BIOSCIENCE, BIOENGINEERING AND BIOTECHNOLOGY
Journal homepage: www.jakraya.com/journal/bbb

REVIEW ARTICLE

Effect of Natural Antimicrobials on Foodborne Pathogens and Shelf Life: A Review

BG Mane*[1], SK Khurana[1], Shivani Choudhary[1] and Himani Dhanze[2]

[1]College of Veterinary and Animal Sciences, CSK-HPKV, Palampur-176062 (HP), India.
[2]Division of Veterinary Public Health, Indian Veterinary Research Institute, Izatnagar-243 122 (UP), India.

*Corresponding Author:

B.G. Mane

Email: drbandu_176@gmail.com

Received: 18/11/2014

Revised: 29/12/2014

Accepted: 30/12/2014

Abstract

The emerging multi-drug resistance in food borne pathogens and consumers demand for minimally processed fresh natural foods has paved the path for natural antimicrobials to be used in food industry. Various plant materials had been used in food for their flavour and to increase the taste. Apart from these properties, these extracts and essential oils act as antioxidants and antimicrobials without affecting the quality attributes of foods. Keeping these facts, in the present review various natural extracts and essential oils have been discussed in relations to their effectiveness against foodborne pathogens, shelf life extension and spoilage microorganism.

Keywords: Food Spoilage, Food preservation, Food pathogens, Natural antimicrobial.

1. Introduction

The ever increasing demand of consumers for chemical and antibiotic free food along with the emerging multi-drug resistance in food borne pathogens has paved the path for natural antimicrobials to be used in food industry. Recently plant extracts and essential oils have received a lot of attention for use in food products due to their antioxidant and antimicrobial activities as well as flavour properties (Dhanze and Mane, 2012). Tiwari *et al.* (2009) reviewed antimicrobials from a range of plant, animal, and microbial sources for their potential applications in food systems. According to them natural antimicrobials can be used alone or in combination with other novel preservation technologies to facilitate the replacement of traditional approaches. Prakash *et al.* (2013) carried out a study to determine the antimicrobial activity of the fruit peel extracts of *Maclura pomifera* (Orange), *Punica gramatum* (Pomegranate or Anar), *Musa balbisiana* (Banana), *Citruslimetta* (Sweet lime or Mousambi), *Malus domestica* (Apple), *Carica papaya* (Papaya) and *Mangifera indica* (Mango) and stated that they had moderate to mild inhibiting effect on pathogenic bacteria. In this manuscript brief overview of studies on natural antimicrobial is discussed.

2. Recent Works on Effectiveness of Natural Antimicrobial in Foods Systems: Indian Perspective

The extracts, juice, oils, paste and powders were used to assess their antioxidant and antimicrobial effect against various foodborne pathogens and shelf life. Rauha *et al.* (2000) studied the antimicrobial activity of thirteen phenolic substances and twenty nine extracts prepared from Finnish plant materials against selected microbes. Flavone, quercetin and naringenin were effective in inhibiting the growth of the organisms. Elgayyar *et al.* (2001) found that the basil oil had been effective against emerging food borne pathogen like *E. coli O: 157:H7*. Kumar and Begum (2002) showed that *E. coli* was highly sensitive to 80 percent ethanolic extract of *Leucas aspera* and moderately sensitive to *Thespesia populnea* extract and less sensitive to the extract of *Achyranthes aspera*. Singh *et al.* (2002) studied antibacterial activity of the essential oils extracted from the seeds of seven plant spices i.e. *Anethum graveolens*, *Carum capticum*, *Coriandrum sativum*, *Cuminum cyminum*, *Foeniculum vulgare*, *Pimpinella anisum* and *Seseli indicum* against eight pathogenic bacteria. They observed that the oil of *C. capticum*, *C. cyminum* and *A. graveolens* was very effective against all tested bacteria. Jayaprakasha *et al.* (2003) reported that the grape seed extract displayed antimicrobial activity against major food borne pathogen like *Bacillus cereus, Staphylococcus aureus* and *Escherichia coli*. Voravuthikunchai *et al.* (2004) tested antibacterial activity of aqueous and ethanolic extracts of thirty eight medicinal plant species commonly used in Thailand, against different strains of *Escherichia coli*, including six strains of *Escherichia* *coli* O157:H7, *Escherichia coli* O26:H11, *Escherichia coli* O111:NM, *Escherichia coli* O22; five strains of *Escherichia coli* isolated from bovine; and *Escherichia coli* ATCC 25922. Both aqueous and ethanolic extracts of *Quercus infectoria* and aqueous extract of *Punica granatum* were highly effective against *Escherichia coli* O157:H7. Gopanraj *et al.* (2005) reported that the essential oil from the rhizomes of *Hedychium larsenii* M. showed moderate antibacterial activity against Gram-positive and Gram-negative bacteria. Negi *et al.* (2005) tested the extract of Seabuckthorn (*Hippophae rhamnoides* L.) seeds for their anitibacterial activity and found the MIC values of methanolic extract for *Bacillus cereus*, *Bacillus coagulans*, *Bacillus subtilis*, *Listeria monocytogenes*, *Yersinia enterocolitica*, to be 200, 300, 300, 300, and 350 ppm, respectively. Duraipandiyan *et al.* (2006) indicated that ten plant extracts out of eighteen plant extracts exhibited antimicrobial activity against one or more of the tested nine bacterial strains (*Bacillus subtilis*, *Staphylococcus aureus, Staphylococcus epidermidis*, *Enterococcus faecalis*, *Escherichia coli, Klebsiella pneumonia, Pseudomonas aeruginosa*, *Ervinia sp* and *Proteus vulgaris*) at three different concentrations of 1.25, 2.5 and 5 mg/disc. Among the plants tested *Acalypha fruticosa*, *Peltophorum pterocarpum, Toddalia asiatica*, *Cassia auriculata*, *Punica granatum* and *Syzygium line are* were most active. Mahida and Mohan (2006) examined methanol extracts of twenty two Indian plants belonging to twelve families and found them effective against more than one organism, with the results being comparable to that of antibiotics. Out of the plants tested *Blumea lacera* (Burm f.), *Canscora diffusa* (Vahl), *Cassia alata* L., *C. biflora* L., *C. fistula* L. (Ceasalpiniaceae), and *Putranjiva roxburghii* Wall (Euphorbiaceae) extracts were found to be more effective against both Gram-positive and Gram-negative bacteria. Parekh *et al.* (2006) screened twelve plants for their antibacterial potentiality, viz., *Abutilon indicum* L., *Acorous calamus* L., *Ammania baccifera* L., *Argyrea nervosa* Burm. F., *Bauhinia variegata* L., *Crataeva religiosa* Forst., *Hedychium spicatum* L., *Holarrhena antidysenterica* L., *Piper nigrum* L., *Plumbago zeylanica* L., *Psoralea corylifolia* L., *Saussurea lappa* Costus against five bacterial strains, viz., *Bacillus cereus*, *Staphylococcus aureus*, *Klebsiella pneumoniae*, *Escherichia coli*, *Pseudomonas pseudoalcaligenes*. They revealed that plant extracts were more active against gram-positive bacteria than gram-negative bacteria. Chauhan *et al*. (2007) reported that Seabuckthorn (*Hippophae rhamnoides*) seeds aqueous extract possessed antibacterial activities against *Listeria monocytogenes* and *Yersinia enterocolitica* and implicated that the extract had potential for natural preservation. Sofia *et al.* (2007) conducted a study employing cinnamon extract and reported it to be having good inhibitory activity against *Escherichia coli*, *Bacillus cereus* and *Staphylococcus aureus*. Jagtap *et al.* (2009) found ethanol extract of brahmi leaves to be highly sensitive against the various food borne pathogens. Khan *et al.* (2009) stated that multidrug resistant (MDR) strains of *Escherichia coli* were sensitive to crude ethanolic extracts *Acacia nilotica*, *Syzygium aromaticum* and *Cinnamum zeylanicum.* Sharma *et al*. (2009) determined the antibacterial activity of aqueous, ethanol and acetone extracts of *Corriander sativum*, *Abutilon indicum*, *Boerhavia diffusaandrographis paniculata*, *Plantago ovata*, *Bacopa monnieri*, *Bauhinia variegata*, *Flacouratia ramontchi*, *Embelia tfgerium*, *Euphorbia ligularia*, *Zinziber officinale*, *Terminalia chebula*, *Azadirachta indica*, *Ocimum sanctum* and *Cinnamomum cassia* was against 33 bacterial isolates. They reported that crude extracts of the selected plants especially the acetone and ethanol extracts exhibited significant activity against UTI pathogens. Chanda *et al*. (2010) reported the antimicrobial activity of peels of seven fruit and vegetables against eleven microorganisms. The *Mangifera indica* peel showed best and promising antimicrobial activity. Gram-negative bacteria were found more susceptible than Gram-positive bacteria which contradicted the previous reports that plant extracts are more active against Gram positive bacteria than Gram negative bacteria. Sudarshan *et al.* (2010) recently used the ginger and garlic essential oils as decontaminants with very promising results against *Staphylococcal counts*, *E. coli* and *Salmonella*. Upadhyay *et al.* (2010) conducted a study on the antibacterial effects aqueous and hydroalcoholic extracts of *Hippophae rhamnoides* L. (Seabuckthorn) (SBT) and showed that leaf extracts of Seabuckthorn had growth inhibiting effect against *Bacillus cereus*, *Pseudomonas aeruginosa*, *Staphylococcus aureus* and *Enterococcus faecalis*. Michel *et al*. (2011) reported that crude ethanolic extract from *Hippophaë rhamnoides* L. (Elaeagnaceae) leaf, stem, root and seed, were active against Gram positive and negative bacteria. Verma and Chaudhary (2011) showed that the fruit extract of *C. carandas* in dichloromethane showed antibacterial activity against the *E. coli*. Arora *et al.* (2012) assessed antibacterial properties of crude extracts of sea buckthorn (*Hippophae rhamnoides*L.) pomace, seeds and leaves against seventeen foodborne pathogens. The methanolic extract of leaves exhibited a low minimum inhibitory concentration (MIC) value of 125 µg/ml against *Listeria monocytogenes*. Gupta *et al.* (2012) characterized the antimicrobial effect of six Indian tropical fruit residues against five Gram-positive bacteria and four Gram-negative bacteria. Among the all tested extracts, the best antimicrobial activity was shown by *Carissa carandas* and *Artocarpus lachoocha*. Kamaraj *et al.* (2012) evaluated the antibacterial properties of crude extracts from leaf and flower of *Aristolochia indica*, *Cassia angustifolia*, leaf of *Catharanthus roseus*, *Diospyros melanoxylon*, *Dolichos biflorus*, *Gymnema sylvestre* and *Justicia procumbens* against Gram-positive and Gram-negative bacteria including *Escherichia coli*. The inhibitory zone observed against *E. coli* was 20 mm in case of leaf methanol extract of *A. indica*. The MIC values of flower extract of *A. Indica* showed against *E. coli* was 24.2g/ml leaf.

3. Recent Works on Effectiveness of Natural Antimicrobial in Foods Systems: Global Perspective

Most of the work on effectiveness of natural antimicrobial was directed foodborne pathogen and very less attention was provided for their effect against spoilage microorganism except recent work of Dhanze *et al.* (2013). However, studies on antioxidant effect were available using natural extracts, juices, oils, powder and pastes specifically in animal origin foods. In one of the study, Cutter (2000) conducted a series of experiments to determine the effectiveness of a commercially available, generally recognized as safe, herb extract against *Escherichia coli* O157:H7, *Salmonella Typhimurium* and *Listeria monocytogenes* associated with beef. They suggested that the use of herb extracts may afford some reductions of pathogens on beef surfaces. In another study, Ahmad and Beg (2001) observed a broad-spectrum antimicrobial activity of ethanolic extracts of twelve plants (*L. inermis*, *Eucalyptus* sp., *H. antidysentrica*, *H. indicus*, *C. equistifolia*. *T. belerica*, *T. chebula*, *E. officinalis*, *C. sinensis*, *S. aromaticum* and *P. granatum*) against drug-resistant bacteria i.e. *Escherichia coli*, *Staphylococcus aureus*, *Salmonella paratyphi*, *Shigella dysenteriae*, *Bacillus subtilis* and *Candida albicans*. Sakagami *et al.* (2001) described that the extracts from four plant species, *Limonium californicum* (Boiss.) *A. Heller*, *Cupressus lustianica* Miller, *Salvia urica* Epling and *Jusiaea peruviana* L. were effective in inhibiting verotoxin production by enterohemorrhagic *Escherichia coli* O157: H7 (EHEC). Delaquis *et al.* (2002) used essential oils from dill (*Anethum graveolens* L.), coriander (seeds of *Coriandrum sativum* L.), cilantro (leaves of immature *C. sativum* L.) and eucalyptus (*Eucalyptus dives*) against gram-positive bacteria and gram-negative bacteria and determined their antimicrobial activity. Friedman *et al.* (2002) reported that twenty-seven essential oils and twelve oil compounds were having bactericidal activity against *Campylobacter jejuni*, *Escherichia coli* O157:H7, *Listeria monocytogenes* and *Salmonella enterica*. The oils that were most active against *E. coli* were oregano, thyme, cinnamon, palmarosa, bay leaf, clove bud, lemon grass, and allspice oils. Olasupo *et al.* (2003) evaluated the inhibitory activity of several natural organic compounds alone or in combination with nisin against *Escherichia coli*. They reported that the individual natural organic compounds showed inhibitory activity against the two Gram-negatives but their combinations with nisin showed no improvement of antimicrobial activity. Burt *et al.* (2004) studied the antibacterial activity of essential oils (e.g. carvacrol, thymol, eugenol, perillaldehyde, cinnamaldehyde, cinnamic acid) against gram positive and gram negative bacteria including *Escherichia coli* O157:H7 at levels between 0.2 and 10 microl ml (-1). Gram-negative organisms were reported to be slightly less susceptible than gram-positive bacteria. Friedman *et al.* (2004) assessed seventeen plant essential oils and nine oil compounds for antibacterial activity against *Escherichia coli* O157:H7 in apple juices and reported that the ten compounds most active against *E. coli* were carvacrol, oregano oil, geraniol, eugenol, cinnamon leaf oil, citral, clove bud oil, lemongrass oil, cinnamon bark oil, and lemon oil. Mucete *et al.* (2005) reported the antibacterial activity of horseradish root extract against *Esherichia coli* and antifungal activity against *Candida albicans* and *Aspergillus niger* which are generally involved in food spoilage. Fu *et al.* (2007) stated that the essential oils from clove (*Syzygium aromaticum* (L.) and rosemary (*Rosmarinus officinalis* L.) possessed significant antimicrobial effects against many microorganisms including *Escherichia coli*. The MICs of clove oil ranged from 0.062 percent to 0.500 percent (v/v), while the MICs of rosemary oil ranged from 0.125 percent to 1.000 percent (v/v). Oussalaha *et al.* (2007) evaluated twenty eight essential oils for their antibacterial properties, against four pathogenic bacteria (*Escherichia coli* O157:H7, *Listeria monocytogenes* 2812 1/2a, *Salmonella Typhimurium* SL 1344 and *Staphylococcus aureus*). Results showed that the most active essential oils against bacteria tested were *Corydothymus capitatus*, *Cinnamomum cassia*, *Origanum heracleoticum*, *Satureja montana* and *Cinnamomum verum* (bark). Zhang *et al.* (2009) reported that the combination of rosemary and liquorice spice extracts inhibited not only the growth of *L. monocytogenes*, but were also effective against pathogenic species of bacteria such as *E. coli*, *Pseudomonas fluorescens* and *Lactobacillus sake* in vacuum packaged hams and modified atmosphere packaged fresh pork chops. Tajkarimia *et al.* (2010) described that herbs and spices containing essential oils (EOs) when used in the range of 0.05–0.1%

demonstrated activity against pathogens, such as *Salmonella Typhimurium*, *Escherichia coli* O157:H7, *Listeria monocytogenes*, *Bacillus cereus* and *Staphylococcus aureus*, in food systems. Abdullah *et al.* (2012) showed that *Mangifera indica* peels were a potent antibacterial inhibitor for both Gram-positive and Gram-negative bacteria. Ait-Ouazzoua *et al.* (2012) evaluated the antimicrobial activity of the essential oils (EOs) of *Mentha pulegium* L., *Juniperus phoenicea* L. and *Cyperus longus* L. from Morocco. The antimicrobial activity of these EOs has been evaluated against seven bacteria of significant importance for food hygiene. According to the results, *M. pulegium* showed the best bacteriostatic and bactericidal effect, followed by *J. phoenicea* and *C. longus*. Cicerale *et al.* (2012) described that olive oil phenolic compounds have potentially beneficial biological effects in humans and animals resulting from their antimicrobial, antioxidant and anti-inflammatory activities. Kyung (2012) reported that alliums are inhibitory against multi-drug-resistant microorganisms and often work synergistically with common antimicrobials. Belda-Galbisa *et al.* (2013) evaluated the effect of different concentrations of carvacrol (0.1–0.25 μL/mL) and citral (0.25–1.5 μL/mL), at different storage temperatures (8–37 °C) against *Escherichia coli* O157:H7. Carvacrol showed a greater effectiveness than citral. Kim *et al.* (2013) evaluated antimicrobial activities of 70 percent ethanolic extracts of ten leafy green vegetables (LGV) commonly consumed in East Asia, against *Escherichia coli*, *Salmonella enterica*, *Shigella flexneri*, *Listeria monocytogenes*, *Staphylococcus aureus* and *Bacillus subtilis*, using agar well diffusion and broth-microdilution tests. Among all LGV, extracts of chamnamul (Pimpinella brachycarpa) and fatsia (*Aralia elata*) exhibited outstanding antimicrobial properties. Roundsa *et al.* (2013) determined the effects of apple and olive extracts, onion powder, and clove bud oil on *E. coli* O157:H7. Olive extract at 3 percent reduced *E. coli* O157:H7 to below detection. Reductions of up to 1 log were achieved with apple extract.

4. Recent Work on Effectiveness of Plants Extracts on Foodborne Pathogens and Shelf Life

4.1 Citrus Fruits

The effectiveness of oils and vapours of citrus fruits were evaluated for their antimicrobial activity against wide variety of spoilage and pathogenic microorganisms (Kirbaslar *et al.,* 2009; Shahid *et al.,* 2009; Espina *et al.,* 2011; Saima *et al.,* 2011; Roy *et al.,* 2012; Settannia *et al.,* 2012). While the acitivity was specifically tested against *E. coli* (Fisher and Phillips, 2006; Johann *et al.,* 2007; Mishra *et al.,* 2012) and reported significant antimicrobial activity against the various strains of *E. coli*. Fisher and Carol (2008) reported that the essential oil of citrus fruits like orange, lemon and bergamot had good antimicrobial activity against *Escherichia coli O157*, *Campylobacter jejuni*, *Listeria monocytogens*, *Bacillus cereus and Staphylococus aureus*. Lee and Najiah (2009) stated that the crude extract of *Citrus microcarpa* showed antimicrobial activity against seven bacterial reference strains, namely, *Escherichia coli* (ATCC 25922), *Citrobacter freundii* (ATCC 8090), *Aeromonas hydrophila* (ATCC 49140), *Pseudomonas aeruginosa* (ATCC 35032), *Streptococcus agalatiae* (ATCC 13813), *Edwardsiella tarda* (ATCC 15947), and *Yersinia enterocolitica* (ATCC 23715) with the MIC values ranging from 7.8 to 31.3 mg mL^{-1}. Singh and Bilal (2009) studied the antimicrobial potency of C*itrus sinensis* peel and oil against *Escherichia coli* with the formation of 17 mm wide zone of inhibition. Pandey *et al.* (2011) showed that ethanolic, methanolic, ethyl acetate and hot water extract of lemon fruit peels, seeds and juice displayed promising evidence of antibacterial activity against bacteria (*E. coli, P. aeruginosa and S. aureus*).

4.2. Pomegranate

The extracts of pomegranate (*Punica granatum*) was found to be effective against the wide variety of micro-organism (Prashanth *et al*., 2001; Negi and Jayaprakasha, 2006; Opara *et al*., 2009; Devatkal *et al.,* 2013). The extract of pomegranate (*Punica granatum*) exhibited substantial antimicrobial activity against *E. coli* (Meléndez and Capriles, 2006; Naz *et al.,* 2007; McCarrell *et al.,* 2008; Pradeep *et al.,* 2008; Khan *et al.,* 2011), while (Voravuthikunchai *et al.,* 2005) reported that the ethanolic extract from *Punica granatum* pericarp was effective against different strains of enterohemorrhagic *Escherichia coli* O157: H7 including other strains of enterohemorrhagic *E. coli*. Fawole *et al.* (2012) tested antibacterial activity of methanolic extracts from peels of seven commercially grown pomegranate cultivars on Gram-positive and Gram-negative bacteria (*Escherichia coli* and *Klebsiella pneumonia*). Methanolic peel extracts showed strong broad-spectrum activity against Gram-positive and Gram-negative bacteria, with the minimum inhibitory concentrations (MIC) ranging from 0.2 to 0.78 mg/ml. Nuamsetti *et al.* (2012) reported that *Escherichia coli*, *Bacillus subtilis*, *Staphylococcus aureus* and *Salmonella Typhimurium* were sensitive to hot water, 95% ethanol, and acetone extracts of pomegranate fruit peels and arils (with seeds),with hot-water extract of the peels being most potent with the minimal inhibitory concentration of 207 mg/ml against *E. coli*.

4.3. Ginger

Ginger is one of the most used condiments for preparation of various dishes in India. The antimicrobial and antioxidant activity of ginger has been reported (Habsahaet *et al.*, 2000). The antimicrobial activity of ginger extract was also reported against *E. coli* (Ekwenye and Elegalam, 2005; Gupta and Ravishankar, 2005; Nanasombat and Lohasupthawee, 2005; Indu *et al.*, 2006; Chen *et al.*, 2008; Auta *et al.*, 2011). The antimicrobial activity was also reported against *E. coli* O157:H7 (Gupta and Ravishankar, 2005; Sutherland *et al.*, 2009), while Ushimaru *et al.* (2007) showed that methanolic extract (70 percent) of ginger (*Zingiber officinale*) was effective against *E. coli* with MIC (50 percent and 90 percent) equal to 6.97 mg/ml. However, Kaushik and Goyal (2011) studied the crude aqueous and organic extracts of rhizome of *Zingiber officinale* Roscoe (ginger) against *Escherichia coli* and suggested that methanolic crude and organic extracts displayed antibacterial effect but aqueous extracts were ineffective. Similarly, Gull *et al.* (2012) showed that ethanolic and methanolic extracts of ginger had significant antimicrobial effect on *Escherichia coli* isolates but the ginger aqueous extract was only mildly effective. Pokhrel *et al.* (2012) examined the antibacterial activity of crude ethanolic extracts and essential oils of Ginger (*Zingiber officinale*) against five strains of diarrhoea causing *Escherichia coli*. They showed the *E. coli* strains were susceptible to the essential oils but not to the crude extracts.

4.4. Curry Leaves

Murraya Koenigii Linn commonly known as Meethi neem, belongs to the family *Rutaceae*. The curry tree is native to India and it is found almost everywhere in the Indian subcontinent excluding the higher levels of Himalayas. Curry leaves is found to be effective as antioxidant, antidiabetic, antibacterial, antihypertensive, cytotoxic and also in the treatment of bronchial respiratory difficulties (Dhanze, 2011). The leaves are used traditionally as spice in curry and other eatables. The effect of the curry leaves extract was observed against foodborne pathogens (Zachariah, 2009; Harika *et al.*, 2010; Malwal *et al.*, 2010) with significant antimicrobial activity. Ningappa *et al.* (2010) assessed the antibacterial activity of a monomeric protein isolated from *Murraya Koenigii* L. (curry leaves) and showed that it effectively inhibited *Escherichia coli*, with MIC values ranging from 13 to 24 µg/ml. Baskaran *et al.* (2011) observed that ethanol, methanol, ethyl acetate, acetone, chloroform, petroleum ether, hexane and aqueous extracts of *Murraya Koenigii* displayed antibacterial activity against the Gram-positive and Gram-negative bacteria, while *Escherichia coli* showing maximum susceptibility to acetone extract (zone of inhibition=16.20±0.20). Das and Biswas (2012) showed that ethyl acetate and dichloromethane soluble partitionate of methanolic leaf extract of *Murraya Koenigii* exhibited mild activity against *Escherichia coli* forming zone of inhibition of 9 mm to 11 mm.

4.5. Radish

The radish extracts was employed by various workers to find out their antimicrobial activity against foodborne pathogens (Al-Delaimy and Ali, 1970; Abdou *et al.*, 1972; Kivanc and Kunduhoglu, 1997; Jahangir *et al.*, 2010). Mucete *et al.* (2005) reported the antibacterial activity of horseradish root extract against *Esherichia coli* and antifungal activity against *Candida albicans* and *Aspergillus niger* which are generally involved in food spoilage. Beevi *et al.* (2009) investigated acetone and hexane extracts derived from the root, stem, and leaf of *Raphanus sativus* for their antibacterial activity against foodborne and resistant pathogens. Of the different parts of *R. sativus* studied, root tended to be more active than the stem and leaf extracts in inhibiting the bacterial growth. Kumar *et al.* (2010) used extracts of some Indian culinary leaves (radish, curry, coriander, mint leaves etc.) to analyse them for the possible antimicrobial potential by testing them against different bacteria by using agar-disc diffusion method. Janjua *et al.* (2013) analyzed different extracts of peels of edible root of *Raphanus sativus L. var niger* for in vitro antibacterial activity against different gram positive and gram negative bacteria. Highest zone of inhibition (28 ± 1.2 mm was observed against *E. coli* for petroleum ether extract. They concluded that peels of *R. sativus*, generally wasted, have important medicinal constituents. Ward *et al.* (1998) used the volatile horseradish distillates/oil in beef hamburger and cooked roast beef and assessed its bactericidal activity against most dangerous strain of *Escherichia coli* O157:H7, *Listeria monocytogens* and *Staphylococus aureus* which are major food borne pathogens.

4.6. Seabuckthorn

Recently seabuckthorn extracts was evaluated against the fodborne pathogens and extends the shelf life. Dhanze *et al.* (2013) reported that aqueous extract of seabuckthorn leaves significantly lowered the ($P <$ 0.05) standard plate count (SPC), psychrophilic count (PC), coliform count (CC), and yeast and mold count (YMC) on chicken leg as compared with the control. While the 3% seabuckthorn leaf extract treatment resulted in significant (*P* < 0.05) lowering of SPC, PC, CC and YMC through 7 days. Negi *et al*. (2005) tested the extract of Seabuckthorn (*Hippophae rhamnoides* L.) seeds for their anitibacterial activity and found the MIC values of methanolic extract for *Bacillus cereus*, *Bacillus coagulans*, *Bacillus subtilis*, *Listeria monocytogenes*, *Yersinia enterocolitica*, to be 200, 300, 300, 300, and 350 ppm, respectively. Chauhan *et al.* (2007) reported that Seabuckthorn (*Hippophae rhamnoides*) seeds aqueous extract possessed antibacterial activities against *Listeria monocytogenes* and *Yersinia enterocolitica* and implicated that the extract had potential for natural preservation. Upadhyay *et al.* (2010) conducted a study on the antibacterial effects aqueous and hydroalcoholic extracts of *Hippophae rhamnoides* L. (Seabuckthorn) (SBT) and showed that leaf extracts of Seabuckthorn had growth inhibiting effect against *Bacillus cereus*, *Pseudomonas aeruginosa*, *Staphylococcus aureus* and *Enterococcus faecalis*. Michel *et al.* (2011) reported that crude ethanolic extract from *Hippophaë rhamnoides* L. (Elaeagnaceae) leaf, stem, root and seed, were active against Gram positive and negative bacteria. Arora *et al*. (2012) assessed antibacterial properties of crude extracts of seabuckthorn (*Hippophae rhamnoides*L.) pomace, seeds and leaves against seventeen foodborne pathogens. The methanolic extract of leaves exhibited a low minimum inhibitory concentration (MIC) value of 125 µg/ml against *Listeria monocytogenes.*

5. Conclusion

Based on the different studies, it is finally concluded that few extracts have antimicrobial activity against various foodborne pathengns as well as these extracts have antimicrobial activity against range of spoilage microorganisms and extends the shelf life. These extracts can be effectively used as alone in combinations with other extracts or other preservation methods to protect the consumer from foodborne pathogens and early spoilage of the foods.

References

Abdou IA, Abou-Zeid AA, El-Sherbeeny MR and Abou-El-Gheat ZH (1972). Antimicrobial activities of *Allium sativum*, *Allium cepa*, *Raphanus sativus*, *Capsicum frutescens*, *Eruca sativa*, *Allium kurrat* on bacteria. *Qualitas Plantarum et Materiae Vegetabiles,* 22(1):29-35.

Abdullah N, Zulkifli KS, Abdullah A, Aziman N and Kamarudin WSSW (2012). Assessment on the antioxidant and antibacterial activities of selected fruit peels. *International Journal of ChemTech Research,* 4(4):1534-1542.

Ahmad I and Beg AZ (2001). Antimicrobial and phytochemical studies on 45 Indian medicinal plants against multi-drug resistant human pathogens. *Journal of Ethnopharmacology,* 74(2): 113-213.

Ait-Ouazzoua A, Loråna S, Arakrakb A, Laglaouib A, Rotaa C, Herreraa A, Pagåna R and Conchello P (2012). Evaluation of the chemical composition and antimicrobial activity of *Mentha pulegium*, *Juniperus phoenicea*, and *Cyperus longus* essential oils from Morocco. *Food Research International,* 45(1): 313-319.

Al-Delaimy KS and Ali SH (1970). Antibacterial action of vegetable extracts on the growth of pathogenic bacteria. *Journal of the Science of Food and Agriculture,* 21(2): 110-112.

Arora R, Mundra S, Yadav A, Srivastava RB and Stobdan T (2012). Antimicrobial activity of seed, pomace and leaf extracts of sea buckthorn (*Hippophae rhamnoides* L.) against foodborne and food spoilage pathogens. *African Journal of Biotechnology,* 11(45): 10424-10430.

Auta KI, Galadima AA, Bassey JU, Olowoniyi OD, Moses OO and Yako AB (2011). Antimicrobial properties of the ethanolic extracts of *Zingiber officinale* (Ginger) on *Escherichia coli* and *Pseudomonas aeruginosa*. *Research Journal of Biological Sciences,* 6(1): 37-39.

Baskaran C, Rathabai V and Kanimozhi D (2011). Screening for antimicrobial activity and phytochemical analysis of various leaf extract of *Murraya Koenigii* C. *International Journal of Research in Ayurveda and Pharmacy,* 2 (6): 1807-1810.

Beevi SS, Mangamoori LN, Dhand V and Ramakrishna DS (2009). Isothiocyanate profile and selective antibacterial activity of root, stem, and leaf extracts derived from *Raphanus sativus* L. *Foodborne Pathogens and Disease,* 6(1): 129-136.

Belda-Galbisa CM, Pina-Péreza MC, Leufvénb A, Martíneza A and Rodrigo D (2013). Impact assessment of carvacrol and citral effect on *Escherichia coli* K12 and *Listeria innocua* growth. *Food Control,* 33(2): 536-544.

Burt S (2004). Essential oils: their antibacterial properties and potential applications in foods-a review. *International Journal of Food Microbiology,* 94(3):223-253.

Chanda S, Baravalia Y, Kaneria M and Rakholiya K (2010). Fruit and vegetable peels – strong natural source of antimicrobics. In: *A. Mendez-Vilas, Ed., Current Research Technology and Education Topics in Applied Microbiology and Microbial Biotechnology. Formatex Research Center, Spain. 2: 444-450.*

Chauhan AS, Negi PS and Ramteke RS (2007). Antioxidant and antibacterial activities of aqueous extract of Seabuckthorn (*Hippophae rhamnoides*) seeds. *Fitoterapia,* 78(7-8):590-592.

Chen IN, Chang CC, Ng CC, Wang CY, Shyu YT and Chang TL (2008). Antioxidant and antimicrobial activity of Zingiberaceae plants in Taiwan. *Plant Foods for Human Nutrition,* 63(1):15-20.

Cicerale S, Lucas LJ and Keast RSJ (2012). Antimicrobial, antioxidant and anti-inflammatory phenolic activities in extra virgin olive oil. *Current Opinion in Biotechnology*, 3(2):129-135.

Cutter CN (2000). Antimicrobial effect of herb extracts against *Escherichia coli* O157: H7, *Listeria monocytogenes* and *Salmonella Typhimurium* associated with beef. *Journal of Food Protection,* 63(5): 601-607.

Das BN and Biswas BK (2012). Antibacterial and cytotoxic activities of the leaf extract of *Murraya koenigii. International Journal of Life Science, Biotechnology and Pharma Research*,1(3): 59-62.

Delaquis PJ, Stanich K, Girard B and Mazza G (2002). Antimicrobial activity of individual and mixed fractions of dill, cilantro, coriander and eucalyptus essential oils. *International Journal of Food Microbiology,* 74(1-2): 101-109.

Devatkal SK, Jaiswal P, Jha SN, Bharadwaj R and Viswas KN (2013). Antibacterial activity of aqueous extract of pomegranate peel against *Pseudomonas stutzeri* isolated from poultry meat. *Journal of Food Science and Technology,* 50(3): 555-560.

Dhanze H (2011). Studies on prevalence, characterization and antimicrobial effects on *Salmonella* isolates from egg, chicken and meat. *M. V. Sc. Thesis. Department of Veterinary Public Health and Epidemiology, CSK Himachal Pradesh Krishi Vishvavidyalaya, Palampur, India.*

Dhanze H and Mane BG (2012). Plant materials as natural antimicrobials for decontamination and reduction of food-borne pathogens -a review. *Indian Food Packer,* 66(4): 54-60.

Dhanze H, Khurana SK and Mane BG (2013). Effect of seabuckthorn leaf extract on microbiological quality of raw chicken during extended periods of storage. *Journal of Food Quality*, 36(1): 59-66.

Duraipandiyan V, Ayyanar M and Ignacimuthu S (2006). Antimicrobial activity of some ethno-medicinal plants used by Paliyar tribe from Tamil Nadu, India. *BMC Complementary and Alternative Medicine*, 6: 35.

Ekwenye UN and Elegalam NN (2005). Antimicrobial activity of Ginger (*Zingiber officinale* Roscoe) and Garlic (*Allium sativum* L.) extracts on *Escherichia coli* and *Salmonella typhi*. *International Journal of Molecular Medicine and Advance Sciences,* 1(4): 411-417.

Elgayyar M, Draughon FA, Golden DA and Mount JR (2001). Antimicrobial activity of essential oils from plants against selected pathogenic and saprophytic microorganisms. *Journal of Food Protection,* 64(7): 1019-1024.

Espina L, Somolinos M, Lorán S, Conchello P, García D and Pagán R (2011). Chemical composition of commercial citrus fruit essential oils and evaluation of their antimicrobial activity acting alone or in combined processes. *Food Control*, 22(6): 896-902.

Fawole OA, Makunga NP and Opara UL (2012). Antibacterial, antioxidant and tyrosinase-inhibition activities of pomegranate fruit peel methanolic extract. *BMC Complementary and Alternative Medicine,* 12: 200.

Fisher K and Carol P (2008). Potential antimicrobial uses of essential oils in food: is citrus the answer. *Trends in Food Science and Technology,* 19(3): 156-164.

Fisher K and Phillips CA (2006). The effect of lemon, orange and bergamot essential oils and their components on the survival of *Campylobacter jejuni*, *Escherichia coli* O157, *Listeria monocytogenes*, *Bacillus cereus* and *Staphylococcus aureus* in vitro and in food systems. *Journal of Applied Microbiology,* 101(6): 1232-1240.

Friedman M, Henika PR and Mandrell RE (2002). Bactericidal activities of plant essential oils and some of their isolated constituents against *Campylobacter jejuni*, *Escherichia coli*, *Listeria monocytogenes* and *Salmonella enterica*. *Journal of Food Protection,* 65(10):1545-1560.

Friedman M, Henika PR, Levin CE and Mandrell RE (2004). Antibacterial activities of plant essential oils and their components against *Escherichia coli* O157:H7 and *Salmonella enterica* in apple juice. *Journal of Agricultural and Food Chemistry,* 52(19): 6042-6048.

Fu Y, Zu Y, Chen L, Shi X, Wang Z, Sun S and Efferth T (2007). Antimicrobial activity of clove and rosemary essential oils alone and in combination. *Phytotherapy Research,* 21(10): 989-994.

Gopanraj G, Dan M, Shiburaj S, Sethuraman MG and George V (2005). Chemical composition and antibacterial activity of the rhizome oil of *Hedychium larsenii*. *Acta Pharmeutica,* 55(3): 315-320.

Gull I, Saeed M, Shaukat H, Aslam SM, Samra ZQ and Athar AM (2012). Inhibitory effect of *Allium sativum* and *Zingiber officinale* extracts on clinically important drugresistant pathogenic bacteria. *Annals of Clinical Microbiology and Antimicrobials*, 11: 8.

Gupta P, Sharma A and Verma AK (2012). GC/MS profiling and antimicrobial effect of six Indian tropical fruit residues against clinically pathogenic bacterial strain. *International Journal of Advances in Pharmaceutical Research,* 3(10): 1229-1235.

Gupta S and Ravishankar S (2005). A comparison of the antimicrobial activity of garlic, ginger, carrot, and turmeric pastes against *Escherichia coli* O157:H7 in laboratory buffer and ground beef. *Foodborne Pathogens and Disease,* 2(4): 330-340.

Habsaha M, Amrana M, Mackeena MM, Lajisa NH, Kikuzakib H, Nakatanib N, Rahmanc AA, Ghafard and Alie AM (2000). Screening of Zingiberaceae extracts for antimicrobial and antioxidant activities. *Journal of Ethnopharmacology,* 72(3): 403-410.

Harika VC, Padmavathi P, Rao KRSS and Phani RSCH (2010). In-vitro anti microbial activity of leaf powder. *International Journal of Research in Pharmaceutical and Biomedical Sciences,* 1(2): 128-131.

Indu MN, Hatha AAM, 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 *Aeromonas hydrophila*. *Brazilian Journal of Microbiology,* 37(2): 153-158.

Jagtap NS, Khadabadi SS, Ghorpade DS, Banarase NB and Naphade SS (2009). Antimicrobial and antifungal activity of *Centella asiatica* (L.) Urban, Umbeliferae. *Research Journal of Pharmacology and Technology,* 2(2): 328-330.

Jahangir M (2010). Study of different biological activities of *Raphanus sativus* L. (red radish). *Biological Activites of Red Radish:* Chapter-8. Pages 121-128.

Janjua S, Shahid M and Fakhir-i-Abbas (2013). Phytochemical analysis and *in vitro* antibacterial activity of root peel extract of *Raphanus sativus* L. var niger. *Advancement in Medicinal Plant Research,* 1(1): 1-7.

Jayaprakasha GK, Selvi T and Sakariah KK (2003). Antibacterial and antioxidant activities of grape (*Vitis vinifera*) seed extracts. *Food Research International,* 36(2): 117-122.

Johann S, Oliveira VL, Pizzolatti MG, Schripsema J, Braz-Filho R, Branco A and Smânia Jr A (2007). Antimicrobial activity of wax and hexane extracts from *Citrus* spp. peels. *Memórias do Instituto Oswaldo Cruz,* 102(6): 681-685.

Kamaraj C, Rahuman AA, Siva C, Iyappan M and Kirthi AV (2012). Evaluation of antibacterial activity of selected medicinal plant extracts from south India against human pathogens. *Asian Paicfic Journal of Tropical Disease,* 2(supplement-1): S296-S301.

Kaushik P and Goyal P (2011). Evaluation of various crude extracts of *Zingiber officinale* rhizome for potential antibacterial activity: a study In vitro. *Advances in Microbiology,* 1(1): 7-12.

Khan JA and Hanee S (2011). Antibacterial properties of *Punica granatum* peels. *International Journal of Applied Biology and Pharmaceutical Technology,* 2(3): 23-27.

Khan R, Islam B, Akram M, Shakil S, Ahmad AA, Ali SM, Siddiqui M and Khan AU (2009). Antimicrobial activity of five herbal extracts against multi drug resistant (MDR) strains of bacteria and fungus of clinical origin. *Molecules,* 14(2): 586-597.

Kim SJ, Cho AR and Han J (2013). Antioxidant and antimicrobial activities of leafy green vegetable extracts and their applications to meat product preservation. *Food Control,* 29(1): 112-120.

Kirbaslar FG, Tavman A, Dülger B and Türker G (2009). Antimicrobial activity of Turkish citrus peel oils. *Pakistan Journal of Botany,* 41(6): 3207-3212.

Kivanc M and Kunduhoglu B (1997). Antimicrobial activity of fresh plant juice on the growth of bacteria and yeasts. *Journal of Qafqaz University,* 1: 27-31.

Kumar R, Mehta A and John J (2010). Antioxidant and antimicrobial potential of Indian culinary leaves. *Asian Journal of Experimental Biological Sciences, 470 (SPL 2010)*: 96-99.

Kumar RU and Begum VH (2002). Antimicrobial studies of some selected medicinal plants. *Ancient Science of Life,* 21(4): 230-239.

Kyung KH (2012). Antimicrobial properties of allium species. *Current Opinion in Biotechnology,* 23(2): 142-147.

Lee S and Najiah M (2009). Antimicrobial property of 2-Hydroxypropane-1,2,3-Tricarboxylic acid isolated from *Citrus microcarpa*extract. *Agricultural Sciences in China,* 8(7): 880-886.

Mahida Y and Mohan JSS (2006). Screening of Indian plant extracts for antibacterial activity. *Pharmaceutical Biology,* 44(8): 627-631.

Malwal M and Sarin R (2010). Antimicrobial efficacy of *Murraya Koenigii* (Linn.) spreng root extracts. *Indian Journal of Natural Products and Resources,* 2(1): 48-51.

McCarrell EM, Gould SWJ, Fielder MD, Kelly AF, Sankary WE and Naughton DP (2008). Antimicrobial activities of pomegranate rind extracts: enhancement by addition of metal salts and vitamin C. *BMC Complementary and Alternative Medicine,* 8: 64.

Meléndez PA and Capriles VA (2006). Antibacterial properties of tropical plants from Puerto Rico. *Phytomedicine,* 13(4): 272-276.

Michel T, Destandau E, Le Floch G, Lucchesi ME and Elfakir C (2011). Antimicrobial, antioxidant and phytochemical investigations of seabuckthorn (*Hippophaë rhamnoides* L.) leaf, stem, root and seed. *Food Chemistry,* 131(3): 754-760.

Mishra RP, Yadav S and Anjali (2012). Study of antimicrobial activities of *Citrus limetta*. *Journal of Pharmaceutical and Biomedical Sciences,* 19(15):1-4.

Mucete D, Borozan A, Radu F, Jainu I and Alexa E (2005). Research about the antimicrobial action of some active principles in *Armoracia Rusticana*. *Agroalimentary Processes and Technology,* 11(1): 237-242.

Nanasombat S and Lohasupthawee P (2005). Antibacterial activity of crude ethanolic extracts and essential oils of spices against *Salmonellae* and other enterobacteria. *KMITL Science and Technology Journal,* 5(3): 527-538.

Naz S, Siddiqi R, Ahmad S, Rasool SA and Sayeed SA (2007). Antibacterial activity directed isolation of compounds from *Punica granatum*. *Journal of Food Science,* 72(9): M341-M345.

Negi PS and Jayaprakasha GK (2006). Antioxidant and antibacterial activities of *Punica granatum* peel extracts. *Journal of Food Science,* 68(4): 1473-1477.

Negi PS, Chauhan AS, Sadia GA, Rohinishree YS and Ramteke RS (2005). Antioxidant and antibacterial activities of various seabuckthorn (*Hippophae rhamnoides* L.) seed extracts. *Food Chemistry,* 92(1): 119-124.

Ningappa MB, Dhananjaya BL, Dinesha R, Harsha R and Srinivas L (2010). Potent antibacterial property of APC protein from curry leaves (*Murraya Koenigii* L.). *Food Chemistry,* 118(3): 747-750.

Nuamsetti T, Dechayuenyong P and Tantipaibulvut S (2012). Antibacterial activity of pomegranate fruit peels and arils. *Science Asia,* 39: 319-322.

Olasupo NA, Fitzgerald DJ, Gasson MJ and Narbad A (2003). Activity of natural antimicrobial compounds against *Escherichia coli* and *Salmonella enterica* serovar Typhimurium. *Letters in Applied Microbiology,* 37(6): 448-451.

Opara LU, Al-Ani MR and Al-Shuaibi YS (2009). Physico-chemical properties, vitamin C content, and antimicrobial properties of pomegranate fruit (*Punica* *granatum* L.). *Food and Bioprocess Technology,* 2(3): 315-321.

Oussalaha M, Cailleta S, Saucierc L and Lacroix M (2007). Inhibitory effects of selected plant essential oils on the growth of four pathogenic bacteria: *E. coli* O157:H7, *Salmonella Typhimurium*, *Staphylococcus aureus* and *Listeria monocytogenes*. *Food Control,* 18(5): 414-420.

Pandey A, Kaushik A and Tiwari SK (2011). Evaluation of antimicrobial activity and phytochemical analysis of *Citrus limon. Journal of Pharmaceutical and Biomedical Sciences,* 13(17): 1-7.

Parekh J, Karathia N and Chanda S (2006). Screening of some traditionally used medicinal plants for potential antibacterial activity. *Indian Journal of Pharmaceutical Science,* 68(6): 832-834.

Pokhrel S, Singh R, Gautam P, Dixit KV and Das AJ (2012). Comparison of antimicrobial activity of crude ethanolic extracts and essential oils of spices against five strains of diarrhea causing *Escherichia coli*. *International Journal of Pharmacy and Life Sciences,* 3(4): 1624-1627.

Pradeep BV, Manojbabuand MK and Palaniswamy M (2008). Antibacterial activity of *Punica granatum* L. against gastro-intestinal tract infection causing organisms. *Ethnobotanical Leaflets,* 12(1): 1085-1089.

Prakash A, Mathur K, Vishwakarma A, Vuppu S and Mishra B (2013). Comparative assay of antioxidant and antibacterial properties of Indian culinary seasonal fruit peel extracts obtained from Vellore, Tamilnadu. *International Journal of Pharmaceutical Sciences Review and Research,* 19(1): 131-135.

Prashanth D, Asha MK and Amit A (2001). Antibacterial activity of *Punica granatum*. *Fitoterapia,* 72(2): 171-173.

Rauha JP, Remes S, Heinonen M, Hopia A, Kähkönen M, Kujala T, Pihlaja K, Vuorela H and Vuorela P (2000). Antimicrobial effects of Finnish plant extracts containing flavonoids and other phenolic compounds. *International Journal of Food Microbiology,* 56(1): 3-12.

Roundsa L, Havensa CM, Feinsteinb Y, Friedmanc M and Ravishankar S (2013). Concentration-dependent inhibition of *Escherichia coli* O157:H7 and heterocyclic amines in heated ground beef patties by apple and olive extracts, onion powder and clove bud oil. *Meat Science,* 94(4): 461-467.

Roy SD, Bania R, Chakraborty J, Goswami R, Laila R and Ahmed SA (2012). Pharmacognostic, phytochemical, physicochemical property and antimicrobial activity studies of lemon peel oil. *Journal of National Product and Plant Resources,* 2(3): 431-435.

Saima S, Muafia S, Zahida P, Jabeen KS and Razia K (2011). Volatile components, antioxidant and antimicrobial acivity of *Citrus aurantium* var. bitter orange peel oil. *Pharmacology Online*, 2: 499-507.

Sakagami Y, Murata H, Nakanishi T, Inatomi Y, Watabe K, Iinuma M, Tanaka T, Murata J and Long FA (2001). Inhibitory effect of plant extracts on production of verotoxin by enterohemorrhagic *Escherichia coli* O157:H7. *Journal of Health Science*, 47(5): 473-477.

Settannia L, Palazzolob E, Guarrasia V, Aleod A, Mamminad C, Moschettia G and Germanàa MA (2012). Inhibition of foodborne pathogen bacteria by essential oils extracted from citrus fruits cultivated in Sicily. *Food Control,* 26(2): 326-330.

Shahid M, Muhammad S, Saima S, Rauf A, Razia K and Zahida P (2009). Volatile components, antioxidant and antimicrobial activity of *Citrus acida* var. sour lime peel oil. *Journal of Saudi Chemical Society,* 13(2): 195-198.

Sharma A, Verma R and Ramteke P (2009). Antibacterial activity of some medicinal plants used by tribals against UTI causing pathogens. *World Applied Sciences Journal,* 7 (3): 332-339.

Singh A and Bilal AR (2009). In vitro antibiotic activity of isolated volatile oil of *Citrus sinensis*. *International Journal of Pharmaceutical Research and Development,* 7(1): 1-4.

Singh G, Kapoor IP, Pandey SK, Singh UK and Singh RK (2002). Studies on essential oils: part 10; antibacterial activity of volatile oils of some spices. *Phytotherapy Research,* 16(7): 680-682.

Sofia PK, Prasad R, Vijay VK and Srivastava AK (2007). Evaluation of antibacterial activity of Indian spices against common foodborne pathogens. *International Journal of Food Science and Technology,* 42(8): 910.

Sudarshan S, Fairoze N, Wilfred-Ruban S, Badhe R and Raghunath BV (2010). Effect of aqueous extract and essential oils of ginger and garlic as decontaminant in chicken meat. *Research Journal of Poultry Sciences,* 3(3): 58-61.

Sutherland J, Miles M, Hedderley D, Li J, Devoy S, Sutton K and Lauren D (2009). In vitro effects of food extracts on selected probiotic and pathogenic bacteria. *International Journal of Food Sciences and Nutrition,* 60(8): 717-727.

Tajkarimia MM, Ibrahima SA and Cliverb DO (2010). Antimicrobial herb and spice compounds in food. *Food Control,* 21(9): 1199-1218.

Tiwari BK, Valdramidis VP, O’ Donnell CP, Muthukumarappan K, Bourke P and Cullen PJ (2009). Application of natural antimicrobials for food preservation. *Journal of Agricultural and Food Chemistry,* 57(14): 5987-6000.

Upadhyay NK, Kumar MS and Gupta A (2010). Antioxidant, cytoprotective and antibacterial effects of Sea buckthorn (*Hippophae rhamnoides* L.) leaves. *Food and Chemical Toxicology,* 48(12): 3443-3448.

Ushimaru PI, Silva MTNda, Di Stasi LC, Barbosa L and Fernandes Junior A (2007). Antibacterial activity of medicinal plant extracts. *Brazilian Journal of Microbiology,* 38(4): 717-719.

Verma S and Chaudhary HS (2011). Effect of *Carissa carandas* against clinically pathogenic bacterial strains. *Journal of Pharmacy Research,* 4(10): 3769.

Voravuthikunchai S, Lortheeranuwat A, Jeeju W, Sririrak T, Phongpaichit S and Supawita T (2004). Effective medicinal plants against enterohaemorrhagic *Escherichia coli* O157:H7. *Journal of Ethnopharmacology*, 94(1): 49-54.

Voravuthikunchai S, Sririrak T, Limsuwan S, Supawita T, Iida T and Honda T (2005). Inhibitory effects of active compounds from *Punica granatum* pericarp on verocytotoxin production by enterohemorrhagic *Escherichia coli* O157: H7. *Journal of Health Science,* 51(5): 590-596.

Ward SM, Delaquis PJ, Holley RA and Mazza G (1998). Inhibition of spoilage and pathogenic bacteria on agar and pre-cooked roasted beef by volatile horseradish distillates. *Food Research International,* 31: 19-26.

Zachariah SM, Muthumani P and Ramaseshu K (2009). Phytochemistry and antimicrobial screening of stem bark of *Murraya Koenigii* (Linn) Spreng. *The Internet Journal of Pharmacology,* 6(2): 117-120.

Zhang H, Kong B, Xiong YL and Sun X (2009). Antimicrobial activies of spice extracts against pathogenic and spoilage bacteria in modified atmosphere packaged fresh pork and vacuum packaged ham slices stored at 4 °C. *Meat Science,* 81(4): 686-692.