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ANTIBACTERIAL ACTIVITY OF PLANT ESSENTIAL OILS AGAINST *STAPHYLOCOCCUS AUREUS* ISOLATED FROM BOVINE MASTITIS

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ABSTRACT

Bovine mastitis is a disease of cows and buffaloes, mainly caused by *Staphylococcus aureus*, which not only affects milk production but also causes enormous economic losses. Various antibiotics have been used for their treatment, but due to long-term and inappropriate use, resistance has developed in *S. aureus* to these drugs. That's why mostly plant essential oils have been used as an alternative treatment against *S. aureus* for the treatment of this disease. Moreover, essential oils from various plants have been shown to exhibit different antibacterial activities against *S. aureus* isolated from mastitic cows and buffaloes (bovine mastitis) at different concentrations. Furthermore, these plant-derived essential oils contain various compounds, and their combined effect makes it difficult for bacteria to develop resistance to these oils. These essential oils also exert their antibacterial activity against *S. aureus* by disrupting cell membrane integrity, decreasing metabolic activity, and diminishing energy production. This results in the leakage of cellular components and insufficient ATP production, which leads to bacterial cell death. This review discusses the importance of plant essential oils relative to antibiotics for treating *S. aureus*. It also explains the antibacterial activity of different plant-derived essential oils at various concentrations and under different conditions against Staphylococcus aureus isolated from mastitic cows and buffaloes. Limitations of these essential oils are also briefly described here.

***Keywords*:** Antibacterial activity, Bovine mastitis, Cows and buffaloes, Limitations, Mechanism of action, Plant essential oils.

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1. INTRODUCTION

Mastitis is classified into two types, clinical and subclinical (Gonçalves et al. 2020; Sharun et al. 2021; Tomanić et al. 2023). In clinical mastitis, signs such as udder inflammation, swelling, redness and warmth are visible. Along with these udder signs, changes in milk, such as discoloration and clots, are also seen (Sharun et al. 2021). Subclinical mastitis lacks visible signs (Gonçalves et al. 2018; Gonçalves et al. 2020; Susanty et al. 2025). Mastitis increases culling rates, huge financial and economic losses, and decreased milk production and quality (Gonçalves et al. 2018; Sharun et al. 2021; Du et al. 2022; Wani et al. 2022; Arikan et al. 2024). According to one study, a farmer typically earns 6000-8000 Rs per month from one milking cow. From multiple cows (all dairy farming activities), a farmer earns 9000–10000 Rs per month. And milk yield loss due to mastitis in a cow is 6–7kg of milk/day, while a healthy cow produces 9–10kg of milk/day, which causes a huge drop in milk production (milk production–4kg/day). Due to a decrease in milk production from the cow, daily earnings drop from 413–458 Rs to almost 306–335 Rs (Wani et al. 2022). In cows and buffaloes this disease is called bovine mastitis (Ali et al. 2021). Bovine mastitis is a common and economically important disease of dairy cows and buffaloes that is mainly caused by *Staphylococcus aureus* (Zaatout et al. 2020; Abdeen et al. 2021; Mishra et al. 2024; Abd El-Razik et al. 2025). *Staphylococcus aureus* (*S. aureus*) is a coccus, a facultative anaerobe, gram-positive, and catalase-positive. It has a capacity for growth in various temperatures and pH levels, and is a major cause of foodborne outbreaks (Bhunia

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2008; da Silva et al. 2020). Antibiotics such as, cefixime, cephalothin, neomycin, penicillin, streptomycin, tetracycline, ampicillin, and ceptaxime have been mostly used for the treatment of bovine mastitis. But due to long-term and inappropriate usage of antibiotics, resistance have been developed in *S. aureus* (Abdeen et al. 2021; Căşaru et al. 2024; Salman et al. 2024). Although antibiotics cause problems, but some of them are still effective against *S. aureus* in bovine mastitis. That's why, there is need to fine some alternatives, so that in future if they cause problems, there should be some alternatives that can be used for the treatment of this disease (Ogbuadike et al. 2023; Liu et al. 2023). Therefore, many alternatives have been discovered for the treatment of this disease and control of antibiotic resistance (Cheng and Han 2020; Tomanić et al. 2023; Căşaru et al. 2024). One of them is the use of plant essential oils (Căşaru et al. 2024).

Plant essential oils are natural, volatile, and have promising antimicrobial potential (Cerioli et al. 2018; Abers et al. 2021; Salman and Imran 2022). Essential oils can be extracted from every part of plant like, leaves, flowers, buds, bark, roots, rhizomes and stem (Batool et al. 2023; Bülbül et al. 2023; Sharma et al. 2023). They are extracted from plants by using different extraction techniques, but steam distillation and hydrodistillation are commonly used techniques globally. Commonly found phytochemicals in these essential oils are terpenoids, hydrocarbons (of low molecular weight), and their oxygenated derived compounds (Sharma et al. 2023). These oils have different kinds of biological potential, like antimicrobial, insecticidal, anti-inflammatory, antioxidant, insect repellent, pain relievers, anticancer, and cytotoxic (Bangulzai et al. 2022; Salman and Imran 2022; Sharma et al. 2023; Özüiçli and Baykalır 2024). That's why, they have been used in different industries and fields like, cosmetics, aromatherapy, food preservation, biopesticides, insecticides industries, incense, perfume, and fragrance (Sharma et al. 2023).

In the medical field, essential oils have been used for the control and treatment of different disease-causing pathogens and diseases (Imran and Alsayeqh 2022; Al-Hoshani et al. 2023; Issa 2024; Ratajac et al. 2024). One of them is bovine mastitis in which essential oils have been shown their best antibacterial effects for the treatment of this disease (Gonçalves et al. 2024; Munive Nuñez et al. 2024). These essential oils are safe for host at specific concentration. Like, essential oils of *Minthostachys verticillata* stem and leaves are also safe for the cows' mammary glands upto 250 µg/ml concentration (Moliva et al. 2023). These plant-derived essential oils have also been used instead of antibiotics because bacteria cannot easily develop resistance against these oils due to the combined effect of different compounds in them, as compared to antibiotics, which contain a single molecule (Bassolé and Juliani 2012; Ramsay et al. 2018). Moreover, these are promising substitutes for conventional drugs because they can block several cellular mechanisms of bacteria (Budri et al. 2015). That's why these essential oils have been mostly used in the treatment of this disease, alone or their combination with antibiotics due to their best antibacterial activities against *S. aureus* (Buldain et al. 2020). These oils also have biofilm-inhibiting activity produced by S. aureus (Moliva et al. 2023), which is not explained here. This review discusses the importance of plant essential oils as compared to antibiotics against *S. aureus*. It also explains antibacterial activity of different plant-derived essential oils at different concentrations and conditions, against *Staphylococcus aureus* that is isolated from mastitic cows and buffaloes. Limitations of these essential oils are also briefly described here.

1.1. Importance of Essential Oils as Compared to Antibiotics against *S. aureus*

Essential oils have been giving best results as compared to antibiotics against *S. aureus*. Such as, in one study, *S. aureus* showed resistance against several ampicillin, chloramphenicol, cefixime, kanamycin, cephalothin, novobiocin, penicillin, and streptomycin, while, essential oils of different plants (*Thymus serpillum*, *Cinnamomum zeylanicum*, *Syzygium aromaticum*, *Mentha piperita*) showed their best antibacterial activities against this multidrug-resistant bacteria (Căşaru et al. 2024). In another study, *S. aureus* also showed high resistance against amoxicillin-clavulanic, ampicillin, cefoxitin, and ceptaxime. While, EOs like, cactus oil showed inhibitory effects against *S. aureus* at 100, 50 and 25% concentrations. Apart from tea, geranium, and thyme oils, which also exhibited antibacterial activity at different concentrations (Salman et al. 2024), Abd El-Hamid et al. (2023) concluded that *S. aureus* showed complete resistance to cefoxitin, while highly resistant to ampicillin, gentamicin, and erythromycin. As compared to these antibiotics, essential oils of eugenol, carvacrol, and linalool showed excellent antibacterial activities by forming ZOIs of 20-37mm and giving MIC values of 0.5-8µg/mL range, against this bacterium (Abd El-Hamid et al. 2023). These results underscore the importance of plant essential oils and conclude that they can be used as an alternative treatment for *S. aureus*, compared with antibiotics.

1.2. Antibacterial Activity of Plant Essential Oils against *Staphylococcus aureus*

Different plant essential oils exhibit antibacterial activity against *Staphylococcus aureus*, isolated from mastitic cows and buffaloes (Căşaru et al. 2024; Munive Nuñez et al. 2024), at different concentrations, as shown in Table 1. Like, Aouadhi et al. (2024) investigated antibacterial activity of eight plant essential oils and concluded that *Thymus capitatus* and *Trachyspermum ammi* exhibit best antibacterial activities against *S. aureus*, by forming ZOI of 26-45

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and 25-40 mm (range from small to significant value), respectively as compared to the other plant oils. While the range (from small to significant value) of ZOIs obtained from other plant essential oils e.g., *Eucalyptus globulus*, *Eucalyptus camaldulensis*, *Artemisia absinthium*, *Myrtus communis*, *Mentha pulegium*, and *Cymbopogon citratus* were 14-25, 16-19, 14-17, 16-21, 14-15, and 18-44mm, respectively (Aouadhi et al. 2024). Schlemper et al. (2023) also concluded that 625 and 2500µg/mL concentrations of thyme and geranium essential oils inhibited 80 and 60% *S. aureus*,

Table 1: Antibacterial activity of plant essential oils against *Staphylococcus aureus* that is isolated from bovine mastitis (2023-2024)

Plant	Plant parts used for oil extraction	Conditions	Concentrations	*Staphylococcus aureus* isolated/obtained from/samples obtained from	Results	References
Artemisia absinthium	N. A	37°C, 24h	0.07-50%	Clinical bovine mastitis	MIC=3.125-12.5%	Aouadhi et al. 2024
Azadirachta indica	N. A	N. A	N. A	Mastitic cows	Effective	Kouaho et al. 2024
Citrus limon	N. A	N. A	N. A	Mastitic cows	Strong inhibition ≤100µg/mL	Kouaho et al. 2024
Cinnamomum zeylanicum	N. A	N. A	N. A	N. A	MIC= 0.098%	Caneschi et al. 2024
Cinnamomum zeylanicum	N. A	24h	Integral EO	Mastitic cows	ZOI= 26 mm	Cășaru et al. 2024
Cinnamomum zeylanicum	N. A	24h	½ dilution	Mastitic cows	ZOI=22 mm	Cășaru et al. 2024
Cinnamomum zeylanicum	N. A	24h	¼ dilution	Mastitic cows	ZOI=20 mm	Cășaru et al. 2024
Citrus aurantium bergamia	N. A	37°C, 24 h	N. A	Cows with Subclinical mastitis	MIC=0.277–4.435	Munive Nuñez et al. 2024
Coriandrum sativum	N. A	N. A	1-3%	Mastitic cows	Inhibit bacterial growth	Albuquerque et al. 2023
Copaifera reticulata	N. A	37°C, 24 h	N. A	Cows with Subclinical mastitis	MIC=1.11–17.76	Munive Nuñez et al. 2024
Cymbopogon citratus	Leaves	37±1°C, 24h (incubation)	0.39-50mg/mL	Clinical mastitis cases	MIC range (small to large value) =0.39-1.56mg/mL	Lopes et al. 2023
Cymbopogon citratus	N. A	37°C, 24h	0.07- 50%	Clinical bovine mastitis	MIC=3.125%	Aouadhi et al. 2024
Cymbopogon citratus	N. A	N. A	30 µl/mL	Mastitic cows	Effective	Gonçalves et al. 2024
Eucalyptus camaldulensis	N. A	37°C, 24h	0.07-50%	Clinical bovine mastitis	MIC=3.125-12.5%	Aouadhi et al. 2024
Eucalyptus globulus	N. A	37°C, 24h (incubation)	0.07-50%	Clinical bovine mastitis	MIC=6.25%	Aouadhi et al. 2024
Eugenia brejoensis	Leaves	37°C, 24 h	1,024 to 8µg/mL	Bovine mastitis	MIC range=64-256µg/mL	da Silva et al. 2024
Eugenia gracillima	Leaves	37°C, 24 h	1,024 to 8µg/mL	Bovine mastitis	MIC range=64-1,024µg/mL	da Silva et al. 2024
Eugenia pohliana	Leaves	37°C, 24 h	1,024 to 8µg/mL	Bovine mastitis	MIC and MBC range=64- 256µg/mL	da Silva et al. 2024
Eugenia stictopetala	Leaves	37°C, 24 h	1,024 to 8µg/mL	Bovine mastitis	MIC range= 64-512µg/mL	da Silva et al. 2024
Lippia graveolens	Leaves	24 and 48 h	25 µL	Bovine mastitis	Largest ZOI	Vargas-monter et al. 2023
Lippia origanoides	N. A	N. A	60 µl/mL	Mastitic cows	Effective	Gonçalves et al. 2024
Melaleuca alternifolia	Leaves	N. A	10%	Bovine mastitis	100% growth inhibition	Carrasco et al. 2024
Mentha piperita	N. A	N. A	N. A	N. A	Showed antibacterial effects	Rahchamani et al. 2023
Mentha piperita	N. A	24h	Integral EO	Mastitic cows	ZOI= 12 mm	Cășaru et al. 2024
Mentha piperita	N. A	24h	½ dilution	Mastitic cows	ZOI=10 mm	Cășaru et al. 2024
Mentha piperita	N. A	24h	¼ dilution	Mastitic cows	ZOI= 6 mm	Cășaru et al. 2024
Mentha pulegium	N. A	37°C, 24h	0.07-50%	Clinical bovine mastitis	MIC=6.25-12.5%	Aouadhi et al. 2024
Mentha pulegium	N. A	N. A	N. A	N. A	Showed antibacterial effects	Rahchamani et al. 2023
Minthostachys verticillata	Leaves and stem		4 and 6mg/mL	Clinical cases of bovine mastitis	Decrease bacterial load	Moliva et al. 2023
Myrtus communis	N. A	37°C, 24h	0.07-50%	Clinical bovine mastitis	MIC=3.125%	Aouadhi et al. 2024
Ocimum basilicum	N. A	37°C, 24 h (incubation)	N. A	Cows with Subclinical mastitis	MIC=0.149–2.378	Munive Nuñez et al. 2024
Origanum vulgare	N. A	N. A	N. A	Bovine mastitis	Significant antibacterial activity	Hartfiel et al. 2024
Origanum vulgare	N. A	N. A	1-3%	Mastitic cows	Inhibit bacterial growth	Albuquerque et al. 2023
Pelargonium graveolens	N.A	36.5°C, 24 h	N. A	Bovine mastitis	MIC_{60}=2500µg/mL	Schlemper et al. 2023
Syzygium aromaticum	N. A	N. A	1-3%	Mastitic cows	Inhibit bacterial growth	Albuquerque et al. 2023
Salvia Rosmarinus	N. A	N. A	N. A	Bovine mastitis	Significant antibacterial activity	Hartfiel et al. 2024

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Syzygium aromaticum	N. A	24h	Integral EO	Mastitic cows	ZOI=13 mm	Cășaru et al. 2024
Syzygium aromaticum	N. A	24h	½ dilution	Mastitic cows	ZOI=10 mm	Cășaru et al. 2024
Syzygium aromaticum	N. A	24h	1/4 dilution	Mastitic cows	ZOI=6 mm	Cășaru et al. 2024
Trachyspermum ammi	N. A	37°C, 24h	0.07-50%	Clinical bovine mastitis	MIC=0.048-0.195%	Aouadhi et al. 2024
Thymus capitatus	N. A	37°C, 24h	0.07- 50%	Clinical bovine mastitis	MIC=0.048-0.195%	Aouadhi et al. 2024
Thymus serpillum	N. A	24h	Integral EO	Mastitic cows	ZOI=20 mm	Cășaru et al. 2024
Thymus serpillum	N. A	24h	½ dilution	Mastitic cows	ZOI=18 mm	Cășaru et al. 2024
Thymus serpillum	N. A	24h	¼ dilution	Mastitic cows	ZOI=12 mm	Cășaru et al. 2024
Thymus vulgaris	N. A	36.5°C, 24 h	N. A	Bovine mastitis	MIC_{80}= 625µg/mL	Schlemper et al. 2023
Thymus vulgaris L.	Leaves	37±1°C, 24h	0.39-50mg/mL	Clinical mastitis cases	MIC range (small to large value) =0.39-1.56mg/mL	Lopes et al. 2023
Thymus vulgaris	N. A	N. A	1-3%	Mastitic cows	Inhibit bacterial growth	Albuquerque et al. 2023
Zingiber officinale	N. A	N. A	N. A	Mastitic cows	Strong inhibition	Kouaho et al. 2024
Zingiber officinale	N. A	37°C, 24 h	N. A	Cows with Subclinical mastitis	MIC=4.605–36.84	Munive Nuñez et al. 2024
Cinnamon oil	N. A	37°C, 24h (incubation)	0.4-6%	Mastitic cows and buffaloes	MIC=0.5%	Mishra et al. 2024

representing that thyme essential oil is more effective than geranium. According to another study by Munive Nuñez et al. (2024), *Ocimum basilicum* (mean MIC=1.561±0.223) and *Citrus aurantium bergamia* (mean MIC=2.782±0.228) essential oils showed higher antibacterial activity than *Copaifera reticulata* (mean MIC=6.541±1.705) and *Zingiber officinale* (mean MIC=18.58±2.138) (Munive Nuñez et al. 2024). In another study, essential oils of *Eugenia brejoensis*, *E. gracillima*, *E. stictopetala*, and *E. pohliana* leaves showed good antibacterial activity against *S. aureus* at MIC ranges of 64-256, 64-1,024, 64-512, and 64-256µg/mL, respectively (da Silva et al. 2024). Further, Moliva et al. (2023) tested 2 types of essential oils EO1 and EO2 of *Minthostachys verticillata* stem and leaves, against *S. aureus* and concluded that both essential oils inhibit the growth of this bacterium. MIC ranges of EO1 and EO2 were 13.7-114.6mg/mL and 288-2307mg/mL, respectively. While, according to Mishra et al. (2024), Cinnamon essential oil also showed antibacterial activity against *S. aureus* at 1-3%. Moreover, Lopes et al. (2023) investigated the antibacterial activity of *Cymbopogon citratus* and *Thymus vulgaris* L. leaves' essential oils against *S. aureus* and concluded that *Cymbopogon citratus* oil (MIC range small to large value=0.39-1.56mg/mL) and *Thymus vulgaris* (MIC range small to large value=0.39-1.56mg/mL) show better antibacterial activities. Leaves of *Eucalyptus grandis* (MIC range small to large value=6.35 - 50mg/mL), *Lavandula dentata* (MIC range small to large value=12.5-25mg/mL), and *Mentha piperita* (MIC range small to large value=3.12-12.5mg/mL) oils also exhibited antibacterial activities but less than *C. citratus* and *T. vulgaris.* Moreover, *E. grandis*, *L. dentata*, and *M. piperita* essential oils did not exhibit bactericidal activities, but only showed bacteriostatic. Optical density results showed that the essential oils of *C. citratus* and *L. dentata* had MICs of 50-0.39 and 50-6.35mg/mL, respectively. These highly variable standard deviations may be due to the effects of essential oils on bacterial growth patterns (Lopes et al. 2023).

Apart from single plant essential oil, combination of essential oils of different plants also exhibits the best antibacterial activity against *S. aureus*. Like, in one study by Schlemper et al. (2023), a combination of thyme and geranium essential oils lowered the MIC=312/625µg/mL. This reduction in MICs was 50 and 75%, respectively, for both oils (Schlemper et al. 2023). In another study, a mixture of essential oils of *T. serpillum, C. zeylanicum, S. aromaticum*, and *M. piperita* exhibited antibacterial activities by forming a ZOI of 11 mm against *S. aureus* (Cășaru et al. 2024). Furthermore, when combined with antibiotics, essential oils show higher antibacterial activity at lower concentrations against *S. aureus* (Buldain et al., 2022). Like the *Melaleuca armillaris* essential oil and erythromycin exhibited synergistic antibacterial activity against *S. aureus* under specific conditions. Like, at pH=7.4, MIC ($\mu LmL^{-1}/\mu gmL^{-1}$) range (from small to large value) of essential oils/ erythromycin was 6.25 /0.125-64 (Buldain et al. 2022). According to another study, a combination of *Melaleuca armillaris* essential oil/rifaximin also showed better antibacterial activities under different conditions. Like, at pH=7.4, 6.5 and 5, MIC values (µLmL-1/µgmL-1) of this combination were 6.25/0.002, 3.1/0.008, and 1.6/0.004, respectively (Buldain et al. 2020). These results showed that the combined effect of essential oil and antibiotics enhanced their antibacterial activity at a lower concentration, against this bacterium (Buldain et al., 2022). Moreover, the same plant essential oil in different studies also showed different antibacterial activities against *S. aureus,* as shown in Table 1.

Plant essential oils exert their antibacterial effects against *S. aureus* by decreasing metabolic activity and diminishing energy production through altering the membrane potential, which results in an impairment of the proton equilibrium, insufficient ATP production, and inconsistent membrane functioning, as shown in Fig. 1. By damaging cell membrane integrity, these oils also result in leakage of DNA, RNA and cytoplasmic material that

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eventually leads to bacterial cell lysis. Lack of structural proteins and essential enzymes, impaired bacterial growth and cell death. Essential oils also promote metabolic collapse and growth reduction by down-regulating the key genes associated with energy metabolism (β-GAL, ATPase, ALPase), cell wall formation (murB, PBP), DNA repair and duplication (RecN, RecF, holA), and the downstream processes of the tricarboxylic acid cycle (OGDH=oxoglutarate dehydrogenase, DLST=dihydrolipoamide succinyl transferase, and DLD=dihydrolipoamide dehydrogenase). At last, all these combined outcomes result in significant membrane rupture, hampered metabolism, protein breakdown, diminished DNA processes and eventually *S. aureus* lysis and cell death (Wang et al. 2020).

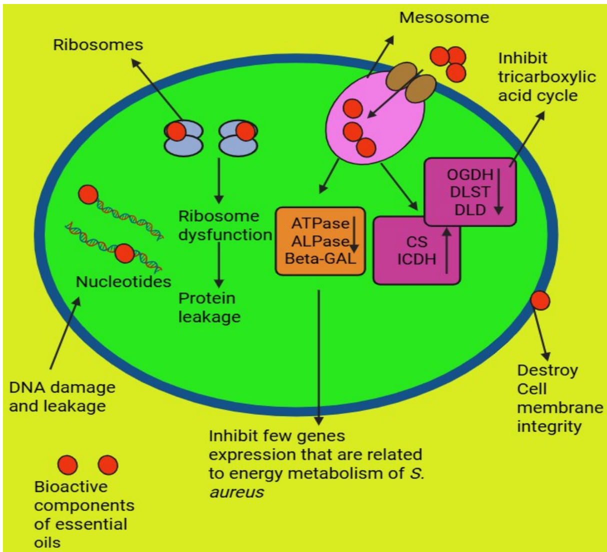

Fig. 1: Possible antibacterial mechanism of action of pant essential oils against *Staphylococcus aureus*.

1.3. Limitations

Although plant essential oils have shown better antibacterial activities against *S. aureus*, they have some limitations (Tomanić et al. 2022; Căşaru et al. 2024). Like, the chemical composition of different essential oils depends upon plant species, harvest time, extraction methods, conditions, cultivation, and storage, which makes it difficult to use them as a standard treatment because of these variations (Bakkali et al. 2008; EFSA CEF Panel 2010; JECFA 2020; National Institutes of Health 2020). Furthermore, most studies are in vitro, making it difficult to conclude that these essential oils can be used safely and effectively as a therapy (Tomanić et al. 2022). Moreover, some components of essential oils (e.g., cinnamaldehyde, thymol, carvacrol, and eugenol) can be harmful at high concentrations or with long-term use. That's why their toxic effects on animals and in milk for human use should be carefully evaluated (Guénette et al. 2007). Their mechanism of action is variable, complex, and not well defined (e.g., membrane disruption), which makes their optimization and regulatory approval difficult (Posadzki et al. 2012; Lee et al. 2018). As essential oils are volatile, they can oxidize rapidly, thereby decreasing their potential (Guénette et al. 2007; Michiels et al. 2008; Caneschi et al. 2023). Some essential oils do not show their bactericidal activities against *S. aureus* (Munive Nuñez et al. 2024). Like, *Foeniculum vulgare* did not cause mortality of *S. aureus*, even at high concentration. It may also contain biofilm-forming genes (Munive Nuñez et al. 2024). That's why future studies must focus on investigating the long-lasting effects of essential oil treatment, including appropriate dosage, application techniques, and potential drug or treatment combinations. It is essential to ensure that these compounds are safe and effective for managing bovine mastitis without negatively impacting human health or milk quality (Munive Nuñez et al. 2024).

2. CONCLUSION

Plant essential oils have shown excellent antibacterial activity against *Staphylococcus aureus* isolated from mastitic cows and buffaloes. Their activities against this bacterium vary with different concentrations and conditions. Moreover, these essential oils exhibit greater antibacterial activity against *S. aureus* than antibiotics. That's why they can be used as an alternative treatment for bovine mastitis. Despite these advantages, plant essential oils also have some limitations. The chemical composition of different essential oils depends on various factors (plant species, conditions, cultivation, harvest time, extraction methods, and storage), which makes it

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challenging to use them as a standard treatment. Moreover, most studies are in vitro, which makes it difficult to assess their safety and efficacy. Furthermore, their mechanism of action cannot be well-defined due to their high complexity and variability. The efficacy of these essential oils is also decreased because they are volatile and can oxidize quickly. That's why more studies should be conducted to determine their extract dose, safety, and mechanism of action, especially in vivo.

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REFERENCES

Abd El-Hamid MI, El-Tarabili RM, Bahnass MM, Alshahrani MA, Saif A, Alwutayd KM, Safhi FA, Mansour AT, Alblwi NAN, Ghoneim MM, Elmaaty AA, Al-Harthi HF and Bendary MM, 2023. Partnering essential oils with antibiotics: proven therapies against bovine Staphylococcus aureus mastitis. Frontiers in Cellular and Infection Microbiology 13: 1–11. https://doi.org/10.3389/fcimb.2023.1265027

Abd El-Razik KA, Soror AH, Sedky D, Fouad EA and Arafa AA, 2025. Detection of methicillin-resistant Staphylococcus aureus (MRSA) from bovine subclinical mastitis in Egypt using Real-Time PCR. International Journal of Veterinary Science 14(1): 188-195. https://doi.org/10.47278/journal.ijvs/2024.215

Abdeen EE, Mousa WS, Abdel-Tawab AA, El-Faramawy R and Abo-Shama UH, 2021. Phenotypic, genotypic and antibiogram among Staphylococcus aureus isolated from bovine subclinical mastitis. Pakistan Veterinary Journal 41(2): 289–293. http://dx.doi.org/10.29261/pakvetj/2021.008

Abers M, Schroeder S, Goelz L, Sulser A, St Rose T, Puchalski K and Langland J, 2021. Antimicrobial activity of the volatile substances from essential oils. BMC Complementary Medicine and Therapy 21: 1–14. https://doi.org/10.1186/s12906-021-03285-3

Albuquerque KRS, Purgato GA, Píccolo MS, Rodrigues FF, Pizziolo VR, Muñoz GD, Rossi CC and Diaz MAN, 2023. Formulations of essential oils obtained from plants traditionally used as condiments or traditional medicine active against Staphylococcus aureus isolated from dairy cows with mastitis. Letters in Applied Microbiology 76. https://doi.org/10.1093/lambio/ovad034

Al-Hoshani N, Zaman MA, Al Syaad KM, Salman M, Rehman TU and Olmeda AS, 2023. Assessment of repellency and acaricidal potential of Nigella sativa essential oil using Rhipicephalus microplus ticks. Pakistan Veterinary Journal 43: 606–610. http://dx.doi.org/10.29261/pakvetj/2023.054

Ali T, Kamran N, Raziq A, Wazir I, Ullah R, Shah P, Ali MI, Han B and Liu G, 2021. Prevalence of mastitis pathogens and antimicrobial susceptibility of isolates from cattle and buffaloes in Northwest of Pakistan. Frontiers in Veterinary Science 8: 1–7. https://doi.org/10.3389/fvets.2021.746755

Aouadhi C, Jouini A, Maaroufi K and Maaroufi A, 2024. Antibacterial effect of eight essential oils against bacteria implicated in bovine mastitis and characterization of primary action mode of Thymus capitatus essential oil. Antibiotics 13: 1–12. https://doi.org/10.3390/antibiotics13030237

Arikan MS, Mat B, Alkan H, Çevrimli MB, Akin AC, Başar EK and Tekindal MA, 2024. Determination of subclinical mastitis prevalence in dairy cows in Türkiye through meta-analysis and production loss calculation. Pakistan Veterinary Journal 44: 391–399. http://dx.doi.org/10.29261/pakvetj/2024.142

Bakkali F, Averbeck S, Averbeck D and Idaomar M, 2008. Biological effects of essential oils: A review. Food and Chemical Toxicology 46: 446–475. https://doi.org/10.1016/j.fct.2007.09.106

Citation: Mustafa S, Saleem MI, Shahid S, Nazar M, Zaka F, Kaleem QM, Butt AA, Mahfooz A, Tahir S and Khan AMA, 2025. Antibacterial activity of plant essential oils against *Staphylococcus aureus* isolated from bovine mastitis. Agrobiological Records 22: 97-105. https://doi.org/10.47278/journal.abr/2025.052

Bangulzai N, Ahmed SF, Kashif M, Fatima M, Ahmed M and Mushtaq N, 2022. Antifungal activity of essential oils extracted from different plants against Penicillium digitatum causing green mold of citrus. International Journal of Agriculture and Biosciences 11: 75–83. https://doi.org/10.47278/journal.ijab/2022.011

Bassolé IH and Juliani HR, 2012. Essential oils in combination and their antimicrobial properties. Molecules 17: 3989–4006. https://doi.org/10.3390/molecules17043989

Batool S, Munir F, Sindhu Zud, Abbas RZ, Aslam B, Khan MK, Imran M, Aslam MA, Ahmad M and Chaudhary MK, 2023. In vitro anthelmintic activity of Azadirachta indica (neem) and Melia azedarach (bakain) essential oils and their silver nanoparticles against Haemonchus contortus. Agrobiological Records 11: 6–12. https://doi.org/10.47278/journal.abr/2023.002

Bhunia AK, 2008. Foodborne Microbial Pathogens: Mechanisms and Pathogenesis. Springer, New York, USA.

Budri PE, Silva NCC, Bonsaglia ECR, Fernandes Júnior A, Araújo Júnior JP, Doyama JT, Gonçalves JL, Santos MV and Fitzgerald-Hughes D, 2015. Effect of essential oils of Syzygium aromaticum and Cinnamomum zeylanicum and their major components on biofilm production in Staphylococcus aureus strains isolated from milk of cows with mastitis. Journal of Dairy Science 98: 5899–5904. https://doi.org/10.3168/jds.2015-9442

Bülbül T, Özdemir V and Bülbül A, 2023. Evaluation of peppermint (Mentha piperita L.) essential oil as a digestive tract regulator in broilers. Kafkas University Veterinary Faculty Journal 29: 491–496.

Buldain D, Gortari Castillo L, Buchamer AV, Aliverti F, Bandoni A, Marchetti L and Mestorino N, 2020. Melaleuca armillaris essential oil in combination with rifaximin against Staphylococcus aureus isolated from dairy cows. Frontiers in Veterinary Science 7: 1–10. https://doi.org/10.3389/fvets.2020.00344

Buldain D, Gortari Castillo L, Buchamer AV, Bandoni A, Marchetti L and Mestorino N, 2022. In vitro synergistic interaction between Melaleuca armillaris essential oil and erythromycin against Staphylococcus aureus isolated from dairy cows. Frontiers in Veterinary Science 9: 1-11. https://doi.org/10.3389/fvets.2022.1005616

Caneschi A, Bardhi A, Barbarossa A and Zaghini A, 2023. Plant essential oils as a tool in the control of bovine mastitis: An update. Molecules 28: 1–29. https://doi.org/10.3390/molecules28083425

Caneschi A, Scarafile D, Zaghini A, Mattarelli P and Scozzoli M, 2024. Antibacterial activity of essential oils against streptococci and staphylococci causing bovine mastitis. In: ICRPN 2024, pp: 769–769.

Carrasco SBV, Curay RR, Mazon-Velez D, Morales MC, Moreira JM and Bayas-Morejón F, 2024. Evaluation of the effectiveness of tea tree (Melaleuca alternifolia) essential oil against three bacterial genera isolated from bovine mastitis. Journal of Medicinal and Pharmaceutical Chemistry Research 6: 968–980.

Căşaru C, Bulgaru A, Negru E, Daneș M and Daneș D, 2024. Antibacterial effect of essential oils against bacterial strains isolated from cows with mastitis. Scientific Works. Series C, Veterinary Medicine 70(2): 143–148.

Cerioli MF, Moliva MV, Cariddi LN and Reinoso EB, 2018. Effect of the essential oil of Minthostachys verticillata (Griseb.) Epling and limonene on biofilm production in pathogens causing bovine mastitis. Frontiers in Veterinary Science 5: 1–8. https://doi.org/10.3389/fvets.2018.00146

Cheng WN and Han SG, 2020. Bovine mastitis: risk factors, therapeutic strategies, and alternative treatments—A review. Asian-Australasian Journal of Animal Science 33: 1699–1713. https://doi.org/10.5713/ajas.20.0156

da Silva AC, Rodrigues MX and Silva NCC, 2020. Methicillin-resistant Staphylococcus aureus in food and the prevalence in Brazil: A review. Brazilian Journal of Microbiology 51: 347–356. https://doi.org/10.1007/s42770-019-00168-1

da Silva AT, Rosa DS, Tavares MRS, Souza RFS, Navarro DMAF, de Aguiar JCRF, da Silva MV and da Costa MM, 2024. Essential oils of Eugenia spp. (Myrtaceae) show in vitro antibacterial activity against Staphylococcus aureus isolates from bovine mastitis. Brazilian Journal of Microbiology 55: 3081–3096. https://doi.org/10.1007/s42770-024-01489-6

Du XX, Sherein SA, Liu P, Haque MA and Khan A, 2022. Bovine mastitis: behavioral changes, treatment and control. Continental Veterinary Journal 2(1): 15–23. http://dx.doi.org/10.71081/cvj/2022.002

EFSA CEF Panel, 2010. Scientific opinion on Flavouring Group Evaluation 60 (FGE.60): Consideration of eugenol and related hydroxyallylbenzenes evaluated by JECFA (65th meeting). EFSA Journal 8: 1632.

Gonçalves JL, Kamphuis C, Martins CMMR, Barreiro JR, Tomazi T, Gameiro AH, Hogeveen H and dos Santos MV, 2018. Bovine subclinical mastitis reduces milk yield and economic return. Livestock Science 210: 25–32. https://doi.org/10.1016/j.livsci.2018.01.016

Gonçalves JL, Kamphuis C, Vernooij H, Araújo JP, Grenfell RC, Juliano L, Anderson KL, Hogeveen H and dos Santos MV, 2020. Pathogen effects on milk yield and composition in chronic subclinical mastitis in dairy cows. Veterinary Journal 262: 1–7. https://doi.org/10.1016/j.tvjl.2020.105473

Gonçalves SF, Souza GAA, Lopes IMG, de Almeida AC, Oliveira LF, Santos EMS and da Silva LMV, 2024. Modeling the sensitivity profile of different genotypes of methacycline-resistant Staphylococcus aureus to the essential oils of Cymbopogon citratus and Lippia origanoides. Journal of Pharmacy and Biological Sciences.

Guénette SA, Ross A, Marier JF, Beaudry F and Vachon P, 2007. Pharmacokinetics of eugenol and its effects on thermal hypersensitivity in rats. European Journal of Pharmacology 562: 60–67. https://doi.org/10.1016/j.ejphar.2007.01.044

Hartfiel L, Toso F, Benitez V, Tonini MP, Roma D, Pérez Mansilla R and Mañas F, 2024. Evaluación de la actividad antimicrobiana de sustancias activas obtenidas de Lithraea molleoides, Origanum vulgare y Rosmarinus officinalis frente a microorganismos productores de mastitis bovina. Vetec Revista Académica de Investigación, Docencia y Extensión de las Ciencias Veterinarias 5: 58–60.

Imran A and Alsayeqh A, 2022. Anticoccidial efficacy of Citrus sinensis essential oil in broiler chicken. Pakistan Veterinary Journal 42: 461–466. http://dx.doi.org/10.29261/pakvetj/2022.082

Citation: Mustafa S, Saleem MI, Shahid S, Nazar M, Zaka F, Kaleem QM, Butt AA, Mahfooz A, Tahir S and Khan AMA, 2025. Antibacterial activity of plant essential oils against *Staphylococcus aureus* isolated from bovine mastitis. Agrobiological Records 22: 97-105. https://doi.org/10.47278/journal.abr/2025.052

Issa NA, 2024. Evaluation of the antimicrobial activity of essential oils against veterinary pathogens, multidrug-resistant bacteria and dermatophytes. Pakistan Veterinary Journal 44: 260–265. http://dx.doi.org/10.29261/pakvetj/2024.165
JECFA, 2020. Eugenol. In: Safety Evaluation of Certain Food Additives and Contaminants. WHO Food Additives Series 44. World Health Organization: Geneva, Switzerland. Available online: https://inchem.org/documents/jecfa/jecmono/v44jec08.htm (accessed on 22 October 2025).
Kouaho FH, Gouro AS and Toure A, 2024. Antibacterial power of lemon essential oil, ginger and their synergy with neem vegetable oil on mastitis pathogenic germs of dairy cows from the Poro Region in Ivory Coast. Journal of Research in Environmental and Earth Sciences 10: 22–35.
Lee SC, Wang SY, Li CC and Liu CT, 2018. Anti-inflammatory effect of cinnamaldehyde and linalool from the leaf essential oil of Cinnamomum osmophloeum Kanehira in endotoxin-induced mice. Journal of Food and Drug Analysis 26: 211–220. https://doi.org/10.1016/j.jfda.2017.03.006
Liu J, Zhang X, Niu J, Han Z, Bi C, Mehmood K, Farraj DAA, Alzaidi I, Iqbal R and Qin J, 2023. Complete genome of multi-drug resistant Staphylococcus aureus in bovine mastitic milk in Anhui, China. Pakistan Veterinary Journal 43(3): 456–462. http://dx.doi.org/10.29261/pakvetj/2023.052
Lopes TS, Fussieger C, Theodoro H, Silveira S, Pauletti GF, Ely MR, Lunge VR and Streck AF, 2023. Antimicrobial activity of essential oils against Staphylococcus aureus and Staphylococcus chromogenes isolated from bovine mastitis. Brazilian Journal of Microbiology 54: 2427–2435. https://doi.org/10.1007/s42770-023-01031-0
Michiels J, Missotten J, Dierick N, Fremaut D, Maene P and De Smet S, 2008. In vitro degradation and in vivo passage kinetics of carvacrol, thymol, eugenol and trans-cinnamaldehyde along the gastrointestinal tract of piglets. Journal of the Science of Food and Agriculture 88: 2371–2381. https://doi.org/10.1002/jsfa.3358
Mishra D, Shrivastav A, Shrivastava N, Ranjan R, Kumar N, Singh SK, Chatur Y, Niranjan AK and Upadhyay N, 2024. Antimicrobial and antibiofilm activity of cinnamon oil on Staphylococcus aureus isolated from cattle milk with mastitis. Asian Journal of Dairy and Food Research 1–10.
Moliva MV, Cariddi LN, Pereyra ER, Raviolo JM, Sambuceti N, Posadaz A, Campra NA and Reinoso EB, 2023. Evaluation of antibacterial and antibiofilm properties of Minthostachys verticillata essential oils against bovine Staphylococcus aureus strains. Biocatalysis and Agricultural Biotechnology 50: 1–7. https://doi.org/10.1016/j.bcab.2023.102697
Munive Nuñez KV, Abreu ACS, Almeida JM, Gonçalves JL, Bonsaglia ÉCR, dos Santos MV and Silva NCC, 2024. Antimicrobial activity of selected essential oils against Staphylococcus aureus from bovine mastitis. Dairy 5: 54–65. https://doi.org/10.3390/dairy5010005
National Institutes of Health, 2020. LiverTox: Clinical and Research Information on Drug-Induced Liver Injury. National Institute of Diabetes and Digestive and Kidney Diseases: Bethesda, MD, USA. Available online: https://www.ncbi.nlm.nih.gov/books/NBK551727 (accessed on 22 October 2025).
Ogbuadike EC, Nkadimeng SM, Igwe CC, Dzoyem JP, Qekwana DN, Petzer IM and McGaw LJ, 2023. An in vitro study on the potential of selected South African plant extracts to prevent and treat bovine mastitis. South African Journal of Botany 154: 98–107. https://doi.org/10.1016/j.sajb.2023.01.028
Özüiçli M and Baykalır Y, 2024. Evaluation of efficiency of thyme oil, Cinnamomum verum, Melaleuca viridiflora, Syzygium aromaticum essential oils, and amitraz for Varroa mite (Acari: Varroidae) control in honey bee (Hymenoptera: Apidae) colonies under field conditions. Kafkas University Veterinary Faculty Journal 30: 541–548.
Posadzki P, Alotaibi A and Ernst E, 2012. Adverse effects of aromatherapy: A systematic review of case reports and case series. International Journal of Risk & Safety in Medicine 24: 147–161. https://doi.org/10.3233/JRS-2012-0568
Rahchamani R, Noori S and Bayat Kouhsar J, 2023. Antibacterial effect of essential oils of peppermint and pennyroyal on major bovine mastitis bacteria. New Findings in Veterinary Microbiology 6: 64–75.
Ramsay RR, Popovic-Nikolic MR, Nikolic K, Uliassi E and Bolognesi ML, 2018. A perspective on multi-target drug discovery and design for complex diseases. Clinical and Translational Medicine 7: 1–14. https://doi.org/10.1186/s40169-017-0181-2
Ratajac R, Pavlićević A, Petrović J, Stojanov I, Orčić D, Štrbac F and Simin N, 2024. In vitro evaluation of acaricidal efficacy of selected essential oils against Dermanyssus gallinae. Pakistan Veterinary Journal 44(1): 93–98. http://dx.doi.org/10.29261/pakvetj/2023.123
Salman M and Imran A, 2022. In-vitro anticoccidial evaluation of Citrus sinensis essential oil against Eimeria oocysts. Agrobiological Records 10: 15–18. https://doi.org/10.47278/journal.abr/2022.020
Salman MB, Eldin AIAZ, Eissa N, Maher A, Aish AE and Abd El-Moez SI, 2024. Evaluation of the effectiveness of some essential oils against zoonotic methicillin-resistant Staphylococcus aureus isolated from dairy products and humans. Journal of Advanced Veterinary and Animal Research 11: 306–316. http://doi.org/10.5455/javar.2024.k778
Schlemper GC, Castelani L, de Souza GM, Soares WVB and Junior LCR, 2023. Antimicrobial activity of the interaction between essential oils against resistant Staphylococcus aureus isolates from bovine mastitis. Concilium 23(19): 228–239. https://doi.org/10.53660/CLM-2098-23P38
Sharma A, Gumber K, Gohain A, Bhatia T, Sohal HS, Mutreja V and Bhardwaj G, 2023. Importance of essential oils and current trends in use of essential oils (aromatherapy, agrofood, and medicinal usage). In: Essential Oils. Academic Press, pp: 53–83.
Sharun K, Dhama K, Tiwari R, Gugjoo MB, Iqbal Yatoo M, Patel SK, Pathak M, Karthik K, Khurana SK, Singh R, Puvvala B, Amarpal, Singh R, Singh KP and Chaicumpa W, 2021. Advances in therapeutic and managemental approaches of bovine mastitis: a comprehensive review. Veterinary Quarterly 41: 107–136. https://doi.org/10.1080/01652176.2021.1882713

ISSN: 2708-7182 (Print); ISSN: 2708-7190 (Online)
Open Access Journal

Susanty H, Arief, Hellyward J, Ratni E, Alzahra W, Sopiah S and Ananda, 2025. Prevalence and microbial profiles of subclinical mastitis in dairy goats and their impact on milk quality in West Sumatra, Indonesia. International Journal of Veterinary Science 14(6): 1251-1256. https://doi.org/10.47278/journal.ijvs/2025.087

Tomanić D, Božin B, Čabarkapa I, Kladar N, Radinović M, Maletić M and Kovačević Z, 2022. Chemical composition, antioxidant and antibacterial activity of two different essential oils against mastitis-associated pathogens. Acta Veterinaria 7: 45–58.

Tomanić D, Samardžija M and Kovačević Z, 2023. Alternatives to antimicrobial treatment in bovine mastitis therapy: a review. Antibiotics 12: 1–16. https://doi.org/10.3390/antibiotics12040683

Vargas-Monter J, Sifuentes-Saucedo DM, Zaragoza-Bastida A and Nieto-Aquino R, 2023. Antibacterial activity of oregano (Lippia graveolens) essential oil against Staphylococcus aureus in vitro. Journal of Natural & Agricultural Sciences 10(27). ISSN 2410-356X.

Wang X, Shen Y, Thakur K, Han J, Zhang JG, Hu F and Wei ZJ, 2020. Antibacterial activity and mechanism of ginger essential oil against Escherichia coli and Staphylococcus aureus. Molecules 25: 1–17. https://doi.org/10.3390/molecules25173955

Wani SA, Haq U, Parray OR, Nazir QUA, Mushtaq M, Bhat RA, Parrah JU, Chakraborty S, Dhama K and Yatoo MI, 2022. A brief analysis of economic losses due to mastitis in dairy cattle. Indian Veterinary Journal 99: 27–31.

Zaatout N, Ayachi A and Kecha M, 2020. Staphylococcus aureus persistence properties associated with bovine mastitis and alternative therapeutic modalities. Journal of Applied Microbiology 129: 1102–1119. https://doi.org/10.1111/jam.14706

Citation: Mustafa S, Saleem MI, Shahid S, Nazar M, Zaka F, Kaleem QM, Butt AA, Mahfooz A, Tahir S and Khan AMA, 2025. Antibacterial activity of plant essential oils against *Staphylococcus aureus* isolated from bovine mastitis. Agrobiological Records 22: 97-105. https://doi.org/10.47278/journal.abr/2025.052