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

Zohreh Nematollahi, Maryam Ebrahimi, Mojtaba Raeisi, Yousef Dadban Shahamat, Masood Ghodsi Moghadam, Mohammad Hashemi, Shiva Shabani, Hessam Shirzad

a. Food, Drug and Natural Products Health Research Center, Golestan University of Medical Sciences, Iran. b. Laboratory Sciences Research Center, Golestan University of Medical Sciences, Gorgan, Iran. c. Infectious Disease Research Center, Golestan University of Medical Sciences, Gorgan, Iran. d. Environmental Health Research Center, Golestan University of Medical Sciences, Gorgan, Iran. e. Student Research Committee, Mashhad University of Medical Sciences, Mashhad, Iran. f. Department of Nutrition, Faculty of Medicine, Mashhad University of Medical Sciences, Mashhad, Iran. g. Food and Drug Deputy, Golestan University of Medical Sciences, Gorgan, Iran.

*Corresponding author: Laboratory Sciences Research Center, Golestan University of Medical Sciences, Gorgan, Iran. Postal code: 4917887399. E-mail address: Raeisi.mojtaba@yahoo.com

ARTICLE INFO

Article type: Review article

Article history: Received: 27 May 2020 Revised: 13 July 2020 Accepted: 10 September 2020

DOI: 10.29252/jhehp.6.3.1

Keywords: Cinnamon Essential oil Antimicrobial effect Foodborne diseases

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 concern 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, Hersh-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 (spiced by E. coli) and flavored milk (spiced 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 synergistic 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 Cinnamon 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 cytoplasmatic 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 cytoplasmatic 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].
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.

Acknowledgments

Hereby, we extend our gratitude to the National Institute for Medical Research Development for the financial support of this research project (Grant No. 964459).

References

1. Muthuswamy S, Rupasinghe H, Stratton G. Antimicrobial Effect of Cinnamon Bark Extract on Escherichia coli O157: H7, Listeria innocua and Fresh-Cut Apple Slices. J Food Safety. 2008; 28(4): 534-49.
2. Mostafa AA, Al Askar AA, Almaary KS, Dawoud TM, Sholkamy EN, Bakri M. Antimicrobial Activity of some Plant Extracts Against Bacterial Strains Causing Food Poisoning Diseases. Saudi J Biol Sci. 2018; 25(2): 361-6.
3. Burt S. Essential Oils: Their Antibacterial Properties and Potential Applications In Foods. A Review. Int J Food Microbiol. 2004; 94(3): 223-53.
4. Sadeghi A, Ebrahimii M, Raeisi M, Nematoillahi Z. Biological Control of Foodborne Pathogens and Aflatoxins by Selected Probiotic Lab Isolated from Rice Bran Sourdough. Biocontrol. 2018; 130: 70-9.
5. Bharath M, Azeem M, Basha S, Keerthan H. Antimicrobial Activity of Cinnamon Extracts against Foodborne Pathogens E. Coli, S. Typhimurium and S. aureus and L. Monocytogenes. Curr Nutr Food Sci. 2016; 11(6): 86-72.
6. Nabavi S, Di Lorenzo A, Izadi M, Sobarzo Sanchez E, Daglia M, Nabavi SM. Antibacterial Effects of Cinnamon: from Farm to Food, Cosmetic and Pharmaceutical Industries. Nutrients. 2015; 7(9): 7729-48.
7. Rakshit M, Ramalingam C. In-vitro Antibacterial and Antioxidant Activity of Cinnamon (Cinnamomum zeylanicum) Aqueous Bark Extract in Reference to Its Total Phenol Content as Natural Preservative to Food. Int J Biol Biotechn. 2011; 8(4): 529-37.
8. Raeisi M, Tajik H, Aminzare M, Sangin Abadi S, Yarahmadi A, Yarahmadi M. The Role of Nisin, Monolaurin, and Edta in Antibacterial Effect of Rosmarinus Officinalis L and Cinnamomum zeylanicum Blume Essential Oils on Foodborne Pathogens. J Essent Oil Bear Pl. 2016; 19(7): 1709-20.
9. Aminzare M, Abassi Z, Amiri E, Hashemi M, Raeisi M, Mousavi N, et al. Colibacillosis Phytotherapy: an Overview. On the Most Important World Medicinal Plants Effective on Escherichia Coli. J Pharmaceut Sci Res. 2017; 9(5): 629.
10. Akhondzadeh Basti A, Aminzare M, Razavi Rohani S, Khajani A, Noori N, Jebelli Javan A, et al. The Combined Effect of Lysozyme and Zataria multiflora Essential Oil on Vibrio Parahaemolyticus. J Med Plants. 2014; 2(30): 27-34.
11. Moradi M, Hassani A, Ehsani A, Hashemi M, Raeisi M, Naghibi S, et al. Phytochemical and Antibacterial Properties of Origanum vulgare spp. Gracile Growing Wild in Kurdistan Province of Iran. J Food Qual Hazards Control. 2014; 1(4): 120-4.
12. Moritz CMF, Rall VLM, Saeki MJ, Fernandes Junior A. Assessment of Antimicrobial Activity of Cinnamon (Cinnamomum zeylanicum) Essential Oil Combined with Edta and Polyethylene Glycol In Yogurt. Acta Sci Technol. 2015; 99: 104-10.
13. Rahnama M, Ashghary M. Antimicrobial Effects of Plant Essential Oils Rosemary, Cinnamon, Oregano and Cumin, Alone and in Combination with Nisin against Salmonella Typhimurium. J Zoonoses Res. 2013; 1: 17-25.
14. Cui H, Zhou H, Lin L, Zhao C, Zhang X, Xiao Z, et al. Antibacterial Activity and Mechanism of Cinnamon Essential Oil and Its Application in Milk. Food Control. 2016; 62(2).
15. Sian B, Cai YZ, Brooks JD, Gorke H, Chemistry F. Antibacterial Properties and Major Bioactive Components of Cinnamon Stick (Cinnamomum Burmannii): Activity against Foodborne Pathogenic Bacteria. J Agric Food Chem. 2007; 55 (14): 5484-90.
16. Vazirian M, Alehabib S, Jamalifar H, Fazeli M, Toosi AN, Khanavi M. Antimicrobial Effect of Cinnamon (Cinnamomum verum J. Presl) Bark Essential Oil in Cream-Filled Cakes and Pastries. Res J Pharm. 2015; 2(4): 11-6.
17. Prasad KN, Yang B, Dong X, Jiang G, Zhang H, Xie H, et al. Flavonoid Contents and Antioxidant Activities From Cinnamomum Species. Innov Food Sci Emerg. 2000; 10(4): 627-32.
18. Nimje PD, Garg H, Gupta ASN, Katyar M, Ramalingam C. Comparison of Antimicrobial Activity of Cinnamomum zeylanicum and Cinnamomum Cassia on Food Spoilage Bacteria and Water Borne Bacteria. Der Pharmacia Lettre. 2013; 5(1): 53-9.
19. Ooi LS, Li Y, Kam SL, Wang H, Wong EY, Ooi V. Antimicrobial Activities of Cinnamon oil and Cinnamaldehyde from the Chinese Medicinal Herb Cinnamomum Cassia Blume. Am J Chin Med. 2006; 34(3): 511-22.
20. Sangal A. Role of Cinnamon as Beneficial Anti diabetic Food Adjunct: A Review. Adv Appl Sci Res. 2011; 2(4): 440-50.
21. Vangalapati M, Satya NS, Prakash DS, Avanigadda S. A Review on Pharmacological Activities and Clinical Effects of Cinnamon Species. *Res J Pharm Biol Chem Sci*. 2012; 3(1): 653-63.

22. Hosseini SM, Razavi SH, Mousavi SM. Studies on Physical, Mechanical, Antibacterial and Microstructural Properties of Chitosan Edible Films Containing Thyme and Cinnamon Essential Oils. *Elec J Food ProcESS Pres.* 2010; 33(6): 727-43.

23. Raesi M, Tabareai A, Hashemi M, Behnampour N. Effect of Sodium Alginate Coating incorporated with Nisin, *Cinnamomum zeylanicum*, and Rosemary Essential Oils on Microbial Quality of Chicken Meat and Fate of Listeria monocytogenes during Refrigeration. *Int J Food Microbiol*. 2016; 238: 139-45.

24. Smith Palmer A, Stewart J. Fyle L. Antimicrobial Properties of Plant Essential Oils and Essences against Five Important Food-borne Pathogens. *Let Appl Microbiol*. 1998; 26(2): 118-22.

25. Firouzi R, Azadbakht M, Nahinejad A. Anti-listerial Activity of Essential Oils of Some Plants. *J Appl Anim Res*. 1998; 14(1): 75-80.

26. Smith Palmer A, Stewart J. Fyle L. The Potential Application of Plant Essential Oils as Natural Food Preservatives in Soft Cheese. *Food Microbiol*. 2001; 18(4): 463-70.

27. Smith Palmer A. Stewart J. Fyle L. Influence of Subinhibitory Concentrations of Plant Essential Oils on the Production of Enterotoxins a and b and α-Toxin by Staphylococcus Aureus. *J Med Microbiol*. 2004; 53(10): 1023-7.

28. Hersch Martinez P, Leanos Miranda B, Solorzano-Santos FF. Antibacterial Effects of Commercial Essential Oils and Oils of Some Plants. *J Appl Anim Res*. 1998; 14(1): 75-80.

29. Senhaji O, Faid M, Elachoumi M. Antibiosis By Cinnamon Extracts Against Antibiotic Resistant Strains. *Int J Agric Biol*. 2005; 7(3): 724-8.

30. Ojagh S, Rezaei M, Razavi S, Hosseini S. Investigation of Antibacterial Activity Cinnamon Bark Essential Oil (*Cinnamomum zeylanicum*) in Vitro Antibacterial Activity Against Five Food Spoilage Bacteria. *Iran J Food Sci Technol*. 2012; 9(35): 67-76.

31. Herman A, Herman AP, Domagalska BW, Młynarczyk A. Essential Oils and Herbal Extracts as Antimicrobial Agents in Cosmetic Emulsion. *Indian J Microbiol*. 2013; 53(2): 232-7.

32. Hsieh PC, Mau JL, Huang S. Antimicrobial Effect of Various Combinations of Plant Extracts. *Food Microbiol*. 2001; 18(1): 35-43.

33. Yuste J, Fung D. Inactivation of *Salmonella Typhimurium* and Escherichia Coli O157:H7 in Apple Juice by a Combination of Nisin and Cinnamon. *J Food Prot*. 2004; 67(2): 371-7.

34. Valero M, Salmeron M. Antibacterial Activity of 11 Essential Oils Against Bacillus Cereus in Tyndallized Carrot Broth. *Int J Food Microbiol*. 2003; 85(1-2): 73-81.

35. Gohi P, López P, Sánchez C, Gómez-Lus R, Becerril R, Nerín C. Antimicrobial Activity in the Vapour Phase of A Combination of Cinnamon and Clove Essential Oils. *Food Chem*. 2009; 116(4): 982-9.

36. Noori N, Tooryan F, Sokni N, Akhondzadeh A, Misaghi A. Preservation Effect of *Cinnamomum zeylanicum* Blume, Essential Oil and Storage Temperature on the Growth of E. Coli O157:H7 in Hamburger Using Hurdle Technology. *Food Sci Tech*. 2010; 7(27): 35-42.

37. Shan B, Cai YZ, Brooks JD, Corke H. Potential Application of Spice and Herb Extracts as Natural Preservatives in Cheese. *J Med Food*. 2011; 14(3): 284-90.

38. Mashak Z, Moradi B, Moradi B. The Combined Effect of *Zataria multiflora* Boiss. and *Cinnamomum zeylanicum* Nees. Essential Oil on the Growth of Bacillus cereus in a Food Model System. *J Med Plants*. 2012; 2(42): 62-73.

39. Jamshidi M, Barzegar M, Sahara M, Technology F. Effect of Gamma Irradiation on the Antioxidant and Antimicrobial Activities of Cinnamon Powder. *J Nutr Sci Food Tech*. 2013; 7(4): 73-82.

40. Dussault D, Vu KD, Lacroix M. In Vitro Evaluation of Antimicrobial Activities of Various Commercial Essential Oils, Oleoresin and Pure Compounds against Food Pathogens and Application in Ham. *Mear Sci*. 2014; 96(1): 514-20.

41. Gupta C, Garg AP, Unjyal RC, Kumar M. Comparative Analysis of the Antimicrobial Activity of Cinnamon Oil and Cinnamon Extract on Some Food-Borne Microbes. *Afr J Microbiol Res*. 2008; 2(9): 247-51.

42. Becerril R, Gómez-Lus R, Goni P, López P, Nerín C. Combination of Analytical and Microbiological Techniques to Study the Antimicrobial Activity of a New Active Food Packaging Containing Cinnamon or Oregano against E. Coli and S. Aureus. *Anat Bional Chem*. 2007; 388(5-6): 1003-11.

43. Palombo EA, Semple S. Antibacterial Activity of Traditional Australian Medicinal Plants. *J Ethnopharmacol*. 2001; 77(2-3): 151-7.

44. Ribeiro Santos R, Andrade M, De Melo NR, dos Santos FR, De Araújo Neves I, De Carvalho MG, et al. Biological Activities and Major Components Determination in Essential Oils Intended for A Biodegradable Food Packaging. *Ind Crop Prod*. 2017; 97: 201-10.

45. Shareef A. Evaluation of Antibacterial Activity of Essential Oils of *Cinnamomum Sp.* and *Boswellia Sp.* *J Basrah Res*. 2011; 37(5A): 60-71.

46. Oussalah M, Caillet S, Saucier L, Lacroix M. Inhibitory Effects of Selected Plant Essential Oils on the Growth of Four Pathogenic Hacteria: E. Coli O157:H7, *Salmonella typhimurium*, Staphylococcus aureus and Listeria monocytogenes. *Food Control*. 2007; 18(5): 414-20.

47. Gabriel D, Vuicicic Boras V, Batelja Vuletic L, Vuletic M, Pavelic B, Glavina A. Cinnamon Chewing Gum Induced Oral Allergic Contact Stomatitis. *Res J Pharm Biol Chem*. 2019; 10(3): 29-31.