



The Antibacterial Activity of Cinnamon Essential oil against Foodborne Bacteria: A Mini-Review

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ABSTRACT

Background: Essential oils are volatile components which produced by different parts of the medicinal plants. These components have antibacterial potential and have been used throughout the world as a common, time-tested spice. The present study aimed to assess the antibacterial effects of cinnamon essential oil on several foodborne bacteria, including *Staphylococcus aureus*, *Bacillus cereus*, *Listeria monocytogenes*, *Escherichia coli*, *Salmonella typhimurium*, and *Pseudomonas aeruginosa*.

Methods: Literature search was performed in databases such as PubMed, Google Scholar, SID, Scopus, ScienceDirect, and Elsevier to find the relevant articles published during 1987-2018 using keywords such as medicinal plants, cinnamon essential oil, foodborne diseases, and foodborne pathogens.

Results: Cinnamon essential oil has been reported to have several antibacterial components, which could inhibit the growth of some foodborne pathogens. Therefore, it could be used in foods, cosmetics, and hygienic industries alone or in combination with other antimicrobial agents to reduce the risk of contamination and increase the shelf life of foods.

Conclusion: Proper doses of cinnamon essential oil can be applied as a food preservative in the food industry as long as the taste of the food is not affected.

1. Introduction

Food safety is a major global health concerns today. Approximately one-tenth of the world's population becomes ill due to the consumption of contaminated foods, and almost 420,000 die each year due to foodborne diseases.

Microorganisms are the main cause of the high prevalence of foodborne diseases worldwide [1]. Most cases of food poisoning are associated with bacterial contamination, especially gram-negative bacteria such as *Salmonella typhi*, *Escherichia coli*, and *Pseudomonas aeruginosa*. Moreover, gram-positive bacteria such as *Staphylococcus aureus* and *Bacillus cereus* are considered



to be infectious agents, which could cause foodborne diseases or spoilage [2]. According to statistics, 30% of the populations in industrialized countries develop foodborne infections each year [3]. Therefore, there have been growing concerns regarding food safety, attracting attention to the use of natural antimicrobial agents for the proper control of foodborne pathogenic and spoilage bacteria [1,4].

Historically, herbs and spices have been used as antioxidants, flavoring and appetizer compounds, and antimicrobial compounds against the spoilage caused by foodborne pathogenic bacteria. Herbs and spices have bacteriostatic and bactericidal effects and are able to inhibit the growth of numerous microorganisms, thereby increasing the shelf life of foods and preventing the decomposition of lipids through strong antioxidant activity [5-7].

Recently, food industries have become more interested in the use of natural preservatives [8]. Natural additives such as essential oils (EOs) and herbal extracts have been considered economically for their medicinal effects, low toxicity, and cost-effectiveness [9]. Furthermore, the interest in the potential applications of EOs has increased due to the antibiotic resistance phenomenon and development of natural preservatives in food production. In addition, EOs may represent an alternative to chemical antimicrobial agents against foodborne bacteria in the future owing to their desirable properties and applicable potential usage [10-12]. In general, the composition of herbal EOs varies depending on the geographical location, plant varieties, plant age, and drying and extraction methods during preparation. Moreover, factors such as temperature, pH, salt concentration, type of organism, and amount of the inoculated organism could affect the antimicrobial activity and minimum inhibitory concentration (MIC) of EOs [13].

Recently, spices have also attracted the attention of researchers with their beneficial physiological functions and antimicrobial properties. Among various spices, cinnamon is used throughout the world as a common, time-tested spice [14-16]. Cinnamon is obtained from several tree species from the genus *Cinnamomum* and is also known as *Cinnamomum verum* and true cinnamon tree (Ceylon cinnamon tree), belonging to the Lauraceae family with 250 species. The plant grows throughout India, China, Sri Lanka, and Australia [17]. The two important types of the plant are known as *C. zeylanicum* and *C. verum*, which are native to India and Sri Lanka, and the other two important species of *C. cassia* and *C. aromaticum* are native to China, Indonesia, Laos, and Vietnam.

Trans-cinnamaldehyde is the main component in the EO derived from the skin of *C. cassia*, while eugenol is the main component of *C. zeylanicum* [18,19]. According to the literature, cinnamon reduces the risk of colon cancer, cardiac diseases, high cholesterol, leukemia, urinary tract infections, and arthritis pain, while it also relieves cramps, improves systematic circulation, stimulates sweating, and removes weakness from the internal organs of the body. Cinnamon is also effective in the treatment of type II diabetes mellitus, insulin resistance, diarrhea, gastrointestinal and digestive disorders, and respiratory symptoms and it could also prevent hemorrhage.

Cinnamon is widely used in the food, cosmetic, and pharmaceutical industries [16]. Considering its fragrance and ability to eliminate mouth odor, cinnamon is also added

to chewing gum as a spice. Previous studies have shown that cinnamon affects various gram-negative and gram-positive bacteria, and its EO has antifungal, antibacterial, antiviral, antiparasitic, larvicidal, nematocidal, insecticidal, anti-inflammatory, and antioxidant properties [6,19-21]. Furthermore, the antimicrobial properties of cinnamon make this spice beneficial in the production of films and edible coatings, which are used for the packaging of various food products [22, 23].

The present study aimed to investigate and review the antibacterial effects of cinnamon essential oil components and their mechanisms against some important foodborne pathogenic bacteria.

2. Materials and Methods

In this study, the literature review was conducted via searching in databases such as PubMed, Google Scholar, SID, Scopus, ScienceDirect, Nature, and Elsevier for the related articles published in Persian and English during 1987-2018 using keywords such as "medicinal plants", "cinnamon essential oil", "foodborne diseases", and "foodborne pathogens". In addition, the search was focused on the terms of bacteria, including "*S. aureus*", "*B. cereus*", "*L. monocytogenes*", "*E. coli*", "*S. typhimurium*", and "*P. aeruginosa*". At the first stage, 98 articles were identified, 47 of which were relevant and selected for the review. Two independent reviewers read the articles and extracted the study data. Notably, a mini-review was conducted based on the data that were published and reported in the selected studies.

3. Results and Discussion

3.1. Impact of Cinnamon EO on Foodborne Pathogens

According to the literature, cinnamon EO could prevent the growth of *L. monocytogenes*, *S. aureus*, and *E. coli* at the concentrations of 0.03%, 0.04%, and 0.05%, respectively, while also killing these bacteria at the concentrations of 0.075%, 0.04%, and 0.1%, respectively [24]. Moreover, the antimicrobial activity of cinnamon EO has been reported with the inhibition zone diameter of 30 mm (IZD) against *L. monocytogenes* [25].

As reported by Smith Palmer *et al.* (2001), the 0.01% concentration of cinnamon EO could reduce *L. monocytogenes* to less than one log/CFU in low-fat soft cheese [26]. In another study, cinnamon EO could significantly reduce the production of enterotoxin A and B of *S. aureus* [27]. In addition, Hersch-Martinez *et al.* (2005) observed that the average IZD of cinnamon EO was 28.6, 18.1, and 11.4 mm for *S. aureus*, *E. coli*, and *P. aeruginosa*, respectively [28]. Another investigation showed that cinnamon ethanol extract could inhibit the growth of *S. aureus*, *E. coli*, and *P. aeruginosa* [29]. Furthermore, the aqueous extract of cinnamon has been reported to protect live cells against harmful hydroxyl radical DNA, which causes damage to the cellular organs. A significant association has also been suggested between the total phenolic content of cinnamon extract and broad-spectrum antibacterial activity against *E. coli*, *S. aureus*, and *B. cereus*, and its antioxidant activity has been confirmed as well ($P < 0.05$) [7].

According to the literature, as can be seen in Table 1 cinnamon EO has potent antibacterial activity against the pathogenic bacteria of meat spoilage, such as *L. monocytogenes* and *E. coli* [30]. In a study in this regard, Muthuswamy *et al.* (2008) proposed that cinnamon extract had more significant antimicrobial activity compared to potassium sorbate against *E. coli* growth in fresh apples during storage and could be used to increase shelf life and ensure food safety [1]. In addition, low concentrations of cinnamon EO could be used in food products such as apple juice (spoiled by *E. coli*) and flavored milk (spoiled by *P. aeruginosa*) to prevent spoilage [18]. Notably, herbal extracts such as cinnamon may inhibit the growth of microorganisms more effectively than methylparaben and could be a proper alternative to cosmetic products, ensuring their microbial purity during consumption and storage [31].

3.2. Combined Effects of Various Antimicrobial Compounds with Cinnamon EO

Several studies have investigated the combined effects of various antimicrobial compounds with cinnamon EO. Accordingly, the combination of three herbal extracts of cinnamon, shallot, and blueberries with the ratio of 8:1:1 could increase the synergistic inhibitory effects. In this regard, the IZDs of the mixture have been reported to be 30, 25, 24, 23, and 14 mm against *Salmonella typhimurium*, *P. aeruginosa*, *L. monocytogenes*, *E. coli*, and *S. aureus*, respectively [32]. In another study, the combined antimicrobial effects of cinnamon EO and nisin were observed within three and seven days on *S. typhimurium* and *E. coli* O₁₅₇:H₇ in apple juice, respectively, and the effects were enhanced by pH reduction [33]. Reports have also suggested that 50 ppm of cinnamon EO could prevent the growth of *B. cereus* at the temperature of 8°C during a 60-day period in carrot broth culture [34].

The combination of cinnamon and clove EOs in the vapor phase at the MIC level has been reported to exert synergetic inhibitory effects on *L. monocytogenes* and *B. cereus* in a dose-dependent manner [35]. Furthermore, 0.03% concentration of cinnamon EO at the temperature of 8°C has been shown to decrease the growth rate of *E. coli* O₁₅₇:H₇ and increase the shelf life of hamburger [36]. In an investigation conducted on cheese samples incorporated with cinnamon and clove extracts, the population of *L. monocytogenes* was reported to be below the detection limit (10² CFU/g) on the third day of storage [37]. On the other hand, Mashak *et al.* (2012) reported that 45 µl/100 ml of *Zataria multiflora* EO in broth combined with 30 µl/100 ml of *Cinnamomum zeylanicum* EO in broth significantly inhibited the growth of *B. cereus* during incubation at the temperature of 10°C ($P < 0.05$) [38].

According to previous findings, the antioxidant and antimicrobial activity of cinnamon EO is maintained when exposed to gamma radiation up to the dose of 25 kGy [39]. On the same note, cinnamon and *Origanum vulgare* added to a slice of meat contaminated with *L. monocytogenes* could decrease the growth rate by 19% and 10%, respectively [40].

A combination composed of cinnamon EO with nisin,

monolaurin, and EDTA has also been reported to have stronger antimicrobial effects against *S. aureus* and *E. coli* compared to cinnamon EO alone [39]. The application of sodium alginate containing nisin and the EOs of rosemary and cinnamon has been shown to increase chicken meat shelf life at refrigerating temperature through inhibiting the growth of some psychrophilic bacteria, such as *L. monocytogenes* and *Pseudomonas* species [23].

3.3. Antimicrobial Mechanisms of Plant EOs

Various mechanisms and pathways are involved in the antimicrobial properties of EOs, most of which are at the molecular level. One possible mechanism is irreversible damage to the bacterial membrane, thereby causing the leakage of the cytoplasmic materials, which leads to bacterial death. Another possible mechanism is inhibiting the production of amylase and protease, which hinders toxin production and electron transport, which causes the cells to coagulate and die [3]. Based on the examination of the morphology of the various bacteria, it could be concluded that cinnamon EO could destroy the bacterial cell membrane and lead to cell lysis and death [41].

Cinnamaldehyde inhibits the action of amino acid decarboxylase, which is active against many pathogenic bacteria. As an electronegative compound, cinnamaldehyde interferes with the biological processes involving electron transfer, thereby preventing the growth of microorganisms [41]. According to the literature, *S. aureus* and *E. coli* treated by cinnamon EO have a wide range of significant disorders, including bubble formation, cytoplasmic coagulation, cellular decomposition, and lack of cytoplasmic materials [42].

Gram-positive bacteria have only one layer in their wall as opposed to gram-negative bacteria, which makes them more sensitive than gram-negative bacteria to antibacterial agents [43]. In fact, the lipopolysaccharide component of the outer membrane of gram-negative bacteria prevents the penetration of the oil compounds [24, 40-44]. The inhibitory effects of EOs and their components are attributed to their hydrophobicity, which enables them to penetrate the bacterium and mitochondria membranes and disrupt the cellular structures. However, the excessive excretion of vital molecules and ions from bacterial cells eventually leads to cell death [41-45].

3.4. Consumption Precautions

EOs are generally recognized as safe (GRAS) since high concentrations of EOs are required for the reduction of bacterial growth in food systems compared to laboratory conditions, which causes changes in the organoleptic properties of food; however, their usage is often limited, and it is paramount to determine the lowest concentration that could prevent the growth of pathogenic bacteria without affecting the quality of foods [24, 46]. In rare cases, acute dermatitis and food allergies have been reported due to the use of cinnamon chewing gum [47]. Furthermore, cinnamaldehyde is known as the real allergen for contact dermatitis [19].

Table 1: Impact of cinnamon essential oil against bacterial food pathogens

The scientific name of cinnamon	Pathogen	Antimicrobial effect	Reference
<i>C. burmannii</i>	<i>Bacillus cereus</i> , <i>Listeria monocytogenes</i> , <i>Staphylococcus aureus</i> , and <i>Escherichia coli</i>	Growth inhibition, cidality effect	[15]
<i>C. zeylanicum</i>	<i>Salmonella typhimurium</i>	Growth inhibition	[11]
<i>C. zeylanicum</i>	<i>L. monocytogenes</i> , <i>S. aureus</i> , and <i>E. coli</i>	Growth inhibition, cidality effect	[31]
<i>C. cassia</i>	<i>S. aureus</i> , and <i>E. coli</i>	Growth inhibition	[30,32]
Cinnamon (In general)	<i>L. monocytogenes</i>	Growth inhibition	[33]
Cinnamon (In general)	<i>L. monocytogenes</i>	Growth decrease	[34]
<i>C. zeylanicum</i>	<i>B. cereus</i>	Growth inhibition	[43]
<i>C. zeylanicum</i>	<i>S. aureus</i> , <i>E. coli</i> , and <i>Pseudomonas aeruginosa</i>	Growth inhibition	[36]
<i>C. cassia</i>	<i>S. aureus</i>	Growth inhibition	[37]
<i>C. cassia</i>	<i>L. monocytogenes</i>	Growth decrease	[37]
Cinnamon (In general)	<i>Staphylococcus aureus</i> , <i>Escherichia coli</i> O ₁₅₇ : H ₇	Growth inhibition	[44]
<i>C. zeylanicum</i>	<i>Escherichia coli</i> O ₁₅₇ : H ₇	Growth decrease	[45]
<i>C. zeylanicum</i>	<i>E. coli</i> , <i>P. aeruginosa</i> , and <i>S. aureus</i>	Growth inhibition	[46]
<i>C. zeylanicum</i>	<i>L. monocytogenes</i> and <i>E. coli</i>	Growth inhibition, cidality effect	[39]

4. Conclusion

According to the results, cinnamon could be used for antimicrobial effects against the main pathogens causing foodborne diseases, as well as creating flavor and aroma in foods. In the future, the application of EOs in consumer services is likely to increase owing to the rise of green consumers, which encourages the use and expansion of the products that are derived from plants.

Authors' Contributions

M.R., M.E., and Y.D., designed the study. M.R., Z.N., M.H., directed the project. H.Sh., M.Gh., M. A., and Sh.Sh., wrote the article. All contributors discussed and commented on manuscript.

Conflict of Interest

The Authors declare that there is no conflict of interest.

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