PLANT SCIENCE TODAY
ISSN 2348-1900 (online)
Vol x(x): xx–xx
https://doi.org/10.14719/pst.2745

HORIZON
e-Publishing Group
HePG

REVIEW ARTICLE

Bio-efficacies of essential oils against food-borne bacteria

Deepika Beniwal & Sarika Gupta*

Department of Biosciences and Biotechnology, Banasthali Vidyapith, Tonk -304022, Rajasthan, India

*Email: sarika.ashish@gmail.com, sarikagupta@banasthali.in

OPEN ACCESS

ARTICLE HISTORY

Received: 03 July 2023
Accepted: 23 November 2023

Available online
Version 1.0 : 31 March 2024

Check for updates

Additional information

Peer review: Publisher thanks Sectional Editor and the other anonymous reviewers for their contribution to the peer review of this work.

Reprints & permissions information is available at https://horizonepublishing.com/journals/index.php/PST/open_access_policy

Publisher's Note: Horizon e-Publishing Group remains neutral with regard to jurisdictional claims in published maps and institutional affiliations.

Indexing: Plant Science Today, published by Horizon e-Publishing Group, is covered by Scopus, Web of Science, BIOSIS Previews, Clarivate Analytics, NAAS, UGC Care, etc
See https://horizonepublishing.com/journals/index.php/PST/indexing_abstracting

CITE THIS ARTICLE

Beniwal D, Gupta S . Bio-efficacies of essential oils against food-borne bacteria. Plant Science Today (Early Access). https://doi.org/10.14719/pst.2745

Abstract

This review examines the impact of essential oils (EOs) in food manufacturing and their potential as natural preservatives. Food is a substance ingested by an organism and assimilated by the organism's cells to supply energy to maintain life and stimulate growth. Chemical preservatives like benzoates, nitrites, sulphites, and sorbates added to the processed food items have various side effects on humans. An approach that uses EOs enhance the shelf-life of the manufactured foods, which have no side effects on the consumer's health. EOs has shown significant antioxidant, and antimicrobial effects in food industries. Due to their various activities, EOs could be used as alternative preservatives to increase the shelf lives of processed food. Additionally, the use of EOs as natural preservatives aligns with the growing consumer demand for clean label and natural ingredients in food products. The potential applications of EOs in food preservation are wide-ranging, including their use in meat products, bakery products, dairy products, and beverages. Moreover, their effectiveness against a wide range of microorganisms, including pathogenic bacteria, yeast, and molds, makes them an attractive option for food preservation. Despite the potential benefits, there are some challenges associated with the use of EOs in food manufacturing. The purpose of this review was to advocate the use of EOs as natural, safe, and eco-friendly preservatives that have the potential to revolutionize the food industry by reducing the use of chemical preservatives and providing consumers with healthier and safer food products.

Keywords

bioactive compounds; antibacterial; antimicrobial; chemical preservatives

Introduction

Bacteria always exist right through the food production and infect food products in various ways, at the farming stage, by workers, fecal contamination by animals and insects. They are also contaminated by post-harvest source like handling by worker, processing equipments and infected from other food. These bacteria cause two major problems to food supplier as food borne-sickness and monetary loss related with food loss because of food contamination (1). The functions of food additives are to reduce or inactivate the bacteria present in street and packed foods (2). Overuse of chemical preservatives lowers food quality since they may be poisonous and cause microbiological deterioration, which alters food patterns and promotes the growth of pathogen. There is also a growing demand by food manufacturer to replace chemical based preservatives from food products in order to reduce their side effects (3) (Table 1). This makes food industries to seek “green” and “clean” logos for their product market outreach. World Health Organization (WHO) are advising consumers and food manufacturers to reduce salt level to reduce the possibility of heart related problems, but salt is commonly used as food preservatives in most processed food. Now a days, consumers are aware of the use of processed food having no chemical preservatives (4). Today’s trend is making use of natural additives or biocides rather than chemical preservatives. Natural components known as “biocides” have the ability to preserve food in a variety of way without having a harmful effect on the environment or people (5). The aim of the study was to show that, using EOs as natural preservatives to preserve food can reduce the need and negative impact of chemical preservatives and, enhance the quality of food products.

Table 1. Side effects of chemical preservatives.

S.No	Food products	Chemical preservatives	Health issues developed by chemical preservatives
1	Juice, tea, coffee	Benzoates	Brain damage, allergies, asthma, and skin rashes
2	Butter, vegetable oils	Butylates	High blood pressure, increase cholesterol level, effect kidney and liver function
3	Candies, bread, cakes, frozen pizza,	Caramel	Cause Vitamin B6 deficiencies, genetic effect and cancer
4	Pork, sausages, potato chips, instant teas, cake mix	Butylated Hydoxyanisole	Effect liver function

Plant based biocides: Essential oils

Plant based extracts are fragrant oily liquids extracted from plants, mostly spices and herbs (6). Essential oils have anti-microbial activity against large variety of toxic microbes (7). Essential oils with high vapour pressure have anti-bacterial potential against microorganisms (through the gas and liquid phase) has been reported under *in vitro* conditions (8). The mixture of EOs from thyme with sage and oregano with marjoram are active against *Listeria monocytogens* and *Escherichia coli*, they were found effective only when applied individually (9). EOs isolated from plant source and spices known for their antibacterial activity (clove, cinnamon, thyme and oregano) and their substance (cinnamaldehyde, carvacrol, eugenol and thymol) exhibit high antibacterial activity (10). EOs and extracts from plants (*Ocimum basilicum, Coriandrum sativum, Citrus limon, Cuminum cyminum, Anethum graveolens, Zingiber officinale, Laurus nobilis, Cymbopogon, Origanum majorana, Myristica fragrans, Salvia rosmarinus, Salvia officinalis, Satureja hortensis, Melaleuca alternifolia*) oils show medium to high activity against food borne pathogens (11). Eugenol is the component with anti-bacterial activity by clove-bud (*Eugenia caryophyllata*) oil, comprising of around 70-90% oil. Oregano oil is common source of carvacrol, which make up 60-70% of the oil (12). EOs are derived from plants and are used in food items to extend the shelf life of food by inhibiting the growth or survival of microbes.

History

The prospective use of various plant extracts and EOs to control the growth of food-borne bacteria *in vitro*. In particular, when applied in vapour phase, the study reports a significant improvement in the efficacy of EOs (13). Anti-microbial property of EOs and mode of action, constituents of EOs, nano-encapsulated EOs, and the mixture that can make possible applications to solve the problem of multi drug-resistant microbes (10). The alcoholic essence of plants was more effective than the aqueous essence of *Camellia sinensis* with significant mycelial growth inhibition, followed by *Citrus limon* and *Citrus limetta* when compared with synthetic preservatives (14). EOs of clove bud and cinnamaldehyde have anti-microbial activity and their mixture was active in reducing the development of *in vitro* inoculated food-borne microbes as well as the natural toxins of watermelon juice (15). Anti-microbial potential of peppermint oil and eugenol was evaluated over 2 (Gram-positive) and 2 (Gram-negative) bacteria. Both oils repressed the development of test bacteria with MICs (minimum inhibitory concentrations) of 0.25% or below (16). Bacterial analysis was conducted on *Panipuri,* a commonly consumed street food to assess the efficacy of EOs against isolated microbes. EOs are natural preservatives and have anti-bacterial nature against the foodborne bacteria found in street foods (17). Isolated EOs by hydro-distillation from the peel of citrus fruit *Citrus reticulate* Blanco were represented by GC-MS method. The main constituents were neryl acetate (1.1%), nerol (2.3%), β-caryophyllene (2.6%), geraniol (3.5%), geranyl acetate (3.9%), neral (14.5%), geranial (19.0%), limonene (46.7%) etc. The anti-fungal activity of the EOs were tested by technique of contaminated food and the volatile potential assay against 5 plants pathogenic fungi (*viz.; Alternari aalternata*, *Curvularia lunata*, *Fusarium oxysporum*, *Helmintho-sporium oryzae* and *Rhizoctonia solani*). In the poisoned food (PF) technique, the MIC for *A. alternata, C. lunata* and *R. solani* is 0.2 mL/100 mL, while the MIC for *H. oryzae* and *F. oxysporum* is >0.2 mL/100 mL (18).

Meats are prone to both oxidative and microbial spoilage; therefore Chitosan-Mint extract can be used as a preservative because it consists of both anti-oxidant and anti-microbial properties. While Mint extract have commendable anti-oxidant activity, it falls shorts in terms of anti-microbial efficacy. Conversely, Chitosan displays excellent anti-microbial properties but lacks robust anti-oxidant activity. In the 1,1-diphenyl-2-picrylhydrazyl (DPPH) assay, the IC_{50} value for the Chitosan-Mint mixture (17.8 µg/mL) was lower than that of Mint extract (23.8 µg/mL). The combination of Chitosan and Mint is strategically employed to maximize the generation of hydroxyl radicals and superoxide radicals (19). Seabuck thorn seeds extract with acetone, chloroform, ethyl acetate and methanol by soxhlet extractor for 8 hrs, exhibited anti-microbial and anti-oxidative potential. MIC values, with respect to MeOH extract (*B. cereus*, *B. coagulans*, *B. subtilis*, *L. monocytogenes*, *Y. entero -colitica*) were discovered to be 200, 300, 300, 300 and 350 ppm (20). Another study reported the anti-bacterial activity of EOs (cinnamic acid, carvacrol, euegenol, cinnamaldehyde, thymol and perillaldehyde) having MIC of 0.05–5 µL/mL *in vitro* against (*B. cereus, E. coli*, *L. monocytogenes, S. dysenteria, S. typhimurium* and *S. aureus*). Values are in the middle of 0.2–10 µL/mL, results indicating that gram-positive bacteria are more prone than gram-negative bacteria (6). Utilization of various non-chemical treatments, such as taste compounds, acetic acid, chitosan, deoxyfusapyrone, glucosinolates, fusapyrone, jasmonates, propolis and plants-based EOs, control fungal decaying of vegetables and fruits for prolonging shelf life (21).

The anti-oxidant and anti-microbial activity of phenolic substances extracted from naringenin-producing *S. cerevisiae* strain over the pure flavonoids naringenin and its prenylated derivatives, shows capacity as organic food-additives. Disk diffusion method was used to analyze anti-microbial activity towards (*S. aureus* ATCC 29213 and *E. coli* ATCC 25922) while N, N-dimethyl-p-phenylene diamine (DMPD) chemi-luminescence assay technique was used to determine anti-oxidant activity, based on DMPD radical scavenging potential. Results of yeast metabolites shows both strong anti-microbial and DMPD radical-scavenging potential making it suitable and usable as a source of biotic food additive (22). To ensure that food is safe for customers and of high microbiological quality, farms and the food industry mostly rely on the use of biocides as disinfectants and other antimicrobial agents and preservatives with antimicrobial capabilities. This demonstrates how various food processing methods may have an impact on the emergence of antimicrobial resistance. According to current research, there are various methods via which biocides and other anti-microbials might be chosen to be resistant to related anti-biotics (5). A suitable amount of *Rosmarinus officinalis* EOs is used to enhance the grade of meat because it slows down lipid oxidation and reduces the rancidity (23). The analysis explores two substitutes for regulating the growth of *L. monocytogenes* in raw cattle's meat, both relying on the utilization of rosemary and thyme EOs. This represents a novel and promising natural/organic approach to control pathogenic bacteria in meat industry (24). While the EOs of Baill (*Croton blanchetianus*) demonstrates effectiveness as an antibacterial components *in vitro*, their efficacy on fresh meat declines, necessitating an increase in the concentration of EOs to inhibit bacterial growth. The outcome showed a bacteriostatic impact against *Salmonella enteritidis* and a bacteriocidal effect against *Aeromonas hydrophila* and *Listeria monocytogenes* (25). Anti-microbial potential of two extracts from *Olea europaea* L. and wine, both rich in poly-phenols and three standards predicted as anti-oxidants (oleuropein, quercetin and hydroxytyrosol) were analyzed against five bacterial species (*E. coli*, *S. cerevisiae, S. poona*, *Bacillus cereus* and *C. albicans*) (26).

Composition of essential oils (EOs) and bacteriocins

EOs contain around 20–60 different bioactive components, with only two or three main elements existing at a high concentration of 20%–70% in comparision to others. Factors like location, natural habitats, maturity stage, harvest season, or extraction technique may have an impact on the components (27). EOs are type of secondary metabolites synthesized by plants that helps plants by protecting them against abiotic and biotic stress. They are primarily composed of other aromatic components, terpenes and aliphatic components that have lower molecular weight (6). Terpenes have chemical formula $(C_5H_8)_n$ and are categorized into many different groups: $(C_{10}H_{16})$ monoterpenes, $(C_{15}H_{24})$ sesquiterpenes, $(C_{20}H_{32})$ diterpenes, and $(C_{30}H_{40})$ triterpenes. Monoterpenes constitute major bioactive components about 90% of essential oils and are formed in the cell cytoplasm via the pathway of mevalonic acid. The major component includes hydrocarbons in the form of monoterpene, monoterpene alcohols, sesquiterpene alcohol, oxygenated monoterpenes, diterpenes, oxygenated sesquiterpenes, phenols, coumarins and aldehydes (27). Phenolic compounds with hydroxyl (-OH) groups like eugenol, thymol and carvacrol, are the highly effective against food-borne microbes as they interact with cell membranes of bacteria, leading to the outflow of cytoplasmic materials (28). The (Table 2) in this document mentions common EOs and their significant constituents (29–33).

Antibacterial mechanism of action of essential oils (EOs)

The anti-microbial properties of EOs are achieved through complex biochemicals sequential reaction that depends on the specific chemical component found in the oils (34). The action mechanism of EOs is highly turn on the main chemical components as well as the type of microorganisms targeted. EOs can control the microbial growth (bacteriostatic and fungistatic) or damage bacterial and fungal cells. To measure antimicrobial activity, scientists use a method called MIC (minimum inhibitory concentration), determined the little concentration of EOs have an anti-microbial property that can inhibit the growth of a microbes after a period of incubation (6). The antibacterial effects of EOs are caused by destabilizing the cellular structure of microorganisms, resulting in the destruction of membrane increase permeability and integrity. As a result, cellular activities such as energy production and membrane transport are disrupted. The lipophilic nature of EOs allowed them to enter opening channels of cell membrane of bacteria, causing the outflow of cytoplasmic components and cause ion loss (35). Additionally, the anti-bacterial effects of EOs can alter proton pumps and deplete ATP, resulting in a cascade effect that affects other cell organelles. Various constituents of essential oils, like trans-cinnamaldehyde, linalyl acetate, carvacrol, menthol and thymol, produce different antibacterial effects. For example, thymol, menthol, and linalyl acetate perturb the lipid-fraction of plasma membranes of bacteria, while carvacrol alters the composition of fatty-acids, affecting cell membrane permeability and fluidity. Trans-

Table 2. Essential oils with their major components.

S.No	Essential oil	Part	Major components	Methods for extraction of EOs	References
1	*Mentha arvensis*	Leaves	**Monoterpenoid:** iso-menthone (3.7%), menthone (4.3%), pulegone (1.3%) and Menthol (86.1%), **Aliphatic hydrocarbon:** Limonene (1.0%)	Steam-distillation	29
2	*Origanum vulgar*	Leaves and stem	**Monoterpene:** γ-terpene (23.69%) and Thymol (45.43%)	Steam-distillation	30
3	*Citrus limon* var. *pompai*	Leaves	**Aliphatic:** Limonene (29.8%) **Monoterpene:** Myrcene (9.7%), linalool (9.1%), and geraniol (8.9%)	Steam-distillation	31
4	*Syzygium aromaticum*	Bud	**Eugenyl acetate** (~20%) **caryophyllene** (12–17%) **Eugenol** (70–90%),	Steam-distillation	32
5	*Cinnamon zeylandiucum*	Stem	**Cinnamaldehyde** (50–90%), **Eugenol** (2–15%) and **Terpens:** Limonene (5–12%)	Steam-distillation	33

cinnamaldehyde penetrate into periplasm of the cell and interrupt bacterial cell functions (36) (Fig. 1).

Several food-borne bacteria, including *B. cereus, E. coli, L. monocytogenes, Salmonella* sp.*, S. aureus* can cause severe illness in humans (37). EOs of cedar is most inhibitory at the concentration of 100 and 300 ppm against *B. cereus* T and *C. botulinum* 62A (38). Studies have also been conducted on the antimicrobial activity of EOs and their bioactive elements against food-borne bacteria (39–48) (Table 3).

Essential oils in food industry as a preservatives

Here are some of the uses of EOs as food additives:

Food industry

In meat goods, it has been discovered that essential oils derived from herbs such as thyme, rosemary, and oregano possess antibacterial properties against food borne bacteria. For instance, a study found that a mixture of oregano and thyme EOs could help to reduce the growth of *L. monocytogenes* in cooked ham (49).

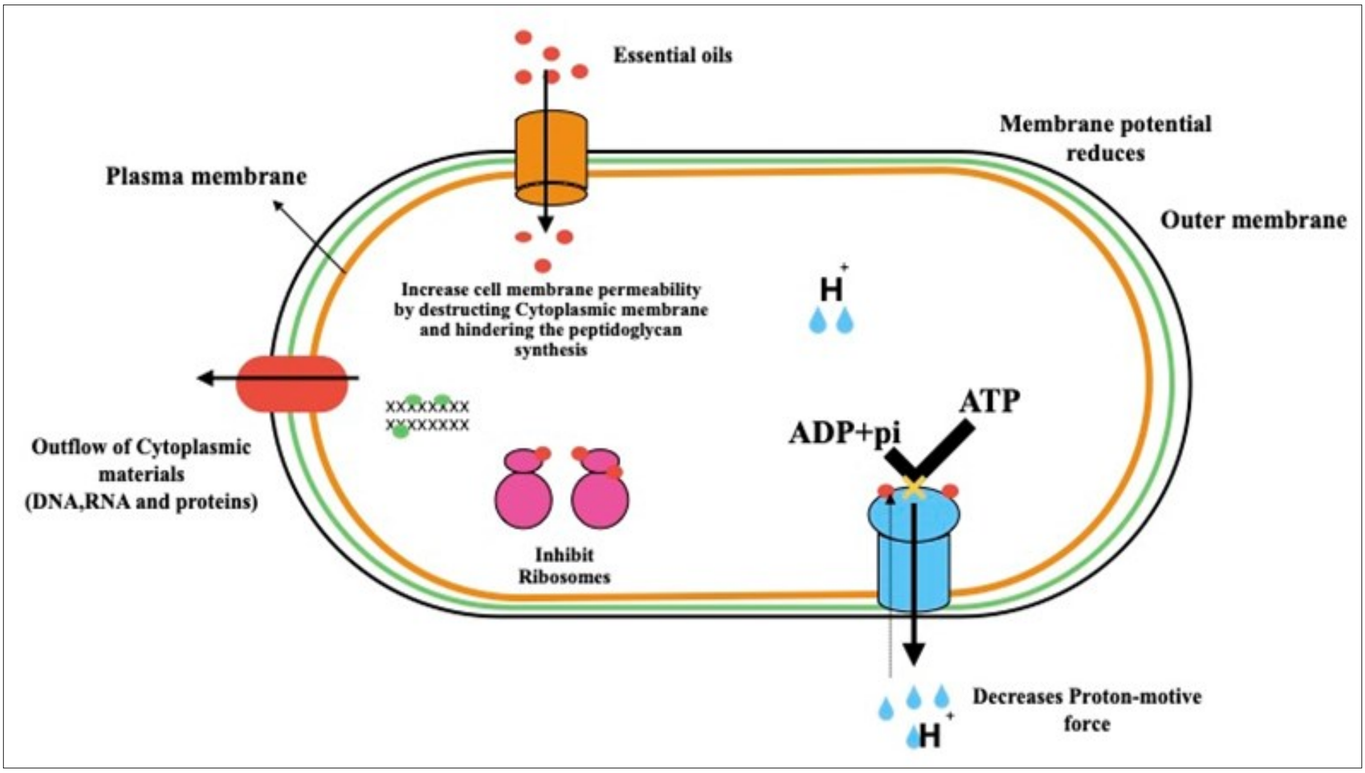

Fig. 1. Feasible anti-bacterial mechanism of action of EOs with their possible target sites.

Table 3. Essential oils and their bioactive components against food bacteria.

S.No	Essential oil	Major bioactive components with antimicrobial effects	Bacteria	References
1	*Mentha spicata*	Carone (78.76%), Limonene (11.5%)	*Listeria monocytogenes*	39
2	*Citrus uranium*	Limonene (77.37%)	*Staphylococcus aureus*	40
3	*Pistacia lentischi,*	β-mycerne (15.18%), Caracrol (29.19%)	*L. monocytogenes*	41
4	*Zingiber officinale*	α-zongiberene (24.96%), β-sesquiphellandrene (12.74%)	*L. monocytogenes, Salmonella*	42
5	*Mentha pulegium*	Pulegone (26.68%), Piperitenone (16.88%)	*L. monocytogenes*	43
6	*Coraiandrum sativum*	β-linalool (66.07%)	*Bacillius subtilis*	44
7	*Rosmarinus officinalis, Thymus vulgarise*	Thymol (25.05%) , p-cymene (39.18%), 1,8-cineole (45.27%) and Borneol (12.94%),	*Yersinia enterocoliti, L. monocytogenes, Salmonella enteritis, Escherichia coli,* and *Pseu-*	45
8	*Cymbopogon citratus*	Neral (50%), Geranial (35%)	*S. aureus, E. coli, Salmonella choleraesuis* and *L. monocytogenes*	46
9	*Cymbopogon citratus*	Neral (39%), Geranial (33.3%)	*S. aureus, E. coli, Bacillus cere-*	47
10	*Bunium persicum*	Cuminaldehyde (11.4%)	*E. coli O157:H7 L. monocytogenes*	48

Dairy products

Essential oils extracted from plants such as cinnamon, clove, and thyme have been found to inhibiting the growth of bacteria that cause spoilage and foodborne illness in dairy products. For example, a study found that by adding of clove EOs to yogurt helped to inhibit the growth of *E. coli* and *S. aureus* (50).

Bakery products

Essential oils extracted from plants such as cinnamon, thyme, and oregano have been found to have antimicrobial effects against bacteria and mold in bakery products. For instance, a study found that by adding oregano EOs to bread dough helped to inhibit the growth of mold during storage (51).

Beverages

Essential oils extracted from plants such as citrus, peppermint, and thyme have been found to have antimicrobial effects against bacteria and yeast in beverages. Also, a study found that the addition of lemon EOs to orange juice helped to reduce the growth of bacterial contamination during storage (52). It shows great significance to note that the users of EOs as preservatives by the food producers is still in its early stages and need to research to examine the safety and effectiveness. In addition, it is essential for food manufacturers to follow strict guidelines and regulations regarding the uses of EOs as food additives.

Conclusion

Consumers increasingly seek natural alternatives to chemical preservatives in the food industry. Plant-based compounds like essential oils (EOs) hold promise as effective biocides. These EOs can be applied directly or after ultra-filtration to preserve food, making it healthier and extending its shelf life. A small amount of EOs is needed for food technology to work, which can increase the EOs commercial potential while reducing their effect on the sensory aspects of food. They have the potential to improve food stability while being stored, inhibit the growth of bacteria that cause spoilage and foodborne illnesses, and reduce oxidation, making them effective natural preservatives. They are eco-friendly and safe for human consumption, making them suitable as additives for street food.

Acknowledgements

The authors express their gratitude towards Professor Ina Aditya Shastri, Vice Chancellor, Banasthali Vidyapith, Rajasthan for providing research facilities.

Authors' contributions

SG provided guidance, designed the study and performed the statistical analysis. DB wrote the first draft of the manuscript, managed the analyses of the study through managing the literature searches. Both authors read and approved the final manuscript.

Compliance with ethical standards

Conflict of interest: The authors declare that they have no conflict of interests.

Ethical issues: None.

References

1. Scallan E, Hoekstra RM, Angulo FJ, Tauxe RV, Widdowson MA, Roy SL, Jones LJ and Griffin MP. Foodborne illness acquired in the United States e major pathogens. Emerging Infectious Diseases 2011;17(1): 7-15. https://doi.org/10.3201/eid1701.P11101
2. Davidson PM, Sofos NJ and Branen LA. Antimicrobials in foods (3rd edditon). Boca Rotan 2005. CRC Press, ISBN: 9780429116841. https://doi.org/10.1201/9781420028737

3. David JRD, Steenson LR and Davidson PM. Expectations and applications of natural antimicrobials to foods: a guidance document for users, suppliers, research and development and regulatory agencies. Food Protection Trends 2013;33(4): 238-247.

4. World Health Organization. The World health report : 2002 : Reducing the risks, promoting healthy life. World Health Organization 2002. https://apps.who.int/iris/handle/10665/42510

5. Oniciuc AE, Likotrafiti E, Molina AA, Prieto M, Lopez M and Ordonez AA. Food processing as a risk factor for antimicrobial resistance spread along the food chain. Journal of Food Science. 2019;30: 21-26. http://dx.doi.org/10.1016/j.cofs.2018.09.002

6. Burt S. Essential oils: their antibacterial properties and potential applications in food – A review. International journal of Food Microbiology 2004;94(3):223–253. https://doi.org/10.1016/j.ijfoodmicro.2004.03.022

7. Dadalioglu I and Evrendilek GA. Chemical composition and antibacterial effects of essential oils of Turkish oregano, bay laurel, Spanish lavender and fennel on common foodborne pathogen. Journal of Agriculture and Food Chemistry 2004;52(26): 8255-8260. https://doi.org/10.1021/jf049033e

8. Elgayyar M, Draughon FA, Golden DA and Mount JR. Antimicrobial activity of essential oil from plants against selected pathogenic and saprophytic microorganism. Journal of food protection 2001;64(7): 1019-1024. https://doi.org/10.4315/0362-028x-64.7.1019

9. Gutierrez J, Barry- Ryan C and Bourke P. The antimicrobial efficacy of plant essential oil combinations and interactions with food ingredients. International Journals of Food Microbiology 2008;124(1):91-97. https://doi.org/10.1016/j.ijfoodmicro.2008.02.028

10. Chauhan S, Sharma K and Guleria S. Antimicrobial activity of some Essential Oils- Present status and future perspectives, Journal of Medicines 2017;4(3):58. https://doi.org/10.3390/medicines4030058

11. Davidson P M, Critzer F J and Taylor T M. Naturally occurring antimicrobials for minimally processed foods. Annual Review of Food Science and Technology 2013;4:163-190. https://doi.org/10.1146/annurev-food-030212-182535

12. Alma MH, Ertas M, Nitz S and Kollmannsberger H. Chemical composition and content of essential oil from the bud of cultivated Turkish clove (Syzygium aromaticum L.). BioResources 2007; 2(2): 265-269.

13. Nalla VK, Chauhan N, Sharma B, Bhatt KA and Ganti P. Microbial Contaminants in Commercial Beverages: Health Concerns and Suggestive Preservative Methods. Research & Reviews: A Journal of Microbiology and Virology 2019;9(1): 1–9.

14. Mohanka R and Priyanka. Plant extract as natural food preservatives against spoilage fungi from processed food. International Journal of Current microbiology and Applied Sciences, 2014;3 (8): 91-98. http://www.ijcmas.com

15. Siddiqua S, Anusha AB, Ashwini S L and Negi. Antibacterial activity of cinnamaldehyde and clove oil: effect on selected foodborne pathogens in model food system and watermelon juice. Journal of Food Science and Technology 2015;52(9):5834-5841. https://doi.org/10.1007/s13197-014-1642-x

16. Catherine AA, Deepika H and Negi SP. Antibacterial Activity of Eugenol and Peppermint Oil in Model Food System. Journal of Essential Oil Research 2012;24(5):481-486. http://dx.doi.org/10.1080/10412905.2012.703513

17. Das M, Rath CC and Mohapatra BU. Bacteriology of most popular street food (panipuri) and inhibitory effect of essential oils on bacterial growth. Journal of Food Science and Technology 2011;49(5): 564-571. https://doi.org/10.1007/s13197-010-0202-2

18. Chutia M, Bhuyan PD, Pathak MG, Sarma TC and Boruah P. Antifungal activity and chemical composition of Citrus reticulate Blanco essential oils against phytopathogen from North East India. Food Science and Technology 2009;42(3):777-780. http://dx.doi.org/10.1016/j.lwt.2008.09.015

19. Kanatt RS, Chander R and Sharma A. Chitosan and mint mixture: A new preservative for meat and meat products. Food Chemistry 2008;107(2):845-852. http://dx.doi.org/10.1016/j.foodchem.2007.08.088

20. Negi SP, Chauhan SA, Sadia AG, Rohinishree SY and Ramteke SA. Antioxidant and antibacterial activities of various seabuckthorn seed extracts. Journal of Food Chemistry 2005;92(1): 119-124. http://dx.doi.org/10.1016/j.foodchem.2004.07.009

21. Tripathi P and Dubey KN. Exploitation of natural products as an alternative strategy to control postharvest fungal rotting of fruit and vegetables. Journal of Postharvest Biology and Technology 2004;32(3): 235-245. https://doi.org/10.1016/j.postharvbio.2003.11.005

22. Kuan NR, Lyu X, Mark R and Chen NW. Antimicrobial and antioxident activity of phenolic metabolites from flavonoid- producing yeast: potential as natural food preservatives. Journal of Food Chemistry 2019;270(1):123-129. http://dx.doi.org/10.1016/j.foodchem.2018.07.077

23. Kahraman T, Issa G, Bingol BE, Kahraman BB and Dumen E. Effect of rosemary essential oil and modified-atmosphere packaging (MAP) on meat quality and survival of pathogens in poultry fillets. Brazilian Journal of Microbiology 2015;46(2): 591-599. https://doi.org/10.1590/S1517-838246220131201

24. Oliveira MMM, Brugnera FD and Piccoli HR. Essential oils of thyme and rosemary in the control of Listeria monocytogenes in raw beef. Brazilian Journal of Microbiology 2014;44(4): 1181-1188. https://doi.org/10.1590/s1517-83822013000400022

25. Melo AFG, Costa VCA, Garino F, Medeiors SR, Madurga SM and Neto QV. The sensitivity of bacterial foodborne pathogens to Croton blanchetianus Baill essential oil. Brazilian Journal of Microbiology 2014;44(4):1189-1194. http://dx.doi.org/10.1590/S1517-83822014005000009

26. Serra TA, Matias AA, Nunes MVA, Silva S, Duarta MC, et al. In-vitro evaluation of olive and grape based natural extracts as potential preservatives for food. Innovative Food Science and Emerging Technologies 2008;9(3):311-319. http://dx.doi.org/10.1016/j.ifset.2007.07.011

27. Arumugam G, Swamy MK, Sinniah UR. Plectranthusamboinicus (Lour.) Spreng: Botanical, Phytochemical, Pharmacological and Nutritional Significance. Molecules. 2016;21(4):369. https://doi.org/10.3390/molecules21040369

28. Gyawali R, Ibrahim SA. Natural products as antimicrobial agents. Food Control 2014;46:412-29. https://doi.org/10.1016/j.foodcont.2014.05.047

29. Chagas EC, Majolo C, Monteiro PC, Oliveira MRD, Gama PE and Bizzo HR. Composition of essential oils of Mentha species and their antimicrobial activity against Aeromonas spp. J. Essent. Oil Res. 2010; 32:209–215. http://dx.doi.org/10.1080/10412905.2020.1741457

30. Vinciguerra V, Rojas F, Tedesco V, Giusiano G and Angiolella L. Chemical characterization and antifungal activity of Origanum vulgare, Thymus vulgaris essential oils and carvacrol against Malassezia furfur. Nat. Prod. Res. 2019;33:3273–3277. https://doi.org/10.1080/14786419.2018.1468325

31. Fancello F, Petretto GL, Zara S, Sanna ML, Addis R and Maldini M. Chemical characterization, antioxidant capacity and antimicrobial activity against food related microorganisms of Citrus limon var. pompia leaf essential oil. LWT Food Sci. Technology 2016;69:579–585. https://doi.org/10.1016/j.lwt.2016.02.018

32. Bauer K, Garbe D, Surburg H. Common Fragrance and Flavor Materials: Preparation, Properties and Uses. Weinheim: WileyVCH; 2001. ISBN: 978-3-527-61237-6

33. Lens-Lisbonne C, Cremieux A, Maillard C, Balansard G. Methodes d'evaluation de l'activite´ antibacterienne des huiles essentielles: application aux essences de thym et de cannelle. J Pharm Belg. 1987;42(5):297– 302.

34. Nazzaro F, Fratianni F, De Martino L, Coppola R, De Feo V. Effect of essential oils on pathogenic bacteria. Pharmaceuticals 2013;6 (12):1451-74. http://dx.doi.org/10.3390/ph6121451

35. Raut JS, Karuppayil SM. A status review on the medicinal properties of essential oils. Industrial Crops and Products 2014; 62:250-64. http://dx.doi.org/10.1016/j.indcrop.2014.05.055

36. Trombetta D, Castelli F, Sarpietro MG, Venuti V, Cristani M, Daniele C, et al. Mechanisms of Antibacterial Action of Three Monoterpenes. Antimicrob Agents Chemother 2005;49(6):2474-8. http://dx.doi.org/10.1128/AAC.49.6.2474-2478.2005

37. Turgis M, Vu KD, Dupont C, Lacroix M. Combined antimicrobial effect of essential oils and bacteriocins against foodborne pathogens and food spoilage bacteria. Food Research International 2012;48(2):696-702.

38. Chaibi A, Ababouch LH, Belasri K, Boucetta S, Busta FFDdMAeB, Institut Agronomique et Veterinaire Hassan II, RabatInstitute, P.O. Box 6202, Rabat (Morocco)). Inhibition of germination and vegetative growth of Bacillus cereus T and Clostridium botulinum 62A spores by essential oils. 1997; v. 14. https://doi.org/10.1006/fmic.1996.0075

39. Moosavy, MH, Esmaeili S and Mostafavi E. Antibacterial effect of Mentha spicata essential oil on Listeria monocytogenes in traditional lighvan cheese. J. Food Saf. 2013;33:509–514. https://doi.org/10.1111/jfs.12083

40. Djenane, D. Chemical profile, antibacterial and antioxidant activity of Algerian citrus essential oils and their application in Sardina pilchardus. Foods 2015;4:208–228. https://doi.org/10.3390/foods4020208

41. Djenane D, Yangüela J, Montañés L, Djerbal M and Roncalés P. Antimicrobial activity of Pistacia lentiscus and Satureja montana essential oils against Listeria monocytogenes CECT 935 using laboratory media: efficacy and synergistic potential in minced beef. Food Control 2011;22:1046–1053. https://doi.org/10.1016/j.foodcont.2010.12.015

42. Noori S, Zeynali F and Almasi H. Antimicrobial and antioxidant efficiency of nanoemulsion-based edible coating containing ginger (Zingiber officinale) essential oil and its effect on safety and quality attributes of chicken breast fillets. Food Control 2018;84:312–320. https://doi.org/10.1016/j.foodcont.2017.08.015

43. Sadeghi E, Mohammadi A, Jamilpanah M, Bashiri M and Bohlouli S. Antimicrobial effects of Mentha pulegium essential oil on Listeria monocytogenes in Iranian white cheese. J. Food Qual. Hazards Control 2016;3:20–24. Available online at: http://jfqhc.ssu.ac.ir/article-1-226-en.html

44. Kačániová M, Galovičová L, Ivanišová E, Vukovic N L, Štefániková J, Valková V, et al. Antioxidant, antimicrobial and antibiofilm activity of coriander (Coriandrum sativum L.) essential oil for its application in foods. Foods 2020;9:282. https://doi.org/10.3390/foods9030282

45. Iseppi R, Sabia C, de Niederhäusern S, Pellati F, Benvenuti S, Tardugno R, et al. Antibacterial activity of Rosmarinus officinalis L. and Thymus vulgaris L. essential oils and their combination against food-borne pathogens and spoilage bacteria in ready-to -eat vegetables. Nat. Prod. Res. 2019;33:3568–3572. https://doi.org/10.1080/14786419.2018.1482894

46. Ortega RLA, Silva EBA, Vargas AI, Gonzalez AGA, Cruz VMR, Nazzaro F, et al. Combination of Cymbopogon citratus and Allium cepa essential oils increased antibacterial activity in leafy vegetables. J. Sci. Food Agric. 2017;97: 2166–2173. https://doi.org/10.1002/jsfa.8025

47. Vazirian M, Kashani ST, Ardekani MRS, Khanavi M, Jamalifar, Fazeli MR, et al. Antimicrobial activity of lemongrass (Cymbopogon citratus (DC) Stapf.) essential oil against food-borne pathogens added to cream-filled cakes and pastries. J. Essen. Oil Res. 2012;24:579–582. https://doi.org/10.1080/10412905.2012.729920

48. Ehsani A, Hashemi M, Naghibi SS, Mohammadi S and Khalili SS. Properties of Bunium persicum essential oil and its application in Iranian white cheese against *Listeria monocytogenes* and *Escherichia coli* O157: H7. J. Food Saf. 2016;36:563–570. https://doi.org/10.1111/jfs.12277

49. Yousefi M, Khorshidian N and Hosseini H. Potential Application of Essential Oils for Mitigation of *Listeria monocytogenes* in Meat and Poultry Products. Frontier in nutrition 2020;7:577287. https://doi.org/10.3389/fnut.2020.577287

50. Alayoubi M, Cakici A and Rimawi F. Use of different essential oils in concentrated yogurt as natural preservative. International Journal of Food Engineering Research. 2017;37(3): e12323. https://doi.org/10.17932/IAU.IJFER.2015.003/ijfer_v06i2001

51. Passarinho ATP, Dias NF, Camilloto G P, Cruz RS, Otoni CG, Moraes ARF, and Soares NdFF. (2014). Sliced Bread Preservation through Oregano Essential Oil-Containing Sachet. Journal of Food Process Engineering, 2014;37(1), 53–62. https://doi.org/10.1111/jfpe.12059

52. Eveline, Puteri GTPDM, Yakhin AL and Kartawiria I. Enhancement and Preservation of Fresh Orange Juice Using Citrus Essential Oils. Journal of Agricultural Science and Technology B 7 (2017)49-61. https://doi.org/10.17265/2161-6264/2017.01.005