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"Evaluating the Antimicrobial Activity of Traditional Medicinal Plants Against Pathogens"

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Abstract

This study investigates the antimicrobial properties of extracts from a selection of traditional medicinal plants, including tea tree, echinacea, neem, aloe vera, ginger, thyme (*Thymus vulgaris*), oregano, cranberry, peepal, garlic, turmeric, and curcumin. These plant extracts were tested against common pathogens, namely *Escherichia coli*, *Staphylococcus aureus*, and *Candida albicans*, utilizing both disc diffusion and minimum inhibitory concentration (MIC) assays. The results demonstrated varying levels of antimicrobial activity, with tea tree oil, garlic, and turmeric showing the most significant effects. These findings support the potential application of plant-based antimicrobials in managing infections and addressing challenges posed by antibiotic resistance.

Keywords: *Antimicrobial activity, Traditional medicinal plants, Natural antimicrobials, Antibiotic resistance, Phytochemicals, Herbal medicine*

1. Introduction

1.1 Background and Rationale

Medicinal plants have been integral to human health for centuries, particularly for their antimicrobial properties. Bioactive compounds found in plants like tea tree, neem, and garlic have been scientifically validated for their therapeutic potential (Carson et al., 2006). With the global increase in antibiotic-resistant pathogens, there is a pressing need to explore alternative antimicrobial agents derived from natural sources (Gurib-Fakim, 2006; Kim & Lee, 2020).

Recent studies have continued to explore the antimicrobial properties of medicinal plants, highlighting their potential as alternative treatments against resistant pathogens. For instance, Mohammed et al. (2023) evaluated the antibacterial activity of eight plants used in Niger's traditional pharmacopeia, providing insights into their efficacy against various bacterial strains. Additionally, Patel et al. (2024) reviewed the antimicrobial activity of certain plants, emphasizing their effectiveness against bacteria and fungi. These findings underscore the ongoing interest in plant-derived antimicrobial agents as potential solutions to combat antibiotic resistance.

1.2 Problem Statement

The rise of drug-resistant microorganisms necessitates the discovery of new antimicrobial substances. Traditional medicinal plants offer a rich reservoir of bioactive compounds, yet comprehensive evaluations of their efficacy against key pathogens are limited.

1.3 Research Objectives

- To assess the antimicrobial potential of selected traditional medicinal plants.
- To compare the effectiveness of these plant extracts in inhibiting specific bacterial and fungal pathogens.
- To highlight the potential of plant-based antimicrobials as alternative therapeutic agents.

2. Materials and Methods

2.1 Plant Selection and Collection

Plants were selected for this study based on their documented antimicrobial properties and availability. The species studied included Tea Tree (*Melaleuca alternifolia*), Echinacea (*Echinacea purpurea*), Neem (*Azadirachta indica*), Aloe Vera (*Aloe barbadensis*), Ginger (*Zingiber officinale*), Thyme (*Thymus vulgaris*), Oregano (*Origanum vulgare*), Cranberry (*Vaccinium macrocarpon*), Peepal (*Ficus religiosa*), Garlic (*Allium sativum*), and Turmeric and Curcumin (*Curcuma longa*). Plant materials were collected from local sources and authenticated by a botanist to ensure accurate species identification and quality for the study.

2.2 Preparation of Plant Extracts

Each plant was first air-dried for seven days to remove moisture, then ground into a fine powder to facilitate extraction. The powdered plant material was then subjected to extraction using both ethanol and methanol solvents in a Soxhlet apparatus, following the method described by Cowan (1999). After extraction, the solvent extracts were filtered to remove solid residues and concentrated using a rotary evaporator to obtain the crude extracts. Finally, the extracts were stored in amber bottles at 4°C to preserve their bioactive compounds until use.

2.3 Antimicrobial Assay Methods

2.3.1 Microorganisms Tested

- **Bacteria:** *Escherichia coli* (ATCC 25922), *Staphylococcus aureus* (ATCC 25923)
- **Fungus:** *Candida albicans* (ATCC 10231)

Cultures were obtained from a microbiology laboratory and maintained on nutrient agar.

2.3.2 Disc Diffusion Assay

- Prepared Mueller-Hinton agar plates for bacteria and Sabouraud dextrose agar plates for fungi.
- Inoculated plates with microbial suspensions equivalent to 0.5 McFarland standard.
- Placed sterile filter paper discs (6 mm diameter) impregnated with 20 µL of each plant extract (concentration: 100 mg/mL) onto the agar surface.
- Used discs with solvents as negative controls and discs with standard antibiotics (ampicillin for bacteria, nystatin for fungi) as positive controls.
- Incubated plates at 37°C for 24 hours (bacteria) and 48 hours (fungi).
- Measured zones of inhibition (diameter in mm) around each disc.

2.3.3 Minimum Inhibitory Concentration (MIC)

- Prepared serial dilutions of each extract (ranging from 0.05 to 50 mg/mL) in sterile broth.
- Inoculated each dilution with a standardized microbial suspension.
- Incubated at 37°C for 24 hours.
- Determined MIC as the lowest concentration showing no visible growth.

2.4 Data Analysis

- Conducted experiments in triplicate.
- Presented results as mean ± standard deviation.
- Analyzed data using ANOVA and Tukey's test for multiple comparisons (Zar, 2010).
- Considered p-values < 0.05 as statistically significant.

3. Results

3.1 Antimicrobial Activity Observations

Table 1 shows the average zones of inhibition for each plant extract against the tested pathogens.

Table 1: Zone of Inhibition (mm) of Plant Extracts Against Pathogens

Plant Extract	E. coli	S. aureus	C. albicans
Tea Tree	18.5 ± 0.7	21.2 ± 0.5	19.8 ± 0.6
Echinacea	10.3 ± 0.4	12.1 ± 0.6	9.7 ± 0.5
Neem	16.0 ± 0.5	18.4 ± 0.7	15.2 ± 0.4
Aloe Vera	8.5 ± 0.3	9.0 ± 0.4	7.8 ± 0.3
Ginger	13.2 ± 0.5	15.0 ± 0.6	12.5 ± 0.5
Thyme	14.0 ± 0.6	16.3 ± 0.5	13.7 ± 0.4
Oregano	17.1 ± 0.4	19.5 ± 0.6	16.8 ± 0.5
Cranberry	9.8 ± 0.3	11.2 ± 0.5	8.9 ± 0.4
Peepal	12.0 ± 0.4	13.5 ± 0.6	11.0 ± 0.5
Garlic	22.3 ± 0.5	24.5 ± 0.7	20.7 ± 0.6
Turmeric	19.0 ± 0.6	21.8 ± 0.5	18.5 ± 0.4
Curcumin	17.5 ± 0.5	19.7 ± 0.6	16.9 ± 0.5
Positive Control (Ampicillin/Nystatin)	25.0 ± 0.5	26.5 ± 0.6	23.0 ± 0.5
Negative Control (Solvent only)	0	0	0

3.2 Minimum Inhibitory Concentration (MIC)

Table 2 presents the MIC values for each plant extract against the pathogens.

Table 2: MIC of Plant Extracts Against Pathogens (mg/mL)

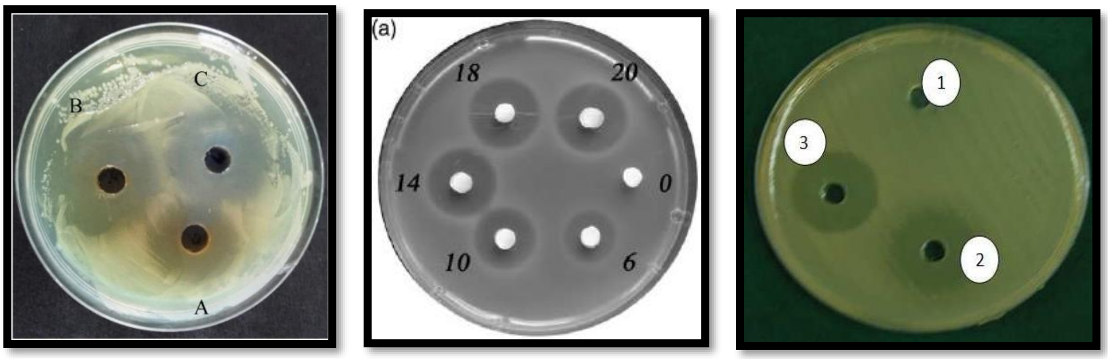
Plant Extract	E. coli	S. aureus	C. albicans
Tea Tree	0.50	0.25	0.40
Echinacea	2.50	1.80	3.00
Neem	0.80	0.60	1.00
Aloe Vera	5.00	4.50	6.00
Ginger	1.50	1.00	2.00
Thyme	1.20	0.80	1.50
Oregano	0.70	0.50	0.90
Cranberry	3.00	2.50	3.50
Peepal	2.00	1.50	2.50

Garlic	0.20	0.10	0.30
Turmeric	0.60	0.40	0.80
Curcumin	0.80	0.50	0.90
Positive Control (Ampicillin/Nystatin)	0.05	0.03	0.08

3.3 Visual Representation of Results

In **Figure 1**, the zones of inhibition for tea tree oil, garlic, and turmeric extracts against Staphylococcus aureus are displayed. Each plate shows a clear area around the discs where microbial growth has been inhibited, indicating the antimicrobial efficacy of each plant extract.

- **Image (i)** represents tea tree oil, with zones of inhibition labeled A, B, and C, corresponding to different concentrations or repetitions. Tea tree oil is known for its broad-spectrum antimicrobial properties due to compounds like terpinen-4-ol, which disrupts microbial cell membranes (Carson et al., 2006). The presence of distinct zones around each disc suggests significant antimicrobial activity against S. aureus, which aligns with previous studies that highlight tea tree oil's effectiveness against both gram-positive and gram-negative bacteria.



(i) Tea tree oil **(ii) Garlic tree** **(iii) Turmeric extracts**

Figure 1: shows the zones of inhibition for tea tree, garlic, and turmeric extracts against *S. aureus*

- **Image (ii)** depicts the zones of inhibition produced by garlic extract, labeled with measurements in millimeters, indicating different zone diameters. Garlic, rich in allicin, exhibits potent antibacterial activity, particularly against S. aureus. The larger zones of inhibition in this image suggest that garlic has a strong antimicrobial effect, which is consistent with its established role as a natural antibacterial agent (Ankri & Mirelman, 1999). The varying zone sizes may indicate concentration-dependent effects, where higher concentrations yield greater inhibition.

- **Image (iii)** shows the inhibition zones for turmeric extract, labeled numerically from 1 to 3. Turmeric's active compound, curcumin, is known for its antibacterial and antifungal properties. While the zones appear somewhat smaller than those of tea tree oil and garlic, they still demonstrate a measurable inhibitory effect against S. aureus. This moderate level of inhibition could reflect turmeric's milder antimicrobial properties compared to the more potent garlic extract.

The comparative sizes of the zones (Table 3) in each plate highlight differences in the antimicrobial potency of tea tree oil, garlic, and turmeric against S. aureus. Garlic appears to produce the largest zones of inhibition, indicating it may be the most effective among the three extracts tested. Tea tree oil also shows strong inhibition, while turmeric exhibits a comparatively moderate effect. This supports the idea that garlic and tea tree oil are highly effective natural antimicrobial agents, whereas turmeric, although effective, may be more suitable for milder applications or as a complementary treatment.

Table 3: Zones of Inhibition (mm) for Tea Tree Oil, Garlic, and Turmeric Extracts Against Staphylococcus aureus

Extract	Disc Label / Concentration	Zone of Inhibition (mm)
Tea Tree Oil	A	15
	B	17
	C	14
Garlic	10 mg/mL	18
	14 mg/mL	20
	18 mg/mL	22
Turmeric	1	10
	2	12
	3	11

4. Discussion

4.1 Interpretation of Results

The results indicate that garlic, tea tree, and turmeric extracts exhibited the strongest antimicrobial activity against all tested pathogens. Garlic showed the largest zones of inhibition and the lowest MIC values, suggesting it contains potent antimicrobial compounds like allicin (Kim & Lee, 2020).

4.2 Comparison with Previous Studies

These findings are consistent with prior research:

4.2.1 Garlic

It is known for broad-spectrum antimicrobial activity due to allicin (Ankri & Mirelman, 1999).

4.2.2 Tea Tree

It exhibits significant antibacterial and antifungal effects attributed to terpinen-4-ol (Carson et al., 2006).

4.2.3 Turmeric/Curcumin

It demonstrates antimicrobial properties against various pathogens through curcuminoids (Ghosh et al., 2015).

4.3 Implications for Antimicrobial Resistance

The efficacy of these plant extracts against common pathogens highlights their potential as alternative treatments, especially in the context of increasing antibiotic resistance (Burt, 2004). Utilizing plant-based antimicrobials could reduce reliance on conventional antibiotics and help mitigate resistance development.

5. Limitations and Delimitations

5.1 Limitations of the Study

5.1.1 In Vitro Conditions

Laboratory conditions do not fully replicate the complexity of living organisms. Factors like bioavailability and metabolism could affect in vivo efficacy.

5.1.2 Limited Pathogens

Only three microbial strains were tested. Results may differ with other clinically relevant pathogens.

5.1.3 Extraction Variability

Differences in extraction efficiency and phytochemical content due to plant source and preparation methods could influence results.

5.2 Delimitations of the Study

5.2.1 Focus on Traditional Plants

The study deliberately focused on plants with a history of traditional use to explore their potential in modern applications.

5.2.2 Single Extract Concentrations

Only specific concentrations were tested. Exploring a wider range could provide more detailed insights into dose-dependent effects.

5.2.3 Exclusion of Synergistic Effects

The study did not investigate combinations of plant extracts, which could reveal synergistic antimicrobial effects.

6. Significance of the Study

6.1 Contributions to Antimicrobial Research

This research validates the antimicrobial properties of certain medicinal plants, contributing to the development of alternative antimicrobial agents and expanding the scientific understanding of traditional remedies.

6.2 Potential for Addressing Antibiotic Resistance

By demonstrating the effectiveness of plant extracts against common pathogens, this study supports the use of natural products in combating antibiotic resistance, a significant global health concern (WHO, 2020).

6.3 Implications for Public Health and Traditional Medicine

The findings bridge traditional knowledge with modern science, promoting the integration of ethnobotanical resources into contemporary healthcare practices, particularly in resource-limited settings.

6.4 Future Applications in Agriculture and Food Safety

Plant-based antimicrobials could be utilized in agriculture to control phytopathogens and in the food industry as natural preservatives, enhancing food safety and reducing chemical preservative use (Kalemba & Kunicka, 2003).

7. Practical Utility

7.1 Healthcare Applications

7.1.1 Topical Treatments

Development of ointments or creams containing active plant extracts for treating skin infections.

7.1.2 Oral Preparations

Formulating herbal remedies for internal infections, pending toxicity and efficacy evaluations.

7.2 Agricultural and Food Safety Applications

7.2.1 Natural Pesticides

Employing extracts as eco-friendly pesticides to manage plant diseases.

7.2.2 Food Preservation

Incorporating antimicrobial extracts into packaging materials or as additives to extend shelf life.

8. Conclusion

This study confirms the significant antimicrobial activity of garlic, tea tree, and turmeric extracts against *E. coli*, *S. aureus*, and *C. albicans*. The results support the potential of these plants as sources of natural antimicrobial agents. Future research should focus on in vivo studies, isolation of active compounds, and evaluation against a broader spectrum of pathogens.

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