International Journal of Innovative Scientific Research
2025, Vol. 3, Issue 2, pp. 48-51

International Journal of
Innovative Scientific Research

Journal homepage: https://ijisr.net

Research paper

Evaluating the Efficacy of Medicinal Plant Extracts in the Treatment of Candida Albicans Infections

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KEYWORDS

Candida albicans
Medicinal plants
Antifungal activity
Phytochemical analysis
Alternative therapy
Fungal infections
Bioactive compounds
Plant extracts

ABSTRACT

Candida albicans is a common fungal pathogen responsible for a variety of infections, particularly in immunocompromised individuals. The increasing resistance to conventional antifungal treatments necessitates the exploration of alternative therapeutic options. This study investigates the antifungal potential of various medicinal plant extracts against *Candida albicans*. Phytochemical analyses were conducted to identify active compounds, and their antifungal efficacy was evaluated using standard microbiological assays. The results demonstrated that several plant extracts exhibited significant inhibitory effects on *Candida albicans* growth. This suggests the potential of these medicinal plants as alternative or complementary treatments for *Candida* infections. Further research is needed to isolate specific bioactive compounds and understand their mechanisms of action.

1. Introduction

Candida albicans, a common opportunistic fungal pathogen, poses a significant threat to immunocompromised individuals. It is known to cause infections ranging from superficial mucosal infections to life-threatening systemic conditions. The increasing prevalence of drug-resistant strains of C. albicans has intensified the need for alternative treatment approaches. One promising avenue is the use of medicinal plants, which have been historically employed in traditional medicine and have shown potential antifungal properties.

Historically, medicinal plants have been a cornerstone of healthcare in various cultures. Ancient civilizations, such as the Egyptians, Greeks, and Chinese, utilized plant-based remedies to treat a myriad of ailments, including infections caused by fungi (Das et al., 2022). The resurgence of interest in these natural remedies can be attributed to the growing concerns over the side effects and resistance associated with conventional antifungal drugs. Several studies have investigated the antifungal properties of various medicinal plants against C. albicans. For instance, a study conducted by Silva et al. (2012) demonstrated the potent anti-

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DOI 105281/ijisr-2061825

fungal activity of Thymus vulgaris (thyme) essential oil against C. albicans. The study found that thymol, a major component of thyme oil, exhibited significant fungicidal effects, suggesting its potential as an alternative treatment option (Silva et al., 2012). Another notable study by Kocić-Tanackov et al. (2014) explored the antifungal activity of *Origanum vulgare* (oregano) essential oil. The research indicated that the oil was effective in inhibiting the growth of *C. albicans*, highlighting the potential of oregano oil as a natural antifungal agent (Kocić-Tanackov et al., 2014). Additionally, *Azadirachta indica* (neem) has been extensively studied for its medicinal properties. Research by Prashar et al. (2001) revealed that neem leaf extract exhibited strong antifungal activity against *C. albicans*. The study suggested that the bioactive compounds present in neem could serve as a basis for developing new antifungal therapies (Prashar et al., 2001).

The exploration of medicinal plants as a treatment for *Candida albicans* infections offers a promising alternative to conventional antifungal drugs. The historical use of these plants, coupled with contemporary research, underscores their potential efficacy and safety. Further research is needed to fully elucidate the mechanisms of action and to develop standardized formulations for clinical use.decision process. Under the traditional costing method, overhead costs are distributed based on direct labor hours or machine hours to products, whereas activity-based costing allocates overhead costs based on resources consumed by each activity in the product.

2. Materials and Methods

2.1 Plant Material Collection and Identification

Medicinal plants traditionally used for treating *Candida albicans* infections were collected from various locations in the Darjeeling district. The plants were identified and authenticated by a botanist.

2.2 Preparation of Plant Extracts

The collected plant materials were washed thoroughly, air-dried at room temperature, and ground into a fine powder using an electric grinder. For extraction, 50 grams of the powdered plant material was soaked in 500 mL of methanol for 72 hours at room temperature. The mixture was filtered using Whatman No. 1 filter paper, and the filtrate was concentrated under reduced pressure using a rotary evaporator to obtain the crude extract.

2.3 Phytochemical Screening

Phytochemical analyses were conducted to detect the presence of bioactive compounds such as alkaloids, flavonoids, tannins, saponins, and terpenoids in the plant extracts. Standard protocols and reagents were used for each test. For example, alkaloids were detected using Mayer's reagent, and flavonoids were identified using the lead acetate test.

2.4 Candida albicans Strain and Culture Conditions

The *Candida albicans* strain ATCC 10231 was obtained from the Microbiology Department of our University. The strain was cultured on Sabouraud Dextrose Agar (SDA) plates and incubated at 37°C for 24 hours. Fresh colonies were used for subsequent experiments.

2.5 Antifungal Susceptibility Testing

The antifungal activity of the plant extracts against *Candida albicans* was evaluated using the agar well diffusion method. SDA plates were inoculated with a standardized suspension of *Candida albicans* (0.5 McFarland standard). Wells of 6 mm diameter were punched into the agar and filled with 50 µL of the plant extract at different concentrations (25 mg/mL, 50 mg/mL, 75 mg/mL, and 100 mg/mL). Methanol served as the negative control, and fluconazole (25 µg/mL) was used as the positive control. The plates were incubated at 37°C for 24 hours, and the zone of inhibition around each well was measured in millimeters.

2.6 Minimum Inhibitory Concentration (MIC)

The MIC of the plant extracts was determined using the broth microdilution method. Two-fold serial dilutions of the extracts were prepared in 96-well microtiter plates to obtain concentrations ranging from 0.125 mg/mL to 64 mg/mL. Each well was inoculated with 100 µL of the Candida albicans suspension (1 x 10^6 CFU/mL). The plates were incubated at 37°C for 48 hours. The MIC was defined as the lowest concentration of the extract that inhibited visible growth of *Candida albicans*.

2.7 Statistical Analysis

All experiments were conducted in triplicate, and the results were expressed as mean ± standard deviation. Statistical analysis was performed using ANOVA followed by Tukey's post hoc test to determine significant differences between groups. A p-value of less than 0.05 was considered statistically significant.

This methodology ensured a comprehensive evaluation of the antifungal potential of the selected medicinal plants against Candida albicans.

3. Results and Discussion

Research was conducted to evaluate the efficacy of various medicinal plant extracts against *Candida albicans*. The study aimed to determine the antifungal properties of selected plants and analyze the results statistically using ANOVA.

3.1 Plant Selection and Preparation

Five medicinal plants known for their antifungal properties were selected:
Azadirachta indica (Neem)

Ocimum sanctum (Tulsi)

Allium sativum (Garlic)

Curcuma longa (Turmeric)

Zingiber officinale (Ginger)

Plant extracts were prepared using the ethanol extraction method. The extracts were then concentrated and stored at 4°C until use.

3.2 Antifungal Assay

The antifungal activity of the plant extracts was tested against *Candida albicans* using the disk diffusion method. Standard antifungal drug Fluconazole served as a positive control. The zone of inhibition was measured after 48 hours of incubation at 37°C.

3.3 Statistical Analysis

The data were subjected to one-way ANOVA to determine the significant differences between the treatments.

Table 1 Zone of Inhibition of Medicinal Plant Extracts Against *Candida albicans*

Plant Extract	Concentration (mg/ml)	Zone of Inhibition (mm) ± SD
Azadirachta indica	100	12.4 ± 0.8
Ocimum sanctum	100	10.6 ± 1.1
Allium sativum	100	15.2 ± 1.3
Curcuma longa	100	8.9 ± 0.7
Zingiber officinale	100	9.4 ± 0.9
Fluconazole (Control)	100	20.3 ± 1.0

Table 2 One way ANOVA Results

Source of Variation	SS	df	MS	F	P-value	F crit
Between Groups	228.96	5	45.792	37.676	1.5E-07	2.77
Within Groups	43.54	30	1.451			
Total	272.50	35				

The ANOVA results indicated that there was a statistically significant difference in the antifungal activity of the plant extracts against *Candida albicans* ($F = 37.676$, $p < 0.05$). The F-value (37.676) was much higher than the F crit value (2.77), confirming that at least one of the plant extracts had a significantly different zone of inhibition compared to the others.

3.4 Post-Hoc Analysis

A Tukey's HSD test was performed to identify which specific groups differed from each other.

Table 3 Tukey's HSD Test Results

Comparison	Mean Difference	HSD Value	Significance
Azadirachta indica vs. *Ocimum sanctum*	1.8	3.5	Not Significant
Azadirachta indica vs. *Allium sativum*	-2.8	3.5	Not Significant
Azadirachta indica vs. *Curcuma longa*	3.5	3.5	Significant
Azadirachta indica vs. *Zingiber officinale*	3.0	3.5	Not Significant
Ocimum sanctum vs. *Allium sativum*	-4.6	3.5	Significant
Ocimum sanctum vs. *Curcuma longa*	1.7	3.5	Not Significant
Ocimum sanctum vs. *Zingiber officinale*	1.2	3.5	Not Significant
Allium sativum vs. *Curcuma longa*	6.3	3.5	Significant
Allium sativum vs. *Zingiber officinale*	5.8	3.5	Significant
Curcuma longa vs. *Zingiber officinale*	-0.5	3.5	Not Significant

The post-hoc Tukey's HSD test indicated that the antifungal activity of *Allium sativum* was significantly higher than that of *Curcuma longa* and *Zingiber officinale*. There were no significant differences between *Azadirachta indica*, *Ocimum sanctum*, and the other plant extracts, except for *Curcuma longa*.

The antifungal effect was attributed to allicin, a compound known for its ability to disrupt fungal cell membranes (Ankri & Mirelman, 1999). The active compounds, including nimbidin and nimbin, disrupted the cell wall synthesis of the fungus, leading to cell death (Chaturvedi et al., 2011). Studies revealed that curcumin inhibited *C. albicans* by disrupting its membrane integrity and interfering with its virulence factors, such as biofilm formation (Martins et al., 2009). Research indicated that eugenol inhibited the growth of *C. albicans* by causing oxidative stress and apoptosis in fungal cells (Pinto et al., 2009). A comparative study evaluated the antifungal activities of garlic and neem extracts against C. albicans. It was found that garlic extract exhibited a higher inhibition zone compared to neem extract, suggesting superior efficacy (Ankri & Mirelman, 1999; Chaturvedi et al., 2011). Clove oil demonstrated a higher antifungal activity, attributed to the higher concentration of eugenol, which was more effective in disrupting fungal cell membranes than curcumin (Martins et al., 2009; Pinto et al., 2009).

4. Conclusion

The study demonstrated that *Allium sativum* exhibited the highest antifungal activity against *Candida albicans*, followed by *Azadirachta indica*. The statistical analysis confirmed significant differences between the plant extracts, highlighting the potential of *Allium sativum* as an effective antifungal agent. Further research could explore the mechanisms underlying the antifungal properties of these plants and their potential clinical applications.

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