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The Possible Role of Natural Food Additives for Controlling the Food Infection Bacteria

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Abstract: The food born bacteria can be transferred to human through consumption of contaminated food result in sporadic or outbreak onset. These days, due to consumer's request; research surveys have concentrated on application of natural preservatives to replace the ordinary chemical sanitizers as well as classical antimicrobial for healthier nutrition and avoiding the multidrug resistance phenomenon. Raising awareness of consumers about natural and healthy products enhances the popularity of plants extracts and spices. This new access should be useful for combating food borne bacterial pathogens; moreover, the shelf-life of food would be sustained.
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Introduction

Now days, the Food borne Disease Epidemiology Reference Group (FERG) was set up by the World Health Organization (WHO) to keep an eye on food borne diseases over the world. FERG supervised about 31 food borne pathogens that induced the highest morbidity and mortality among human population. The enormous of these infectious hazards exist in developing nations, with the majority of the infections and deaths take place in young beneath the age of five years (**WHO, 2018**).

Eventually, chemical sanitizers, as peracetic acid (PAA) and chlorine are ordinarily used to diminish microbial contaminants of several fresh vegetables and fruits as well as ready-to-eat food (RTE) products. But a lot of these chemicals are corroding and can deteriorate food processing tools besides they are not environmentally-friend **(Pinela and Ferreira, 2017)**. Moreover, the direction to natural competing will overcome the public health threading of food born poisoning bacteria antimicrobial resistance **(Quinto *et al*., 2019)**.

In recent years, a huge number of researches have been performed for studying the antibacterial activity of natural products. Plants, particularly herbs and spices, are being given more attention. These days, there are more thanone thousand plants with known antimicrobial efficacies, and over 30,000 antimicrobial outputs have been insulated from plants **(Zheng *et al*., 2016)**.

Spices have been utilized as food and flavoring hundreds years ago besides as remedy and food preservatives in recent times. A lot of spices; such as cinnamon, clove, curcumin, oregano, rosemary and thyme have been settled to keep food protected from pathogenic bacterial contamination **(Jessica *et al*., 2017)**. Furthermore, the spices secondary metabolites are often recognized as safe antimicrobial agents, with sparse adverse body impacts. Thus, spices could be nominated to display and evolve novel antimicrobial factors versus food borne human hazards **(Kaptan and Sivri, 2018)**.

This issue has concentrated on the utilization of natural anti food poisoning bacteria originated from plant sources.

1. Spices

1.1. Oregano

Oregano (*Origanum vulgare*), a spice belonged to family *Lamiaceae*, has been utilized as food flavoring and seasoning since prolonged time. Carvacrol and thymol are considered the prime constituents related with antimicrobial activities in oregano extract **(Rodriguez-Garcia *et al*., 2016)**.

1.2. Thyme

Thyme (*Thymus vulgaris*), a spice belonged to family *Lamiaceae*; is a dwarf tree domestic to the western Mediterranean zone. Thyme is vastly utilized as a spice to give distinctive flavor to foods. Recently, investigations gave attention to thyme as an efficient antimicrobial agent, and utilized to combat food poisoning bacteria **(Assiri *et al.*, 2016)**. The master active component of thyme is thymol, which interestingly exerted its antimicrobial activity by different ways against Gram-positive and Gram-negative bacteria **(Qing *et al.*, 2017)**.

1.3. Rosemary

Rosemary (*Rosmarinus officinalis*), a spice belonged to the *Lamiaceae* family, is a permanent mini-tree with nice odor and sprungs worldwide. Rosemary has been anticipated in pharmaceutical and medical products. Also it acts as a flavoring agent, antioxidant and microbicide **(Azizkhaniand Tooryan, 2015)**.

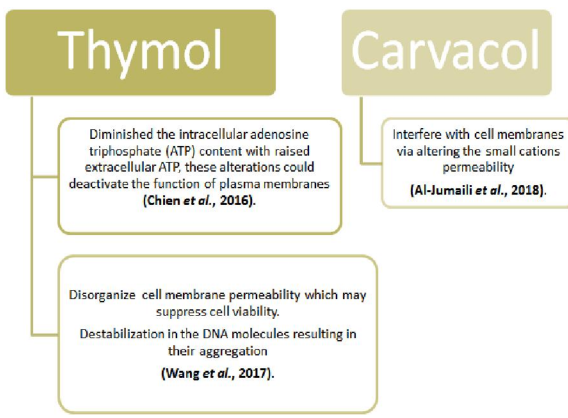

Fig. (1): The antibacterial mechanisms of both thymol and carvacol.

1.4. Clove

Clove (*Eugenia caryohyllata*), a spice belonged to family *Myrtaceae*, is broadly utilized as antiseptic versus infectious illnesses as periodontal sickness due to its antimicrobial efficiency opposed to oral bacteria **(Marchese *et al.*, 2017)**. Clove is also currently enforced in food industry as a natural germicidal, raising shelf-life due to the bactericidal dynamic versus food borne hazards. The antimicrobial property of the clove oil and extract is probably attributed to their master active component; eugenol **(Hu *et al.*, 2018)**.

1.5. Garlic

Garlic (*Allium sativum*) a spice belonged to the *Liliaceae* family, and used widely in medicine and natural spice for extending of food shelf life.

In a study, it was found that fresh garlic exhibited the strongest antibacterial effect on microorganisms in raw chicken sausage followed by garlic powder then garlic oil (**Sallam *et al.*, 2004).** Another investigation declared that the freeze-dried powder showed the best activity against *S. typhimurium*, *E. coli*, *B. cereus* and *S. aureus* among varied drying procedures **(Rahman *et al.*, 2006)**. Even when cut garlic to pieces, it still exerted a powerful antibacterial impact in room temperature stored raw meatballs and refrigerator stored ground beef against aerobic mesophilic and psychrophilic bacteria **(Aydin *et al.*, 2007)**.

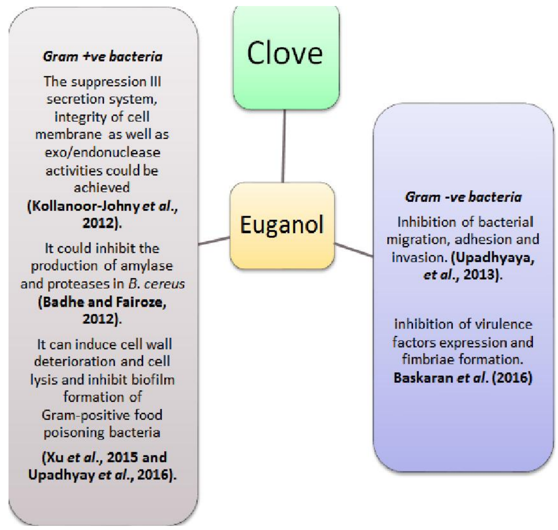

Fig. (2): The antibacterial mechanisms of euganol, (clove).

Fujisawa *et al.* (2009) revealed that the garlic extract had an influence of almost of the streptomycin and vancomycin versus *S. aureus* by 1-2% and 8% respectively, rather than 0.2% of that of colistin against *E. coli*. In the same manner, garlic aqueous extract induced significant antibacterial efficacy versus *S. aureus* existence in hamburger stored at 4°C for 1-2 weeks and -18°C for one, two and three months **(Mozaffari Nejad *et al.*, 2014)**.

The potent inhibitory effect of garlic on food pathogens is referred to allicin (organic thiosulfinate), the main antibacterial of garlic. The oxygen in the structure (-S (=O)-S-) of allicin result in the S-allyl moiety liberation, which could be an aggressive agent versus bacteria. Also, it can break through the cellular membranes and wall; result in their damage, and death of bacterial cell **(Fujisawa *et al.*, 2009)**.

1.6. Cinnamon

Cinnamon (*Cinnamomumzeylanicum*), a spice belonged to family *Lauraceae*, is broadly placed in soups, pickles, and appetizing dishes. Also, as its antimicrobial action is proven, cinnamon is also utilized in food additives and cosmetics. It is also act as health-boosting agents to address gastrointestinal and urinary inflammatory illness **(Nabavi *et al.*, 2015)**.

1.7. Ginger

Ginger (*Zingiberofficinale*), a spice belonged to family of *Zingiberaceae*, is broadly utilized as a component in food, pharmaceutical, cosmetic, and other manufactures **(Park *et al.*, 2008)**. Some volatile components which are responsible for antimicrobial properties in ginger were camphene, á-pinene, linalool and borneol **(An *et al.*, 2016)**.

Ginger was confirmed to have antimicrobial activities in many studies; food borne *L. monocytogenes* and *E. coli* (**Thongson *et al.*, 2005, Indu *et al.*, 2006)**. Furthermore, it was found that both solvent and ion method extracted ginger oils had antibacterial activity against *Bacillus subtilis*, *Bacillus nutto*, *Samonellanewport*, *Samonellaenteritidis*, *Campylobacterjejuni* and *Campylobacter coli* in vitro (**Sa-Nguanpuag *et al.*, 2011)**.

1.8. Basil

Basil (*Ocimumbasilicum*) is considered one of the oldest natural spices, which is broadly hired in the flavoring of condiments, baked goods and desserts. Basil oil was also utilized in perfumes, as well as in oral and dental products **(Suppakul *et al.*, 2003)**.

In surveys, basil EOs performed potent effects on *B. cereus, B. subtilis E. coli*, *L. monocytogenes*, *S. aureus, S. typhimurium* and *Shigella* sp. strains **(Hussain *et al.*, 2008**, **Kaya *et al.*, 2008 and Beatovic *et al.*, 2015)**.

The active compound of basil oil was methyl chavicol, but the mechanisms of action have been rarely surveyed. Therefore, future researches are needed **(Semeniuc *et al.*, 2017)**.

1.9. Fennel

Fennel (*Foeniculum vulgare*), a spice belonged to family *Umbellifarae*, is broadly grown in moderate temperature areas as well as the tropical zone for its aromatic fruits, and cooking components **(Singh *et al.*, 2006)**.

Considerable studies discussed the antibacterial activities of fennel against various food borne bacteria; *E. coli* and *Proteus merabilis* (*P. merabilis*), *B. subtilis*, *S. typhimurium*, and *S. dysenteriae* (**Zellagui *et al.* 2011, Diao *et al.*, 2015)**.

The antibacterial activity of fennel seed EO is assigned to its ability to break the cell membrane permeability resulting in electrolytes losses, lack of proteins, diminishing sugars then finally, resulting in the decomposition and cell death **(Manzoor *et al.*, 2016)**.

1.10. Turmeric

Curcuma longa, (Turmeric) "a well-known spice" is used for miscellaneous health benefits in addition to culinary uses. Curcumin is the prime constituent of turmeric, it can suppress the bacterial cytokinesis through induction of filament formation, so can probably inhibit the bacterial cell proliferation **(Kaur *et al.*, 2010)**. Actually, it was obvious that the aqueous curcumin extract supplementation by 0.3% (w/v) to the cheese resulted in the lowering of bacterial counts of *S. typhimurium* and *E. coli* 0157:H7. Furthermore, it has minimized the *B. cereus*, *S. aureus*, and *L. monocytogenes* contamination after two weeks of cold storage **(Hosny *et al.*, 2011)**.

Afrose *et al.* (2015) conducted a study to detect the antibacterial profile of crude turmeric, aqueous turmeric extract versus *S. aureus* and *E. coli*. The results revealed a complete inhibition of the two bacterial growths through the broth dilution technique. Turmeric aqueous, methanol and ethanol extracts were evaluated in vitro for their antibacterial effect on *S. aureus* sub sp. *aureus* and *B. subtilis*. The data revealed variable activities of alcoholic extracts; as crude ethanol extract had a booster suppression effect on the growth of both bacterial species than that of crude methanol extract **(Irshad *et al.*, 2018)**.

2. Plant and Fruits

Not only, have spices showed the antibacterial activity but also, other plant leaves extracts and fruits peels can do.

Al-Ashaal *et al.* (2018) discussed the antimicrobial performance of *Atropa belladonna* leaves and callus extracts versus *C. jejuni, E. coli, L. monocytogenes, S. aureus* and *S. typhi,* and which constitute the most important food borne pathogens. The study exhibited a strong antibacterial activity of *A. belladonna* against the tested strains with the inhibition zones diameters were in increasing order from *L. monocytogenes* C. *jejuni S. typhi E.coli S.aureus*in concentration depending manner. The results clarified that the antibacterial efficiency of *A. belladonna* were directly correlated to coumarin and rutin flavonoid phenolics concentrations.

Another study examined the prepared extracts of *Azadirachtaindica* (Neem) and *Moringa oleifera* for their antimicrobial effect on *E.faecalis in vitro*. The evaluation revealed that the microbicidal impact of the *M. oleifera* extract was recorded at a concentration of 75μg/ml while a concentration of 25μg/ml was reported for *A. indica* with growth inhibition zone of 44.83 ± 0.98 and 35.5 ± 1.05, respectively. The required concentration of *A. indica* for exerting a bactericidal effect on *S. aureus*, was greatly higher than the previous investigation >500 µg/ml **(Singaravelu *et al*., 2019)**.

Fruit peels and leaves extracts also comprise antimicrobial compounds acting on various MDR bacteria; *Mangiferaindica* 'mango' **(Dzotam and Kuete, 2017)**, *Psidiumguajava* 'Guava'**(Wang *et al*., 2017)**, Pomegranate extract **(Rosas-Burgos *et al*., 2017),** Citrus peel extract, lemon grass, and lime peel extracts **(Caputo *et al*., 2018)**.

3. The Application of Spices in Food Industry:-

Spices could be used as both antibacterial agents and natural antioxidants in meat products; Clove and its functional extracts have been integrated into films with high, moderate and low molecular chitosan mass, **(Hernández-Ochoa *et al*., 2011)** and the trial showed that the low molecular mass chitosan with 2% ethyl heptanoate extract exhibited antibacterial efficiency versus a majority of the examined food-borne bacteria. Biologically active clove essential oil particles were encapsulated to reduce their hydrophobicity forming inclusion complexes and showed an increasing in their stability without losing their antibacterial activity versus the tested food origin *E. coli* ATCC 25922 and *L. monocytogenes* ATCC 19114 **(Anaya‑Castro *et al*., 2017)**. Mexican oregano was encapsulated by co-precipitation method, which provided volatility reduction and kept the antibacterial efficiency against two food poisoning *L. monocytogenes* and *E. coli* **(Anaya‑Castro *et al*., 2017)**. Also, oregano oils and extracts were packaged by means of spray-drying process **(Baranauskaite *et al*., 2017)** or could be emulsified in surfactants like Tween 80 **(Doost *et al*., 2017);** agent with improving of the Physico-mechanical properties besides enforcing their antimicrobial performance. The starch packaging films of carvacrol that prepared with chitosan fully prohibited *L. monocytogenes* growth on RTE ham during 4 weeks of storage **(Zhao *et al*., 2019)**. Thymol microcapsules were presented by oil-in-water emulsions at different concentrations and were prosperity fitted as microbial inhibitors **(Ulloa *et al*., 2017)**. Another method; thymol was prepared using a co-precipitation technique as inclusion complexes. The systematic conditions optimization enhanced both the production of the complex and the antibacterial performance compared to former reported methods that have been applied to other agents **(Al‑Nasiri *et al*., 2018)**. Cinnamon was packed with liposome-encapsulated as particles. This package form was found to be more stable, with notable anti-biofilm activity against MRSA **(Cui *et al*., 2016)**. Another study revealed the increased antimicrobial efficiency of spray dried microcapsules combination of cinnamon oil coated with wall materials (maltodextrin, whey protein and Arabic gum) **(Felix *et al*., 2017)**.

An another concept, the use of natural additives in ultraprocessed meat can diminish the use of artificial additives and consequently, the health risks they represent, preserving the practicality of this food type and put in consideration the natural appeal required by new consumers. Antioxidants represent a class of additives that could be replaced with natural extracts in meat products. These compounds rise the shelf life of foods as a result of inhibiting the lipids' oxidation, proteins and pigments denaturation, preserving features such as aroma, color, taste, texture, even the overall quality of the product **(Damodaran *et al*., 2010)**. Numerous investigations have been proceeded in recent years seeking the use of extracts of spices, fruits and vegetable residues as antioxidants in meat products. Rosemary supplementation minimizes free radicals, so used as a natural antioxidant, this ability could be of a valuable consider, in high unsaturated fatty acids meat types as rabbit and mutton meat resulting in increasing these meat shelf life **(Hakim *et al*., 2017)**. Thus, the natural spices antioxidants can be utilized in numerous types of meat products, especially the ultraprocessed ones, without inducing losses in the quality and shelf life, comparing to the synthetic antioxidants. The use of natural plant extracts is becoming a substantial shift in the control of oxidative alterations in meat products during storage **(Coskun, *et al*., 2014)**.

Prolonging the shelf life of meat products is essential for both industry and consumers and is fulfilled through protection versus lipid oxidation, discoloration and microbial growth. Novel technologies in the scope of packaging have the topic of their interaction with the food product, in the concern of modifying or maintaining parameters to promote the quality of the product packaged during its shelf life. Among these innovations are active packagings, which consist of the integration of components into the packaging; releasing or absorbing materials for packaged food or the environment, prolonging shelf life and preserving or improving food inputs.

The prim mechanism is the action as a barrier versus the passage of oxygen and water, minimizing oxidation reactions and keeping moisture. The active antioxidant packages are of great importance, thinking that the oxidation reactions emerged as causing alterations in the food. The manufacture of these packs is by the coalition of an antioxidant or a combination of them to minimize the oxidation of the product. Active packaging relied on natural antioxidants is promising agents to raise the shelf life of lipid enriched foods, involving meat products **(Lopez-De-Dicastillo *et al*., 2012).**

The use of additives in active packaging offers several advantages, dose released in a controlled way, being exist in the food lower amounts of active agents, thus raising the safety of the consumer. Moreover, because these constituents are not directly added to the food, their interaction with the different food components is reduced, which is an advantage, as some antioxidant agents added to the food may partially lose their activity due to the product composition. However, some factors may affect the efficiency of antioxidant packaging, such as antioxidant and food features, storage and distribution status, and antioxidant-polymer interaction, a complex process **(Jéssica *et al*., 2019).**

4. Spices and plants dosing:

However, considering the variation in extraction solvent, extraction procedures, and dosage of samples, it is harsh to directly compare these data with each other. More significantly, the inhibitory actions of spice extracts on multi-drug resistant bacteria were relatively less recorded.

Gull *et al.* (2011) exposed that eight drug-resistant bacteria were prohibited by ginger extract at a concentration of 100 mg/ml. **Mandal *et al.* (2011)** revealed that methicillin-resistant *S. aureus* was inhibited by ethanol extracts (20 µl, 10 mg/ml) of cinnamon, clove, and cumin. In like manner, ethanol extracts (50 µL, 100 mg/mL) of cinnamon, ginger, clove, and cumin induce great effect on the high level gentamicin-resistant enterococci isolates **(Revati *et al.* 2015)**.

Curcumin has a long instituted safety record; a dose from 0–3 mg/kg body weight of curcumin is considered an Allowable Daily Intake (ADI) value. Several attempts on healthy subjects have corroborated the safety and efficacy of curcumin. Despite this well-established safety, some negative drawbacks have been accounted. Seven topics have uptaken 500–12,000 mg in a dose response study and regarded for 72 has suffered diarrhea, headache, rash, and yellow stool. Also, uptaking an extended dose of 0.45 to 3.6 g/day curcumin for one to four months declared nausea and diarrhea and elevation in serum alkaline phosphatase and lactate dehydrogenase levels **(Kocaadam and Şanlier, 2017)**.

5. Spices and plants bioavailability:

Considering, polyphenols which are the prime active ingredients of medicinal plants and spices; their dietary supply has a poor intestinal absorption into systemic circulation. Polyphenols are either metabolized by gut flora and/or the liver (post-absorption), and/or cleared from the body rapidly. The previous surveillance regarding low bioavailability supposed that the action of dietary polyphenols may be localized to the gut **(D'Archivio *et al*., 2010)**.

Moringaoleifera cold methanol extract exposed the existence of alkaloids, flavonoids, carbohydrates, cardiac glycosides, saponins, tannins, and terpenes. A dose of 4,000 mg kg^{-1}showed signs of acute toxicity, while mortality was reported at 5,000 mg kg^{-1}, but in rat the median lethal dose of the extract was 3,873 mg kg^{-1}. Noadverse effect was monitored at concentrations lower than 3,000 mg kg-1. Sub-acute running of the seed extract resulted in significant ($p<0.05$) elevation in the levels of alanine and aspartate transferases (ALT and AST), and significant ($p<0.05$) lowering in weight of experimental rats, at 1,600 mg kg^{-1}. The study deduced that the extract of seeds of *M. oleifera* is safe both for medicinal and nutritional use **(Ajibade *et al*., 2013).**

6. Spices and plants and immunity:

Different mechanisms of action and antimicrobial abilities of herbal remedies relief on their numerous beneficial features; immunomodulatory nature with enhancement of both humoral and cell mediated immunity as well ameliorating stress and immunosuppression; cytokine regulation; anti-inflammatory, antioxidative and suppirsing pathogens by a variety of pathways **(Dhama *et al*., 2013)**.

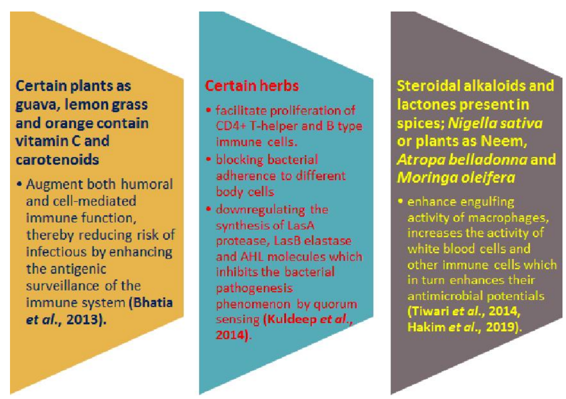

Fig. (3): Some immune pathways induced by spices and plants.

Conclusion

Relevant natural compounds as essential oils which obtained from spices, plants leaves, and fruits peel. Herbs and spices could act as safe natural feed supplements which might add a nutritive and protective value to the processed food during preservation instead of chemical sanitizers. Plant essential oils are earning a vast interest in the food industry for their prospect as decontaminating agents, termed generally "Recognized as Safe (GRAS)". The great success of these natural products in reducing or killing food born pathogens encourage developing of modern techniques dealing with these natural antibacterial to improve their efficiency.

References

1. Abu-Elyazeed RR, Wierzba TF, Frenck RW, Putnam SD, Rao MR, Savarino SJ, Kamal KA, Messih IA, El-Alkamy SA and Clemensu S. (2004). Epidemiology of *Shigella*-Associated Diarrhea in Rural Egyptian Children. *The American journal of tropical medicine and hygiene.*, 71(3):367-72.
2. Afrose R, Saha SK, Banu LA, Ahmed AU, Shahidullah AS, Gani A, Sultana S, Kabir MR and Ali MY. (2015). Antibacterial Effect of *Curcuma longa* (Turmeric) Against *Staphylococcus aureus* and *Escherichia coli*. *Mymensingh Med J*. 24(3):506-15.
3. Agaoglu S, Dostbil N and Alemdar S. (2007). Antimicrobial activity of some spices used in the meat industry. *Bull. Vet. Inst. Pulawy*., 51:53–57.
4. Ajibade TO, b Arowolo R and Olayemi FO. (2013). Phytochemical screening and toxicity studies on the methanol extract of the seeds of *Moringaoleifera*. *J Complement Integr Med*., 7(10): 15.
5. Al Maqtari M, Alghalibi SM and Alhamzy EH. (2011). Chemical composition and antimicrobial activity of essential oil of *Thymus vulgaris* from Yemen. *Turk. J. Biochem*., 36:342–349.
6. Al-Ashaal HA, Abuelnaga A, Ahmed AE and Sahar S. (2018). Anti Food Poisoning Pathogenic Bacteria in Correlation to Coumarins and Flavonoids of *Atropa belladonna* Field Plant and *in vitro* Cultures. *J. Pharm. Sci. and Res*., 10(2):235-239.
7. Aliakbarlu J, and Shameli F. (2013). In vitro antioxidant and antibacterial properties and total phenolic contents of essential oils from *Thymus vulgaris*, T. Kotschyanus, Ziziphoratenuior and Z. Clinopodioides. *Turk. J. Biochem*., 38:425–431.
8. Al-Jumaili A, Kumar A, Bazaka K and Jacob MV. (2018). Plant Secondary Metabolite-Derived Polymers: A Potential Approach to Develop Antimicrobial Films. *Polymers*., 10(5): 515.
9. Al-Nasiri G, Cran MJ, Smallridge AJ and Bigger SW. (2018). Optimization of β-cyclodextrin inclusion complexes with natural antimicrobial agents: thymol, carvacrol and linalool. *J Microencapsul*., 35(1):26-35.
10. Al-Turki AI. (2007). Antibacterial effect of thyme, peppermint, sage, black pepper and garlic hydrosols against *Bacillus subtilis* and *Salmonella enteritidis*. *J. Food Agric. Environ*., 5:92–94.
11. Al-Turki AI. (2007). Antibacterial effect of thyme, peppermint, sage, black pepper and garlic hydrosols against *Bacillus subtilis* and *Salmonella enteritidis*. *J. Food Agric. Environ*., 5:92–94.
12. An K, Zhao D, Wang Z, Wu J, Xu Y and Xiao G. (2016). Comparison of different drying methods on Chinese ginger (*Zingiberofficinale* Roscoe): Changes in volatiles, chemical profile, antioxidant properties, and microstructure. *Food Chem*., 197 B: 1292-300.
13. Anaya‐Castro MA, Ayala‐Zavala JF, Munoz‐Castellanos L, Hernadez‐Ochoa L, Peydecastaing J and Durrieu V. (2017). β-Cyclodextrin inclusion complexes containing clove (*Eugenia caryophyllata*) and Mexican oregano (*Lippiaberlandieri*) essential oils: Preparation, physicochemical and antimicrobial characterization. Food Pack. *Shelf Life*, 14: 96.
14. Assiri AM, Elbanna K, Abulreesh HH and Ramadan MF. (2016). Bioactive Compounds of Cold-pressed Thyme (*Thymus vulgaris*) Oil with Antioxidant and Antimicrobial Properties. *J Oleo Sci*., 65(8):629-40.
15. Aydin A, Bostan K, Erkan ME and Bingöl B. (2007). The antimicrobial effects of chopped garlic in ground beef and raw meatball (ciğköfte). *J Med Food*., 10(1):203-7.
16. Azizkhani M and Tooryan F. (2015). Antioxidant and antimicrobial activities of rosemary extract, mint extract and a mixture of tocopherols in beef sausage during storage at 4C. *J. Food Saf*., 35:128–136.
17. Babacan O, Cengiz S and Akan M. (2012). Detection of antibacterial effect of oregano plant on various *Salmonella* serotypes. *Ank. Univ. Vet. Fak. Derg*., 59:103–106.
18. Badhe SR, and Fairoze MN. (2012). Antibacterial efficacy of clove powder of chicken legs spiked with pathogenic reference strains under refrigeration temperature (8 ± 2 °C). *Indian J. Anim. Res*., 46:371–375.
19. Baskaran SA, Kollanoor‐Johny A, Nair MS and Venkitanarayanan K. (2016). Efficacy of plant‐derived antimicrobials in controlling enterohemorrhagic *Escherichia coli* virulence in vitro. *Journal of Food Protection*., 79: 1965–1970.
20. Bayoub K, Baibai T, Mountassif D, Retmane A and Soukri A. (2010). Antibacterial activities of

the crude ethanol extracts of medicinal plants against *Listeria monocytoge*, *nes* and some other pathogenic strains. *Afr. J. Biotechnol*., 9: 4251–4258.
21. Beatovic D, Krstic-Milosevic D, Trifunovic S, Siljegovic J, Glamoclija J, Ristic M and Jelacic S. (2015). Chemical composition, antioxidant and antimicrobial activities of the essential oils of twelve *Ocimumbasilicum* L. cultivars grown in Serbia. *Rec. Nat. Prod*., 9:62–75.
22. Bhatia AK, Kumar A, Goel A and Rahal A. (2013). Immunomodulatory activity of hot aqueous extract of Ocimum sanctum leaves. *Immunol Indian J. Compa. Microbiol*. Infect. Dis., 34: 33-37.
23. Bisht DS, Menon K and Singhal MK. (2014). Comparative antimicrobial activity of essential oils of *Cuminumcyminum* L. and *Foeniculum vulgare* Mill seeds against *Salmonella typhimurium* and *Escherichia coli*. J. Essent. Oil Bear. *Plants*., 17:617–622.
24. Bozin B, Mimica-Dukic N, Simin N and Anackov G. (2006). Characterization of the volatile composition of essential oils of some lamiaceae spices and the antimicrobial and antioxidant activities of the entire oils. *J Agric Food Chem*., 54(5):1822-8.
25. Bulitta JB, Hope WW, Eakin AE, Guina T, Tam VH, Louie A, Drusano GL and Hoover JL. (2019). Generating Robust and Informative Nonclinical In Vitro and In Vivo Bacterial Infection Model Efficacy Data to Support Translation to Humans. *Antimicrob Agents Chemother*., 63(5): e02307-18.
26. Caputo L, Quintieri L, Cavalluzzi MM, Lentini G and Habtemariam S. (2018). Antimicrobial and Antibiofilm Activities of Citrus Water-Extracts Obtained by Microwave-Assisted and Conventional Methods. *Biomedicines*., 6(2). pii: E70.
27. Chadwick A, Ash A, Day J and Borthwick M. (2015). Accidental overdose in the deep shade of night: a warning on the assumed safety of 'natural substances'. *BMJ Case Rep*., 5: (2015) bcr 2015209333.
28. Coskun BK, Calikoglu E, Emiroglu Z K, and Candogan K. (2014). Antioxidant active packaging with soy edible films and oregano or thyme essential oils for oxidative stability of ground beef patties. *Journal of Food Quality., 37*, 203–212.
29. Cristina AS, Carmen RP, Ancut A and Mihaela R. (2017). Antibacterial activity and interactions of plant essential oil combinations against Gram-positive and Gram-negative bacteria. *Journal of food and drug analysis*., 25:403 - 40 8.
30. Cui H, Li W, Li C, Vittayapadung S and Lin L. (2016). Liposome containing cinnamon oil with antibacterial activity against methicillin-resistant *Staphylococcus aureus* biofilm. *Biofouling*., 32(2):215-25.
31. Dal Pozzo M, Viégas J, Santurio DF, Rossatto L, Soares IH, Alves SH and da Costa MM. (2011). Antimicrobial activities of essential oils extracted from spices against *Staphylococcus* spp. isolated from goat mastitis. *Cienc. Rural*., 41:667–672.
32. Damodaran S, Parkin KL and Fennema OR (2010). *Química de Alimentos de Fennema.* Porto Alegre: Artmed (4. ed).
33. D'Archivio M, Filesi C, Varì R, Scazzocchio B and Masella R. (2010): Bioavailability of the polyphenols: status and controversies. *Int J Mol Sci*., 11(4):1321-42.
34. De Souza EL, Stamford T, Lima E, Barbosa JM and Marques M. (2008). Interference of heating on the antimicrobial activity and chemical composition of *Origanum vulgare* L. (*Lamiaceae*) essential oil. *Cienc. Tecnol. Aliment*., 28:418–422.
35. Derde M, Lechevalier V, Guérin-Dubiard C, Cochet MF, Jan S, Baron F, Gautier M, Vié V and Nau F. (2013). Hen egg white lysozyme permeabilizes *Escherichia coli* outer and inner membranes. *J Agric Food Chem*., 61(41):9922-9.
36. Dhama, K, Rajagunalan S, Chakraborty S, Verma AK, Kumar A, Tiwari R and Kapoor S. (2013). Food-borne pathogens of animal origin-diagnosis, prevention, control and their zoonotic significance: A review. *Pak. J. Biol. Sci*., 16: 1076-1085.
37. Diao WR, Hu QP, Zhang H and Xu JG. (2014). Chemical composition, antibacterial activity and mechanism of action of essential oil from seeds of fennel (*Foeniculum vulgare* Mill.) *Food Control*., 35:109–116.
38. Doost AS, Sinnaeve D, De Neve L and de Meeren PV. (2017). Influence of non-ionic surfactant type on the salt sensitivity of oregano oil-in-water emulsions. *Colloids and Surfaces A Physicochemical and Engineering Aspects.*, 38: 525.
39. Dzotam JK and Kuete V. (2017). Antibacterial and Antibiotic-Modifying Activity of Methanol Extracts from Six Cameroonian Food Plants against Multidrug-Resistant Enteric Bacteria. *Biomed Res Int*., 2017:1583510.
40. EFSA, (2016). The European Union summary report on trends and sources of zoonoses, zoonotic agents and food-borne outbreaks in 2015. *EFSA J*., 14(12): 4634.
41. Felix PHC, Birchal VS, Botrel DA, Marques GR and Borges SVJ. (2017). Physicochemical and

Thermal Stability of Microcapsules of Cinnamon Essential Oil by Spray Drying. *Food Process. Preserv*., 41, 12919.
42. Foodnet, (2019). Centers for Disease Control and Prevention.; 2019 (Available at: https://www.cdc.gov/foodnet/index.html. [Accessed 21 December 2018].
43. Fujisawa H, Watanabe K, Suma K, Origuchi K, Matsufuji H, Seki T and Ariga T. (2009). Antibacterial potential of garlic-derived allicin and its cancellation by sulfhydryl compounds. *Biosci Biotechnol Biochem*., 73(9):1948-55.
44. Geremew T, Kebede A and Andualem B. (2015). The role of spices and lactic acid bacteria as antimicrobial agent to extend the shelf life of metataayib (traditional Ethiopian spiced fermented cottage cheese). *J Food Sci Technol*., 52(9):5661-70.
45. Gull I, Saeed M, Shaukat H, Aslam SM, Samra ZQ and Athar AM. (2011). Inhibitory effect of Allium sativum and Zingiberoffcinale extracts on clinically important drug resistant pathogenic bacteria. Ann. Clin. *Microbiol. Antimicrob*.11:8.
46. Gupta C, Garg AP, Uniyal RC and Kumari A. (2008). Comparative analysis of the antimicrobial activity of cinnamon oil and cinnamon extract on some food-borne microbes. *Afr. J. Microbiol. Res*., 2:247–251.
47. Hosny IM, El Kholy WI, Murad HA and El Dairouty RK. (2011). Antimicrobial activity of Curcumin upon pathogenic microorganisms during manufacture and storage of a novel style cheese 'Karishcum'. *Journal of American Science*., 7:611–618.
48. Hu Q, Zhou M and Wei S. (2018). Progress on the Antimicrobial Activity Research of Clove Oil and Eugenol in the Food Antisepsis Field. *J Food Sci*., 83(6):1476-1483.
49. Hussain AI, Anwar F, Hussain Sherazi ST and Przybylski R. (2008). Chemical composition, antioxidant and antimicrobial activities of basil (*Ocimumbasilicum*) essential oils depends on seasonal variations. *Food Chem*., 108(3):986-95.
50. Hussien J, Teshale C and Mohammed J. (2011). Assessment of the antimicrobial effects of some Ethiopian aromatic spice and herb hydrosols. *Int. J. Pharmacol*., 7: 635–640.
51. Hyun JE, Bae YM, Song H, Yoon JH and Lee SY. (2015). Antibacterial effect of various essential oils against pathogens and spoilage microorganisms in fresh produce. *J. Food Saf*., 35:206–219.
52. Indu MN, Hatha A, Abirosh C, Harsha U and Vivekanandan G. (2006). Antimicrobial activity of some of the south-Indian spices against serotypes of *Escherichia coli, Salmonella, Listeria monocytogenes* and *Aeromonashydrophila*. *Braz. J. Microbiol*., 37:153–158.
53. Indu MN, Hatha A, Abirosh C, Harsha U and Vivekanandan G. (2006). Antimicrobial activity of some of the south-Indian spices against serotypes of *Escherichia coli, Salmonella, Listeria monocytogenes* and *Aeromonashydrophila*. *Braz. J. Microbiol*., 37:153–158.
54. Irshad S, Muazzam A, Shahid Z and Dalrymple MB. (2018). *Curcuma longa* (Turmeric): An auspicious spice for antibacterial, phytochemical and antioxidant activities. *Pak J Pharm Sci*., 6: (Supplementary):2689-2696.
55. Jessica E T, Gassara F, Kouassi AP, Brar SK, and Belkacemi K. (2017). Spice use in food: Properties and benefits. *Crit Rev Food Sci Nutr*., 57(6):1078-1088.
56. Joe MM, Jayachitra J and Vijayapriya M. (2009). Antimicrobial activity of some common spices against certain human pathogens. *J. Med. Plants Res*., 3: 1134–1136.
57. Joshi RK. (2018). Role of Natural Products against Microorganisms. *Am J Clin Microbiol Antimicrob*., 1(1): 1005.
58. Kaptan B and Sivri GT. (2018). Utilization of Medicinal and Aromatic Plants in Dairy Products. *J Adv Plant Sci*., 1: 207.
59. Kaur S, Modi NH, Panda D and Roy N. (2010). Probing the binding site of curcumin in *Escherichia coli* and *Bacillus subtilis* Fts Z--a structural insight to unveil antibacterial activity of curcumin. *Eur J Med Chem*., 45(9):4209-14.
60. Kaya I, Yigit N and Benli M. (2008). Antimicrobial activity of various extracts of *Ocimumbasilicum* L. and observation of the inhibition effect on bacterial cells by use of scanning electron microscopy. *Afr J Tradit Complement Altern Med*., 5(4):363-9.
61. Keskin D and Toroglu S. (2011). Studies on antimicrobial activities of solvent extracts of different spices. *J Environ Biol*., 32(2):251-6.
62. Kirk MD, Pires SM, Black RE, Caipo M, Crump JA and Devleesschauwer B. (2015). World Health Organization estimates of the global and regional disease burden of 22 food borne bacterial, protozoal, and viral diseases, 2010: a data synthesis. *PLoS Med*., 12: e1001921.
63. Kocaadam B and Şanlier N. (2017). Curcumin, an active component of turmeric (*Curcuma longa*), and its effects on health. *Crit Rev Food Sci Nutr*., 57(13):2889-2895.
64. Kollanoor ‐ Johny A, Mattson T, Baskaran, S A, Amalaradjou M A, Babapoor S, March B, and Venkitanarayanan K. (2012). Reduction of

Salmonella enterica serovarenteriti discolonization in 20‐day‐old broiler chickens by the plant‐derived compounds trans‐cinnamaldehyde and eugenol. *Applied and Environmental Microbiology*, 78: 2981– 2987.
65. Kozłowska M, Laudy AE, Przybył J, Ziarno M and Majewska E. (2015). Chemical Composition and Antibacterial Activity of Some Medicinal Plants from Lamiaceae Family. *Acta Pol Pharm*., 72(4):757-67.
66. Krajcova E, Greifova M and Schmidt S. (2008). Study of antimicrobial activity of selected plant extracts against bacterial food contaminants. *J. Food Nutr. Res*., 47:125–130.
67. Kuldeep D, Tiwari R, Sandip C, Mani S, Amit K, Karthik M, Yaqoob WA, Shoor VS and Anu R. (2014). Evidence Based Antibacterial Potentials of Medicinal Plants and Herbs Countering Bacterial Pathogens Especially in the Era of Emerging Drug Resistance: An Integrated Update. *International Journal of Pharmacology*, 10: 1-43.
68. Kumar D, Kumar P and Pandey J. (2018). Binary grafted chitosan film: Synthesis, characterization, antibacterial activity and prospects for food packaging. *Int J Biol Macromol*., 115:341-348.
69. Mandal S, Deb Mandal M, Saha K and Pal NK. (2011). In vitro antibacterial activity of three Indian spices against methicillin-resistant *Staphylococcus aureus*. *Oman Med. J*., 26: 319–323.
70. Manzoor AR, Bilal AD, Shahnawaz NS, Bilal AB and Mushtaq AQ. (2016). *Foeniculum vulgare*: A comprehensive review of its traditional use, phytochemistry, pharmacology, and safety. *Arabian Journal of Chemistry*, 2016: S1574-S1583.
71. Marques JD, Volcao LM, Funck GD, Kroning IS, da Silva WP, Fiorentini AM and Ribeiro GA. (2015). Antimicrobial activity of essential oils of *Origanum vulgare* L. and *Origanummajorana* L. against *Staphylococcus aureus* isolated from poultry meat. *Ind. Crop. Prod*., 77: 444–450.
72. Mozaffari Nejad AS, Shabani S, Bayat M and Hosseini SE. (2014). Antibacterial Effect of Garlic Aqueous Extract on *Staphylococcus aureus* in Hamburger. *Jundishapur J Microbiol*., 7(11): e13134.
73. Nabavi SF, Di Lorenzo A, Izadi M, Sobarzo-Sánchez E, Daglia M and Nabavi SM. (2015). Antibacterial Effects of Cinnamon: From Farm to Food, Cosmetic and Pharmaceutical Industries. *Nutrients*, 7(9):7729-48.
74. Park M, Bae J and Lee DS. (2008). Antibacterial activity of [10]-gingerol and [12]-gingerol isolated from ginger rhizome against periodontal bacteria. *Phytother Res*., 22(11):1446-9.
75. Pina-Pérez MC, Martínez-López A and Rodrigo D. (2012). Cinnamon antimicrobial effect against *Salmonella typhimurium* cells treated by pulsed electric fields (PEF) in pasteurized skim milk beverage, *Food Research International*, 48: (2) 777-783.
76. Qing L, Xiao M, Ya L, Cai-Ning Z, Guo-Yi T and Hua-Bin L. (2017). Antibacterial and Antifungal Activities of Spices. *Int J Mol Sci*.,18(6): 1283.
77. Quinto EJ, Caro I, Villalobos-Delgado LH, Mateo J, De-Mateo-Silleras B, Redondo-Del-Río MP. (2019). Food Safety through Natural Antimicrobials. *Antibiotics (Basel).*8(4). pii: E208.
78. Radhakrishnan K, Thangamani P and Balakrishnan V. (2014): Antibacterial and phytochemical analysis of stem and root extracts of Calotropisgigantea against selected pathogens. *Malaya J. of Biosc.,* 1: 49-55.
79. Rahman MS, Al-Sheibani HI, Al-Riziqi MH, Mothershaw A, Guizani N and Bengtsson G. (2006). Assessment of the anti-microbial activity of dried garlic powders produced by different methods of drying. *Int. J. Food Prop*., 9:503–513.
80. Revati S, Bipin C, Chitra PB and Minakshi B. (2015). In vitro antibacterial activity of seven Indian spices against high level gentamicin resistant strains of enterococci. *Arch Med Sci*., 11(4):863-8.
81. Rodriguez-Garcia I, Silva-Espinoza BA, Ortega-Ramirez LA, Leyva JM, Siddiqui MW, Cruz-Valenzuela MR, Gonzalez-Aguilar GA and Ayala-Zavala JF. (2016). Oregano Essential Oil as an Antimicrobial and Antioxidant Additive in Food Products. *Crit Rev Food Sci Nutr*., 56(10):1717-27.
82. Rosas-Burgos EC, Burgos-Hernández A, Noguera-Artiaga L, Kačániová M, Hernández-García F, Cárdenas-López JL and Carbonell-Barrachina ÁA. (2017). Antimicrobial activity of pomegranate peel extracts as affected by cultivar. *J Sci Food Agric*., 97(3):802-810.
83. Sallam KI, Ishioroshi M and Samejima K. (2004). Antioxidant and antimicrobial effects of garlic in chicken sausage. *Lebenson Wiss Technol*., 37(8):849-855.
84. Sa-Nguanpuag K, Kanlayanarat S, Srilaong V, Tanprasert K and Techavuthiporn C. (2011). Ginger (*Zingiberofficinale*) oil as an antimicrobial agent for minimally processed produce: A case study in shredded green papaya. *Int. J. Agric. Biol*., 13: 895–901.

85. Santos JC, Carvalho CD, Barros TF and Guimaraes AG. (2011). In vitro antimicrobial activity of essential oils from oregano, garlic, clove and lemon against pathogenic bacteria isolated from *Anomalocardiabrasiliana*. *Semin. Cienc. Agrar*., 32:1557–1564.
86. Santoyo S, Cavero S, Jaime L, Ibañez E, Señoráns FJ and Reglero G. (2006). Supercritical carbon dioxide extraction of compounds with antimicrobial activity from Origanum vulgare L.: determination of optimal extraction parameters. *J Food Prot*., 69(2):369-75.
87. Semeniuc CA, Pop CR, Rotar AM. (2017). Antibacterial activity and interactions of plant essential oil combinations against Gram-positive and Gram-negative bacteria. *J Food Drug Anal*., 25(2):403-408.
88. Shan B, Cai Y. Z, Brooks JD, and Corke H. (2009). Antibacterial and antioxidant effects of five spice and herb extracts as natural preservatives of raw pork. *J. Sci. Food Agric*., 89:1879–1885.
89. Shreaz S, Wani WA, Behbehani JM, Raja V, Irshad M, Karched M, Ali I, Siddiqi WA and Hun LT. (2016). Cinnamaldehyde and its derivatives, a novel class of antifungal agents. *Fitoterapia*., 112:116-31.
90. Singaravelu S, Sankarapillai J, Sasidharn Chandrakumari A and Sinha P. (2019). Effect of *Azadirachtaindica* Crude Bark Extracts Concentrations against Gram-Positive and Gram-Negative Bacterial Pathogens. *J Pharm Bioallied Sci*., 11(1):33-37.
91. Singh G, Maurya S, de Lampasona MP and Catalan C. (2006). Chemical constituents, antifungal and antioxidative potential of *Foeniculum vulgare* volatile oil and its acetone extract. *Food Control*. 17:745–752.
92. Suppakul P, Miltz J, Sonneveld K and Bigger SW. (2003). Antimicrobial properties of basil and its possible application in food packaging. *J Agric Food Chem*., 51(11):3197-207.
93. Tavassoli SK, Mousavi SM, Emam-Djomeh Z and Razavi SH. (2011). Chemical composition and evaluation of antimicrobial properties of *Rosmarinus officinalis* L. essential oil. *Afr. J. Biotechnol*., 10:13895–13899.
94. Thongson C, Davidson PM, Mahakarnchanakul W and Vibulsresth P. (2005). Antimicrobial effect of Thai spices against *Listeria monocytogenes* and *Salmonella typhimurium* DT104. *J. Food Prot*., 68:2054–2058.
95. Tiwari R, Verma AK, Chakraborty S, Dhama K and Singh SV. (2014). Neem (*Azadirachtaindica*) and its potential for safeguarding health of animals and humans: A review. *J. Biol. Sci.,* 14: 110-123.
96. Toroglu S. (2011). In-vitro antimicrobial activity and synergestic/ antagnostic effect of interactions between antibiotics and some spice essential oils. *J Environ Biol*., 32(1):23-9.
97. Turki AI, Ei-Ziney MG and Abdel-Salam AM. (2008). Chemical and anti-bacterial characterization of aqueous extracts of oregano, marjoram, sage and licorice and their application in milk and labneh. *J. Food Agric. Environ*., 6:39–44.
98. Ulloa PA, Guarda A, Valenzuela X, Rubilar JF and Galotto MJ. (2017). Modeling the release of antimicrobial agents (thymol and carvacrol) from two different encapsulation materials. *Food Sci. Biotech*., 26: 1763.
99. United States Department of Agriculture USDA, www.fsis.usda.gov.
100. Upadhyay A, Upadhyaya I, Mooyottu S, and Venkitanarayanan K. (2016). Eugenol in combination with lactic acid bacteria attenuates *Listeria monocytogenes* virulence in vitro and in invertebrate model *Galleria mellonella*. *Journal of Medical Microbiology*, 65:443– 455.
101. Upadhyaya I, Upadhyay A, Kollanoor‐Johny A, Darre MJ and Venkitanarayanan K. (2013). Effect of plant derived antimicrobials on *Salmonella enteritidis* adhesion to and invasion of primary chicken oviduct epithelial cells in vitro and virulence gene expression. *International Journal of Molecular Sciences*., 14: 10608– 10625.
102. Varga E, Bardocz A, Belak A, Maraz A, Boros B, Felinger A, Boszormenyi A and Horvath G. (2015). Antimicrobial activity and chemical composition of thyme essential oils and the polyphenolic content of different thymus extracts. *Farmacia*., 63:357–361.
103. Wang L, Wu Y, Huang T, Shi K and Wu Z. (2017). Chemical Compositions, Antioxidant and Antimicrobial Activities of Essential Oils of *Psidiumguajava* L. Leaves from Different Geographic Regions in China. *Chem Biodivers*., 14:9.
104. Wang LH, Zhang ZH, Zeng XA, Gong DM and Wang MS. (2017). Combination of microbiological, spectroscopic and molecular docking techniques to study the antibacterial mechanism of thymol against *Staphylococcus aureus*: membrane damage and genomic DNA binding. *Anal Bioanal Chem*., 409(6):1615-1625.
105. Wang Q, Ou Z. B, Lei HW, Zeng XH, Ying Y and Bai WD. (2012. Antimicrobial activities of a new formula of spice water extracts against food

borne bacteria. *J. Food Process Preserv*., 36:374–381.
106. Weerakkody NS, Caffin N, Turner MS and Dykes GA. (2010). In vitro antimicrobial activity of less-utilized spice and herb extracts against selected food-borne bacteria. *Food Control*., 21:1408–1414.
107. Xu JG, Liu T, Hu QP and Cao XM. (2016). Chemical Composition, Antibacterial Properties and Mechanism of Action of Essential Oil from Clove Buds against *Staphylococcus aureus*. *Molecules*., 21(9): 1194.
108. Zellagui A, Gherraf N, Elkhateeb A, Hegazy M, Mohamed TA, Touil A, Shahat AA and Rhouati S. (2011). Chemical constituents from Algerian *Foeniculum Vulgare* aerial parts and evaluation of antimicrobial activity. *J. Chil. Chem., Soc*., 56:759–763.
109. Zheng J, Zhou Y, Li Y, Xu DP, Li S, and Li HB. (2016). Spices for Prevention and Treatment of Cancers. *Nutrients*., 8(8): E495.

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