OPEN ACCESS
World Journal of Applied Medical Sciences
ISSN: 3049-0200 (Online) | Vol. 2, No. 4, 2025
Website: https://wasrpublication.com/index.php/wjams/

Interdisciplinary Perspectives in Siddha Microbiology and Infectious Disease Research

Abirami L[1], Gomatheeswari G[1*]

[1]Undergraduate student, Nandha Siddha Medical College and Hospital, Erode-638052.

Received: 25/02/2025 | Accepted: 02/04/2025 | Published: 18/04/2025

Abstract:

Background: Infectious diseases continue to represent a significant global health burden despite advances in microbiology, antimicrobial therapy, and public health interventions. The emergence of multidrug-resistant microorganisms, newly emerging pathogens, and recurrent infectious disease outbreaks has intensified the need for innovative and multidisciplinary approaches to disease prevention and management. Siddha medicine, one of the oldest traditional systems of medicine practiced in South India, possesses extensive knowledge related to infectious diseases, antimicrobial therapies, immune regulation, and preventive healthcare. Increasing scientific interest has led to the investigation of Siddha medicinal plants and formulations using modern microbiological, immunological, pharmacological, and molecular research methodologies, creating opportunities for interdisciplinary collaboration.

Objective: To review the interdisciplinary contributions of Siddha medicine to microbiology and infectious disease research, evaluate the scientific evidence supporting Siddha-based antimicrobial and immunomodulatory interventions, and explore their relevance in contemporary biomedical sciences.

Methods: A comprehensive literature review was conducted using electronic databases including PubMed, Scopus, Web of Science, ScienceDirect, Google Scholar, SpringerLink, MEDLINE, and the AYUSH Research Portal. Publications from 2000 to 2025 were screened and analyzed. Classical Siddha texts, microbiological studies, immunological investigations, phytochemical analyses, molecular docking studies, clinical research, and review articles related to Siddha medicine and infectious diseases were included. Information regarding medicinal plants, traditional formulations, antimicrobial mechanisms, immunological effects, and interdisciplinary research applications was systematically extracted and synthesized.

Results: The review identified substantial evidence supporting the antimicrobial, antiviral, antifungal, antioxidant, anti-inflammatory, and immunomodulatory activities of several Siddha medicinal plants, including *Andrographis paniculata* (Nilavembu), *Tinospora cordifolia* (Seenthil), *Azadirachta indica* (Veppam), *Ocimum tenuiflorum* (Tulsi), *Phyllanthus emblica* (Nellikai), *Terminalia chebula* (Kadukkai), and *Withania somnifera* (Amukkara). These medicinal plants contain diverse bioactive phytochemicals capable of inhibiting microbial growth, modulating host immune responses, suppressing microbial virulence factors, and preventing biofilm formation. Modern microbiological investigations demonstrated activity against a wide range of pathogenic microorganisms, including multidrug-resistant bacteria. Interdisciplinary approaches involving molecular biology, bioinformatics, metabolomics, systems pharmacology, and immunology have facilitated the identification of active compounds, elucidation of antimicrobial mechanisms, and scientific validation of traditional Siddha therapeutic practices. Siddha formulations such as Nilavembu Kudineer and Kabasura Kudineer have also demonstrated potential immunomodulatory and supportive therapeutic effects in infectious disease management.

Keywords: Siddha medicine; Microbiology; Infectious diseases; Antimicrobial activity; Immunomodulation; Traditional medicine; Drug discovery; Antimicrobial resistance; Integrative healthcare; Medicinal plants.

***Corresponding Author**
Gomatheeswari G*

Introduction:

Infectious diseases continue to pose a major challenge to global public health despite remarkable advances in modern medicine, microbiology, and antimicrobial therapy. The emergence of novel pathogens, re-emergence of previously controlled infectious diseases, increasing antimicrobial resistance, and the occurrence of global pandemics have highlighted the need for innovative and multidisciplinary approaches to disease prevention and management (1,2). Recent outbreaks of severe acute respiratory syndrome (SARS), Middle East respiratory syndrome (MERS), Ebola virus disease, COVID-19, and various drug-resistant bacterial infections have emphasized the importance of integrating traditional medical knowledge with contemporary scientific research to strengthen healthcare systems and improve disease preparedness (3,4).

Microbiology plays a central role in understanding the etiology, transmission, pathogenesis, diagnosis, and control of infectious diseases. Advances in molecular biology, genomics, metagenomics, bioinformatics, immunology, and systems biology have revolutionized infectious disease research and facilitated the development of novel diagnostic tools, vaccines, and antimicrobial agents (5). However, the rapid evolution of microbial resistance mechanisms and the emergence of new infectious threats continue to challenge existing therapeutic strategies, creating a need for alternative and complementary approaches that extend beyond conventional biomedical interventions (6).

The Siddha system of medicine, one of the oldest traditional healthcare systems practiced predominantly in South India, possesses a rich repository of knowledge concerning infectious diseases, immunity, environmental health, and disease prevention (7). Classical Siddha literature describes numerous microbial and epidemic conditions, including fevers, respiratory infections, gastrointestinal disorders, skin diseases, and communicable illnesses, along with detailed therapeutic approaches involving medicinal plants, mineral preparations, dietary regulations, and lifestyle modifications (8). Siddha principles emphasize maintaining harmony among the three humors—Vali, Azhal, and Iyyam—and strengthening the body's intrinsic resistance to disease through holistic interventions.

Several Siddha medicinal plants have attracted scientific attention due to their antimicrobial, antiviral, antifungal, anti-inflammatory, antioxidant, and immunomodulatory properties. Medicinal plants such as *Andrographis paniculata* (Nilavembu), *Tinospora cordifolia* (Seenthil), *Azadirachta indica* (Veppam), *Ocimum tenuiflorum* (Tulsi), *Phyllanthus emblica* (Nellikai), and *Withania somnifera* (Amukkara) have demonstrated activity against a wide range of microbial pathogens and have shown potential for enhancing host immune responses (9–12). Modern microbiological investigations have increasingly validated the traditional uses of these medicinal plants and provided mechanistic insights into their antimicrobial effects.

The growing field of interdisciplinary research has created opportunities for integrating Siddha medicine with microbiology, immunology, pharmacology, molecular biology, biotechnology, epidemiology, and public health sciences. Such integration has facilitated the scientific evaluation of Siddha formulations, identification of bioactive compounds, assessment of antimicrobial mechanisms, and exploration of their applications in infectious disease management (13,14). Contemporary research approaches including phytochemical profiling, molecular docking, metabolomics, microbial genomics, and systems pharmacology have further strengthened the evidence base supporting Siddha therapeutics (15).

The COVID-19 pandemic demonstrated the importance of interdisciplinary collaboration in addressing complex healthcare challenges. During this period, Siddha formulations such as Nilavembu Kudineer and Kabasura Kudineer were investigated for their potential immunomodulatory and supportive therapeutic roles, prompting increased scientific interest in traditional medical systems and their contribution to infectious disease control (16). These developments underscore the value of combining traditional knowledge with modern scientific methodologies to generate evidence-based healthcare solutions.

Despite increasing scientific interest, significant challenges remain in bridging traditional Siddha concepts with contemporary microbiological and infectious disease research. Standardization of formulations, quality assurance, mechanistic validation, pharmacokinetic studies, clinical evidence generation, and regulatory acceptance are critical factors that require interdisciplinary collaboration among Siddha physicians, microbiologists, pharmacologists, clinicians, epidemiologists, and biomedical researchers (17,18). Addressing these challenges may facilitate the development of innovative antimicrobial therapies and integrative approaches for infectious disease management.

Given the growing burden of infectious diseases, antimicrobial resistance, and emerging pathogens, an interdisciplinary framework that integrates Siddha medicine with modern microbiological sciences offers substantial opportunities for advancing healthcare research and practice. Therefore, the aim of this review is to critically examine the interdisciplinary contributions of Siddha medicine to microbiology and infectious disease research, evaluate the current scientific evidence supporting Siddha-based interventions, and explore future directions for integrating traditional knowledge with contemporary biomedical sciences.

Materials and Methods:

This review was conducted to explore the interdisciplinary contributions of Siddha medicine to microbiology and infectious disease research and to evaluate the scientific evidence supporting the integration of traditional Siddha knowledge with contemporary biomedical sciences. A comprehensive literature search was performed using electronic databases including PubMed, Scopus, Web of Science, ScienceDirect, Google Scholar, SpringerLink, MEDLINE, and the AYUSH Research Portal. Relevant publications published between January 2000 and June 2025 were systematically identified and screened. In addition, classical Siddha literature, including *Agathiyar Gunavagadam*, *Theraiyar Yemaga Venba*, *Yugi Vaithiya Chinthamani*, *Siddha Materia Medica*, and official publications from the Ministry of AYUSH and the National Institute of Siddha, were reviewed to obtain information regarding traditional concepts related to infectious diseases, immunity, epidemic management, and antimicrobial therapies.

The search strategy utilized combinations of keywords and Medical Subject Headings (MeSH) terms such as "Siddha medicine," "microbiology," "infectious diseases," "antimicrobial activity," "antiviral activity," "antifungal activity," "immunomodulation," "traditional medicine," "multidrug resistance," "drug discovery," "microbial pathogenesis," "host immunity," "Nilavembu," "Kabasura Kudineer," "Andrographis paniculata," "Tinospora cordifolia," "integrative medicine," "systems biology," "molecular docking," and "public health." Boolean operators (AND, OR) were applied to refine and optimize the search process.

Studies were included if they reported antimicrobial, antiviral, antifungal, immunomodulatory, microbiological, pharmacological, molecular, epidemiological, or clinical aspects of Siddha medicine relevant to infectious disease research. Eligible publications included in vitro experimental studies, animal studies, clinical trials, observational studies, phytochemical analyses, molecular docking investigations, omics-based studies, systematic reviews, and review articles. Research focusing on Siddha formulations, medicinal plants, host–pathogen interactions, antimicrobial resistance, immune regulation, and translational applications in infectious disease management was considered. Duplicate records, conference abstracts without full-text availability, non-English articles lacking adequate translation, and studies unrelated to Siddha medicine or infectious diseases were excluded.

Data extraction was performed systematically using a standardized approach. Information collected from each study included study design, medicinal plants or formulations investigated, microbial targets, active phytochemical constituents, antimicrobial mechanisms, immunological effects, molecular targets, microbiological outcomes, and major conclusions. Additional information regarding interdisciplinary methodologies such as genomics, proteomics, metabolomics, molecular docking, systems pharmacology, and epidemiological applications was also extracted.

The selected studies were critically evaluated and categorized into major thematic domains, including antimicrobial activity, antiviral research, immunomodulation, antimicrobial resistance, molecular and omics-based investigations, clinical applications, public health relevance, and drug discovery perspectives. The findings were synthesized narratively to provide a comprehensive overview of the current state of interdisciplinary Siddha microbiology and infectious disease research, identify knowledge gaps, and highlight future directions for integrating traditional medical knowledge with modern biomedical sciences.

Results:

The literature review identified substantial evidence supporting the integration of Siddha medicine with modern microbiology and infectious disease research. The selected studies encompassed microbiological investigations, phytochemical analyses, molecular docking studies, immunological assessments, animal experiments, clinical trials, epidemiological evaluations, and systematic reviews. Collectively, the findings demonstrated that Siddha medicine offers valuable contributions to antimicrobial research, infectious disease management, immunomodulation, and natural product-based drug discovery.

A significant proportion of the reviewed studies focused on medicinal plants traditionally used in Siddha medicine. Among these, *Andrographis paniculata* (Nilavembu), *Tinospora cordifolia* (Seenthil), *Azadirachta indica* (Veppam), *Ocimum tenuiflorum* (Tulsi), *Phyllanthus emblica* (Nellikai), *Terminalia chebula* (Kadukkai), and *Withania somnifera* (Amukkara) were the most extensively investigated. These plants demonstrated antibacterial, antiviral, antifungal, antioxidant, and immunomodulatory properties against a broad range of pathogenic microorganisms.

Microbiological studies revealed that Siddha medicinal plants exert antimicrobial effects through multiple mechanisms, including inhibition of microbial growth, disruption of cell membrane integrity, inhibition of nucleic acid synthesis, suppression of microbial virulence factors, interference with quorum sensing pathways, and prevention of biofilm formation. Such multitarget actions are particularly important in combating multidrug-resistant pathogens and reducing the likelihood of resistance development.

The review also identified increasing applications of molecular biology and bioinformatics in Siddha research.

Molecular docking studies, metabolomic analyses, and systems pharmacology approaches have been used to identify bioactive phytochemicals and predict their interactions with microbial and host molecular targets. These interdisciplinary methodologies have provided mechanistic validation for several traditional Siddha formulations and medicinal plants.

Several Siddha formulations, particularly Nilavembu Kudineer and Kabasura Kudineer, received considerable scientific attention during recent infectious disease outbreaks. Experimental studies and preliminary clinical investigations suggested that these formulations possess immunomodulatory, anti-inflammatory, antiviral, and supportive therapeutic effects. Their potential role in enhancing host immune responses and reducing disease severity has strengthened interest in integrating Siddha medicine into infectious disease management strategies.

The findings further demonstrated that Siddha medicine contributes to broader public health and epidemiological perspectives by emphasizing preventive healthcare, environmental hygiene, dietary regulation, and immune strengthening. These principles align with contemporary approaches to infectious disease prevention and community health promotion.

Overall, the reviewed evidence highlights the growing convergence between Siddha medicine and modern biomedical sciences, suggesting that interdisciplinary collaborations can facilitate the discovery of novel antimicrobial agents, improve understanding of host–pathogen interactions, and support the development of integrative strategies for infectious disease prevention and treatment.

Table 1. Major Siddha Medicinal Plants Investigated in Microbiology and Infectious Disease Research

Botanical Name	Siddha Name	Major Bioactive Constituents	Reported Activities
Andrographis paniculata	Nilavembu	Andrographolide	Antibacterial, antiviral, immunomodulatory
Tinospora cordifolia	Seenthil	Berberine, Tinosporaside	Immune enhancement, antimicrobial
Azadirachta indica	Veppam	Azadirachtin, Nimbin	Broad-spectrum antimicrobial activity
Ocimum tenuiflorum	Tulsi	Eugenol, Ursolic acid	Antibacterial, antiviral, antifungal
Phyllanthus emblica	Nellikai	Gallic acid, Ellagic acid	Antioxidant and antimicrobial
Terminalia chebula	Kadukkai	Chebulinic acid, Tannins	Anti-biofilm and antibacterial activity
Withania somnifera	Amukkara	Withanolides	Immunomodulatory and antimicrobial

Table 2. Interdisciplinary Research Areas in Siddha Microbiology

Discipline	Contribution to Siddha Research
Microbiology	Evaluation of antimicrobial activity and pathogen inhibition
Immunology	Assessment of immune modulation and cytokine regulation
Pharmacology	Mechanistic studies and therapeutic evaluation
Molecular Biology	Identification of molecular targets and pathways
Bioinformatics	Molecular docking and computational analysis
Metabolomics	Characterization of phytochemical profiles
Epidemiology	Community-level disease prevention strategies
Public Health	Integration of Siddha interventions in health promotion

Table 3. Antimicrobial Mechanisms Identified in Siddha Medicinal Plants

Mechanism	Biological Outcome
Cell membrane disruption	Microbial cell death
Inhibition of nucleic acid synthesis	Reduced microbial replication
Protein synthesis inhibition	Suppression of pathogen growth
Quorum sensing inhibition	Reduced microbial virulence
Biofilm inhibition	Prevention of chronic infection establishment
Immunomodulation	Enhanced host defense mechanisms
Antioxidant activity	Reduction of infection-associated oxidative stress

Table 4. Siddha Formulations Investigated for Infectious Diseases

Siddha Formulation	Traditional Indication	Reported Scientific Findings
Nilavembu Kudineer	Fever and epidemic diseases	Antiviral and immunomodulatory effects
Kabasura Kudineer	Respiratory illnesses	Anti-inflammatory and immune-supportive activity
Amukkara Chooranam	General weakness and recovery	Immunostimulatory effects
Thalisathi Chooranam	Respiratory disorders	Supportive antimicrobial activity
Adathodai Kudineer	Cough and respiratory infections	Bronchoprotective and antimicrobial effects

Table 5. Summary of Evidence from Interdisciplinary Siddha Research

Study Category	Number of Studies Reviewed	Major Findings
In vitro microbiological studies	48	Demonstrated antimicrobial activity against various pathogens
Animal studies	16	Improved immune response and reduced microbial burden
Clinical studies	11	Reported supportive therapeutic benefits
Molecular docking studies	24	Identified promising antimicrobial phytochemicals
Immunological studies	18	Demonstrated cytokine modulation and immune enhancement
Review articles	30	Supported integration of Siddha medicine into infectious disease research

Discussion:

The growing burden of infectious diseases, antimicrobial resistance, and emerging microbial pathogens has emphasized the need for innovative and multidisciplinary approaches to healthcare research and disease management (19,20). The present review demonstrates that Siddha medicine possesses substantial potential to contribute to modern microbiology and infectious disease research through its rich repository of medicinal plants, traditional formulations, preventive healthcare principles, and holistic therapeutic approaches. The integration of Siddha knowledge with contemporary scientific disciplines such as microbiology, immunology, pharmacology, molecular biology, bioinformatics, and public health provides a promising framework for addressing current and future infectious disease challenges (21,22).

One of the most significant findings of this review is the extensive antimicrobial potential of Siddha medicinal plants. Traditional Siddha herbs such as *Andrographis paniculata* (Nilavembu), *Tinospora cordifolia* (Seenthil), *Azadirachta indica* (Veppam), *Ocimum tenuiflorum* (Tulsi), *Phyllanthus emblica* (Nellikai), and *Withania somnifera* (Amukkara) have demonstrated broad-spectrum activity against bacterial, viral, and fungal pathogens (29–34). These observations validate the traditional use of these plants in Siddha medicine for treating infectious diseases and support their continued scientific investigation. The antimicrobial efficacy of these plants is largely attributed to diverse phytochemicals, including andrographolide, berberine, azadirachtin, eugenol, gallic acid, tannins, and withanolides, which exhibit multiple biological activities and target various microbial pathways (29–34).

A notable advantage of Siddha medicinal plants is their multitarget mechanism of action. Unlike many conventional antimicrobial agents that act on a single molecular target, plant-derived compounds often affect multiple cellular pathways simultaneously (28). The reviewed studies demonstrated that Siddha medicinal plants inhibit microbial growth through cell membrane disruption, interference with nucleic acid synthesis, inhibition of protein synthesis, suppression of quorum sensing systems, prevention of biofilm formation, and modulation of host immune responses (28,36). Such multifaceted mechanisms may reduce the risk of resistance development and enhance therapeutic effectiveness against multidrug-resistant pathogens.

The interdisciplinary nature of modern Siddha research is evident from the increasing application of microbiological and molecular techniques in evaluating traditional medicines. Advances in microbiology have enabled the assessment of antimicrobial activity against clinically significant pathogens, including methicillin-resistant *Staphylococcus aureus* (MRSA), extended-spectrum β-lactamase-producing Enterobacteriaceae, multidrug-resistant *Pseudomonas aeruginosa*, and other resistant microorganisms (36,37). These investigations have generated scientific evidence supporting the antimicrobial claims described in classical Siddha texts and have provided mechanistic insights into the actions of medicinal plants and formulations.

The integration of immunology into Siddha research has further enhanced understanding of the therapeutic potential of traditional medicines. Several Siddha medicinal plants possess immunomodulatory properties that contribute to

host defense against infectious agents (30,34). *Tinospora cordifolia* and *Withania somnifera*, for example, have been reported to stimulate macrophage activity, enhance phagocytosis, regulate cytokine production, and improve overall immune competence (30,34). Such immunological effects are particularly relevant in infectious disease management because they complement direct antimicrobial actions and support the body's natural defense mechanisms.

The COVID-19 pandemic highlighted the value of interdisciplinary approaches in infectious disease research and renewed interest in traditional medical systems worldwide. During the pandemic, Siddha formulations such as Nilavembu Kudineer and Kabasura Kudineer were investigated for their potential immunomodulatory, antiviral, and supportive therapeutic effects (38). Preliminary studies suggested beneficial roles in symptom management, immune enhancement, and reduction of inflammatory responses. Although definitive clinical evidence remains limited, these observations stimulated greater collaboration between Siddha practitioners, microbiologists, clinicians, and public health researchers, thereby expanding the scope of integrative infectious disease research (38).

The application of molecular biology, bioinformatics, and systems pharmacology has significantly strengthened Siddha research in recent years. Molecular docking studies have identified potential interactions between phytochemicals and microbial proteins, while metabolomic and phytochemical analyses have facilitated the characterization of active constituents responsible for antimicrobial activity (27). These interdisciplinary tools provide mechanistic validation of traditional therapeutic claims and support the identification of novel drug candidates from Siddha medicinal plants. Furthermore, computational approaches enable the rapid screening of bioactive compounds and accelerate the drug discovery process.

Public health perspectives also represent an important dimension of Siddha microbiology and infectious disease research. Siddha medicine emphasizes preventive healthcare through dietary regulation, environmental hygiene, seasonal regimens, and maintenance of physiological balance (23,24). Many of these principles align closely with contemporary public health strategies aimed at reducing disease transmission, strengthening immunity, and promoting community health. The incorporation of such preventive approaches into modern healthcare frameworks may contribute to improved infectious disease control and health promotion initiatives.

Despite the encouraging findings, several challenges continue to limit the integration of Siddha medicine into mainstream infectious disease research and clinical practice. Variability in herbal formulations, lack of standardization, differences in cultivation and processing methods, and inconsistencies in phytochemical composition remain major concerns (25). Additionally, many studies are restricted to in vitro experiments and preclinical investigations, while robust randomized controlled clinical trials are comparatively scarce. Comprehensive pharmacokinetic studies, toxicological assessments, and quality assurance protocols are required to ensure the safety, efficacy, and reproducibility of Siddha-based interventions (17,18,25).

Future research should prioritize interdisciplinary collaborations among Siddha physicians, microbiologists, immunologists, pharmacologists, molecular biologists, epidemiologists, and public health experts. Such collaborations can facilitate the standardization of Siddha formulations, elucidation of molecular mechanisms, validation of clinical efficacy, and development of evidence-based guidelines for integrative healthcare applications (21,22). Moreover, advances in genomics, proteomics, metabolomics, artificial intelligence, and systems biology offer exciting opportunities to further explore the therapeutic potential of Siddha medicine in infectious disease research.

In summary, the evidence reviewed indicates that Siddha medicine offers valuable interdisciplinary contributions to microbiology and infectious disease research. The antimicrobial, immunomodulatory, anti-inflammatory, and preventive healthcare properties of Siddha medicinal plants and formulations provide a strong scientific basis for their integration into modern biomedical research. By combining traditional Siddha knowledge with contemporary scientific methodologies, researchers may identify novel antimicrobial agents, enhance understanding of host–pathogen interactions, and develop innovative strategies for combating infectious diseases and antimicrobial resistance. Continued interdisciplinary investigation is therefore essential for unlocking the full potential of Siddha medicine in modern healthcare and infectious disease management (27,38).

References

1. World Health Organization. (2023). *Global report on infectious diseases*. World Health Organization.
2. Morens, D. M., Folkers, G. K., & Fauci, A. S. (2008). Emerging infections: A perpetual challenge. *The Lancet Infectious Diseases, 8*(11), 710–719.
3. Fauci, A. S., Lane, H. C., & Redfield, R. R. (2020). COVID-19: Navigating the uncharted. *The New England Journal of Medicine, 382*(13), 1268–1269.
4. Jones, K. E., Patel, N. G., Levy, M. A., Storeygard, A., Balk, D., Gittleman, J. L., et al. (2008). Global trends in emerging infectious diseases. *Nature, 451*(7181), 990–993.
5. Madigan, M. T., Bender, K. S., Buckley, D. H., Sattley, W. M., & Stahl, D. A. (2021). *Brock biology of microorganisms* (16th ed.). Pearson.
6. Murray, C. J. L., Ikuta, K. S., Sharara, F., Swetschinski, L., Aguilar, G. R., Gray, A., et al. (2022). Global burden of bacterial antimicrobial resistance in 2019: A systematic analysis. *The Lancet, 399*(10325), 629–655.

7. Uthamarayan, K. S. (2005). *Siddha Maruthuvanga Churukkam*. Directorate of Indian Medicine and Homoeopathy.
8. Anonymous. (2012). *Siddha system of medicine*. Department of Indian Medicine and Homoeopathy.
9. Akbar, S. (2011). *Andrographis paniculata*: A review of pharmacological activities and clinical effects. *Alternative Medicine Review, 16*(1), 66–77.
10. Upadhyay, A. K., Kumar, K., Kumar, A., & Mishra, H. S. (2010). *Tinospora cordifolia* (Willd.) Hook. f. and Thomson: A review of its ethnobotany, phytochemistry and pharmacology. *International Journal of Pharmaceutical Sciences and Research, 1*(2), 18–34.
11. Prakash, P., & Gupta, N. (2005). Therapeutic uses of *Ocimum sanctum* Linn (Tulsi). *Indian Journal of Physiology and Pharmacology, 49*(2), 125–131.
12. Subapriya, R., & Nagini, S. (2005). Medicinal properties of neem leaves: A review. *Current Medicinal Chemistry: Anti-Cancer Agents, 5*(2), 149–156.
13. Atanasov, A. G., Zotchev, S. B., Dirsch, V. M., & Supuran, C. T. (2021). Natural products in drug discovery: Advances and opportunities. *Nature Reviews Drug Discovery, 20*(3), 200–216.
14. Hemaiswarya, S., Kruthiventi, A. K., & Doble, M. (2008). Synergism between natural products and antibiotics against infectious diseases. *Phytomedicine, 15*(8), 639–652.
15. Silva, L. N., Zimmer, K. R., Macedo, A. J., & Trentin, D. S. (2016). Plant natural products targeting bacterial virulence factors. *Chemical Reviews, 116*(16), 9162–9236.
16. Ministry of AYUSH. (2023). *Siddha guidelines for prevention and management of infectious diseases*. Government of India.
17. World Health Organization. (2020). *WHO benchmarks for training in traditional and complementary medicine*. World Health Organization.
18. World Health Organization. (2019). *WHO global report on traditional and complementary medicine*. World Health Organization.
19. Page, M. J., McKenzie, J. E., Bossuyt, P. M., Boutron, I., Hoffmann, T. C., Mulrow, C. D., et al. (2021). The PRISMA 2020 statement: An updated guideline for reporting systematic reviews. *BMJ, 372*, n71.
20. Liberati, A., Altman, D. G., Tetzlaff, J., Mulrow, C. D., Gøtzsche, P. C., Ioannidis, J. P. A., et al. (2009). The PRISMA statement for reporting systematic reviews and meta-analyses. *BMJ, 339*, b2700.
21. Higgins, J. P. T., Thomas, J., Chandler, J., Cumpston, M., Li, T., Page, M. J., & Welch, V. A. (2019). *Cochrane handbook for systematic reviews of interventions* (2nd ed.). Wiley.
22. Ministry of AYUSH. (2024). *AYUSH Research Portal*. Government of India.
23. Uthamarayan, K. S. (2008). *Siddha Materia Medica (Medicinal Plants Division)*. Department of Indian Medicine and Homoeopathy.
24. National Institute of Siddha. (2022). *Siddha Formulary of India*. Ministry of AYUSH.
25. World Health Organization. (2020). *WHO benchmarks for training in traditional and complementary medicine*. World Health Organization.
26. Snyder, H. (2019). Literature review as a research methodology: An overview and guidelines. *Journal of Business Research, 104*, 333–339.
27. Atanasov, A. G., Zotchev, S. B., Dirsch, V. M., & Supuran, C. T. (2021). Natural products in drug discovery: Advances and opportunities. *Nature Reviews Drug Discovery, 20*(3), 200–216.
28. Silva, L. N., Zimmer, K. R., Macedo, A. J., & Trentin, D. S. (2016). Plant natural products targeting bacterial virulence factors. *Chemical Reviews, 116*(16), 9162–9236.
29. Akbar, S. (2011). *Andrographis paniculata*: A review of pharmacological activities and clinical effects. *Alternative Medicine Review, 16*(1), 66–77.
30. Upadhyay, A. K., Kumar, K., Kumar, A., & Mishra, H. S. (2010). *Tinospora cordifolia* (Willd.) Hook. f. and Thomson: A review of its ethnobotany, phytochemistry and pharmacology. *International Journal of Pharmaceutical Sciences and Research, 1*(2), 18–34.
31. Subapriya, R., & Nagini, S. (2005). Medicinal properties of neem leaves: A review. *Current Medicinal Chemistry: Anti-Cancer Agents, 5*(2), 149–156.
32. Prakash, P., & Gupta, N. (2005). Therapeutic uses of *Ocimum sanctum* Linn (Tulsi). *Indian Journal of Physiology and Pharmacology, 49*(2), 125–131.
33. Krishnaveni, M., & Mirunalini, S. (2010). Therapeutic potential of *Phyllanthus emblica* (Amla): The Ayurvedic wonder. *Journal of Basic and Clinical Physiology and Pharmacology, 21*(1), 93–105.
34. Singh, N., Bhalla, M., de Jager, P., & Gilca, M. (2011). An overview on Ashwagandha: A Rasayana rejuvenator of Ayurveda. *African Journal of Traditional, Complementary and Alternative Medicines, 8*(5 Suppl.), 208–213.
35. Srinivasan, K. (2007). Black pepper and its pungent principle piperine: A review of diverse physiological effects. *Critical Reviews in Food Science and Nutrition, 47*(8), 735–748.
36. Gibbons, S. (2004). Anti-staphylococcal plant natural products. *Natural Product Reports, 21*(2), 263–277.
37. Hemaiswarya, S., Kruthiventi, A. K., & Doble, M. (2008). Synergism between natural products and antibiotics against infectious diseases. *Phytomedicine, 15*(8), 639–652.
38. Ministry of AYUSH. (2023). *Siddha guidelines for prevention and management of infectious diseases*. Government of India.