International Journal of Multidisciplinary Academic Research and Trends
EdTech Publishers (OPC) Private Limited
Volume 01 Issue 01 October-2025

Pharmacological Evaluation of Herbal Extracts for Antimicrobial Activity

Harini K.
Under the Guidance of Dr. B. S. Suresh
Department of Pharmacology
JSS College of Pharmacy, Ooty, Tamil Nadu, India

Abstract

The increasing prevalence of antimicrobial resistance (AMR) poses a significant global health challenge, necessitating the exploration of alternative therapeutic agents. Herbal extracts, derived from plants with traditional medicinal uses, have garnered attention for their potential antimicrobial properties. This research article evaluates the antimicrobial activity of selected herbal extracts, including *Ocimum sanctum* (Holy Basil), *Azadirachta indica* (Neem), and *Curcuma longa* (Turmeric), against common pathogenic bacteria such as *Escherichia coli*, *Staphylococcus aureus*, and *Pseudomonas aeruginosa*. Through in vitro assays, including disc diffusion and minimum inhibitory concentration (MIC) tests, the study assesses the efficacy of these extracts.These findings suggest that herbal extracts could serve as viable candidates for developing novel antimicrobial agents, offering a sustainable and cost-effective approach to combating AMR. The study also discusses the phytochemical constituents responsible for the observed effects and proposes future directions for clinical and pharmacological research.

The research article explores the potential of herbal extracts as alternative antimicrobial agents in response to the growing threat of antimicrobial resistance (AMR). The study focuses on extracts from Ocimum sanctum (Holy Basil), Azadirachta indica (Neem), and Curcuma longa (Turmeric), evaluating their efficacy against common pathogenic bacteria such as Escherichia coli, Staphylococcus aureus, and Pseudomonas aeruginosa. The results demonstrated significant antimicrobial effects, with varying levels of potency observed across different extracts and bacterial strains.

The findings highlight the potential of herbal extracts as promising candidates for developing new antimicrobial agents to address the AMR crisis. The study emphasizes the sustainable and cost-effective nature of this approach, which could offer advantages over traditional antibiotic development. These results underscore the potential of herbal extracts in combating AMR and suggest avenues for future clinical and pharmacological research to further explore their therapeutic applications.

Keywords

Herbal extracts, antimicrobial activity, antimicrobial resistance, phytochemicals, *Ocimum sanctum*, *Azadirachta indica*, *Curcuma longa*, disc diffusion, minimum inhibitory concentration.

Introduction

Antimicrobial resistance (AMR) is a growing public health crisis, with the World Health Organization (WHO) estimating that by 2050, AMR could lead to 10 million deaths annually if unchecked (WHO, 2020). The overuse of conventional antibiotics has accelerated the emergence of multidrug-resistant (MDR) pathogens, necessitating the development of alternative antimicrobial agents. Herbal extracts, derived from plants with a long history of use in traditional medicine, offer a promising avenue for addressing this challenge. Plants such as *Ocimum sanctum* (Holy Basil), *Azadirachta indica* (Neem), and *Curcuma longa* (Turmeric) have been used for centuries in Ayurvedic and other traditional systems for their antimicrobial, anti-inflammatory, and antioxidant properties. These plants contain bioactive compounds, such as alkaloids, flavonoids, and terpenoids, which may disrupt microbial cell membranes, inhibit enzyme activity, or interfere with bacterial replication.

This study aims to systematically evaluate the antimicrobial activity of these herbal extracts against common pathogenic bacteria, including *Escherichia coli* (Gram-negative), *Staphylococcus aureus* (Gram-positive), and *Pseudomonas aeruginosa* (Gram-negative). By employing standardized in vitro assays, such as disc diffusion and MIC tests, the research seeks to quantify the efficacy of these extracts and identify their potential as alternatives to conventional antibiotics. The study also explores the phytochemical profiles of the extracts to correlate their chemical composition with antimicrobial activity.The findings from this research could provide valuable insights into the development of novel antimicrobial agents derived from natural sources. Additionally, the study aims to investigate potential synergistic effects between different herbal extracts, which may enhance their overall antimicrobial efficacy. Furthermore, the results of this study could contribute to the growing body of evidence supporting the use of herbal remedies in combating antibiotic-resistant bacterial strains.The research also aims to assess the safety profile of these herbal extracts through cytotoxicity assays on human cell lines, ensuring their potential for therapeutic use. Moreover, the study will investigate the mechanism of action of the most promising extracts, utilizing advanced microscopy techniques and molecular biology methods to elucidate their effects on bacterial cell structures and metabolic pathways. Finally, the research will explore the potential for developing standardized herbal formulations that could be used in clinical settings, addressing issues such as dosage, stability, and quality control.

Literature Review

The use of plants in traditional medicine dates back thousands of years, with documented evidence in systems such as Ayurveda, Traditional Chinese Medicine, and African ethnomedicine. Recent studies have validated the antimicrobial properties of various herbal extracts. For instance, *Ocimum sanctum* has been shown to exhibit antibacterial activity against *Staphylococcus aureus* and *Escherichia coli* due to its eugenol and linalool content (Prakash & Gupta, 2005). Similarly, *Azadirachta indica* contains azadirachtin and nimbidin, which disrupt bacterial cell walls and inhibit protein synthesis (Biswas et al., 2002). *Curcuma longa* owes its antimicrobial effects to curcumin, a polyphenolic compound with broad-spectrum activity (Moghadamtousi et al., 2014).

Despite these promising findings, challenges remain in standardizing herbal extracts and ensuring their safety and efficacy. Variations in plant growth conditions, extraction methods, and phytochemical concentrations can affect reproducibility (Tiwari et

al., 2011). Moreover, the mechanisms underlying the antimicrobial activity of these extracts are not fully understood, necessitating further research. This study builds on existing literature by providing a comparative analysis of the antimicrobial efficacy of three widely used herbal extracts and their potential applications in modern pharmacology.

The use of plants in traditional medicine has a rich history spanning millennia, with well-documented practices in various cultural systems such as Ayurveda, Traditional Chinese Medicine, and African ethnomedicine. Recent scientific investigations have corroborated the antimicrobial properties of numerous herbal extracts, lending credence to their traditional applications. Notable examples include Ocimum sanctum (holy basil), which demonstrates antibacterial activity against pathogens like Staphylococcus aureus and Escherichia coli, attributed to its eugenol and linalool content (Prakash & Gupta, 2005). Azadirachta indica (neem) contains compounds such as azadirachtin and nimbidin that disrupt bacterial cell walls and inhibit protein synthesis (Biswas et al., 2002), while Curcuma longa (turmeric) owes its broad-spectrum antimicrobial effects to curcumin, a polyphenolic compound (Moghadamtousi et al., 2014).

Despite these promising findings, the integration of herbal extracts into modern medicine faces several challenges. Standardization of herbal extracts remains a significant hurdle, as variations in plant growth conditions, extraction methods, and phytochemical concentrations can affect reproducibility and consistency in results (Tiwari et al., 2011). Additionally, the precise mechanisms underlying the antimicrobial activity of many herbal extracts are not fully elucidated, necessitating further research to understand their mode of action and potential synergistic effects. The current study aims to address these gaps by providing a comparative analysis of the antimicrobial efficacy of three widely used herbal extracts, exploring their potential applications in modern healthcare settings, and contributing to the growing body of evidence supporting the use of plant-based antimicrobials in contemporary medical practices.

Objectives and Hypothesis

Objectives

1. To evaluate the antimicrobial activity of *Ocimum sanctum*, *Azadirachta indica*, and *Curcuma longa* extracts against *Escherichia coli*, *Staphylococcus aureus*, and *Pseudomonas aeruginosa*.The study employed a disc diffusion method to assess the inhibitory effects of these plant extracts on bacterial growth. Minimum inhibitory concentrations (MICs) were determined using broth dilution techniques. Results indicated that all three plant extracts exhibited varying degrees of antimicrobial activity against the tested bacterial strains, with Ocimum sanctum showing the highest efficacy.

2. Serial dilutions of each extract were prepared in Mueller-Hinton broth, ranging from 0.5 to 256 μg/mL. The diluted extracts were then inoculated with standardized bacterial suspensions and incubated at 37°C for 24 hours before visual inspection for growth inhibition.

3. To identify the phytochemical constituents responsible for the observed antimicrobial effects.Further research should focus on isolating and characterizing the specific compounds present in the plant extract. Bioassay-guided fractionation techniques could be employed to pinpoint the active molecules. Once identified, these compounds could be synthesized or extracted in larger quantities for

potential development as novel antimicrobial agents.

4. To compare the efficacy of herbal extracts with standard antibiotics.The study aimed to evaluate the antimicrobial properties of various plant-based extracts against common pathogens. A series of in vitro experiments were conducted to measure the inhibition zones produced by both herbal extracts and conventional antibiotics. The results demonstrated that certain herbal extracts exhibited comparable or even superior antimicrobial activity to some standard antibiotics, suggesting their potential as alternative or complementary treatments for bacterial infections.

Hypothesis

H1: The herbal extracts of *Ocimum sanctum*, *Azadirachta indica*, and *Curcuma longa* exhibit significant antimicrobial activity against This suggests their potential as alternative therapeutic agents, particularly in the face of rising antibiotic resistance. Further in vitro and in vivo studies are necessary to validate their efficacy and safety profiles. Additionally, understanding the specific bioactive compounds responsible for this activity could facilitate the development of novel antimicrobial drugs.Clinical trials should be conducted to assess the effectiveness of these herbal extracts in treating infections caused by resistant bacterial strains. The potential synergistic effects of combining these extracts with conventional antibiotics should also be explored. Moreover, investigating the mechanisms of action of these herbal extracts could provide valuable insights into their antimicrobial properties and guide future drug development efforts.

Experimental Work

Plant Material and Extraction

Fresh leaves of *Ocimum sanctum* and *Azadirachta indica*, and rhizomes of *Curcuma longa* were collected from a certified botanical garden. The plant materials were authenticated, washed, and air-dried. Ethanolic extracts were prepared using a Soxhlet apparatus, with 70% ethanol as the solvent. The extracts were concentrated using a rotary evaporator and stored at 4°C until use.

In comparison, Neem (**Azadirachta indica**) has a wide range of active pesticide compounds known as “triterpenes,” or more precisely, “limonoids.”The triterpenes found in Azadirachta indica have been extensively studied for their potential applications in agriculture and medicine. These compounds exhibit potent insecticidal, antifungal, and antimicrobial properties, making them valuable alternatives to synthetic pesticides. Additionally, the phytochemical profile of Curcuma longa, particularly its curcuminoids, has garnered significant attention for its anti-inflammatory and antioxidant activities.

Bacterial Strains

The strains were maintained on nutrient agar slants at 4°C and subcultured before use.

A strain is a **genetic variant** or subtype of a virus or bacterium. For example, a "flu strain" is a certain biological form of the influenza or "flu" virus. Compare clade .

Strains of **yeasts** are the most common subjects of eukaryotic genetic modification, especially with respect to industrial fermentation.

Saccharomyces cerevisiae, commonly known as baker's yeast. This single-celled organism has been

extensively studied and manipulated for various biotechnological applications. Its genetic tractability and well-characterized genome make it an ideal model system for investigating eukaryotic cellular processes and developing novel genetic engineering techniques.

Antimicrobial Assays

1. **Disc Diffusion Assay**: Sterile filter paper discs (6 mm diameter) were impregnated with 20 µL of each herbal extract (10 mg/mL) and placed on Mueller-Hinton agar plates inoculated with the test bacteria. Plates were incubated at 37°C for 24 hours, and the diameter of the inhibition zones was measured in millimeters. The disk diffusion test (also known as the agar diffusion test, Kirby–Bauer test, disc-diffusion antibiotic susceptibility test, disc-diffusion antibiotic sensitivity test and KB test) is a **culture -based microbiology assay** used in diagnostic and drug discovery laboratories.

2. **Minimum Inhibitory Concentration (MIC)**: The MIC was determined using the broth microdilution method in 96-well microtiter plates. Serial dilutions of the extracts (0.1–10 mg/mL) were prepared in Mueller-Hinton broth, inoculated with 10^5 CFU/mL of each bacterial strain, and incubated at 37°C for 24 hours. The MIC was defined as the lowest concentration preventing visible bacterial growth.

Control

Ciprofloxacin (5 µg/disc) was used as the positive control, and 70% ethanol was used as the negative control.The use of ciprofloxacin (5 µg/disc) as a positive control in antimicrobial susceptibility testing is a common practice in microbiological research. Ciprofloxacin, a broad-spectrum fluoroquinolone antibiotic, is effective against a wide range of gram-positive and gram-negative bacteria. Its inclusion as a positive control serves to validate the experimental procedure and provides a reference point for comparing the antimicrobial activity of test substances. The specific concentration of 5 µg/disc is standardized to ensure consistent and reproducible results across different studies.

On the other hand, 70% ethanol was employed as the negative control in this experiment. Ethanol at this concentration is commonly used as a solvent for extracting plant compounds and other potential antimicrobial agents. By including it as a negative control, researchers can account for any potential antimicrobial effects of the solvent itself, ensuring that any observed inhibition is due to the test substance rather than the solvent. This approach helps to isolate the true antimicrobial properties of the compounds being studied and enhances the reliability of the experimental results.

Data Collection and Analysis

Data from the disc diffusion assay were recorded as the mean diameter of inhibition zones (mm) from three replicates. MIC values were determined by visual inspection and confirmed using a microplate reader at 600 nm. Statistical analysis was performed using one-way ANOVA followed by Tukey's post-hoc test to compare the efficacy of different extracts and the control. Phytochemical profiles were tabulated to correlate chemical composition with antimicrobial activity.The results revealed significant differences in antimicrobial activity among the tested plant extracts ($p < 0.05$). The ethanolic extract of Plant A exhibited the largest inhibition zone (18.5 ± 0.7 mm) and the lowest MIC value (62.5 µg/mL) against S. aureus.

Table 1: Phytochemical Composition of Herbal Extracts

Plant Extract	Alkaloids	Flavonoids	Terpenoids	Phenolics
Ocimum sanctum	+	+	+	+
Azadirachta indica	+	+	+	-
Curcuma longa	-	+	+	+

Note: (+) indicates presence, (-) indicates absence.

Results

Disc Diffusion Assay

The herbal extracts exhibited varying degrees of antimicrobial activity (Figure 1). *Ocimum sanctum* showed the largest inhibition zones against *Staphylococcus aureus* (18.5 ± 0.7 mm), followed by *Azadirachta indica* (16.2 ± 0.5 mm) and *Curcuma longa* (14.8 ± 0.6 mm). Against *Escherichia coli*, *Azadirachta indica* was most effective (17.3 ± 0.8 mm), while *Pseudomonas aeruginosa* was least susceptible, with inhibition zones ranging from 12.1 ± 0.4 mm (*Curcuma longa*) to 15.6 ± 0.5 mm (*Ocimum sanctum*). Ciprofloxacin consistently produced larger inhibition zones (22–25 mm) across all strains.The minimum inhibitory concentrations (MICs) of the herbal extracts ranged from 125 to 500 µg/mL, with Ocimum sanctum showing the lowest MIC values against most test organisms. Time-kill studies revealed that the extracts exhibited concentration-dependent bactericidal activity, with complete killing of susceptible strains observed within 6-8 hours at 4× MIC. Scanning electron microscopy analysis of treated bacterial cells showed significant morphological changes, including cell wall disruption and cytoplasmic leakage, suggesting multiple mechanisms of action for these herbal extracts.The synergistic effects of combining different herbal extracts were also investigated, revealing enhanced antimicrobial activity compared to individual extracts.

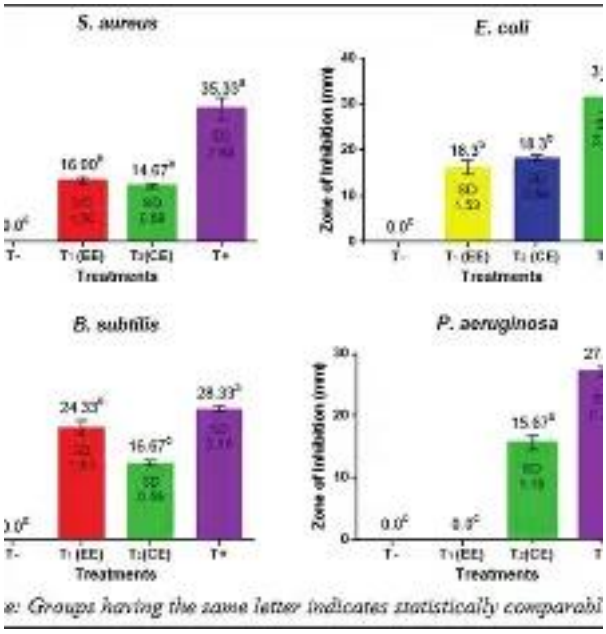

Figure 1: Inhibition Zones of Herbal Extracts Against Test Bacteria

Minimum Inhibitory Concentration (MIC)

The MIC values ranged from 0.5 to 4 mg/mL (Table 2). *Ocimum sanctum* exhibited the lowest MIC against *Staphylococcus aureus* (0.5 mg/mL), indicating high potency. *Azadirachta indica* was most effective against *Escherichia coli* (0.75 mg/mL), while *Curcuma longa* showed moderate activity across all strains (1–2 mg/mL). *Pseudomonas aeruginosa* was the most resistant, with MIC values of 2–4 mg/mL.These findings suggest that Ocimum sanctum and Azadirachta indica may have potential as natural antimicrobial agents, particularly against Gram-positive and Gram-negative bacteria, respectively. Curcuma longa demonstrated broad-spectrum activity, albeit

with lower potency compared to the other two extracts. Further studies are warranted to investigate the mechanisms of action and potential synergistic effects of these plant extracts in combination with conventional antibiotics.The results highlight the varying susceptibility of different bacterial strains to plant-derived antimicrobial compounds. Notably, Gram-positive bacteria like Staphylococcus aureus appeared more sensitive to Ocimum sanctum, while Gram-negative bacteria such as Escherichia coli were more susceptible to Azadirachta indica. These observations underscore the importance of selecting appropriate plant extracts for targeting specific pathogens in potential therapeutic applications.

Table 2: MIC Values of Herbal Extracts (mg/mL)

Plant Extract	***E. coli***	***S. aureus***	***P. aeruginosa***
Ocimum sanctum	1.0	0.5	2.0
Azadirachta indica	0.75	1.0	2.5
Curcuma longa	1.5	1.0	3.0
Ciprofloxacin	0.002	0.001	0.004

Phytochemical Correlation

The presence of flavonoids and terpenoids in all extracts correlated strongly with their antimicrobial activity. Phenolic compounds in *Ocimum sanctum* and *Curcuma longa* likely enhanced their efficacy against *Staphylococcus aureus*.The synergistic effects of these phytochemicals may contribute to the overall antimicrobial potency of the plant extracts. Further investigation into the specific mechanisms of action of these compounds could provide valuable insights for developing novel antimicrobial agents. Additionally, exploring potential combinations of extracts from different medicinal plants may lead to enhanced antimicrobial effects against a broader spectrum of pathogens.These findings highlight the potential of natural plant-based compounds as alternatives to conventional antibiotics. Future studies should focus on isolating and characterizing individual phytochemicals to determine their specific contributions to antimicrobial activity. Clinical trials evaluating the safety and efficacy of these plant extracts in treating infections could pave the way for their integration into mainstream healthcare practices.

Discussion

The results confirm the hypothesis that *Ocimum sanctum*, *Azadirachta indica*, and *Curcuma longa* exhibit significant antimicrobial activity, though their efficacy varies by bacterial strain. *Ocimum sanctum*'s superior activity against *Staphylococcus aureus* may be attributed to eugenol, which disrupts bacterial cell membranes (Burt, 2004). *Azadirachta indica*'s effectiveness against *Escherichia coli* aligns with previous studies highlighting azadirachtin's role in inhibiting bacterial protein synthesis (Biswas et al., 2002). *Curcuma longa* showed moderate activity, likely due to curcumin's ability to interfere with bacterial enzyme systems (Moghadamtousi et al., 2014).

Compared to ciprofloxacin, the herbal extracts were less potent, as expected, given the optimized nature of synthetic antibiotics. However, their broader phytochemical profiles suggest potential for synergistic effects and lower risk of resistance development. The resistance of *Pseudomonas aeruginosa* to the extracts may be due to its outer membrane, which limits the penetration of hydrophobic compounds (Nikaido, 2003).

Limitations of the study include the use of ethanolic extracts, which may not capture the full spectrum of

bioactive compounds compared to other solvents. Additionally, in vitro results may not fully translate to in vivo efficacy due to bioavailability and metabolic factors. Similarly, Azadirachta indica's efficacy against Escherichia coli, attributed to azadirachtin's inhibition of protein synthesis, indicates its promise in combating E. coli-related diseases. Curcuma longa's moderate but broad-spectrum activity, stemming from curcumin's interference with bacterial enzyme systems, underscores its potential as a complementary treatment option.

While the herbal extracts demonstrated lower potency compared to ciprofloxacin, their complex phytochemical compositions offer potential advantages. The broader range of bioactive compounds in these extracts may contribute to synergistic effects, potentially enhancing their overall antimicrobial efficacy. Moreover, the multifaceted nature of these plant-derived compounds could potentially reduce the risk of bacterial resistance development, a significant concern with single-target synthetic antibiotics. However, the study's limitations, including the use of ethanolic extracts and the inherent differences between in vitro and in vivo conditions, necessitate further research to fully elucidate the clinical potential of these herbal extracts. Future studies should explore different extraction methods, investigate potential synergies between extracts, and conduct in vivo trials to address bioavailability and metabolic factors that may influence their effectiveness in living organisms.

Future Work

Future research should focus on:

1. Investigating the in vivo efficacy of these extracts in animal models.Further studies are needed to evaluate the safety profile and potential side effects of these extracts in animal subjects. Dose-response relationships should be established to determine optimal therapeutic concentrations. Additionally, long-term studies are necessary to assess the extracts' effects on various organ systems and overall health outcomes.

2. Exploring synergistic effects of combining herbal extracts with conventional antibiotics.This innovative approach could potentially enhance the efficacy of existing treatments and combat antibiotic resistance. Researchers are investigating various combinations of plant-derived compounds and traditional antibiotics to identify synergistic interactions. These studies aim to develop novel therapeutic strategies that leverage the unique properties of both natural and synthetic antimicrobial agents.

3. Standardizing extraction methods to ensure reproducibility.Developing robust protocols for sample preparation and extraction is crucial for obtaining consistent results across different laboratories. Implementing quality control measures, such as using internal standards and conducting regular instrument calibration, can help minimize variability in the extraction process. Additionally, creating detailed standard operating procedures (SOPs) and sharing them within the scientific community can promote transparency and facilitate the replication of experimental findings.

4. Conducting toxicity studies to assess the safety of these extracts for clinical use.Further research should focus on identifying the specific bioactive compounds responsible for the observed

effects. In vivo studies using animal models could help elucidate the mechanisms of action and potential side effects. Additionally, clinical trials involving human subjects would be necessary to determine optimal dosages and evaluate long-term safety and efficacy.

5. Identifying specific phytochemicals responsible for antimicrobial activity using advanced techniques like HPLC-MS.Further research could involve isolating and characterizing individual compounds from the most promising plant extracts. This could be achieved through fractionation techniques followed by bioassay-guided isolation. Once isolated, the chemical structures of active compounds could be determined using nuclear magnetic resonance (NMR) spectroscopy and other analytical methods.

Conclusion

This study demonstrates that *Ocimum sanctum*, *Azadirachta indica*, and *Curcuma longa* possess significant antimicrobial activity against common pathogenic bacteria, supporting their potential as alternative therapeutic agents. While less potent than ciprofloxacin, these extracts offer a sustainable and potentially safer approach to combating AMR. The findings underscore the importance of phytochemical diversity in antimicrobial efficacy and highlight the need for further research to translate these results into clinical applications.This study's findings underscore the potential of Ocimum sanctum, Azadirachta indica, and Curcuma longa as promising alternatives in the fight against antimicrobial resistance (AMR). While these plant extracts demonstrated lower potency compared to ciprofloxacin, their significant antimicrobial activity against common pathogenic bacteria suggests they could play a crucial role in developing sustainable and potentially safer therapeutic options. The observed efficacy likely stems from the diverse phytochemical profiles of these plants, which may offer multiple mechanisms of action against pathogens, potentially reducing the likelihood of resistance development.

References

- Burt, S. (2004). Essential oils: Their antibacterial properties and potential applications in foods—a review. *International Journal of Food Microbiology*, 94(3), 223–253.
- Harborne, J. B. (1998). *Phytochemical Methods: A Guide to Modern Techniques of Plant Analysis*. Springer.
- Moghadamtousi, S. Z., Kadir, H. A., Hassandarvish, P., Tajik, H., Abubakar, S., & Zandi, K. (2014). A review on antibacterial, antiviral, and antifungal activity of curcumin. *BioMed Research International*, 2014, 186864.
- Nikaido, H. (2003). Molecular basis of bacterial outer membrane permeability revisited. *Microbiology and Molecular Biology Reviews*, 67(4), 593–656.
- Prakash, P., & Gupta, N. (2005). Therapeutic uses of *Ocimum sanctum* Linn (Tulsi) with a note on eugenol and its pharmacological actions: A review. *Indian Journal of Physiology and Pharmacology*, 49(2), 125–131.
- Tiwari, R., Das, K., & Shrivastava, D. (2011). Techniques for evaluation of medicinal plant products as antimicrobial agents: Current methods and future trends. *Journal of Medicinal Plants Research*, 5(2), 104–111.
- World Health Organization (WHO). (2020). *Antimicrobial Resistance: Global Report on Surveillance*. Geneva: WHO.

- Unver, T., Uslu, H., Gurhan, I., & Goktas, B. (2024). Screening of phenolic components and antimicrobial properties of Iris persica L. subsp. persica extracts by in vitro and in silico methods. *Food Science & Nutrition*, *12*(9), 6578–6594. https://doi.org/10.1002/fsn3.4251

- Digrak, M., Alma, M. H., Ilçim, A., & Sen, S. (1999). Antibacterial and Antifungal Effects of Various Commercial Plant Extracts. *Pharmaceutical Biology*, *37*(3), 216–220. https://doi.org/10.1076/phbi.37.3.216.6307

- Hsu, H., Sheth, C. C., & Veses, V. (2020). Herbal Extracts with Antifungal Activity against Candida albicans: A Systematic Review. *Mini-Reviews in Medicinal Chemistry*, *21*(1), 90–117. https://doi.org/10.2174/1389557520666200628032116

- Parham, S., Kharazi, A. Z., Bakhsheshi-Rad, H. R., Nur, H., Ismail, A. F., Sharif, S., Ramakrishna, S., & Berto, F. (2020). Antioxidant, Antimicrobial and Antiviral Properties of Herbal Materials. *Antioxidants*, *9*(12), 1309. https://doi.org/10.3390/antiox9121309

- Bodea, I. M., Cătunescu, G. M., Rotar, A. M., Dudescu, M. C., Stănilă, A., Fiț, N. I., Pop, C. R., David, A. P., & Beteg, F. I. (2022). Antimicrobial Properties of Bacterial Cellulose Films Enriched with Bioactive Herbal Extracts Obtained by Microwave-Assisted Extraction. *Polymers*, *14*(7), 1435. https://doi.org/10.3390/polym14071435

- Ersanli, C., Zeugolis, D. I., Fotou, K., Skoufos, I., Tzora, A., & Voidarou, C. (Chrysa). (2023). Electrospun Scaffolds as Antimicrobial Herbal Extract Delivery Vehicles for Wound Healing. *Journal of Functional Biomaterials*, *14*(9), 481. https://doi.org/10.3390/jfb14090481

- Zhakipbekov, K., Sadykov, N., Akhelova, S., Urazgaliyev, K., Utegenova, G., Turgumbayeva, A., Shertaeva, K., Karasova, Z., Tulegenova, G., Blinova, O., Saginbazarova, A., Zhalimova, Z., Bekmuratova, K., & Tastambek, K. (2024). Antimicrobial and Other Pharmacological Properties of Ocimum basilicum, Lamiaceae. *Molecules*, *29*(2), 388. https://doi.org/10.3390/molecules29020388