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# A REVIEW ON THE NUTRITIONAL VALUE, ANTIMICROBIAL ACTIVITIES AND PRESERVATIVE EFFECTS OF THYME AND CORIANDER

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## ABSTRACT

Thyme and coriander are natural herbs that can be used as natural food additives and used effectively in the food industry, particularly the meat industry. Thyme and coriander are highly nutritious herbs that contain proteins, fats, vitamins, minerals, and other bioactive molecules. Thyme and coriander have documented antioxidant, antibacterial, and anti-inflammatory activities. Coriander, in particular, contains a high concentration of volatile oils, including limonene, geraniol, and linalool. These oils possess a significant role in their antimicrobial properties. Similarly, thyme contains thymol, which has well-documented antimicrobial and antioxidant activities. The purpose of this study was to spotlight the antimicrobial activities of thyme and coriander, and the possibility of employing them as preservatives in the food industry. This literature review showed the possibility to use such natural additives in the extension of the shelf life of meat and meat products, improving aroma and flavor, and therefore, they can be used as ideal food preservatives.

***Keywords***: Thyme, coriander, antimicrobial activities, nutritional values, preservative effects

## INTRODUCTION

The population of the world is expected to reach 9 billion people by 2050. The United Nations (2015) and Wicks *et al.* (2019) agreed that the output of all agricultural food commodities will need to be increased in order to accommodate the expected considerable increase in the population.

A vital component of human nutrition around the world is meat. Meat can be contaminated by microorganisms and chemicals throughout the entire production process (Tshabalala *et al.,* 2021). A wide range of food preservation methods are utilized by the meat manufacturer, in order to guarantee the safety of the food and extend its shelf life. According to Vieira *et al.* (2021), these include bioactive natural chemicals, as well as organic acids, that can extend the shelf life of meat products and maintain the keeping quality.

According to Radnitz *et al.* (2020), numerous essential oils, including thyme oil, possess antibacterial characteristics. These oils demonstrate these capabilities by breaking the lipid bilayer of bacteria and

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causing the breakdown of the cell membrane. In meat products, organic acids have the potential to function as effective natural antimicrobials. They have demonstrated a substantial level of effectiveness; nonetheless, the important issue to consider is the possibility of changes in flavor and color. Organic acids and their salts are known as some of the most often used preservatives in the meat industry (Ben Braek and Smaoui, 2021). These substances are connected with a multitude of benefits; some of which include the widespread acceptance that they are safe, the absence of a maximum daily consumption restriction, the fact that they are affordable, and the ease with which they may be manipulated (Santiesteban-López *et al.,* 2022). According to Luong *et al.* (2020), the microbiological and biochemical degradation of beef products is still being inhibited using both conventional and modern approaches. According to Tornuk *et al.* (2015), the aerobic plate count (APC) is one of the most reliable indications of microbial spoilage in meat. On the other hand, pH, total volatile basic nitrogen (TVBN), and thiobarbituric acid reactive substances (TBARS) are considered the most trustworthy indicators of chemical degradation of meat.

Coriander is a prominent herb that belongs to the Apiaceae family and is largely grown in the subcontinent. Coriander is scientifically known as *Coriandrum sativum L*. According to Kaiser *et al.* (2013), the presence of antioxidants, antibacterial, and anti-inflammatory activities in its leaves is noteworthy. According to Kačániová *et al.* (2020) and Palmieri *et al.* (2020), the leaves naturally contain a high concentration of volatile oils, including limonene, geraniol, and linalool. These oils have a significant role in the antibacterial, antifungal, and antioxidant properties of the leaves. In order to benefit from this plant, it is necessary to acquire these bioactive chemicals by extraction. Traditional extraction techniques that utilize organic solvents could have negative consequences for both the environment and people using them. It is also possible that residues from these solvents will remain in the extracts, which will render them inappropriate for use in the processing of food. Green extraction technologies, on the other hand, are acknowledged for their ability to eliminate dangerous substances, which in turn ensures the creation of safe food for consumption (Soquetta *et al.,* 2018).

The purpose of this study was to shed light on the antimicrobial activities of thyme and coriander and the possibility of employing them as preservatives in the food industry.

## Nutritional value of thyme

The *Serpyllum herba* plant demonstrates heterogeneity across a variety of publications and research. This variability is most likely attributed to a number of factors, including plant variety, genetic differences, ambient circumstances, ecologyical factors, harvesting processes, and analytical techniques utilized. Based on the findings of previous research, on a dry weight basis, *Serpyllum herba* derived from India, has the following: protein (21.4 g/100 g), fat (5.5 g/100 g), carbs (11.9 g/100 g), starch (6.5 g/100 g), and amino acids (2 g/100 g). Wild thyme herbs contain a variety of different types of dietary fiber, including neutral detergent fiber (NDF) at 15.1 g/100 g, acid detergent fiber (ADF) at 10.6 g/100 g, lignin at 3.6 g/100 g, hemicellulose at 4.2 g/100 g, and cellulose at 7.1 g/100 g. There are 4.9 mg of vitamin A, 43.8 mg of vitamin C, and 13.7 mg of vitamin E in the food's vitamin content (mg/100g). The existence of bioactive chemicals is also observed, with (poly) phenols having a concentration of 86.6 mg/g, flavonoids having a concentration of 51.9 mg/g, and phytosterols having a concentration of 45.3 mg/g (Shahar *et al.,* 2023; Vasil'eva *et al.,* 2022).

**Nutritional value of coriander**

Every component of the *C. sativum* plant can be consumed; however, the two most frequently used parts of the plant are fresh leaves and dried seeds. In addition to being used as a vegetable, green leaves are also utilized in salads. These leaves are abundant in proteins, vitamins, and minerals such as calcium, phosphorus, and iron, in addition to fibers and carbohydrates. Essential oil (EO) is found in both the leaves and seeds of the plant. This oil is rich in a variety of compounds that give food products a distinct flavor and also serve as a preservative (Kalemba *et al.,* 2003).

***Coriandrum sativum* essential oil (CSEO)**

This oil is a triglyceride oil that is derived from the seeds of the sativum plant. The primary fatty acid present is petroselinic acid, which is a monounsaturated fatty acid. Therefore, this plant is an excellent source of lipids, particularly those high in petroselinic acid, as well as essential oil, which is abundant in linalool and is derived from both the seeds and the aerial sections of the plant. According to Ganesan *et al.* (2013), mature coriander leaves have a considerable amount of moisture (87.9%), significant amounts of protein (3.3%), large amounts of carbohydrate (total sugars at 6.5%), and significant amounts of total ash (1.7%).

According to the European Food Safety Authority (EFSA, 2013), the CSEO is intended to be marketed as a dietary supplement for adults, who are in good health, with a stated maximum dosage of 600 mg per day. Yeung *et al.* (2011) found that the seeds have a considerable lipid content, which accounts for 28.4% of their total weight. This lipid content has the potential to be extremely profitable in the food company market. Furthermore, corianders provide evidence that Hippocrates made use of coriander in the medical practices of ancient Greece (Grieve, 1971). The use of sativum, either on its own or in combination with other herbal treatments, is recommended for the treatment of dyspeptic disorders, loss of appetite, convulsions, sleeplessness, and anxiety. Furthermore, this CSEO has shown promise as an antihyperglycemic drug, as evidenced by its demonstrated potential in improving blood glucose homeostasis (Gallagher *et al.,* 2003).

**Antimicrobial activities of thyme**

The essential oils that are believed to be the most effective agents against microbial pathogens are those that contain a high concentration of phenolic components. It was mentioned earlier that thyme essential oil is a "natural" preservative that is effective in preventing the growth of microorganisms (Meeran *et al.,* 2012). A synergistic interaction has been discovered among the many components of the essential oil, most notably between carvacrol and its precursor p-cymene (Kalemba *et al.,* 2003). This interaction has been confirmed through previous research. Furthermore, it is crucial to consider the influence of other elements present in these essential oils, including thymol and carvacrol, particularly because these constituents have the potential to demonstrate either antagonistic or synergistic effects (Vardar-Ünlu *et al.,* 2003).

Low temperatures decreased oxygen levels, and a low pH are the ideal physical conditions for maximizing the effectiveness of these oils (Burt, 2004). According to Juven *et al.* (1994), the presence of anaerobic conditions enhances the efficacy of thyme essential oil and thymol in combating bacteria like *Salmonella typhimurium* and *Staphylococcus aureus*. It has also been noted that Gram-positive bacteria are slightly more sensitive to the effects of essential oils than Gram-negative bacteria (Burt, 2004). This is in contrast to the fact that Gram-negative bacteria are also sensitive to essential oils. Nevertheless, the antimicrobial efficacy of these compounds is diminished when they are incorporated into food products due to interactions between the components of essential oil and the constituents of food. As a result, a higher concentration of essential oil is required in order to achieve results comparable to those observed *in vitro* (Singh *et al.,* 2003).

It was discovered that the interaction of thymol with bacteria in the oral cavity results in rupture of the plasma membrane of the bacterial cell. Because of this rupture, intracellular components are released in a very short amount of time. As a result of this infiltration, the presence of thymol leads to a decrease in the amounts of ATP found within the cell. Furthermore, in certain bacterial species, it also hinders the pathways responsible for the production of this vital biomolecule. There is a high probability that the substance infiltration generated by this molecule is responsible for the effect that thymol has on membrane potential (Shapiro and Guggenheim, 1995).

It was demonstrated that thymol has a great efficiency as a growth inhibitor for ruminal bacteria, including *Streptococcus bovis and Selenomonas ruminantium* (Evans and Martín, 2000). Additionally, tests conducted *in vitro* have demonstrated that thyme had strong antibacterial action against a variety of foodborne pathogens, including *Salmonella, Staphylococcus, and E. coli* at essential oil concentrations ranging from 5 to 20 µL (Borugă *et al.,* 2014; Manconi *et al.,* 2018).

The expectorant, anti-inflammatory, antitussive, analgesic, sedative, and anti-broncholytic actions of thyme can be linked to its antifungal, antibacterial, antiparasitic, and antiviral characteristics. Thyme also has anti-broncholytic qualities. In addition, the isomeric phenolic compounds carvacrol and thymol are effective against the pathogen *Bacillus cereus* (Ultee *et al.,* 2002).

The essential oils derived from *Thymus vulgaris* and from *Origanum vulgare* both exhibit strong effectiveness against bacteria throughout a wide range of temperatures (Lambert *et al.,* 2001). An example of this would be the research carried out by Burt et al. (2003), who investigated the impact of the essential oils derived from thyme and oregano, as well as the four principal components of these oils, namely thymol, carvacrol, ρ-cymene, and γ-terpinene, on *E. coli*. The results of their research demonstrated that thymol and carvacrol both contain different bactericidal capabilities, demonstrating that they are almost equally efficient against *E. coli*. The antibacterial capabilities of the essential oil can be attributed to these two components, which exhibit an additive effect. On the other hand, the other primary compounds, notably the precursors ρ-cimene and γ-terpinene, do not have any effect on this particular bacterium. In contrast to the findings of Ultee *et al.* (2000), the absence of synergistic interaction between carvacrol and ρ-cymene is a noteworthy observation. The discrepancies discovered could be attributed to the physiological properties of the bacteria used in each investigation. This is because the cell wall structure of *Escherichia coli* and other Gram-negative bacteria can hinder the effectiveness of ρ-cymene (Vasala *et al.,* 1991).

It was demonstrated, in line with the findings of other studies, that thymol impairs the integrity of the plasma membrane in *E. coli* and modifies the electrical potential of the electrochemical potential. When Dorman and Deans (2000) investigated a variety of plant-derived antimicrobial agents, they discovered that the essential oil of thyme exhibited a wider spectrum of activity than other plant-derived antimicrobial agents. Their investigation of these components individually indicated that the phenolic compounds included in these oils, including thymol and carvacrol, exhibit more efficiency. On the other hand, ρ-cymene was determined to be the component with the least activity. A considerable contrast is detected between the antibacterial efficacy of carvacrol and its methyl ester, which is somewhat less effective. This examination further emphasizes the significance of the hydroxyl group within the phenolic framework, as it demonstrates that the hydroxyl group has a significant impact. In addition, the authors underlined the significance of the position of the hydroxyl group on the benzene ring, which is in opposition to the assertions stated earlier in this section. Besides, Domingo and López-Brea (2003) had hypothesized that the existence of hydroxyl groups in phenolic compounds is correlated with the toxicity of these compounds, and that the positioning of these groups influences the antibacterial efficacy of phenols. Furthermore, *Thymus albicans* and *Thymus mastichina*, both of which are distinguished by the presence of 1,8-cineole as their major component, demonstrate significant inhibitory effects against bacteria such as *Salmonella species, Staphylococcus aureus,* and *L. monocytogenes* as well. According to Faleiro *et al.* (1999), linalool, which is a terminal alcohol, has been shown to possess antibacterial properties against many species of Leishmania (Rosa *et al.,* 2003), as well as other microbes, such as *Lactobacillus plantarum, Citrobacter freundii, and Clostridium sporogenes* (Dorman and Deans, 2000). The ability of alcohols to denature the proteins of microbes is principally responsible for the fact that alcohols have a stronger bactericidal effect (Rota *et al.,* 2004).

**The antimicrobial properties of coriander:**

It has been discovered that aliphatic (2E)-alkenals and alkanals that have been isolated from fresh coriander leaves (Umbelliferae) and have bactericidal activities against *Salmonella choleraesuis sp. ATCC 35640*. The chemical known as (2E)-Dodecenal (C(12)) had the highest level of efficacy, with a minimum bactericidal concentration (MBC) of 6.25 microg/mL (34 microM). The drug known as (2E)-undecenal (C(11)) followed closely behind with an MBC of 12.5 mcg/mL (74 microM). These alpha- and beta-unsaturated aldehydes have been shown to possess bactericidal properties against *Salmonella spp*., according to time-kill curve investigations. They can inhibit *S. choleraesuis* at every stage of growth, and their bactericidal effect can be largely related to the fact that they are nonionic surfactants (Kubo *et al.,* 2004). Although it is most frequently used in culinary applications, coriander essential oil also has a long and illustrious history of use as a traditional healthcare cure. The seeds of *Coriandrum sativum L.* are dried and allowed to fully develop before being subjected to steam distillation to extract the oil. A colorless or pale yellow liquid, which is distinguished by a distinct aroma and a taste that is gentle, sweet, warm, and aromatic. Linalool is the primary component, accounting for around 70% of the total, which is characterized by these characteristics. Burdock and Carabin (2009) conducted a study on rats using oral gavage for 28 days; the No Observed Effect Level (NOEL) for coriander oil was around 160 mg/kg/day. The data from mutagenicity experiments conducted on the spice and its various extracts have generated conflicting results, despite the fact that coriander oil is not considered a clastogenic substance. Furthermore, the oil possesses broad-spectrum antimicrobial activities of broad-spectrum. Although it can induce irritation in rabbits, it does not appear to irritate people and is not considered a sensitizer. This is even though the complete spice has the potential to generate such reactions. The use of coriander oil as a food additive is considered safe at the present usage levels. This is due to coriander oil has been consumed in the past without causing any bad effects, and there has been no evidence of toxicity in the limited studies conducted, and the safety profile of its primary component, linalool, has been established (Burdock and Carabin, 2009).

Coriander essential oil (*Coriandrum sativum*) was tested for its antibacterial effects against Gram-positive and Gram-negative bacteria in a study carried out by Silva *et al.* (2011). The evaluation of antibacterial susceptibility was carried out by employing traditional microbiological techniques in conjunction with flow cytometry for assessing cellular physiology. Furthermore, the findings demonstrated that coriander oil exhibits antibacterial action against every strain of bacteria examined. In particular, it demonstrated bactericidal effects against almost all bacteria tested, except for *Bacillus cereus* and *Enterococcus faecalis*. Such results are noteworthy. The incorporation of propidium iodide, in conjunction with the simultaneous loss of a variety of cellular processes, including efflux activity, respiratory function, and membrane potential, provides evidence that the principal mechanism of action of coriander oil includes the disruption of membranes, which eventually results in the death of cells. According to Silva *et al.* (2011), these findings lend credence to the possibility of incorporating coriander oil into antibacterial compositions through its use.

In addition, the essential oil of coriander was tested to see whether it exhibited synergistic antibacterial properties when combined with six other antibiotics. These antibiotics included cefoperazone, chloramphenicol, ciprofloxacin, gentamicin, tetracycline, and piperacillin. In order to discover synergistic interactions, microdilution susceptibility tests and checkerboard assays were utilized to evaluate the antibacterial activity of coriander oil. When used in conjunction with chloramphenicol, ciprofloxacin, gentamicin, and tetracycline, the results revealed that coriander essential oil exhibited *in vitro* efficiency against *Acinetobacter baumannii*. According to Duarte *et al.* (2012), this *in vitro* interaction has the potential to improve the antibacterial efficiency of antibiotics such as ciprofloxacin, gentamicin, and other antibiotics. It was reported by Fujita *et al.* (2015) that the broth dilution method was utilized in order to evaluate the antibacterial effects of essential oil that was extracted from the fresh leaves of Polygonum odoratum Lour on the foodborne bacterium *Salmonella choleraesuis*.

Using antibiotics against Gram-positive bacteria (including methicillin-susceptible and methicillin-resistant *Staphylococcus aureus*, as well as *S. epidermidis*) and Gram-negative bacteria (such as *Pseudomonas aeruginosa* and *Escherichia coli*), Aelenei *et al.* (2019) investigated the antibacterial properties of coriander essential oil and its primary component, linalool, where it was effective against both Gram-positive and Gram-negative bacteria. A gas chromatography technique was combined with flame ionization and mass spectrometry detection in order to investigate the chemical makeup of the essential oil of coriander. Assays, including broth microdilution and checkerboard, were utilized in order to evaluate the effectiveness of coriander essential oil, linalool, and their combinations with a variety of antibiotics in terms of their antibacterial properties. A total of thirty-four distinct components were present in the essential oil, with linalool being the most abundant component, accounting for 70.11 percent. Both coriander essential oil and linalool had synergistic benefits when used with antibiotics (oxacillin, amoxicillin, gentamicin, ciprofloxacin, and tetracycline) to combat the bacterial strains examined. These synergistic combinations resulted in a considerable reduction in the minimum inhibitory concentrations of the antibiotics, and it was also shown that antibiotic resistance was reversed. The discovery of these medications has the potential to significantly advance the development of novel antibiotics for the treatment of bacterial illnesses.

**Preservative effects of coriander:**

Coriander oil is frequently used as a food ingredient or adjunct in a broad variety of products, including alcoholic drinks, tobacco, confections, pickles, dairy products, chewing gum, and meat sausages. The application limits for coriander oil range from 0.1 to 100 parts per million (ppm). The usefulness of coriander oil against a number of foodborne pathogens, including *S. aureus, C. jejuni, Shiga toxin-producing E. coli, L. monocytogenes,* and *Yersinia enterocolitica* was confirmed. Because of this, both the oil and its principal component, linalool, have been investigated from the perspective of their possible applications in the preservation of food. In order to determine whether coriander oil and linalool are helpful in preventing the growth of microorganisms in food products, evaluations were conducted using both direct addition and inclusion into films. For example, the direct addition of coriander oil (0.02% volume/weight) to minced beef led to a reduction in the number of Entero-bacteriaceae and assisted in the prevention of negative sensory changes associated with the meat spoilage, despite the fact that it did not impede the oxidation of myoglobin (Michalczyk *et al.,* 2012). An additional experiment found that the total elimination of *C. jejuni* was achieved with the direct integration of coriander oil into ground chicken and beef at a concentration of 0.5% (v/w). Following a contact duration of thirty minutes. On the other hand, lesser quantities of oil, specifically 0.1% and 0.25%, were able to obtain decreases in bacterial loads with about two and four logs, respectively (Rattanachaikunsopon and Phumkhachorn, 2010). The antibacterial action of coriander oil was limited against *L. monocytogenes* when it was integrated into a chitosan film, despite these approaches were successfully effective. According to Zivanovic et al.'s (2005) research, the inhibitory effects of essential oil within the chitosan matrix were not as prominent as those of the pure oil. To this day, the only known application of linalool in food preservation is the manufacture of low-density polyethylene (LPDE) films that include this component. The purpose of these films is to reduce the amount of microbiological contamination that occurs in Cheddar cheese (Suppakul *et al.,* 2008). It was shown that LPDE films that contained linalool at a concentration of 0.34% (w/w) considerably reduced the total aerobic bacteria, which resulted in a reduction in the natural microbial load in cheese samples (Suppakul *et al.,* 2008, 2011). The deterioration of food can be caused by microbial contamination. However, a significant percentage of this process can be traced to chemical changes that occur inside the food product itself. Among different chemical processes, oxidative deterioration is particularly significant. This is because it is responsible for the breakdown of pigments and lipids primarily. Therefore, the antioxidant capabilities of essential oils, in conjunction with their antimicrobial effects, are significant in the extension of the shelf life of the food (Bentayeb *et al.,* 2007; Lopez de Dicastillo *et al.,* 2011). Due to its antioxidant characteristics, coriander oil has been investigated for its possible use as an antioxidant in food products, in order to improve the oxidative stability of these products. In the process of preserving Italian salami, it has been successfully utilized as an antioxidant, demonstrating a greater capacity to reduce lipid oxidation compared to synthetic antioxidants. As a result, the shelf life of the product has been extended without a significant alteration in its sensory characteristics (Marangoni and de Moura, 2011a, b). Besides, coriander exhibited superior antioxidant activity during ghee frying compared to other synthetic antioxidants (Patel *et al.,* 2013).

**The preservative effects of thyme:**

Thyme was reported to have potent active compounds that exhibit significant antimicrobial properties against both fungi and bacteria (Oliva *et al.,* 2015). Thymus vulgaris has emerged as a prominent species within its genus, receiving considerable attention in scientific research (Patil *et al.,* 2021; Taghouti *et al.,* 2020). Thyme essential oils have garnered the most interest due to their biologically active constituents, which have demonstrated inhibitory effects on foodborne micro-organisms (Burt *et al.,* 2007; Sepahvand *et al.,* 2021). Despite thyme extracts contain a significant amount of flavonols, phenolic acids, flavanones, flavones, flavonoids, saponins, alkaloids, steroids, and tannins (Nieto, 2020). It is possible to find the essential oil of *Thymus vulgaris* within glandular peltate trichomes, which are found on both the upper and lower surfaces of the leaves. The extraction of oils from the blooming portions of the plant, primarily the leaves and flowers, is normally accomplished through a variety of techniques. These techniques include traditional hydro-distillation, steam distillation, steam and water distillation, maceration, expression, and empyreumatic distillation. Furthermore, in order to address the sensitivity and thermal instability of these compounds, a number of innovative techniques have been developed. These techniques include microwave-assisted essential oil extraction, ohmic extraction, supercritical fluid extraction, pressurized solvent extraction, and ultrasound-assisted extraction (Vouillamoz and Christ, 2020). Terpenoids and phenolic derivatives are the principal components of the essential oil (EO) extracted. These contents include thymol, carvacrol, α-terpineol, 1,8-cineole, borneol, geraniol, p-cymene, thujanol, γ-terpinene, and caryophyllene, as stated by Silva *et al.* (2021).

According to Ed-Dra *et al.* (2021), the composition of essential oils (EOs) is strongly influenced by a wide range of intrinsic, ecological, and technical factors, which results in a variety of distinctive biopreservative effects. The *in vitro* efficiency of thyme essential oil (EO) against important foodborne pathogens and other microbes linked with food has been investigated from 2015 to 2019 by Boskovic *et al.* (2015), Nezhadali *et al.* (2014), and Reyes-Jurado *et al.* (2019). According to the findings of De Carvalho *et al.* (2015), the minimum inhibitory concentration (MIC) of thyme essential oil (EO) against *Listeria monocytogenes* and *Staphylococcus aureus* was 2.5 microliters per milliliter. Similar findings were reported earlier by Rota *et al.* (2008), who indicated that the EO of *Thymus vulgaris (thymol chemotype)* inhibited the growth of various Gram-positive and Gram-negative bacteria, including *Salmonella enteritidis, Salmonella typhimurium, Escherichia coli O157:H7, Escherichia coli, Listeria monocytogenes, Yersinia enterocolitica, Shigella flexneri, Shigella sonnei, and Staphylococcus aureus*, with inhibition zones ranging from 19.6 to 45.0 mm. Additionally, thyme essential oil with higher quantities of thymol, p-cymene, and linalool displayed strong antibacterial action against seven strains of Enterobacteriaceae isolated (Benameur *et al.,* 2019). Within a similar framework, Ed-Dra *et al.* (2021) demonstrated that a half-minimum inhibitory dose (0.25%) of this volatile liquid caused damage that was not fatal to a number of different serotypes of *Salmonella enterica.*

According to Al-Bayati (2008), thyme essential oil has shown effectiveness against several pathogens, except for *Pseudomonas aeruginosa*. These pathogens included *Staphylococcus aureus, Bacillus cereus, and Proteus vulgaris*. Additionally, Kačániová *et al.* (2020) demonstrated that different doses of thyme essential oil (0.750 and 0.375 mL/mL) had substantial antibacterial activities against *Escherichia coli and Bacillus cereus*. In addition, a number of research studies have investigated the inhibitory effects of thyme essential oil on the formation of biofilm. It was demonstrated by Kang *et al.* (2018) that the essential oil of *Thymus vulgaris*, at a concentration of 0.5 mg/mL, prevented the production of biofilm by *Bacillus cereus* by 80.79%. The findings of this study were consistent with the findings of Desai *et al.* (2012), who found that a 24-hour exposure to thyme essential oil at a concentration of 0.25–0.5% considerably reduced the formation of *Listeria monocytogenes* biofilms on stainless steel surfaces and totally inactivated the bacterial cells. Additionally, Liu *et al.* (2020) revealed that thyme oil can limit the production of exopoly-saccharide and reduce cell adhesion in *Enterococcus faecalis* biofilms. This was accomplished by suppressing the transcription of the ebp and epa gene clusters.

Further validation of the antifungal properties of *Thymus vulgaris* was carried out by *Šegvić Klarić et al.* (2007), who compared the inhibitory effects of thyme essential oil and thymol against a variety of fungi. These fungi included *Absidia, Alternaria, Aspergillus, Chaetomium, Cladosporium, Mucor, Penicillium, Rhizopus, Stachybotrys, Trichoderma, and Ulocladium* species. With a minimum inhibitory concentration (MIC) that ranged from 3.2 to 50.2 μg/mL, the essential oil demonstrated a powerful antagonistic activity against the fungal species under investigation. In addition, Oliveira *et al.* (2020) proposed that the essential oil (EO) of thyme exhibits anti-aflatoxigenic qualities. To be more specific, the lowest dose of this volatile ingredient, which was 0.1 μL/mL, resulted in an 80% reduction in the synthesis of aflatoxin B1 by *Aspergillus flavus*, compared to the control group. The results of their molecular research demonstrated that a concentration of 0.25 μL/mL of the essential oil (EO) had a significant impact on the establishment and proliferation of the fungi. This was observed by downregulating all genes investigated, including lipA, meT, and laeA.

The incorporation of thyme essential oil into minced pork contaminated with *Listeria monocytogenes* was done by Aureli *et al.* (1992), in order to demonstrate the effectiveness of the volatile oil in *in vivo* circumstances. The outcomes of this investigation indicated that the application of the EO led to a steady reduction of viable *Listeria monocytogenes* by roughly two logs during the first week of storage. This reduction occurred over the course of the study. Furthermore, Pesavento *et al.* (2015) researched the antibacterial characteristics of beef meatballs treated with essential oil as well, where a concentration of 0.5% of thyme oil exerted bacteriostatic effects against *Listeria monocytogenes* at a temperature of 4°C. On the other hand, concentrations of 1% and 2% gradually reduced the microorganisms present in the samples analyzed. The integration of thyme essential oil into irradiated minced beef had a bacteriostatic effect against *Staphylococcus aureus, Listeria monocytogenes, Escherichia coli, and Salmonella enteriditis* at a temperature of 5 °C, (Barbosa *et al.,* 2009). A similar finding was reported by Amariei *et al.* (2016), about essential oils derived from rosemary (*Rosmarinus officinalis L.*), thyme, and oregano (*Origanum vulgare L.*) at concentrations ranging from 0.5% to 1.5% contributed to the microbiological stability of minced meat. As of the end of the third day, there was a significant decrease in the counts of lactic acid bacteria, yeasts, and molds in the samples supplemented with essential oils, compared to the control group. Because of this, the incorporation of these essential oils resulted in an improvement in the physicochemical qualities of minced meat, which in turn resulted in an extension of its shelf life.

It was established by Huang *et al.* (2021) that the integration of thyme essential oil into Chinese smoked horsemeat sausages significantly reduced the growth of members of the Enterobacteriaceae family. On the other hand, the levels of lactic acid bacteria remained generally stable throughout the various treatments. Additionally, Lucera *et al.* (2009) demonstrated that the incorporation of plant-derived bioactive compounds, specifically thymol and carvacrol, as independent antioxidants into air-packed poultry patties resulted in a significant reduction in lipid oxidation and the maintenance of a more uniform color, compared to the control sample.

There are six unique chemotypes of *Thymus vulgaris* that can be recognized based on the content of the essential oil (Silva *et al.,* 2021). According to Goncalves *et al.* (2017), thymol, which makes up a large amount of thyme essential oil (40-80%) (Burt *et al.,* 2007), is a vital component in the oil's ability to inhibit the growth of microorganisms and perform antioxidant functions. Therefore, this monoterpene derivative of cymene has been investigated for its prospective applications as an antiseptic, antioxidant, and antibacterial agent in both the food industry and the medical field (Silva *et al.,* 2021). It was reported that thymol, a natural biocide, can damage the outer membrane of microbial cells. In addition to facilitating the release of lipopolysaccharides and the uptake of 1-N-phenylnaphthylamine, it also induces modifications in the composition of fatty acids and phospholipids, influences the synthesis of genetic material, permeabilizes and depolarizes the cytoplasmic membrane, and causes the leakage of potassium ions, protons, and ATP.

According to Xu *et al.* (2008), this chain of events ultimately results in a lack of membrane potential and a disruption of the metabolic process that deals with energy. In support of these findings, Trombetta *et al.* (2005) demonstrated that thymol exhibited toxic effects against *Staphylococcus aureus* and *Escherichia coli*. These toxic effects are likely the result of thymol's influence on the lipid bilayer of plasma membranes, which compromises the integrity of cell membranes and causes the release of intracellular components. Similarly, Wang *et al.* (2017) investigated the antibacterial capabilities of thymol against *Staphylococcus aureus*. They discovered that the introduction of this phenolic monoterpene caused changes in the fatty acid composition of the membrane, which in turn caused the membrane's integrity to be disrupted. Additionally, it was shown that thymol interacts with the genomic DNA of *Staphylococcus aureus*, which leads to the aggregation of DNA molecules.

## CONCLUSION

The aforementioned literature clearly showed that thyme and coriander had clear antimicrobial activities, are rich in nutrients, and can be effectively used as natural preservatives in the food industry.

## CONFLICT OF INTEREST

The authors declare they have no conflict of interest.

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# استعراض القيمة الغذائية والأنشطة المضادة للميكروبات وتأثيرات الحفظ للزعتر والكزبرة

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الزعتر والكزبرة هما أعشاب طبيعية يمكن استخدامها كاضافات غذائية طبيعية وتستخدم بفعالية في صناعة الأغذية، وخاصة صناعة اللحوم. يحتوي الزعتر والكزبرة على البروتينات والدهون والفيتامينات والمعادن وجزيئات حيوية نشطة أخرى.الزعتر والكزبرة لهما أنشطة موثقة مضادة للأكسدة ومضادة للبكتيريا ومضادة للالتهابات. تحتوي الكزبرة، بشكل خاص، على تركيز عالٍ من الزيوت الطيارة، بما في ذلك الليمونين، الجيرانيول، واللينالول. تلعب هذه الزيوت دورًا كبيرًا في خصائصها المضادة للميكروبات. وبالمثل، يحتوي الزعتر على الثيمول الذي له أنشطة مضادة للميكروبات ومضادة للأكسدة. الغرض من هذه الدراسة هو تسليط الضوء على الأنشطة المضادة للميكروبات للزعتر والكزبرة وإمكانية استخدامهما كمواد حافظة في صناعة المواد الغذائية. استخلصت هذه المراجعة إمكانية استخدام هذه الإضافات الطبيعية في تمديد فترة صلاحية اللحوم ومنتجات اللحوم، وتحسين الرائحة والنكهة، وبالتالي يمكن استخدامها كمواد حافظة مثالية للأغذية.

الكلمات المفتاحية: الزعتر، الكزبرة، الأنشطة المضادة للميكروبات، القيم الغذائية، تأثيرات الحفظ