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Review Article

An update and comprehensive review of the plant extracts and essential oils as a potential treatment for bacterial mastitis in dairy cattle

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Abstract
Bovine mastitis is the most common disease caused by bacteria, viruses, fungi, and chemicals in dairy herds, causing economic loss and food safety concerns. The treatment and prevention of this disease are primarily through antimicrobial agents. Still, antimicrobial resistance could hamper the effectiveness of conventional drugs for this disease. Furthermore, antimicrobial residues in milk and the environment may endanger human health. This shows that using plants and essential oils (EOs) to prevent mastitis in cattle might be feasible. Several plants are known to possess antimicrobial properties, and plant extracts and EOs are generally considered safe for animals, humans, and the environment. This review article summarizes the ongoing issues encountered in the classical treatment of mastitis and the impact of the most common plant extracts and EOs on bovine mastitis as an alternative method of controlling these pathogens, as well as the drawbacks of using these plant derivatives. Finally, plant extracts and EOs have good antibacterial activity against bacteria isolated from bovine mastitis milk. However, the use of these plant extracts and EOs as medicines requires numerous clinical trials on dairy farms.
Keywords: Essential oils, Plant extract, Bacterial mastitis, Dairy cattle

Introduction

Despite years of study, mastitis remains the most economically destructive and potentially zoonotic disease for the dairy industry and consumers, caused by a variety of organisms and significantly impacts milk quality (Cheng and Han, 2020; Maity and Ambatipudi, 2021). The highest risk of contracting a disease common to humans and animals is when consuming raw milk (Maity and Ambatipudi, 2021). Mastitis costs include direct and indirect costs such as discarding milk, reduced milk production, reduced reproduction, and premature culling and replacement (Griffioen et al., 2016). Mastitis can be classified into two clinical and subclinical groups. The symptoms that are visible with clinical mastitis include milk clots, hardness, and swelling in the teat. However, external changes are not visible in subclinical mastitis (SCM), and the diagnosis is made by counting somatic cells or by means of the California mastitis test (CMT) (Sadek et al., 2016; Lopesa et al., 2020).

The causes of mastitis can be categorized as environmental or contagious factors. Environment-related agents penetrate the cow's udder through the teat canal or *via* passive penetration soon after milking but contagious pathogens are transmitted from one cow to another (Lopesa et al., 2020). The contagious pathogens include *Staphylococcus aureus (S. aureus*), *Streptococcus galactic, Streptococcus dysgalactiae, Mycoplasma* spp., and *Corynebacterium bovis*, while environmental agents fall into *Streptococcus uberis* (*S. uberis*), *Streptococcus faecalis, Citrobacter* spp., *Enterobacter* spp., *Escherichia coli* (*E. coli*), *Klebsiella* spp, and *Pasteurella* spp. (Lopesa et al., 2020). *E. coli* causes mild to severe clinical mastitis, and there are clear signs of inflammation in the affected gland (Lavon et al., 2019). It has been reported that *E. coli O157:H7* can produce *Shiga toxin*. This toxin has been identified as a possible agent of human transmission *via* direct contact and the dairy farm environment (Murinda et al., 2019). Furthermore, *S. aureus* is often considered to be the most important bacterial zoonotic agent, infecting humans and a variety of wild animals, particularly dairy cattle (Peton and Le Loir, 2014; Algharib et al., 2020). *S. uberis* is one of the most significant pathogens of bovine mastitis, causing subclinical and clinical mastitis in both lactating and non-lactating cows (Montironi, 2016). Both clinical and subclinical mastitis is caused by Enterococcus spp., Enterobacteriaceae spp., Bacillus spp., S. chromogenes, Corynebacterium spp., Microbacterium spp., and Kocuria spp. (Ashker et al., 2015). These pathogens and their related toxins induce a set of pathogenesis mechanisms involving inflammation, immune and oxidative disturbance, and septicemia, which ultimately leads to tissue and morphological changes in udder tissue along with biochemical, microbiological, and physical changes in milk (Ezzat Alnakip et al., 2014). Many natural products with antibacterial, antifungal, and antiprotozoal properties that can be used systemically or locally. With the emergence of drug-resistant bacterial strains and the adverse effects of antibiotics and other drug residues in milk, there is a need to choose alternative measures to control bovine mastitis (Reverter et al., 2014). Herbal medicines are emerging as the main source of alternative treatments for important mammalian diseases in the current era of emerging antibiotic resistance due to their potent pharmacological activities, low toxicity, and economic viability (Atef et al., 2019).

Plant extracts exert differential antimicrobial, anti-inflammatory, immunomodulatory, and antioxidant effects against different bacterial species (Atef et al., 2019). It is possible to use certain plants therapeutically. The chemical compounds present in these plants have been shown to have biological properties that may be beneficial to human and animal health (Paz et al., 2018). The use of medicinal plants has led to recent empirical observations that have fueled research into these bioactive substances and the potential for new product development.

An essential oil (EO) is an aromatic and volatile liquid extract and the byproduct of plant metabolism. It is a defense mechanism against pathogens that are considered a substance with significant antimicrobial activity. Some EOs are continuously produced, but others are produced in response to microbial infection or tissue damage (to prevent microbial entry) (Hanif et al., 2018). According to the International Organization for Standardization (ISO), EOs are products obtained by steam distillation from a plant's raw material, mechanical processes from citrus rinds, or distillation following the separation of aqueous phases by physical methods (Gupta et al., 2020). In medicine, these oils are used as anti-inflammatory agents, wound healers, relaxants, antibacterial, immune boosters, and digestive aids (Manion and Widder, 2017). The present paper aims to review the effects of plant extracts and EOs against bovine mastitis and their use as an alternative and complementary treatment, given their properties for use in this area.

Materials and methods

We selected and analyzed the articles related to the effect of plant extracts and EOs on bovine mastitis between 2010 and 2022 through searches on Google Scholar, Science Direct, the National Library of Medicine (PubMed), and Springer Link.

Bovine Mastitis: Common Treatment and Bacterial Resistance

The most common treatment method is the intramammary infusion of antibacterial agents (Pozzo et al. 2012). Most antimicrobial agents are known for their mechanisms of action, which relate to any number of bacterial targets or processes, including inhibition of protein synthesis, inhibition of metabolic pathways, disruption of cell wall synthesis, inhibition of DNA and RNA synthesis, and the lysis of the bacterium membrane (Chandra et al., 2017). Drugs such as ampicillin, penicillin G, streptomycin, gentamicin, erythromycin, ciprofloxacin, oxytetracycline, doxycycline, and trimethoprim/sulfamethoxazole have been used in bovine mastitis and are effective against *S. aureus* (Ismail, 2017). Antibiotics such as amoxicillin and clavulanic acid, ceftiofur, cephalexin, ciprofloxacin, enrofloxacin, streptomycin, gentamicin, marbofloxacin, neomycin, oxacillin, penicillin, tetracycline, and trimethoprim/sulfamethoxazole have been reported to be effective against bacteria such as *Staphylococcus hyicus*, *S. epidermidis*, *S. intermedius, and Corynebacterium spp*. isolated from bovine mastitis (Alba et al., 2019).

Regarding the main mechanism of bacterial resistance to antibacterial agents, we can mention the limitation of drug absorption, altered drug target, receptor inactivation, enzymatic metabolism of antimicrobial agents, biofilm formation, and active drug efflux. These mechanisms may be intrinsically related to microorganisms or acquired from other microorganisms (Reygaert et al., 2018; Varela et al., 2021). The mechanisms used by bacteria to become resistant to antibiotics are very varied and depend on conditions. For example, whether they have developed resistant variants, whether they have experienced differential reproductive success under antibiotic treatment, and whether there has been variation in the population (Baquero, 2011).

According to Ameen et al. (2019), antibiotic-resistant mastitis pathogens were predominant in dairy herds, as they discovered that 90% out of 51 strains of *S. uberis* were highly resistant to penicillin. A large number of *S. aureus* isolates also showed resistance to tetracycline (57% of the strains) and gentamicin (27%). By contrast, many *S. uberis* isolates were susceptible to amoxicillin-clavulanic (80%), erythromycin (84%), oxacillin (73%), and trimethoprim/sulfamethoxazole (84%), and 40% of *E. coli* isolates were resistant to streptomycin (Ameen et al., 2019). Moreover, 33% of isolates were resistant to ampicillin, 24% to trimethoprim–sulphamethoxazole, 20% to ceftriaxone, 16% to cefepime, and 16% to tetracycline (Ameen et al., 2019). High sensitivity was observed for *E. coli* to certain antibiotics, including amoxicillin and clavulanate, ciprofloxacin, and neomycin. Over 60% of the strains were sensitive to these antibiotics. It has been suspected that milk can be a major source of antimicrobial drugs and resistant microorganisms that enter the food chain

(Kromker and Leimbach, 2017). Moreover, 90% of antibiotic residues in milk are the result of mastitis treatment (Kovacevi et al., 2021).

Antibiotic resistance of bacterial strains has increased rapidly, such that current antibiotics may become ineffective within 5 years due to genetic changes (Chandra et al., 2017). For this reason, it is imperative to identify and use alternatives to prevent and treat mastitis in food-producing species, such as nanomaterials, bacteriophages (Gomes and Henriques, 2016), and electrical signals (Willmer, 2019). This review briefly discusses EO and plant extracts that are used for the treatment of bovine mastitis caused by bacteria.

Thymus vulgaris

Thymus vulgaris(*T. vulgaris*) is native to eastern Azerbaijan and southern Europe, from the western Mediterranean to southern Italy. Thymus species of aromatic plants are useful medicinal plants with EOs known as thyme oil which has various therapeutic properties such as B. antimicrobial, cardioprotective, antiseptic, and diuretic effects (Emami Bistgani et al., 2022). A bushy subshrub, *T. vulgaris* has small, fragrant, grey-green leaves and small purple or pink flowers in early summer and grows well in a sunny spot where there is no shade; it prefers a warm, dry climate. Thyme species thrive best in coarse, rough soil, which may be unsuitable for some alternative crops (Hosseinzadeh et al., 2015). Kovacevi et al. (2021) reviewed *T. vulgaris* against clinical and subclinical bovine mastitis. They found Streptococcus spp., *E. coli*, *Enterobacter sakazakii*, *Kelebsiella oxytoca*, *S.aureus, Streptococcus uberis, and Streptococcus dysgalactiae*. Among pathogens, *E. coli* was the most common pathogen identified in six samples (19.35%), followed by five (16.13%) samples with *Streptococcus spp*., while *Staphylococcus spp*., *coagulase negative*, *Streptococcus uberis*, *Streptococcus dysgalactiae*, *Klebsiella oxytoca* , and *Enterobacter sakazakii* each existed in one sample (3.23%). In their study, EO from *T. vulgaris* showed more significant antibacterial potential against *Streptococcus spp*., *Entrobacter sakazakii* and *E. coli* (Kovacevi et al., 2021) (Abboud et al., 2015). The mechanism of action of thymol against microorganisms has not been fully investigated, however, it probably has a mechanism similar to that of carvacrol (Figure 1). The alteration in the cytoplasmic membrane may damage the outer and inner membranes while interfering with the membrane function (Chouhan et al., 2017). ATP and K^+ are also released by contacting a cell membrane, resulting in increased membrane permeability. Amongst various components, only carvacrol, citral, thymol, and trans-cinnamaldehyde (TC) have been effective with lower MIC values against all pathogens such as *Streptococcus* spp., *E. coli, Enterobacter sakazakii, Kelebsiella oxytoca, S.aureus, Streptococcus uberis,* and *Streptococcus dysgalactiae* (Gupta et al., 2020).

A structural study of *T. vulgaris* has shown that thymol (54.17%) is the most abundant compound followed by γ terpinene (22.18%) and p-cymene (16.66%) (Kovacevi et al., 2021). According to the results of Martínez et al. (2021), the most active phytochemicals were terpenes and polyphenols, either alone or in combination with EOs or extracts of plants. Compounds including, isorhamnetin glycoside, luteolin glycoside, hibicuslide C, chryseriol glycosides, and propolin D have been shown to be effective against both Gram-negative (*Vibrio cholerae*) and Gram-positive (*S. aureus)* bacteria by disrupting the plasma membrane and leaking intracellular content, similar to or even more effective than ciprofloxacin used as a reference drug (Tagousop et al., 2018). Mullen (2020) studied the Phyto-Mast known as a commercial product consisting of EOs of *Angelica sinensis*, *Gaultheria procumbens*, *Glycyrrhiza uralensis*, and *T. vulgaris*. He found that only *T. vulgaris* oil had consistent antibacterial activity, and a combination of oils did not show typical dose-response effects.

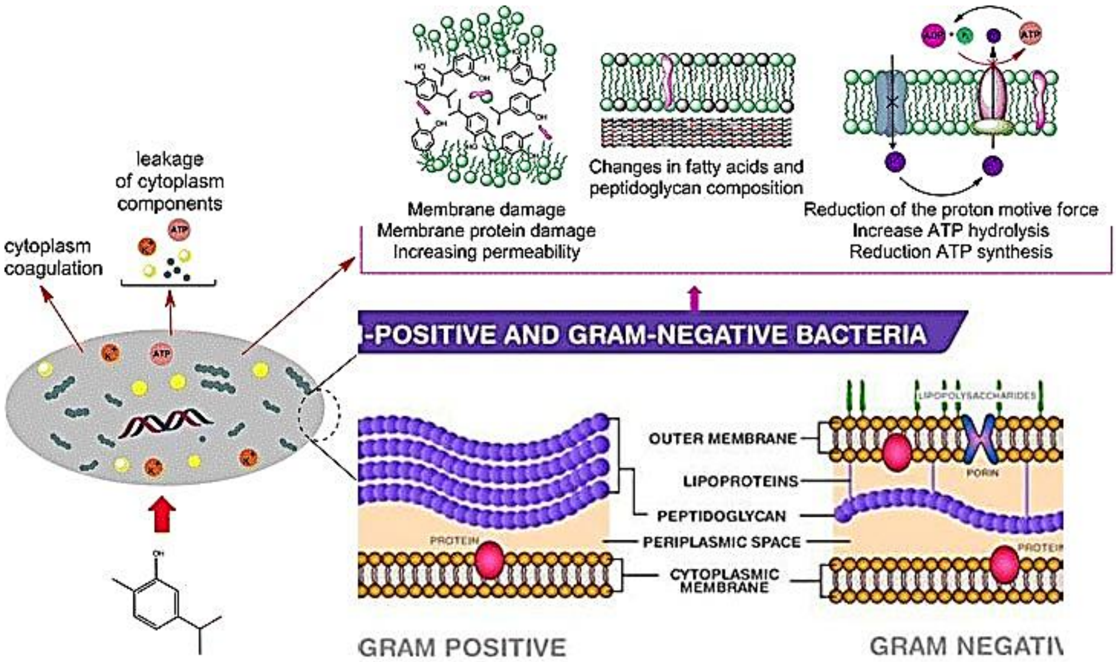

Fig. 1. Mechanism of Carvacrol on alteration in the cytoplasmic membrane and damage to inner and outer membrane (Marinelli et al., 2018)

Minthostachys verticillata

The ethnobotanical aromatic herb, *Minthostachys verticillata* (Griseb) Epling (Lamiaceae), commonly known as ‘‘peperina’’, has a wide range of uses and properties. This species exists in east Azerbaijan (Latifian and Arslanoglu, 2018) as well as in South American countries such as Brazil, Venezuela, Bolivia, Ecuador, and Argentina’s northwest and central regions (Montironi et al., 2022). It is used in folk medicine for sedative its antispasmodic, digestive, and stimulant properties, in addition to treating respiratory ailments, including asthma and bronchitis. Several *in vitro* studies have found that this plant exhibits antibacterial, antiviral, and antifungal properties. According to a study by Cariddi et al. (2011), pulegone (51.7%) and menthone (37.8%) made up the main compounds in *M. verticillata* oil, along with 1.4% of cis-menthone and 1.4% of piperitone. The antibacterial activity of *M. verticillata* against *S. aureus* was assessed by Cecchini et al. (2020) after the incubation of *S. aureus* with various concentrations of EO for 24 h. This study supports the notion that nano-formulations based on natural products are potentially helpful antibacterial agents. *In vitro* and in experimental mouse models, the effect of *M. verticillata* EO on immunomodulation has been demonstrated in terms of both decreasing pro-inflammatory mediators such as histamine and -hexosaminidase and increasing pro-inflammatory cytokines such as IL-10 (Montironi et al., 2019). Additionally, *M. verticillata* EO has proven to be safe in experimental animals by using various routes, it does not cause cytogenotoxicity or toxicity to the bone marrow or blood cells (Escobar et al., 2012). Cerioli et al. (2018) assessed the antibacterial activity of *M. verticillata* EO and limonene against bacteria isolated from bovine mastitis, including *E. coli*, *Bacillus pumilus*, and *Enterococcus faecium*. They used time-kill assays, bacterial lysis, minimum inhibitory concentration (MIC), and minimum bacterial concentration (MBC) to perform their analysis. The result from *M. verticillata* EO indicated an inhibitory effect on all isolates, but limonene inhibited *B. pumilus*. Results obtained from bacterial lysis revealed that *M. verticillata* EO was able to produce 50% of bacterial lysis after 30 min while limonene failed to produce bacterial lysis. *M. verticillata* EO and limonene were studied by Montrioni et al. (2016) for their effectiveness against the *S. aureus* strains isolated from bovine mastitis. It was observed that the MIC value for M. verticillata EO ranged from 14.3 to 114.5 mg/mL and the MBC value ranged from 114.5 to 229 mg/mL while limonene values ranged from 3.3 to 52.5 mg/mL and the MBC was 210 mg/mL (Table 1). Both compounds had antimicrobial potential against *S. aureus* strains isolated from bovine mastitis (Table 2).

Origanum vulgar

Origanum vulgare is one of the species belonging to the Lamiaceae family, which is native to the Mediterranean region and western Eurasia. *Origanum vulgare* L. subsp. viride also grows in the northern part of Iran (Andi and Maskani, 2021). Various traditional healing systems use this aromatic herb as a remedy and spice around the world (Pezzani et al., 2017). Since ancient times, the *Origanum vulgare* plant has been used as an herbal medicine for the treatment of dyspepsia, painful menstruation, rheumatoid arthritis, scrofulosis, and urinary tract disorders (Ocaña-Fuentes et al., 2010; Gulluce et al., 2012; Sarikurkcu et al., 2015;). Previous studies showed that intermammary treatment with oregano essential oil reduced bovine mastitis with *S. aureus* and *E. coli* compared to gentamicin (Cho et al., 2015). The results showed that this extract can be a useful alternative to antibiotics in controlling mastitis (Table 2). Several phenolic compounds are in *Origanum*, such as carvacrol and thymol, making it an effective antibacterial. The primary mechanism by which carvacrol acts on bacteria is through the breakdown of the proton driving force, leading to the depletion of the ATP pool and cell death (Thormar, 2010).

Table 1. MIC and MBC of different plant extracts and essential oil

Essential oil	MIC*	MBC *	REFERECCE
Thymus vulgaris	0.8-3.2mg/mL	1.6-3.2mg/ml	Dal pozzo et al. (2011)
Minthostachys verticillata	14.3-114.5mg/ml	114.5-229mg/ml	Montironi et al. (2016)
Limonene	3.2-52.5mg/ml	210mg/ml	Montironi et al. (2016)
Origanum vulgare	0.62-1.86mg/ml	1.25-2.75mg/ml	Renu gupta et al. (2020)
Cinnamomum zeylanicum	1.6-6.4mg/ml	1.6-6.4mg/ml	Renu gupta et al. (2020)
Thymol	0.2-0.8 mg/ml	0.4-6.2mg/ml	Dal pozzo et al. (2012)
Carvacrol	0.2-1.6mg/ml	0.2-3.2mg/ml	Dal pozzo et al. (2012)

*Minimum inhibitory concentration (MIC)
*Minimum bactericidal concentration (MBC)

Rosemary

It is a widely used medicinal plant (Rosmarinus officinalis) belonging to Lamiaceae family. *Rosemary* officinal leaves are commonly used in traditional Mediterranean cuisine and folk medicine (Ribeiro-Santos et al., 2015). *Rosemary* EO and preparations contain antibacterial, cytostatic, antimutagenic, antioxidant, and anti-inflammatory properties (Milyuhina et al., 2020). Research has shown that rosmarinic acid (RA) reduces tissue damage in some inflammatory diseases, such as acute lung injury, inflammation development, and genesis (Jiang et al., 2017). 1,8-cineole, the main compound of rosemary leaf EOs, has been shown to have significant antibacterial properties against numerous microorganisms such as *E. coli, S. aureus, Bacillus subtilis,* and *Bacillus cereus* (Milyuhina et al., 2020). The anti-inflammatory effects of RA on the inflammation caused by lipopolysaccharide (LPS) in the epithelial cells of mouse mammary tissue have been reported (Jiang et al., 2017). After treatment with RA, they observed significantly improved structural damage to the breast and decreased myeloperoxidase activity. Using the results obtained by qPCR and ELISA, they found that the expression of TNFα, IL-1, and IL-6 decreased in a dose-dependent manner in both tissues and mMECs. Additionally, RA was found to suppress the protein levels of TRAF6, TLR4, IRAKA, MyD88, and p-IKKB. Moreover, RA inhibited the activation of the NF-kB signal transduction pathway by LPS. In conclusion, RA inhabits the NF-kB, MyD88, and TLR4 signaling pathways to attenuate LPS-induced mastitis in dairy cattle.

Table 2. The activity of some essential oils (EOs) and plant extracts against bacteria that cause dairy cattle mastitis.

Plant /Essential oil	Microorganism	Result	References
Origanum vulgare	*Staphylococcus aureus*	A 0.9 ml EO administered twice daily for 3 days into inflamed quarters resulted in decreased WBC and SCC 16 and no detectable *Streptococcus aureus* Or *E. coli* in the milk on the fourth post-treatment day.	Cho et al., 2015
Rosemary EO Cinnamon EO Geranium EO	*Candida albicans*	showed highly antibacterial activity against the *Candida albicans*, with values ranging from 15 to31 g/ml	ksourii et al., 2017
Thyme EO Lavender	*Staphylococcus spp* *Streptococcus* spp	External use of these oils in Vaseline resulted in a greater antibacterial action against the *Staphylococcus spp and Streptococcus spp* for a 100% recovery rate with thymus EO	Abboud et al., 2015
M. verticillata EO	*E. coli, Entrobacter faecium, Bacillus pumilus*	It was discovered that EO has antibacterial Properties by inhibiting the formation of biofilm	Cerioli et al., 2018
Syzygium aromaticum Cinnamomum zeylanicum	*Streptococcus aureus*	The isolated compounds had lower MIC values, indicating a higher antibacterial activity against the *Streptococcus aureus* and all agent-affected biofilm formation	Budri et al., 2015
Thymus vulgaris Lippia graveolens R. ofcinalis Salvia ofcinalis Ocimum basilicum Zingiber ofcinale	*Staphylococcus* spp	At the concentration tested, Zofcinal, Rofcinalis, O. basilicum, S. ofcinalis did not demonstrate antibacterial activity, but Tvulgaris and Lgarveolens were equally active but at lower concentrations.	Pozzo et al., 2011
Cinnamon and Trans-cinnamaldehyde	*Staphylococcus* spp	As a result, EO obtained from cinnamon bark was composed mostly of The EO cinnamaldehyde (68.95%) and eugenol (2.77%), which showed antibacterial activity against *Staphylococcus aureus* (MIC = 2,000 mg/L). EO from cinnamon leaf was composed of eugenol (73.27) which showed antibacterial activity against *Staphylococcus aureus*	Budri et al., 2015

Ocimum sanctum

The plant *Ocimum sanctum*, also known as Tulsi or basil, belongs to the Lamiaceae family (Anusmitha et al., 2022). A variety of antimicrobial compounds confer therapeutic properties on this herb, including the treatment of diabetes, bronchitis, arthritis, and skin diseases (Goyal et al., 2011). An extract of *Ocimum sanctum* is indicated for the treatment of bovine mastitis (Shafi et al., 2016). It improves phagocytes and phagocyte index, which leads to a decrease in bacterial count (Sharun et al., 2022). In a study, 600 mg/kg body weight of *Ocimum sanctum* leaf powder administered to cows with mastitis twice daily for seven days eliminated 69% of infections and reduced somatic cell counts (Sharun et al., 2022).

Cinnamon

The *Cinnamon* plant is widespread in India, China, and Indonesia, and there are two main types of *Cinnamon*: Ceylon and Cassia (Hamidpour et al., 2015). There are many health benefits associated with *Cinnamon* due to its distinctive constituents such as Cinnamyl Alcohol, Cinnamaldehyde, Cinnamic acid, and Coumarin. Some of these activities include antiallergic, antimicrobial, and antioxidant properties (Mohammed, 2020). *Cinnamon* oil in combination with trans-cinnamaldehyde has been shown to be effective in preventing bacteria biofilm formation and killing the bacteria in the biofilm of the clinical strain *S. aureus* (Table 2) (Budri et al., 2015). Moreover, *Cinnamon Cassia* oil has been found to inhibit most pathogens that cause bovine mastitis by disrupting membrane integrity and blocking ATP production (Zhu et al., 2016).

Terminalia chebula

The medicinal plant *Terminalia chebula* is widespread in Iran, India, Burma, and Sri Lanka. It is known as black myrobalan, ink tree, or chebulin. It is used extensively in the preparation of many Ayurvedic formulations for infectious diseases such as chronic ulcers and leukorrhea, as well as skin diseases (Pannu et al., 2021). *Terminalia chebula* is useful in the treatment of subclinical bovine mastitis. *Terminalia chebula* extract at a concentration of 500 g/mL was equally effective as amoxicillin (100 g/mL) against some bacterial such as *E. coli, S. aureus, Bacillus megaterium,* and *Pseudomonas aeruginosa* (Kher et al., 2019).

Prosopis juliflora

Prosopis juliflora (*P. juliflora*) is an invasive plant species that has been used as firewood in many countries for 150 years (Madhu et al., 2020). Alkaloids extracted from *P. juliflora* such as juliflorine, julifloricine, julfloridine, and juliprosinene can be used as an alternative treatment in the therapy of subclinical bovine mastitis (Shah et al., 2018). Previous studies showed that the combination of Juliflorinine and juliprosinene compound in *P. juliflora* has an antibacterial effect against *E. coli*, S. *aureus, Klebsiella pneumoniae*, and *Pseudomonas aeruginosa* (Shah et al., 2018). An intramammary infusion of an affected quarter with normally occurring alkaloids at a concentration of as little as 1%, administered for five consecutive days and nights, resulted in a significant increase in somatic cell count, improved antibacterial activity, and immune modulation simply by amplifying the gene sequence of IL-1 and IL-6 (Shah et al., 2018).

Limitations of using plant extracts and essential oil

The biological activity of plant extracts and EOs is influenced by various factors, such as the type of solvent, the method of plant extraction, phenotype, storage conditions, water, climate, and soil. These factors cause changes in secondary metabolites responsible for their therapeutic and biological properties (Andrade et al., 2017). Also, using a plant extract, or EO as medicine requires multiple clinical trials to prove its effectiveness. Therefore, future studies should pay more attention to the extraction methods, the formulation of plant extracts and essential oils, and the best methods of using these products (Isman, 2017). Other aspects that should be considered are the effect of extracts and essential oils on the immune system and the composition of milk (Abboud et al., 2015).

Therefore, due to the lack of clinical testing, it is suggested that more attention be paid to the clinical evaluation of these extracts and EOs as medicinal products in the future.

Conclusion

Alternative therapies for the treatment of mastitis were discussed in detail in this review. Plant extracts and EOs have properties that could be used to treat mastitis. Several experiments examining the therapeutic effects of common local plants and EOs on mastitis were discussed in this review article. Medicinal plants and EOs, due to their naturalness and great diversity, have the potential to be used as alternative medicines. They are attractive to pharmaceutical companies and have shown good profitability. Due to the resistance of microorganisms to current drugs, plant extracts and EOs are considered viable alternatives for the treatment of mastitis, which should be proven in future experiments.

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Not applicable

Conflict of interest statements

The authors declare that there is no conflict of interests.

Ethical approval

Not applicable.

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