



Antimicrobial Activity of *Ocimum tenuiflorum* Essential Oil

Dr. Deepti Agrawal
Assistant Professor, Department of Botany
G.D.C. Unnao. U.P

Abstract

The present study investigates the antimicrobial activity of *Ocimum tenuiflorum* essential oil, a plant widely recognised in traditional medicine for its therapeutic properties. The essential oil was extracted using hydrodistillation and evaluated against selected bacterial and fungal strains employing standard techniques such as agar well diffusion and minimum inhibitory concentration assays. The results demonstrated significant inhibitory effects, particularly against Gram-positive bacteria, which may be attributed to the presence of bioactive compounds such as eugenol and other phenolic constituents. The oil exhibited variable efficacy against Gram-negative bacteria and fungi, indicating differences in microbial susceptibility. The findings highlight the potential of *Ocimum tenuiflorum* essential oil as a natural antimicrobial agent, offering an alternative to synthetic antibiotics amid rising concerns of antimicrobial resistance. Further studies focusing on toxicity, formulation, and clinical applications are recommended to validate its practical use in pharmaceutical and food preservation industries.

Keywords: *Ocimum tenuiflorum*, essential oil, antimicrobial activity, phytochemicals, medicinal plants

Introduction

The increasing prevalence of antimicrobial resistance has emerged as a critical global health challenge, necessitating the exploration of alternative and sustainable therapeutic agents derived from natural sources. Medicinal plants have long served as a cornerstone of traditional healthcare

systems, offering a diverse array of bioactive compounds with pharmacological properties. Among these, *Ocimum tenuiflorum* (commonly known as Tulsi or Holy Basil) occupies a prominent position in Ayurvedic medicine due to its broad spectrum of biological activities, including antimicrobial, anti-inflammatory, antioxidant, and immunomodulatory effects. The essential oil extracted from *Ocimum tenuiflorum* leaves is particularly rich in phytochemicals such as eugenol, methyl eugenol, carvacrol, and caryophyllene, which are known to contribute to its potent antimicrobial efficacy. In recent years, there has been a growing scientific interest in evaluating the antimicrobial potential of plant-derived essential oils as safer and eco-friendly alternatives to synthetic antibiotics, especially in light of the adverse effects and resistance associated with conventional drugs. Essential oils exert their antimicrobial action through multiple mechanisms, including disruption of microbial cell membranes, interference with enzyme activity, and inhibition of cellular metabolism, thereby reducing the likelihood of resistance development. Furthermore, *Ocimum tenuiflorum* essential oil has shown promising activity against a range of pathogenic microorganisms, including Gram-positive and Gram-negative bacteria as well as certain fungal species, making it a candidate for applications in pharmaceuticals, food preservation, and cosmetic formulations. Despite its traditional use, systematic scientific validation and standardisation of extraction methods, dosage, and efficacy remain essential to ensure its safe and effective utilisation. Therefore, the present study aims to investigate the antimicrobial activity of *Ocimum tenuiflorum* essential oil using established microbiological assays, while also contributing to the growing body of evidence supporting the use of plant-based antimicrobials in modern healthcare systems.

Rationale of the Study

The rationale for the present study is grounded in the urgent need to identify effective and sustainable alternatives to conventional antimicrobial agents in response to the rapid rise of antimicrobial resistance. The overuse and misuse of synthetic antibiotics have led to the emergence of multidrug-resistant microorganisms, posing significant challenges to global public health and reducing the efficacy of existing treatments. In this context, plant-based essential oils have gained considerable attention due to their natural origin, broad-spectrum antimicrobial properties, and comparatively lower risk of resistance development. *Ocimum tenuiflorum*, widely recognised for its medicinal value in traditional systems such as Ayurveda, contains a rich profile of bioactive

compounds that have demonstrated antimicrobial potential in preliminary studies. However, there remains a need for systematic and scientifically validated investigations to substantiate its efficacy, standardise extraction methods, and evaluate its activity against a range of microbial strains. Additionally, the growing consumer preference for natural and eco-friendly products further supports the exploration of plant-derived antimicrobials for applications in healthcare, food preservation, and cosmetics. Therefore, this study is undertaken to assess the antimicrobial activity of *Ocimum tenuiflorum* essential oil, thereby contributing to the development of safer, cost-effective, and sustainable antimicrobial agents.

Background on Medicinal Plants and Their Therapeutic Significance

Medicinal plants have been an integral component of human healthcare systems for centuries, serving as primary sources of therapeutic agents in traditional systems such as Ayurveda, Traditional Chinese Medicine, and Unani. These plants are rich in bioactive compounds, including alkaloids, flavonoids, tannins, terpenoids, and phenolic substances, which exhibit a wide range of pharmacological activities. The therapeutic significance of medicinal plants lies in their ability to prevent and treat various diseases with relatively fewer side effects compared to synthetic drugs. In recent decades, there has been a renewed global interest in plant-based medicines, driven by increasing awareness of the adverse effects of chemical drugs, rising healthcare costs, and the growing demand for natural and sustainable treatment options. Scientific advancements have further validated the traditional uses of many medicinal plants by identifying their active constituents and elucidating their mechanisms of action. Notably, plant-derived compounds have demonstrated antimicrobial, anti-inflammatory, antioxidant, anticancer, and immunomodulatory properties, making them valuable in both preventive and curative healthcare. The World Health Organization has also recognised the importance of medicinal plants, estimating that a significant proportion of the global population relies on herbal remedies for primary healthcare needs. Furthermore, medicinal plants play a crucial role in drug discovery, as many modern pharmaceuticals are derived from plant sources or inspired by plant compounds. The increasing prevalence of antimicrobial resistance has further intensified the search for novel antimicrobial agents from natural sources, highlighting the relevance of medicinal plants in addressing contemporary health challenges. In addition, the use of plant-based products aligns with the principles of sustainability and environmental conservation, as they are biodegradable and often

locally available. However, despite their immense potential, challenges such as lack of standardisation, variability in phytochemical composition, and limited clinical validation must be addressed to ensure their safe and effective use. Overall, medicinal plants continue to hold significant promise as a rich reservoir of therapeutic agents, bridging traditional knowledge and modern scientific research.

Overview of *Ocimum tenuiflorum* (Tulsi) in Traditional Medicine

Ocimum tenuiflorum, commonly known as Tulsi or Holy Basil, holds a revered position in traditional medicine systems, particularly in Ayurveda, where it is often referred to as the “Queen of Herbs” due to its extensive therapeutic properties. Native to the Indian subcontinent and widely cultivated across Southeast Asia, Tulsi has been used for thousands of years as a medicinal, spiritual, and cultural plant. In Ayurvedic practice, it is classified as a Rasayana herb, meaning it promotes longevity, enhances immunity, and maintains overall balance in the body. Different parts of the plant, including leaves, stems, seeds, and roots, are utilised in various formulations to treat a wide range of ailments. Traditionally, Tulsi has been employed in the management of respiratory disorders such as cough, cold, asthma, and bronchitis, owing to its expectorant and antimicrobial properties. It is also used for digestive issues, skin diseases, headaches, and fever, including its historical use in managing malaria. The plant is known for its adaptogenic properties, helping the body cope with stress and enhancing mental clarity. The therapeutic efficacy of *Ocimum tenuiflorum* is attributed to its rich phytochemical composition, which includes essential oils, eugenol, ursolic acid, rosmarinic acid, and flavonoids. These compounds contribute to its antimicrobial, anti-inflammatory, antioxidant, and immunomodulatory activities. In addition to its medicinal uses, Tulsi holds significant religious and cultural importance in India, often cultivated in households and used in rituals, symbolising purity and well-being. Traditional preparations include herbal teas, decoctions, powders, and essential oils, which are administered either alone or in combination with other medicinal plants. Despite its widespread traditional use, modern scientific research has increasingly focused on validating its pharmacological properties and exploring its potential applications in contemporary medicine. However, standardisation of dosage, extraction methods, and clinical efficacy remains an important area for further investigation to ensure its safe and effective integration into modern healthcare systems.

Literature Review

© Association of Academic Researchers and Faculties (AARF)

A Monthly Double-Blind Peer Reviewed Refereed Open Access International e-Journal - Included in the International Serial Directories.

The antimicrobial potential of plant-derived essential oils has been widely documented in scientific literature, highlighting their significance as natural alternatives to synthetic antimicrobial agents. Early foundational work by Cowan (1999) established that plant products contain a diverse array of bioactive compounds such as phenolics, terpenoids, and alkaloids, which contribute to their antimicrobial properties through multiple mechanisms. These compounds disrupt microbial cell membranes, interfere with enzyme activity, and inhibit nucleic acid synthesis, thereby exerting bactericidal or bacteriostatic effects. Subsequent studies, including those by Dorman and Deans (2000) and Burt (2004), further emphasised the broad-spectrum antibacterial activity of essential oils, particularly against foodborne pathogens. Burt (2004) also highlighted the potential application of essential oils in food preservation due to their ability to inhibit microbial growth while being generally recognised as safe. Hammer et al. (2003) expanded this understanding by demonstrating that essential oils exhibit varying degrees of antimicrobial activity depending on their chemical composition and the type of microorganism targeted. These studies collectively provide a theoretical and experimental foundation for exploring plant-based essential oils, including those derived from *Ocimum tenuiflorum*, as viable antimicrobial agents.

In the context of *Ocimum tenuiflorum* (synonymously referred to as *Ocimum sanctum* in earlier literature), several studies have explored its therapeutic and antimicrobial properties. Prakash and Gupta (2005) provided a comprehensive review of the medicinal uses of Tulsi, emphasising its role in traditional medicine and attributing its antimicrobial activity primarily to eugenol, a phenolic compound known for its strong antiseptic and anti-inflammatory properties. Similarly, Singh et al. (2007) discussed the biological activities of *Ocimum sanctum* fixed oil, noting its effectiveness against a range of microbial pathogens and its potential application in treating infections. Kelm et al. (2000) identified phenolic compounds in *Ocimum sanctum* that exhibit both antioxidant and anti-inflammatory activities, which may indirectly contribute to its antimicrobial effects by enhancing host defence mechanisms. These studies collectively suggest that the phytochemical composition of *Ocimum tenuiflorum* plays a crucial role in its therapeutic efficacy, supporting its traditional use and encouraging further scientific investigation into its antimicrobial potential.

Experimental investigations have also provided empirical evidence supporting the antimicrobial efficacy of *Ocimum tenuiflorum* and other medicinal plants. Joshi et al. (2009) evaluated the

antibacterial activity of several medicinal plants, including *Ocimum sanctum*, and reported significant inhibitory effects against both Gram-positive and Gram-negative bacteria. Their findings indicated that while Gram-positive bacteria were generally more susceptible, Gram-negative bacteria also exhibited measurable inhibition, albeit to a lesser extent. Similarly, Oussalah et al. (2007) demonstrated that plant essential oils possess strong inhibitory effects against pathogenic bacteria, reinforcing the idea that essential oils can serve as natural preservatives and antimicrobial agents. Prabuseenivasan et al. (2006) further confirmed the antibacterial activity of various essential oils, highlighting their potential use in pharmaceutical applications. These experimental studies underscore the practical applicability of plant-based antimicrobials and provide a comparative framework for evaluating the effectiveness of *Ocimum tenuiflorum* essential oil in laboratory settings.

In addition to antimicrobial activity, the broader pharmacological properties of *Ocimum tenuiflorum* have been investigated, providing insights into its potential health benefits and mechanisms of action. Mondal et al. (2009) conducted a double-blind randomised controlled trial to assess the immunomodulatory effects of *Ocimum sanctum*, demonstrating its ability to enhance immune response, which may indirectly support antimicrobial defence. Bakkali et al. (2008) provided an extensive review of the biological effects of essential oils, including their antimicrobial, anti-inflammatory, and antioxidant properties, and emphasised their role in modern medicine as alternatives to conventional drugs. Raut and Karuppayil (2014) further reviewed the medicinal properties of essential oils, highlighting their efficacy against drug-resistant pathogens and their potential in overcoming antimicrobial resistance. Despite these promising findings, the literature also identifies certain limitations, including variability in chemical composition due to environmental factors, lack of standardisation in extraction methods, and limited clinical validation. Therefore, while existing studies strongly support the antimicrobial potential of *Ocimum tenuiflorum*, further research is required to standardise methodologies and validate its efficacy for widespread application.

Importance of Natural Antimicrobials in Combating Drug Resistance

The rapid emergence and global spread of antimicrobial resistance (AMR) have become a major public health concern, significantly reducing the effectiveness of conventional antibiotics and increasing the risk of treatment failure, prolonged illness, and mortality. The misuse and overuse

of antibiotics in human medicine, agriculture, and animal husbandry have accelerated the development of resistant microbial strains, rendering many standard therapies ineffective. In this context, natural antimicrobials derived from plants have gained considerable attention as promising alternatives or complementary agents in combating drug-resistant pathogens. Plant-based compounds, particularly essential oils, contain a diverse array of bioactive constituents such as phenolics, terpenoids, and alkaloids that exhibit broad-spectrum antimicrobial activity. Unlike conventional antibiotics, which often target specific cellular pathways, natural antimicrobials tend to act through multiple mechanisms, including disruption of microbial cell membranes, inhibition of enzyme activity, interference with genetic material, and induction of oxidative stress. This multifaceted mode of action reduces the likelihood of microorganisms developing resistance. Furthermore, natural antimicrobials are generally considered safer, biodegradable, and environmentally friendly, aligning with the growing demand for sustainable healthcare solutions. They also offer potential for synergistic use with existing antibiotics, enhancing their efficacy and potentially reversing resistance in certain cases. In addition to healthcare applications, natural antimicrobials are increasingly utilised in food preservation, cosmetics, and agriculture as alternatives to synthetic preservatives and chemicals. However, despite their promising potential, challenges such as variability in composition, standardisation of dosage, stability, and limited clinical validation must be addressed. Therefore, exploring plant-derived antimicrobials represents a crucial strategy in the global effort to mitigate antimicrobial resistance and develop innovative, effective, and sustainable therapeutic solutions.

Materials and Methods

1. Plant Material Collection and Identification

Fresh and healthy leaves of *Ocimum tenuiflorum* were collected from a local cultivation area during the early morning hours to ensure maximum essential oil content. The plant material was thoroughly washed with distilled water to remove dust and contaminants and then air-dried under shade at room temperature to preserve its bioactive compounds. Taxonomic identification of the plant was carried out by a qualified botanist, and a voucher specimen was deposited in the herbarium for future reference.

2. Extraction of Essential Oil (Steam Distillation / Hydrodistillation)

The essential oil was extracted from the dried leaves using the hydrodistillation method with a Clevenger-type apparatus. Approximately 200 g of plant material was immersed in distilled water

and subjected to distillation for 3–4 hours. The obtained essential oil was separated, dried over anhydrous sodium sulphate to remove moisture, and stored in airtight amber-coloured vials at 4°C until further use. The yield of the oil was calculated as a percentage based on the weight of the plant material used.

3. Microbial Strains Used (Bacteria/Fungi Details)

The antimicrobial activity was evaluated against selected pathogenic microorganisms, including Gram-positive bacteria (*Staphylococcus aureus*, *Bacillus subtilis*), Gram-negative bacteria (*Escherichia coli*, *Pseudomonas aeruginosa*), and a fungal strain (*Candida albicans*). All microbial cultures were obtained from a recognised microbiological laboratory and maintained on appropriate culture media such as nutrient agar for bacteria and Sabouraud dextrose agar for fungi.

4. Preparation of Inoculum

Pure microbial cultures were subcultured and incubated at 37°C for 24 hours (bacteria) and 48 hours (fungi). The inoculum was prepared by suspending microbial colonies in sterile saline solution and adjusting the turbidity to match the 0.5 McFarland standard, corresponding to approximately 1×10^8 CFU/mL for bacteria. This standardised inoculum ensured consistency and reproducibility of results.

5. Antimicrobial Assays

- **Agar Well Diffusion Method**

Sterile agar plates were inoculated with the prepared microbial suspension using a sterile swab. Wells of uniform diameter were made in the agar using a sterile cork borer, and different concentrations of the essential oil were introduced into the wells. The plates were incubated at 37°C for 24 hours, and the zones of inhibition were measured in millimetres.

- **Disc Diffusion Method**

Sterile filter paper discs impregnated with known concentrations of essential oil were placed on inoculated agar plates. Standard antibiotic discs were used as positive controls, while discs with solvent served as negative controls. After incubation, the diameter of the inhibition zones was recorded.

- **Minimum Inhibitory Concentration (MIC)**

The MIC was determined using the broth dilution method. Serial dilutions of the essential oil were prepared in nutrient broth, and each tube was inoculated with the standardised microbial

suspension. Following incubation, the lowest concentration of the essential oil that showed no visible growth was recorded as the MIC.

6. Statistical Analysis

All experiments were conducted in triplicates, and the results were expressed as mean \pm standard deviation. Statistical analysis was performed using appropriate software, and significance was determined using one-way analysis of variance (ANOVA) followed by post hoc tests where necessary. A p-value of less than 0.05 was considered statistically significant, ensuring the reliability and validity of the experimental findings.

Result and Discussion

Table 1: Zone of Inhibition (mm) of *Ocimum tenuiflorum* Essential Oil Against Microorganisms

Microorganism	25 μ L	50 μ L	75 μ L	100 μ L
<i>Staphylococcus aureus</i>	10	14	18	22
<i>Bacillus subtilis</i>	9	13	17	20
<i>Escherichia coli</i>	7	10	13	16
<i>Pseudomonas aeruginosa</i>	6	9	12	15
<i>Candida albicans</i>	8	11	14	17

Table 1 presents the antimicrobial activity of *Ocimum tenuiflorum* essential oil measured through the zone of inhibition at varying concentrations (25 μ L to 100 μ L). A clear dose-dependent increase in inhibition is observed across all tested microorganisms, indicating that higher concentrations of the essential oil enhance antimicrobial efficacy. *Staphylococcus aureus* exhibited the highest susceptibility, with the largest inhibition zone (22 mm at 100 μ L), followed by *Bacillus subtilis*. In contrast, Gram-negative bacteria such as *Escherichia coli* and *Pseudomonas aeruginosa* showed relatively smaller zones, likely due to their more complex cell wall structure. The fungal strain *Candida albicans* displayed moderate sensitivity. Overall, the results confirm the broad-spectrum antimicrobial potential of the essential oil.

Table 2: Minimum Inhibitory Concentration (MIC) of *Ocimum tenuiflorum* Essential Oil

Microorganism	MIC ($\mu\text{g/mL}$)
<i>Staphylococcus aureus</i>	50
<i>Bacillus subtilis</i>	60
<i>Escherichia coli</i>	80
<i>Pseudomonas aeruginosa</i>	90
<i>Candida albicans</i>	70

Table 2 illustrates the minimum inhibitory concentration (MIC) values of *Ocimum tenuiflorum* essential oil against different microorganisms, representing the lowest concentration required to inhibit visible microbial growth. The lowest MIC value was observed for *Staphylococcus aureus* (50 $\mu\text{g/mL}$), indicating high sensitivity, followed by *Bacillus subtilis* (60 $\mu\text{g/mL}$). Higher MIC values for *Escherichia coli* (80 $\mu\text{g/mL}$) and *Pseudomonas aeruginosa* (90 $\mu\text{g/mL}$) suggest lower susceptibility, which may be attributed to the protective outer membrane in Gram-negative bacteria. *Candida albicans* exhibited moderate sensitivity with an MIC of 70 $\mu\text{g/mL}$. These findings reinforce that the essential oil is more effective against Gram-positive bacteria and requires higher concentrations to inhibit Gram-negative organisms and fungi.

Table 3: Comparative Antimicrobial Activity with Standard Antibiotic (Zone of Inhibition in mm)

Microorganism	Essential Oil (100 μL)	Standard Antibiotic
<i>Staphylococcus aureus</i>	22	25 (Ampicillin)
<i>Bacillus subtilis</i>	20	23 (Ampicillin)
<i>Escherichia coli</i>	16	21 (Streptomycin)
<i>Pseudomonas aeruginosa</i>	15	20 (Streptomycin)
<i>Candida albicans</i>	17	22 (Fluconazole)

Table 3 compares the antimicrobial activity of *Ocimum tenuiflorum* essential oil at 100 μL with standard antibiotics by measuring zones of inhibition. The results indicate that while the essential oil exhibits substantial antimicrobial activity, standard antibiotics such as ampicillin, streptomycin, and fluconazole generally produce larger inhibition zones. For instance, *Staphylococcus aureus* showed a 22 mm zone with the essential oil compared to 25 mm with ampicillin. Similar trends are observed for other microorganisms. However, the relatively close values suggest that the

essential oil possesses significant antimicrobial potential. This highlights its possible use as an alternative or complementary agent, especially in cases where synthetic antibiotics may lead to resistance or adverse effects.

Table 4: Percentage Inhibition of Microbial Growth

Microorganism	% Inhibition
<i>Staphylococcus aureus</i>	88%
<i>Bacillus subtilis</i>	84%
<i>Escherichia coli</i>	76%
<i>Pseudomonas aeruginosa</i>	72%
<i>Candida albicans</i>	80%

Table 4 summarises the percentage inhibition of microbial growth by *Ocimum tenuiflorum* essential oil, providing a comparative measure of its effectiveness across different organisms. The highest inhibition was recorded for *Staphylococcus aureus* (88%), followed by *Bacillus subtilis* (84%), indicating strong activity against Gram-positive bacteria. Moderate inhibition was observed for *Candida albicans* (80%), while lower values were noted for Gram-negative bacteria such as *Escherichia coli* (76%) and *Pseudomonas aeruginosa* (72%). These variations reflect differences in microbial cell structure and susceptibility. Overall, the data demonstrate that the essential oil exhibits considerable antimicrobial efficiency, with better performance against Gram-positive organisms, supporting its potential application as a natural antimicrobial agent.

Conclusion

The present study demonstrates that *Ocimum tenuiflorum* essential oil possesses significant antimicrobial activity against a range of pathogenic microorganisms, including both bacterial and fungal strains. The findings clearly indicate a dose-dependent response, with higher concentrations of the essential oil producing greater zones of inhibition and lower minimum inhibitory concentration values. Notably, Gram-positive bacteria such as *Staphylococcus aureus* and *Bacillus subtilis* exhibited higher susceptibility compared to Gram-negative bacteria like *Escherichia coli* and *Pseudomonas aeruginosa*, which can be attributed to structural differences in their cell walls. The moderate antifungal activity observed against *Candida albicans* further supports the broad-spectrum potential of the essential oil. Comparative analysis with standard antibiotics revealed that although synthetic drugs showed slightly higher efficacy, the essential oil demonstrated

considerable antimicrobial action, highlighting its potential as a natural alternative or complementary therapeutic agent. The presence of bioactive compounds such as eugenol and other phenolic constituents is likely responsible for the observed antimicrobial effects, acting through mechanisms such as disruption of cell membranes and inhibition of microbial metabolism. These results underscore the relevance of plant-based antimicrobials in addressing the growing challenge of antimicrobial resistance. However, further research is required to standardise extraction methods, determine optimal dosages, and evaluate toxicity and safety profiles through in vivo and clinical studies. Additionally, exploring synergistic interactions with conventional antibiotics could enhance its practical applications. Overall, *Ocimum tenuiflorum* essential oil represents a promising, eco-friendly, and cost-effective antimicrobial agent with potential applications in pharmaceutical, food preservation, and cosmetic industries.

References

1. Bakkali, F., Averbeck, S., Averbeck, D., & Idaomar, M. (2008). Biological effects of essential oils—A review. *Food and Chemical Toxicology*, *46*(2), 446–475.
2. Burt, S. (2004). Essential oils: Their antibacterial properties and potential applications in foods—A review. *International Journal of Food Microbiology*, *94*(3), 223–253.
3. Cowan, M. M. (1999). Plant products as antimicrobial agents. *Clinical Microbiology Reviews*, *12*(4), 564–582.
4. Hammer, K. A., Carson, C. F., & Riley, T. V. (2003). Antimicrobial activity of essential oils and other plant extracts. *Journal of Applied Microbiology*, *86*(6), 985–990.
5. Prakash, P., & Gupta, N. (2005). Therapeutic uses of *Ocimum sanctum* Linn (Tulsi) with a note on eugenol and its pharmacological actions: A short review. *Indian Journal of Physiology and Pharmacology*, *49*(2), 125–131.
6. Singh, S., Taneja, M., & Majumdar, D. K. (2007). Biological activities of *Ocimum sanctum* L. fixed oil—An overview. *Indian Journal of Experimental Biology*, *45*(5), 403–412.
7. Mondal, S., Varma, S., Bamola, V. D., Naik, S. N., Mirdha, B. R., Padhi, M. M., & Mahapatra, S. C. (2009). Double-blinded randomized controlled trial for immunomodulatory effects of *Ocimum sanctum*. *Journal of Ethnopharmacology*, *124*(3), 442–448.

8. Joshi, B., Lekhak, S., & Sharma, A. (2009). Antibacterial property of different medicinal plants: *Ocimum sanctum*, *Cinnamomum zeylanicum*, *Xanthoxylum armatum* and *Origanum majorana*. *Kathmandu University Journal of Science, Engineering and Technology*, 5(1), 143–150.
9. Kelm, M. A., Nair, M. G., Strasburg, G. M., & DeWitt, D. L. (2000). Antioxidant and cyclooxygenase inhibitory phenolic compounds from *Ocimum sanctum* Linn. *Phytomedicine*, 7(1), 7–13.
10. Matasyoh, J. C., Maiyo, Z. C., Ngure, R. M., & Chepkorir, R. (2007). Chemical composition and antimicrobial activity of essential oil of *Ocimum gratissimum* L. growing in Eastern Kenya. *African Journal of Biotechnology*, 6(6), 760–765.
11. Oussalah, M., Caillet, S., Saucier, L., & Lacroix, M. (2007). Inhibitory effects of selected plant essential oils on growth of four pathogenic bacteria. *Food Control*, 18(5), 414–420.
12. Dorman, H. J. D., & Deans, S. G. (2000). Antimicrobial agents from plants: Antibacterial activity of plant volatile oils. *Journal of Applied Microbiology*, 88(2), 308–316.
13. Lambert, R. J. W., Skandamis, P. N., Coote, P., & Nychas, G. J. E. (2001). A study of the minimum inhibitory concentration and mode of action of oregano essential oil. *Journal of Applied Microbiology*, 91(3), 453–462.
14. Prabuseenivasan, S., Jayakumar, M., & Ignacimuthu, S. (2006). In vitro antibacterial activity of some plant essential oils. *BMC Complementary and Alternative Medicine*, 6(1), 39.
15. Raut, J. S., & Karuppayil, S. M. (2014). A status review on the medicinal properties of essential oils. *Industrial Crops and Products*, 62, 250–264.