2018.05.028

Othman M, San Loh H, Wiart C, Khoo TJ, Lim KH, KN. (2011) Optimal methods for evaluating antimicrobial activities from plant extracts. J Microbiol Methods 84(2):161–166. https://doi.org/10.1016/j.mimet.2010.11.008

Patel DK (2023) Morelloflavone as phytomedicine—an ethnopharmacological review on the therapeutical properties, biological efficacy and pharmacological activity. Anti-Infect Agents 21(2):48–58. https://doi.org/10.2174/2211352521666221114114425

Perera MMN, Dighe SN, Katavic PL, Collet TA (2022) Antibacterial potential of extracts and phytoconstituents isolated from *Syncarpia hillii* leaves in vitro. Plants 11:283. https://doi.org/10.3390/plants11030283

Pratheeshkumar P, Son YO, Korangath P, Manu KA, Siveen KS (2015) Phytochemicals in cancer prevention and therapy. BioMed Res Int. https://doi.org/10.1155/2015/324021

Ramasubbu R, Manikandan G, Sasi Kala N (2020) Phytochemical composition and antimicrobial properties of leaf essential oil of Garcinia imberti Bourd. and G. travancorica Bedd. Int. J Adv Sci Technol 29(2):1082–1092

Rethinam G, Duraiswamy A, Reddy GD, Elankani P, Srinivasan SK (2021) Nephroprotective effect of Sphaeranthus amaranthoides Burm f.: Sivakaranthai (a Siddha Kayakalpa drug) against gentamicin induced nephrotoxicity. Adv Tradit Med. https://doi.org/10.1007/s13596-021-00549-8

Rossi F, Amadoro C, Gasperi M, Colavita G (2022) *Lactobacilli* infection case reports in the last three years and safety implications. Nutrients 14(6):1178. https://doi.org/10.3390/nu14061178

Saravana Kumar P, Li Y, He M, Yuvaraj P, Balakrishna K, Ignacimuthu S (2022) Rapid isolation of ricinine, a pyridone alkaloid from *Ricinus communis* (L.) with antifungal properties. J Biol Act Prod Nat 12(1):33–41. https://doi.org/10.1080/22311866.2021.2021985

Shahid M, Law D, Azfaralariff A, Mackeen MM, Chong TF, Fazry S (2022) Phytochemicals and biological activities of *Garcinia atroviridis*. Crit Rev Toxicol 10(11):656. https://doi.org/10.3390/toxics10110656

Shang JH, Cai XH, Feng T, Zhao YL, Wang JK, Zhang LY, Luo XD (2010) Pharmacological evaluation of *Alstonia scholaris*: Anti-inflammatory and analgesic effects. J Ethnopharmacol 129(2):174–181. https://doi.org/10.1016/j.jep.2010.02.011

Teferi S, Sahlemariam Z, Mekonnen M, Tamrat R, Bekana T, Adisu Y, Darge T (2023) Uropathogenic bacterial profile and antibiotic susceptibility pattern of isolates among gynecological cases admitted to Jimma Medical Center, South West Ethiopia. Sci Rep 13(1):7078. https://doi.org/10.1038/s41598-023-34048-4

Thanigaivel A, Chanthini KMP, Karthi S, Vasantha-Srinivasan P, Ponsankar A, Sivanesh H, Senthil-Nathan S (2019) Toxic effect of essential oil and its compounds isolated from *Sphaeranthus amaranthoides* Burm. f. against dengue mosquito vector *Aedes aegypti* Linn. Pestic Biochem Physiol 160:163–170. https://doi.org/10.1016/j.pestbp.2019.08.006

Timpau AS, Miftode RS, Costache II, Petris AO, Miftode I-L, Gheorghe L, Timpau R, Miftode ID, Prepeliuc CS, Coman I, Anton-Paduraru D-T, Tuchilus C, Miftode EG (2023) An overview of the impact of bacterial infections and the associated mortality predictors in patients with COVID-19 admitted to a tertiary center from eastern Europe. Antibiot 12:144. https://doi.org/10.3390/antibiotics12010144

Tung NN, Hanh TTH, Cuong NX, Cuong NT, Quang TH (2022) Antimicrobial phenolic metabolites from the aerial parts of *Orthosiphon aristatus*. Phytochem Lett 52:49–53. https://doi.org/10.1016/j.phytol.2022.09.004

Widyaningrum I, Wulandari DN, Nisa NA, Khalisa PN, Aqilah Z (2022) Comparison of antibacterial activity propionibacterium acnes ethanol extract, water ethanol fraction, and ethyl acetate fraction of orthosiphon aristatus leaves. J Pharm Negat Results. https://doi.org/10.47750/pnr.2022.13.S09.592

Publisher's Note