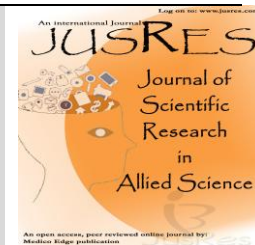




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Essential Oils as Natural Preservatives: Current Applications

Pushpendra Kumar Saket, Somesh Saxena, Dr. Rita Mourya, Dr. Shailesh Jain

SAM College of Pharmacy, SAM Global University, Raisen

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ABSTRACT

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Corresponding Author

***Pushpendra Kumar Saket**

The increasing consumer demand for natural and clean-label products has driven significant research into plant-based alternatives to synthetic preservatives. Essential oils (EOs), volatile aromatic compounds extracted from various plant parts, have emerged as promising natural preservatives due to their potent antimicrobial, antioxidant, and antifungal properties. This review examines the current applications of essential oils in food preservation, cosmetics, and pharmaceutical industries. The antimicrobial efficacy of essential oils is primarily attributed to their phenolic compounds, terpenes, and aldehydes, which disrupt microbial cell membranes and inhibit enzymatic processes. Major essential oils including oregano, thyme, cinnamon, tea tree, and rosemary have demonstrated significant preservative potential across various applications. However, challenges such as volatility, sensory impact, and regulatory considerations continue to limit their widespread commercial adoption. This review synthesizes recent advances in essential oil preservation technology, including encapsulation techniques, synergistic combinations, and novel delivery systems that enhance their stability and efficacy. The findings indicate that essential oils represent a viable and sustainable alternative to synthetic preservatives, with particular promise in organic and natural product formulations.

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1. INTRODUCTION

The preservation of food, cosmetic, and pharmaceutical products has traditionally relied on synthetic chemical preservatives such as sodium benzoate, potassium sorbate, and parabens. However, growing consumer awareness regarding the potential health risks associated with synthetic additives has created a significant market demand for natural preservation alternatives. Essential oils, concentrated hydrophobic liquids containing volatile aroma compounds from

plants, have gained considerable attention as natural preservatives due to their inherent antimicrobial, antifungal, and antioxidant properties.

Essential oils are secondary metabolites produced by aromatic plants as defense mechanisms against pathogens and environmental stresses. These complex mixtures typically contain 20-60 different compounds, with one or two major components comprising 20-70% of the total composition. The preservative efficacy of

essential oils is primarily attributed to their phenolic compounds, monoterpenes, sesquiterpenes, and aldehydes, which exhibit broad-spectrum antimicrobial activity.

2. MECHANISMS OF ANTIMICROBIAL ACTION

Essential oils exert their preservative effects through multiple mechanisms:

Cell Membrane Disruption: The lipophilic nature of essential oil components allows them to partition into microbial cell membranes, altering membrane permeability and leading to cell death. Phenolic compounds such as carvacrol and thymol are particularly effective in this regard.

Enzyme Inhibition: Essential oils can inhibit key enzymatic processes in microorganisms, including those involved in energy production and cell wall synthesis. This mechanism is particularly important for their antifungal activity.

Protein Denaturation: Certain essential oil components can denature microbial proteins, disrupting cellular functions and ultimately leading to cell death.

Oxidative Stress: Many essential oils possess antioxidant properties that can prevent lipid oxidation in food products while simultaneously creating oxidative stress in microbial cells.

3. CURRENT APPLICATIONS

3.1 Food Industry

Essential oils have found extensive applications in food preservation, particularly in:

- **Meat and Poultry Products:** Oregano, thyme, and rosemary oils are commonly used to extend shelf life and prevent spoilage bacteria growth.
- **Dairy Products:** Tea tree and lavender oils have shown efficacy in preserving milk-based products.
- **Baked Goods:** Cinnamon and clove oils provide both flavoring and preservation benefits.
- **Beverages:** Citrus oils serve dual purposes as flavoring agents and natural preservatives.

3.2 Cosmetic Industry

The cosmetic industry has embraced essential oils for their preservative properties in:

- **Skincare Products:** Tea tree, lavender, and eucalyptus oils provide antimicrobial protection.
- **Hair Care Products:** Rosemary and peppermint oils prevent microbial growth while offering additional benefits.
- **Natural Perfumes:** Essential oils serve as both fragrance components and natural preservatives.

3.3 Pharmaceutical Applications

Essential oils are increasingly used in pharmaceutical formulations for:

- **Topical Preparations:** Antimicrobial properties help prevent contamination.
- **Oral Care Products:** Mint, tea tree, and eucalyptus oils provide preservation and therapeutic benefits.
- **Traditional Medicine:** Various essential oils are incorporated into herbal preparations for their preservative effects.

4. MAJOR ESSENTIAL OILS USED AS PRESERVATIVES

Oregano Oil (*Origanum vulgare*): Rich in carvacrol and thymol, oregano oil demonstrates potent antibacterial and antifungal activity. It is particularly effective against foodborne pathogens such as *Escherichia coli* and *Salmonella* species.

Thyme Oil (*Thymus vulgaris*): Contains high concentrations of thymol and carvacrol, making it one of the most potent antimicrobial essential oils. It shows broad-spectrum activity against bacteria, fungi, and yeasts.

Cinnamon Oil (*Cinnamomum verum*): Cinnamaldehyde is the primary bioactive compound responsible for its antimicrobial properties. It is particularly effective against gram-positive bacteria and fungi.

Tea Tree Oil (*Melaleuca alternifolia*): Terpinen-4-ol is the main active component, providing strong antimicrobial and antifungal properties. It is widely used in cosmetic and pharmaceutical applications.

Rosemary Oil (*Rosmarinus officinalis*):
 Contains rosmarinic acid and other phenolic compounds that provide both antimicrobial

and antioxidant properties, making it valuable for preventing both microbial spoilage and oxidative deterioration.

5. Tables

Table 1: Antimicrobial Activity of Major Essential Oils Against Common Spoilage Microorganisms

Essential Oil	Active Compounds	Target Microorganisms	MIC Range (µg/mL)	Applications
Oregano	Carvacrol (60-80%), Thymol (5-10%)	<i>E. coli</i> , <i>S. aureus</i> , <i>Candida albicans</i>	125-500	Food, Cosmetics
Thyme	Thymol (40-60%), Carvacrol (2-5%)	<i>Listeria</i> , <i>Salmonella</i> , <i>Aspergillus</i>	100-400	Food, Pharmaceuticals
Cinnamon	Cinnamaldehyde (65-85%)	<i>Bacillus</i> , <i>Clostridium</i> , Yeasts	200-800	Food, Traditional Medicine
Tea Tree	Terpinen-4-ol (35-48%)	<i>P. aeruginosa</i> , <i>S. epidermidis</i> , Dermatophytes	250-1000	Cosmetics, Personal Care
Rosemary	Rosmarinic acid, 1,8-Cineole	<i>E. coli</i> , <i>B. cereus</i> , Molds	300-1200	Food, Nutraceuticals
Lavender	Linalool (25-45%), Linalyl acetate	<i>S. aureus</i> , <i>C. albicans</i>	400-1600	Cosmetics, Aromatherapy
Eucalyptus	1,8-Cineole (70-85%)	Respiratory pathogens, Fungi	500-2000	Pharmaceuticals, Personal Care
Clove	Eugenol (80-90%)	<i>Streptococcus</i> , <i>Candida</i>	150-600	Food, Dental Products

Table 2: Applications and Concentration Ranges of Essential Oils in Different Industries

Industry Sector	Essential Oil	Product Category	Typical Concentration (%)	Preservation Duration	Regulatory Status
Food	Oregano	Meat Products	0.1-0.5	7-14 days	GRAS
Food	Thyme	Dairy Products	0.05-0.3	5-10 days	GRAS
Food	Cinnamon	Baked Goods	0.2-1.0	14-30 days	GRAS
Food	Rosemary	Oils/Fats	0.02-0.1	30-90 days	GRAS
Cosmetics	Tea Tree	Skincare	0.5-2.0	12-24 months	Approved
Cosmetics	Lavender	Personal Care	0.1-1.0	18-36 months	Approved
Cosmetics	Eucalyptus	Hair Care	0.2-0.8	12-18 months	Approved
Pharmaceuticals	Tea Tree	Topical Preparations	1.0-5.0	24-36 months	Monograph
Pharmaceuticals	Peppermint	Oral Care	0.1-0.5	18-24 months	Monograph
Pharmaceuticals	Eucalyptus	Respiratory Products	0.5-2.0	24-36 months	Monograph

6. CHALLENGES AND LIMITATIONS

Despite their promising potential, essential oils face several challenges as natural preservatives:

Volatility and Stability: Many essential oils are highly volatile and can lose their potency during storage and processing. This limitation necessitates proper packaging and storage conditions.

Sensory Impact: Essential oils can significantly alter the taste, odor, and appearance of products, which may not always be desirable, particularly in food applications.

Cost Considerations: High-quality essential oils are often more expensive than synthetic preservatives, which can impact the economic feasibility of their use.

Regulatory Hurdles: While many essential oils have GRAS (Generally Recognized as Safe) status, regulatory approval for new applications can be complex and time-consuming.

Standardization Issues: Natural variation in essential oil composition can lead to inconsistent preservative efficacy, requiring standardization protocols.

7. RECENT ADVANCES AND FUTURE DIRECTIONS

7.1 Encapsulation Technologies

Recent research has focused on encapsulation techniques to overcome the volatility and stability issues of essential oils. Methods include:

- **Microencapsulation:** Spray drying and coacervation techniques protect essential oils from degradation
- **Nanoencapsulation:** Improved stability and controlled release properties
- **Inclusion Complexes:** Cyclodextrin-based systems enhance solubility and stability

7.2 Synergistic Combinations

Research has demonstrated that combining different essential oils or essential oils with other natural preservatives can enhance antimicrobial efficacy while reducing required concentrations.

7.3 Novel Delivery Systems

Advanced delivery systems including edible films, active packaging, and smart release mechanisms are being developed to optimize essential oil preservation applications.

8. CONCLUSION

Essential oils represent a promising and sustainable alternative to synthetic preservatives across multiple industries. Their broad-spectrum antimicrobial activity, combined with additional benefits such as antioxidant properties and consumer acceptance, positions them as valuable tools in natural product preservation. While challenges related to volatility, sensory impact, and cost remain, ongoing research into encapsulation technologies, synergistic formulations, and novel delivery systems continues to expand their practical applications.

The future of essential oil preservation lies in developing standardized, cost-effective formulations that maintain antimicrobial efficacy while minimizing sensory impact. As consumer demand for natural products continues to grow, essential oils will likely play an increasingly important role in sustainable preservation strategies.

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. Hyldgaard, M., Mygind, T., & Meyer, R. L. (2012). Essential oils in food preservation: mode of action, synergies, and interactions with food matrix components. *Frontiers in Microbiology*, 3, 12.
3. Swamy, M. K., Akhtar, M. S., & Sinniah, U. R. (2016). Antimicrobial properties of plant essential oils against human pathogens and their mode of action: an updated review. *Evidence-Based Complementary and Alternative Medicine*, 2016, 3012462.
4. Pandey, A. K., Kumar, P., Singh, P., Tripathi, N. N., & Bajpai, V. K. (2017). Essential oils: sources of antimicrobials

- and food preservatives. *Frontiers in Microbiology*, 7, 2161.
5. Ribeiro-Santos, R., Andrade, M., Madella, D., Martinazzo, A. P., de Aquino Moura, L., de Melo, N. R., & Sanches-Silva, A. (2017). Revisiting an ancient spice with medicinal purposes: cinnamon. *Trends in Food Science & Technology*, 62, 154-169.
 6. Dhifi, W., Bellili, S., Jazi, S., Bahloul, N., & Mnif, W. (2016). Essential oils' chemical characterization and investigation of some biological activities: a critical review. *Medicines*, 3(4), 25.
 7. Tongnuanchan, P., & Benjakul, S. (2014). Essential oils: extraction, bioactivities, and their uses for food preservation. *Journal of Food Science*, 79(7), R1231-R1249.
 8. Sharifi-Rad, J., Sureda, A., Tenore, G. C., Daglia, M., Sharifi-Rad, M., Valussi, M., ... & Iriti, M. (2017). Biological activities of essential oils: from plant chemoecology to traditional healing systems. *Molecules*, 22(1), 70.
 9. Nazzaro, F., Fratianni, F., Coppola, R., & Feo, V. D. (2017). Essential oils and antifungal activity. *Pharmaceuticals*, 10(4), 86.
 10. Bhavaniramy, S., Vishnupriya, S., Al-Aboody, M. S., Vijayakumar, R., & Baskaran, D. (2019). Role of essential oils in food safety: antimicrobial and antioxidant applications. *Grain & Oil Science and Technology*, 2(2), 49-55.
 11. Ju, J., Xie, Y., Guo, Y., Cheng, Y., Qian, H., & Yao, W. (2019). Application of edible coating with essential oil in food preservation. *Critical Reviews in Food Science and Nutrition*, 59(15), 2467-2480.
 12. Pateiro, M., Barba, F. J., Domínguez, R., Sant'Ana, A. S., Khaneghah, A. M., Gavahian, M., ... & Lorenzo, J. M. (2018). Essential oils as natural additives to prevent oxidation reactions in meat and meat products: a review. *Food Research International*, 113, 156-166.
 13. Chouhan, S., Sharma, K., & Guleria, S. (2017). Antimicrobial activity of some essential oils—present status and future perspectives. *Medicines*, 4(3), 58.
 14. Prakash, B., Kedia, A., Mishra, P. K., & Dubey, N. K. (2015). Plant essential oils as food preservatives to control moulds, mycotoxin contamination and oxidative deterioration of agri-food commodities—potentials and challenges. *Food Control*, 47, 381-391.
 15. Solórzano-Santos, F., & Miranda-Novales, M. G. (2012). Essential oils from aromatic herbs as antimicrobial agents. *Current Opinion in Biotechnology*, 23(2), 136-141.
 16. Valdivieso-Ugarte, M., Gomez-Llorente, C., Plaza-Díaz, J., & Gil, Á. (2019). Antimicrobial, antioxidant, and immunomodulatory properties of essential oils: a systematic review. *Nutrients*, 11(11), 2786.
 17. Raut, J. S., & Karuppayil, S. M. (2014). A status review on the medicinal properties of essential oils. *Industrial Crops and Products*, 62, 250-264.
 18. Rao, J., Chen, B., & McClements, D. J. (2019). Improving the efficacy of essential oils as antimicrobials in foods: mechanisms of action. *Annual Review of Food Science and Technology*, 10, 365-387.
 19. Falleh, H., Ben Jemaa, M., Saada, M., & Ksouri, R. (2020). Essential oils: a promising eco-friendly food preservative. *Food Chemistry*, 330, 127268.
 20. Pisoschi, A. M., Pop, A., Georgescu, C., Turcuş, V., Olah, N. K., & Mathe, E. (2018). An overview of natural antimicrobials role in food. *European Journal of Medicinal Chemistry*, 143, 922-935.
 21. Dima, C., & Dima, S. (2015). Essential oils in foods: extraction, stabilization, and toxicity. *Current Opinion in Food Science*, 5, 29-35.
 22. Ribeiro-Santos, R., Andrade, M., de Melo, N. R., & Sanches-Silva, A. (2017). Use of essential oils in active

- food packaging: recent advances and future trends. *Trends in Food Science & Technology*, 61, 132-140.
23. Sharma, S., Barkauskaite, S., Jaiswal, A. K., & Jaiswal, S. (2021). Essential oils as additives in active food packaging. *Food Chemistry*, 343, 128403.
 24. Kfoury, M., Auezova, L., Fourmentin, S., & Greige-Gerges, H. (2014). Investigation of monoterpenes complexation with hydroxypropyl- β -cyclodextrin. *Journal of Inclusion Phenomena and Macrocyclic Chemistry*, 80(1-2), 51-60.
 25. Wen, P., Zhu, D. H., Wu, H., Zong, M. H., Jing, Y. R., & Han, S. Y. (2016). Encapsulation of cinnamon essential oil in electrospun nanofibrous film for active food packaging. *Food Control*, 59, 366-376.
 26. Ju, J., Chen, X., Xie, Y., Yu, H., Guo, Y., Cheng, Y., ... & Yao, W. (2019). Application of essential oil as a sustained release preparation in food packaging. *Trends in Food Science & Technology*, 92, 22-32.
 27. Peng, Y., & Li, Y. (2014). Combined effects of two kinds of essential oils on physical, mechanical and structural properties of chitosan films. *Food Hydrocolloids*, 36, 287-293.
 28. Hashemi, S. M. B., Khaneghah, A. M., & Koubaa, M. (2017). Essential oil-based nanoformulations as novel methods for food preservation. *Critical Reviews in Food Science and Nutrition*, 57(14), 3095-3103.
 29. Maurya, A., Prasad, J., Das, S., & Dwivedy, A. K. (2021). Essential oils and their application in food safety. *Frontiers in Sustainable Food Systems*, 5, 653420.
 30. Zhang, Y., Liu, X., Wang, Y., Jiang, P., & Quek, S. (2016). Antibacterial activity and mechanism of cinnamon essential oil against *Escherichia coli* and *Staphylococcus aureus*. *Food Control*, 59, 282-289.
 31. Bassolé, I. H. N., & Juliani, H. R. (2012). Essential oils in combination and their antimicrobial properties. *Molecules*, 17(4), 3989-4006.
 32. Scandorieiro, S., de Camargo, L. C., Lancheros, C. A. C., Yamada-Ogatta, S. F., Nakamura, C. V., de Oliveira, A. G., ... & Kobayashi, R. K. T. (2016). Synergistic and additive effect of oregano essential oil and biological silver nanoparticles against multidrug-resistant bacterial strains. *Frontiers in Microbiology*, 7, 760.
 33. Gutierrez, J., Barry-Ryan, C., & Bourke, P. (2008). The antimicrobial efficacy of plant essential oil combinations and interactions with food ingredients. *International Journal of Food Microbiology*, 124(1), 91-97.
 34. Tiwari, B. K., Valdramidis, V. P., O'Donnell, C. P., Muthukumarappan, K., Bourke, P., & Cullen, P. J. (2009). Application of natural antimicrobials for food preservation. *Journal of Agricultural and Food Chemistry*, 57(14), 5987-6000.
 35. Calo, J. R., Crandall, P. G., O'Bryan, C. A., & Ricke, S. C. (2015). Essential oils as antimicrobials in food systems—a review. *Food Control*, 54, 111-119.
 36. Zengin, H., & Baysal, A. H. (2014). Antibacterial and antioxidant activity of essential oil terpenes against pathogenic and spoilage-forming bacteria and cell structure-activity relationships evaluated by SEM microscopy. *Molecules*, 19(11), 17773-17798.
 37. Kon, K. V., & Rai, M. K. (2012). Plant essential oils and their constituents in coping with multidrug-resistant bacteria. *Expert Review of Anti-Infective Therapy*, 10(7), 775-790.
 38. Fisher, K., & Phillips, C. (2008). Potential antimicrobial uses of essential oils in food: is citrus the answer? *Trends in Food Science & Technology*, 19(3), 156-164.
 39. Burt, S. (2004). Essential oils: their antibacterial properties and potential applications in foods—a review. *International Journal of Food Microbiology*, 94(3), 223-253.

40. Lambert, R. J. W., Skandamis, P. N., Coote, P. J., & Nychas, G. J. E. (2001). A study of the minimum inhibitory concentration and mode of action of oregano essential oil, thymol and carvacrol. *Journal of Applied Microbiology*, 91(3), 453-462.
41. Ultee, A., Bennik, M. H. J., & Moezelaar, R. (2002). The phenolic hydroxyl group of carvacrol is essential for action against the food-borne pathogen *Bacillus cereus*. *Applied and Environmental Microbiology*, 68(4), 1561-1568.
42. Ben Arfa, A., Combes, S., Preziosi-Belloy, L., Gontard, N., & Chalier, P. (2006). Antimicrobial activity of carvacrol related to its chemical structure. *Letters in Applied Microbiology*, 43(2), 149-154.
43. Gaysinsky, S., Davidson, P. M., Bruce, B. D., & Weiss, J. (2005). Stability and antimicrobial efficiency of eugenol encapsulated in surfactant micelles as affected by temperature and pH. *Journal of Food Protection*, 68(7), 1359-1366.
44. Cristani, M., D'Arrigo, M., Mandalari, G., Castelli, F., Sarpietro, M. G., Micieli, D., ... & Trombetta, D. (2007). Interaction of four monoterpenes contained in essential oils with model membranes: implications for their antibacterial activity. *Journal of Agricultural and Food Chemistry*, 55(15), 6300-6308.
45. López, P., Sánchez, C., Batlle, R., & Nerín, C. (2005). Solid-and vapor-phase antimicrobial activities of six essential oils: susceptibility of selected foodborne bacterial and fungal strains. *Journal of Agricultural and Food Chemistry*, 53(17), 6939-6946.
46. Cowan, M. M. (1999). Plant products as antimicrobial agents. *Clinical Microbiology Reviews*, 12(4), 564-582.
47. 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.
48. Knobloch, K., Pauli, A., Iberl, B., Weigand, H., & Weis, N. (1989). Antibacterial and antifungal properties of essential oil components. *Journal of Essential Oil Research*, 1(3), 119-128.
49. Carson, C. F., Mee, B. J., & Riley, T. V. (2002). Mechanism of action of *Melaleuca alternifolia* (tea tree) oil on *Staphylococcus epidermidis* determined by time-kill, lysis, leakage, and salt tolerance assays and electron microscopy. *Antimicrobial Agents and Chemotherapy*, 46(6), 1914-1920.
50. Oussalah, M., Caillet, S., Saucier, L., & Lacroix, M. (2007). Inhibitory effects of selected plant essential oils on the growth of four pathogenic bacteria: *E. coli* O157: H7, *Salmonella typhimurium*, *Staphylococcus aureus* and *Listeria monocytogenes*. *Food Control*, 18(5), 414-420.