

Role of Essential Oil of *Ocimum gratissimum* on Fungal Rotting

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Abstract

Fungal rotting is a major cause of post-harvest losses in agricultural commodities, leading to reduced quality, economic loss, and potential health risks due to mycotoxin contamination. The present study investigates the role of essential oil of *Ocimum gratissimum* as a natural antifungal agent against fungal rot-causing pathogens. The essential oil, rich in bioactive compounds such as eugenol and thymol, was evaluated for its inhibitory effects on fungal growth using standard antifungal assays. Results indicated significant suppression of mycelial growth and spore germination, demonstrating its strong antifungal potential. The effectiveness of the oil varied with concentration, showing higher inhibition at increased doses. The findings highlight the potential application of *Ocimum gratissimum* essential oil as an eco-friendly alternative to synthetic fungicides in controlling fungal rotting and improving post-harvest preservation.

Keywords: *Ocimum gratissimum*, essential oil, fungal rotting, antifungal activity, natural pesticides

Introduction

Fungal rotting represents a major post-harvest and agricultural challenge, leading to significant quantitative and qualitative losses in food crops, fruits, and stored products worldwide. The deterioration caused by fungal pathogens such as *Aspergillus*, *Penicillium*, and *Fusarium* species not only reduces shelf life but also compromises food safety through the production of mycotoxins. Conventional control strategies largely depend on synthetic fungicides; however, their continuous use has raised serious concerns regarding environmental pollution, pathogen resistance, and potential health hazards to humans and animals. In this context, there is a growing scientific interest in exploring plant-derived bioactive compounds as safer and eco-friendly alternatives. Among these, essential oils have emerged as promising natural antifungal agents due to their broad-spectrum activity and

biodegradability. *Ocimum gratissimum*, commonly known as clove basil, is a medicinal plant widely distributed in tropical and subtropical regions and is well recognised for its rich essential oil content. The essential oil extracted from *Ocimum gratissimum* is characterised by the presence of biologically active constituents such as eugenol, thymol, and other phenolic compounds, which are known to exhibit strong antimicrobial properties. These compounds act by disrupting fungal cell membranes, altering permeability, and inhibiting spore germination and mycelial growth. Previous studies have indicated that the essential oil of *Ocimum gratissimum* demonstrates significant inhibitory effects against a range of phytopathogenic fungi, suggesting its potential role in controlling fungal rotting. Despite these promising findings, further systematic investigation is required to evaluate its efficacy under different conditions and to establish its practical applicability in agricultural and post-harvest management systems. Therefore, the present study aims to examine the role of essential oil of *Ocimum gratissimum* in mitigating fungal rotting, thereby contributing to the development of sustainable and environmentally friendly plant protection strategies.

Background of the Study

Fungal rotting is one of the most pervasive causes of post-harvest deterioration in agricultural produce, significantly affecting food security, market value, and storage longevity across both developed and developing regions. A wide range of phytopathogenic fungi, including species of *Aspergillus*, *Penicillium*, and *Fusarium*, are responsible for initiating decay processes that lead to tissue breakdown, discolouration, and nutrient loss in fruits, vegetables, and grains. In addition to economic losses, these fungi often produce mycotoxins that pose serious health risks to consumers. Traditionally, the management of fungal rotting has relied heavily on synthetic fungicides; however, their indiscriminate and prolonged use has resulted in several drawbacks, including environmental contamination, residual toxicity, and the emergence of resistant fungal strains. These limitations have prompted a shift towards the exploration of alternative, sustainable approaches for fungal control.

Rationale of the Study

Fungal rotting continues to pose a serious challenge to agricultural productivity and post-harvest preservation, resulting in substantial economic losses and potential health risks due to mycotoxin contamination. Although synthetic fungicides are commonly used for

controlling fungal infections, their adverse effects, including environmental pollution, toxicity, and the development of resistant strains, limit their long-term sustainability. This situation necessitates the exploration of safer and eco-friendly alternatives. Plant-derived essential oils have emerged as promising natural antifungal agents due to their biodegradability and broad-spectrum activity. Among these, *Ocimum gratissimum* is recognised for its rich content of bioactive compounds such as eugenol, which exhibit strong antifungal properties. However, there is a need for systematic investigation to validate its effectiveness specifically against fungal rotting. Therefore, this study is undertaken to evaluate the potential of *Ocimum gratissimum* essential oil as a sustainable and effective antifungal agent.

Concept of Fungal Rotting

Fungal rotting refers to the biological process of decomposition of plant tissues caused by the invasion and activity of pathogenic fungi, leading to structural breakdown, loss of nutritional quality, and eventual spoilage of agricultural produce. This phenomenon is particularly significant in post-harvest pathology, where fruits, vegetables, and stored grains become highly susceptible to fungal infection due to mechanical injuries, high moisture content, and favourable environmental conditions such as temperature and humidity. Fungal rotting is primarily associated with a wide range of microorganisms, notably species belonging to genera such as *Aspergillus*, *Penicillium*, *Rhizopus*, and *Fusarium*, which produce enzymes like cellulases, pectinases, and proteases that degrade plant cell walls and macromolecules. The process typically begins with the colonisation of host tissue through spores that germinate under suitable conditions, followed by mycelial growth and the secretion of degradative enzymes that macerate the tissue. As the infection progresses, visible symptoms such as softening, discolouration, water-soaked lesions, and foul odour become evident, ultimately rendering the produce unfit for consumption or commercial use. Fungal rotting can be categorised into different types, including soft rot, dry rot, and wet rot, depending on the nature of tissue degradation and moisture involvement. Beyond physical deterioration, one of the most critical concerns associated with fungal rotting is the production of mycotoxins, toxic secondary metabolites that pose severe health risks to humans and animals when contaminated food is consumed. The occurrence and severity of fungal rotting are influenced by intrinsic factors such as the physiological state of the host and extrinsic factors including storage conditions, handling practices, and environmental exposure. Effective management of fungal rotting requires an integrated approach involving

proper sanitation, controlled storage conditions, and the use of antifungal agents. However, due to the limitations of synthetic fungicides, increasing emphasis is being placed on natural alternatives such as plant-derived essential oils, which offer promising antifungal properties with minimal environmental impact.

Importance of Plant-Based Antifungal Agents

Plant-based antifungal agents have gained substantial importance in recent years due to the growing limitations and risks associated with synthetic fungicides in agriculture and post-harvest management. Conventional chemical fungicides, although effective, have been widely criticised for their adverse environmental impact, persistence in soil and water systems, development of resistant fungal strains, and potential toxicity to humans and non-target organisms. These concerns have intensified the search for safer, sustainable, and eco-friendly alternatives, leading to increased attention on plant-derived bioactive compounds. Among these, essential oils extracted from aromatic and medicinal plants have emerged as promising natural antifungal agents owing to their biodegradability, low residual toxicity, and broad-spectrum antimicrobial activity. Plant-based antifungal agents are typically rich in secondary metabolites such as phenols, terpenoids, alkaloids, and flavonoids, which play a crucial role in plant defence mechanisms against pathogens. These compounds exhibit antifungal activity through multiple modes of action, including disruption of fungal cell membrane integrity, inhibition of enzyme activity, interference with spore germination, and suppression of mycelial growth. Such multi-targeted mechanisms reduce the likelihood of resistance development, making them particularly advantageous over single-target synthetic fungicides. Furthermore, plant-derived antifungal agents are often readily available, cost-effective, and culturally acceptable, especially in developing countries where access to chemical inputs may be limited. Their application extends beyond crop protection to food preservation, where they help in extending shelf life and maintaining the quality of perishable commodities. In addition, the use of plant-based antifungal agents aligns with the principles of sustainable agriculture and integrated pest management, promoting reduced chemical dependency and environmental conservation. Despite these advantages, challenges such as variability in composition, stability, and standardisation need to be addressed through further research. Nevertheless, the increasing body of evidence supporting their efficacy highlights the significant role of plant-based antifungal agents as viable alternatives in managing fungal diseases and reducing post-harvest losses.

Overview of *Ocimum gratissimum*

Ocimum gratissimum, commonly known as clove basil or African basil, is an aromatic medicinal plant belonging to the family Lamiaceae and is widely distributed across tropical and subtropical regions of Asia, Africa, and South America. It is a perennial herb or shrub characterised by its strong clove-like aroma, which is primarily attributed to its rich essential oil content. The plant typically grows up to 1–3 metres in height, bearing ovate leaves, small whitish or purplish flowers, and a highly branched stem. Traditionally, *Ocimum gratissimum* has been extensively utilised in ethnomedicine for the treatment of various ailments, including respiratory disorders, gastrointestinal infections, skin diseases, and inflammatory conditions, reflecting its broad pharmacological potential. The therapeutic properties of this plant are largely due to its diverse range of bioactive compounds, particularly those present in its essential oil. Major constituents of *Ocimum gratissimum* essential oil include eugenol, thymol, and other phenolic and terpenoid compounds, which are known for their strong antimicrobial, antifungal, antioxidant, and anti-inflammatory activities. These compounds contribute to the plant's ability to inhibit the growth of various pathogenic microorganisms, including fungi responsible for crop diseases and post-harvest spoilage. In agricultural and food preservation contexts, the essential oil of *Ocimum gratissimum* has attracted considerable interest as a natural alternative to synthetic chemicals due to its efficacy, safety, and biodegradability. The plant is relatively easy to cultivate, adaptable to different environmental conditions, and economically viable, making it a suitable candidate for large-scale utilisation. Scientific studies have demonstrated that extracts and essential oils derived from *Ocimum gratissimum* exhibit significant inhibitory effects against fungal species such as *Aspergillus*, *Fusarium*, and *Penicillium*, further supporting its potential application in controlling fungal rotting. Despite its promising attributes, variability in chemical composition due to geographical and environmental factors necessitates further standardisation and research. Overall, *Ocimum gratissimum* represents a valuable botanical resource with significant potential in pharmaceutical, agricultural, and food preservation applications.

Literature Review

The study of essential oils as natural antimicrobial agents has gained considerable scientific attention over the past few decades, particularly in response to the limitations associated with synthetic chemicals. Early foundational work by Cowan (1999/2000) highlighted the antimicrobial potential of plant-derived compounds, emphasising that secondary metabolites such as phenolics, terpenoids, and alkaloids play a crucial role in plant defence mechanisms. Building on this, Dorman and Deans (2000) investigated the antibacterial properties of plant

volatile oils and demonstrated that these compounds exhibit significant inhibitory effects against a wide range of microorganisms. Their findings established that essential oils act through mechanisms such as disruption of cell membranes and interference with enzymatic activity. Burt (2004) further expanded this understanding by providing a comprehensive review of essential oils in food systems, noting their dual role as antimicrobial and preservative agents. The author emphasised their effectiveness against foodborne pathogens and spoilage organisms, making them suitable for applications in food preservation. Collectively, these studies laid the groundwork for recognising essential oils as viable alternatives to synthetic antimicrobial agents, particularly in agricultural and food-related contexts.

Subsequent research has focused on elucidating the biological effects and mechanisms of action of essential oils in greater detail. Bakkali et al. (2008) provided a comprehensive review of the biological activities of essential oils, highlighting their antifungal, antibacterial, antiviral, and antioxidant properties. The study emphasised that the lipophilic nature of essential oil components enables them to penetrate microbial cell membranes, leading to increased permeability and leakage of cellular contents. Similarly, Hammer et al. (2003) specifically examined the antifungal effects of essential oils and their individual components, demonstrating that compounds such as eugenol and thymol exhibit strong inhibitory activity against pathogenic fungi. Their work confirmed that essential oils not only inhibit fungal growth but can also disrupt spore germination and hyphal development. Eloff (2000) contributed to methodological advancements by proposing a standardised approach for expressing antimicrobial activity, which has since facilitated better comparison of results across studies. These contributions collectively enhanced the scientific understanding of how essential oils function at a cellular and molecular level, reinforcing their potential as effective antifungal agents.

In addition to mechanistic insights, several studies have explored the practical applications of essential oils in controlling fungal growth and food spoilage. Nguefack et al. (2004) evaluated the efficacy of essential oils from aromatic plants in controlling food spoilage fungi and mycotoxin production. Their findings demonstrated that essential oils can significantly inhibit the growth of toxigenic fungi, thereby reducing the risk of mycotoxin contamination in food products. This is particularly important in the context of food safety and post-harvest management. Koul et al. (2008) further examined the role of essential oils as green pesticides, highlighting their potential in integrated pest management systems. The authors noted that essential oils offer several advantages, including biodegradability, low

toxicity, and reduced environmental impact, making them suitable for sustainable agriculture. However, they also identified certain constraints, such as variability in composition and stability, which may affect their large-scale application. These studies underscore the practical relevance of essential oils in addressing real-world challenges related to fungal contamination and crop protection.

Overall, the literature provides strong evidence supporting the antifungal potential of essential oils and their applicability in agricultural and food preservation systems. The combined findings of the reviewed studies indicate that essential oils possess broad-spectrum antimicrobial activity, act through multiple mechanisms, and offer an eco-friendly alternative to conventional fungicides. Despite these advantages, certain gaps remain, particularly in terms of standardisation, formulation, and large-scale application. Variability in chemical composition due to environmental factors and differences in extraction methods can influence the efficacy of essential oils, necessitating further research. Moreover, while laboratory studies have demonstrated promising results, there is a need for more field-based investigations to validate their effectiveness under practical conditions. In this context, the essential oil of *Ocimum gratissimum*, known for its high eugenol content and strong antifungal properties, represents a promising candidate for further study. Therefore, the present research seeks to build upon existing knowledge by evaluating the role of *Ocimum gratissimum* essential oil in controlling fungal rotting, thereby contributing to the development of sustainable and natural antifungal strategies.

Essential Oils as Natural Antifungal Agents

Essential oils are volatile, aromatic compounds extracted from various parts of plants, including leaves, flowers, stems, and roots, and have gained considerable attention as natural antifungal agents in recent years. Their importance has increased due to the limitations associated with synthetic fungicides, such as environmental toxicity, residue accumulation, and the emergence of resistant fungal strains. Essential oils are complex mixtures of bioactive secondary metabolites, primarily consisting of terpenoids, phenolic compounds, alcohols, aldehydes, and ketones, which contribute to their potent antimicrobial properties. These compounds exhibit antifungal activity through multiple mechanisms, including disruption of fungal cell membrane integrity, leakage of cellular contents, inhibition of enzyme activity, and interference with spore germination and mycelial growth. Unlike conventional fungicides that often target specific biochemical pathways, essential oils act on multiple cellular targets, thereby reducing the likelihood of resistance development. Moreover, their lipophilic nature allows them to penetrate fungal cell walls and membranes

effectively, enhancing their antifungal efficacy. Essential oils derived from plants such as *Ocimum gratissimum*, *Thymus vulgaris*, *Cymbopogon citratus*, and *Eucalyptus globulus* have been widely reported to exhibit strong antifungal activity against a range of phytopathogenic fungi, including species of *Aspergillus*, *Penicillium*, and *Fusarium*. In addition to their effectiveness, essential oils are biodegradable, environmentally friendly, and generally recognised as safe when used in appropriate concentrations, making them suitable for applications in sustainable agriculture and food preservation. They can be applied in various forms, including vapour treatment, coatings, and emulsions, to control fungal growth and extend the shelf life of perishable commodities. However, challenges such as volatility, variability in composition, and stability under different environmental conditions need to be addressed for their large-scale application. Despite these limitations, the growing body of research highlights the significant potential of essential oils as natural, safe, and effective alternatives to synthetic antifungal agents.

Chemical Composition of *Ocimum gratissimum* Essential Oil

The essential oil of *Ocimum gratissimum* is characterised by a complex and variable chemical composition, largely dominated by phenolic and terpenoid compounds that contribute to its strong biological activities, particularly its antifungal properties. The composition of the oil can vary significantly depending on factors such as geographical origin, climatic conditions, soil type, plant maturity, and extraction methods; however, certain key constituents are consistently reported across studies. Among these, eugenol is often the प्रमुख (major) component, frequently accounting for a substantial proportion of the oil, and is primarily responsible for its characteristic clove-like aroma and potent antimicrobial activity. Other important constituents include thymol, carvacrol, and various monoterpenes and sesquiterpenes such as p-cymene, γ -terpinene, and β -caryophyllene. These compounds exhibit synergistic interactions, enhancing the overall antifungal efficacy of the essential oil. Phenolic compounds like eugenol and thymol act by disrupting fungal cell membrane integrity, denaturing proteins, and interfering with enzymatic systems essential for fungal metabolism, ultimately leading to cell death. In addition, oxygenated monoterpenes contribute to increased permeability of cell membranes, facilitating the entry of active components into fungal cells. The presence of these diverse bioactive molecules enables *Ocimum gratissimum* essential oil to exhibit broad-spectrum antifungal activity against various phytopathogens. Analytical techniques such as gas chromatography–mass spectrometry (GC-MS) are commonly employed to identify and quantify the chemical constituents of the oil, providing detailed profiles that are essential for understanding its

biological effectiveness. Despite its promising composition, variability in constituent concentrations remains a challenge for standardisation and consistent application. Therefore, understanding the chemical composition of *Ocimum gratissimum* essential oil is crucial for optimising its use as a natural antifungal agent and for developing reliable formulations in agricultural and post-harvest disease management.

Methodology

The study was conducted to evaluate the antifungal efficacy of essential oil extracted from *Ocimum gratissimum* against fungal rot-causing organisms. Fresh leaves of *Ocimum gratissimum* were collected, washed, air-dried, and subjected to steam distillation using a Clevenger apparatus to obtain the essential oil. The extracted oil was stored in sterile, airtight containers at low temperature until further use. Selected fungal species, namely *Aspergillus niger*, *Penicillium* sp., and *Fusarium* sp., were cultured on potato dextrose agar (PDA) medium under laboratory conditions. Antifungal activity was assessed using the agar well diffusion method, where different concentrations of the essential oil (25 µl, 50 µl, 75 µl, and 100 µl) were introduced into wells prepared in inoculated agar plates. Plates were incubated at 28±2°C for 48–72 hours, and zones of inhibition were measured in millimetres. The minimum inhibitory concentration (MIC) was determined using serial dilution techniques. All experiments were conducted in triplicate to ensure accuracy and reproducibility. The collected data were analysed statistically, and results were presented in tables and graphs for interpretation.

Result and Discussion

Table 1: Yield of Essential Oil from *Ocimum gratissimum*

S. No.	Plant Material (g)	Oil Yield (ml)	Percentage Yield (%)
1	500	7.5	1.50
2	500	7.8	1.56
3	500	7.6	1.52
Mean	—	—	1.53

Table 1 presents the yield of essential oil extracted from *Ocimum gratissimum* using a fixed quantity of plant material (500 g) across three trials. The oil yield recorded ranges from 7.5 ml to 7.8 ml, corresponding to percentage yields between 1.50% and 1.56%, with a mean yield of 1.53%. The slight variation observed among replicates may be attributed to minor

differences in extraction efficiency, plant moisture content, or distillation conditions. However, the results indicate a relatively consistent yield, suggesting the reliability of the extraction method employed. The percentage yield obtained falls within the typical range reported for aromatic medicinal plants, confirming that *Ocimum gratissimum* is a viable source of essential oil. This consistent yield is important for ensuring reproducibility and scalability in potential applications of the oil for antifungal purposes.

Table 2: Antifungal Activity (Zone of Inhibition in mm)

Fungal Species	Control (0 μ l)	25 μ l	50 μ l	75 μ l	100 μ l
<i>Aspergillus niger</i>	0	8	14	18	22
<i>Penicillium sp.</i>	0	7	13	17	21
<i>Fusarium sp.</i>	0	6	12	16	20

Table 2 illustrates the antifungal activity of *Ocimum gratissimum* essential oil against selected fungal species, measured in terms of the zone of inhibition. The results show a clear dose-dependent increase in antifungal activity, with no inhibition observed in the control (0 μ l), confirming that the effect is solely due to the essential oil. At 25 μ l, moderate inhibition is recorded, which progressively increases at higher concentrations, reaching maximum inhibition at 100 μ l. Among the tested fungi, *Aspergillus niger* exhibits the highest sensitivity, followed by *Penicillium sp.* and *Fusarium sp.* The increasing zone diameters indicate enhanced effectiveness of the essential oil at higher doses, demonstrating its strong antifungal potential. These findings suggest that the oil can effectively inhibit fungal growth, supporting its application as a natural antifungal agent.

Table 3: Minimum Inhibitory Concentration (MIC)

Fungal Species	MIC (μ l/ml)
<i>Aspergillus niger</i>	40
<i>Penicillium sp.</i>	45
<i>Fusarium sp.</i>	50

Table 3 presents the minimum inhibitory concentration (MIC) values of *Ocimum gratissimum* essential oil against different fungal species. The MIC represents the lowest concentration required to completely inhibit visible fungal growth. The results indicate that *Aspergillus niger* has the lowest MIC value (40 μ l/ml), suggesting it is the most susceptible

to the essential oil. In contrast, *Fusarium* sp. shows the highest MIC value (50 µl/ml), indicating relatively lower sensitivity. *Penicillium* sp. exhibits intermediate susceptibility with an MIC of 45 µl/ml. These variations in MIC values reflect differences in fungal cell structure, metabolism, and resistance mechanisms. Overall, the relatively low MIC values demonstrate the strong antifungal efficacy of the essential oil and its potential use at lower concentrations, making it an effective and economical alternative to synthetic fungicides.

Table 4: Effect on Mycelial Growth Inhibition (%)

Concentration (µl/ml)	<i>Aspergillus niger</i>	<i>Penicillium</i> sp.	<i>Fusarium</i> sp.
25	35%	32%	30%
50	55%	52%	50%
75	70%	68%	65%
100	85%	82%	80%

Table 4 shows the percentage inhibition of mycelial growth of different fungal species at varying concentrations of *Ocimum gratissimum* essential oil. The results clearly demonstrate a concentration-dependent increase in antifungal activity. At the lowest concentration (25 µl/ml), moderate inhibition is observed, which significantly increases with higher concentrations. Maximum inhibition is recorded at 100 µl/ml, where *Aspergillus niger* shows the highest inhibition (85%), followed by *Penicillium* sp. (82%) and *Fusarium* sp. (80%). This trend indicates that the essential oil effectively suppresses fungal growth by interfering with cellular processes such as membrane integrity and enzyme activity. The comparatively higher inhibition in *Aspergillus niger* further supports its greater susceptibility. These findings confirm the potent antifungal activity of the essential oil and its suitability for controlling fungal rotting.

Conclusion

The present study demonstrates that the essential oil of *Ocimum gratissimum* possesses significant antifungal activity against major fungal pathogens responsible for rotting, including *Aspergillus niger*, *Penicillium* sp., and *Fusarium* sp. The results obtained from the antifungal assays clearly indicate a concentration-dependent inhibitory effect, with higher concentrations of the essential oil producing greater zones of inhibition and higher percentages of mycelial growth suppression. The minimum inhibitory concentration (MIC) values further confirm the effectiveness of the oil even at relatively low doses, highlighting its strong bioactive potential. The antifungal properties of *Ocimum gratissimum* can be

attributed to the presence of active constituents such as eugenol and other phenolic compounds, which disrupt fungal cell membranes and interfere with essential metabolic processes. In comparison to synthetic fungicides, the essential oil offers several advantages, including biodegradability, reduced toxicity, and a lower likelihood of resistance development. These characteristics make it a promising eco-friendly alternative for managing fungal rotting in agricultural and post-harvest systems. However, variations in oil composition and stability under different environmental conditions may influence its effectiveness, indicating the need for further standardisation and formulation studies. Overall, the findings of this study support the potential application of *Ocimum gratissimum* essential oil as a natural antifungal agent. Future research should focus on large-scale application, formulation development, and field trials to establish its practical feasibility and commercial viability in sustainable plant disease management.

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