Chapter

Application of Essential Oils for Shelf-Life Extension of Seafood Products

Marzieh Moosavi-Nasab, Armin Mirzapour-Kouhdasht and Najme Oliyaei

Abstract

This chapter will discuss the antimicrobial and antioxidant activities of various essential oils on possible shelf-life extension of different seafood products. Furthermore, the effect of antimicrobial coatings incorporated with various essential oils on the shelf-life of seafood products will be investigated. Microbiological and physico-chemical properties such as total count, psychrophilic and lactic acid bacterial count, peroxide test, thiobarbituric acid (TBA) test, total volatile basic nitrogen (TVB-N) test, and pH, also sensory evaluations of seafood products will be included. During this chapter the effect of chemical composition of some essential oils on the antimicrobial and antioxidant activities will be discussed briefly.

Keywords: essential oils, shelf-life, algae, seafood, antimicrobial, antioxidant

1. Introduction

The safety and quality of food is one of the most important factors which concerns the related industries as consumers prefer fresh and minimally/not processed products. Using various technical preservation methods have been reported in order to improve the shelf-life extension of seafood. Generally, these techniques are including simple methods like salting and freezing as well as more complicated methods such as chemical preservation and modified atmosphere packaging. Application of chemical and synthetic preservatives in seafood is globally common and convenient. During the last decades, antimicrobial and antioxidant additives, principally synthetic origin, are added to refrigerated seafood products for shelf-life extension. Nonetheless, consumers are interested in the use of natural origin material as alternative preservatives in food, since the safety risks of synthetic preservatives, excess antioxidants added to food might produce toxicities or mutagenicities, has been proved [1, 2].

Essential oils (EOs) are aromatic oily liquids including terpenoids, sesquiterpenes and possibly diterpenes with different groups of aliphatic hydrocarbons, acids, alcohols, aldehydes, acyclic esters or lactones which obtain from plants [3, 4] and algae extract [5, 6]. EOs are also known for their antioxidant, antimicrobial and pharmaceutical properties, thus, they can use as natural additives or preservatives in foods [7–9]. Moreover, EOs extracted from various plants have shown to possess several biological activities and potential health benefits including antidiabetic,

anti-inflammatory, anti-viral activities and antiprotozoal agent [10]. Among various techniques for extending the shelf-life of refrigerated seafood products, the application of biopolymer-based edible coatings and films are regularly the method of choice. Edible coatings from polysaccharides, proteins, and lipids can extend the shelf life of foods by functioning as a solute, gas, and vapor barriers [11]. Thus, essential oil incorporation into edible coatings or packaging can prevent the food spoilage and extend the food shelf life in particular fish products [12].

Therefore, great attention has been arisen to identified and used EOs in the food industry. This chapter provides an overview of antioxidant and antimicrobial activities of EOs derived from different sources and their potential organoleptic beneficial and applications in shelf life extension of raw fishes.

2. Chemical composition of EOs

2.1 EOs from algae

Algae extracts are proven to be rich sources of metabolites with a wide range of biological activities such as anti-microbial, anti-oxidant, and pharmaceutical activities [13], thus, several extraction methods have been performed to preparation of algal extract [14] and evaluated their nutritional and pharmacological applications, however, a few number of studies focused on the characterization and composition of EOs from algal extracts. Hence, some scientific efforts have been dedicated to study essential oil composition of algae extracts. The GC-MS analysis of chemical composition shows the presence of different groups of essential oil in micro and macroalgae.

Asparagopsis taxiformis is species of red algae (Rhodophyta) which its EOs consist of bromine and iodine-containing haloforms with the smaller amount of other halogenated methanes and several halogenated ethanes, ethanols, formaldehydes, acetaldehydes, acetones, 2-propanols, 2-acetoxypropanes, propenes, epoxypropanes, acroleins, butenones, halogenated acetic and acrylic acids [15]. Two other red seaweeds (Rhodophyta) *Laurencia obtusa* and *Laurencia obtusa* var. pyramidata are also rich in EOs and 28 components in the oil of *L. obtusa* and 27 components in the oil of *L. obtusa* var. *pyramidata* were identified and 2,6-dimethyl-4-oxa-endo-tricyclodecane was the highest account in both red algae [16].

In addition, the brown macroalgae (Phaeophyta) such as *Colpomenia sinuosa*, *Dictyota dichotoma*, *Dictyota dichotoma* var. *implexa*, *Petalonia fascia* and *Scytosiphon lomentaria* are rich in the EOs. The GC/MS analysis discovered the components including hydrocarbons, terpenes, acids, phenols, sulfur-containing compound, aldehydes, naphthalene skeleton and alcohols in *C. sinuosa*, *D. dichotoma*, *D. dichotoma* var. *implexa*, *P. fascia* and *S. lomentaria*. Among these brown seaweeds, *S. lomentaria* is rich in crown ether (18-crown-6-ether). Moreover, the presence of dihexylsulfide in essential oil profile of *C. sinuosa* revealed the potential of *C. sinuosa* for supplying the rare sulfur-containing compound in seaweeds [17]. Ref. [17] discovered the eight (58.41%) for *D. dichotoma* var. *implexa*, 12 (83.53%) for *D. dichotoma*, 4 (91.71%) for *P. fascia*, 6 (87.89%) for *S. lomentaria* and 14 (74.17%) compounds for *C. sinuosa* in total composition of their essential oil.

Recently, there is interest in the microalgae as well as macroalgae for development of EOs. For this respect, the 50 total compositions of the EOs from *Dunaliella salina* extract were identified and octadecanoic acid, methyl ester (27.43%), hexadecanoic acid, methyl ester (Cas) methyl palmitate (24.82%), 9,12,15-octadecatrienoic acid, ethyl ester, (Z,Z,Z) (7.39%), octadecanoic acid (5.03%), pentadecanoic acid (3.60%) were detected as major compounds [18].

Furthermore, the other various microalgae such as *Stichococcus bacillaris*, *Phaeodactylum tricornutum*, *Microcystis aeruginosa* and *Nannochloropsis oculata* extracts exhibited the antileukemic effects which was related to their EOs. According to [6] findings, the essential oil profile of *S. bacillaris* consist of 5,6-dihydroergosterol, ergost-7-en-3-ol, (3beta)-(CAS)5,6,22,23-tetrahydroergosterol, N-methoxy-N-methylacetamide, 9-octadecenamide, (Z)- and pentan-1,3-dioldiisobutyrate, 2,2,4-trimethyl-compounds. While, *P. tricornutum* essential oil include pentan-1,3-dioldiisobutyrate, 2,2,4-trimethyl-compound. Tricosane (CAS) n-Tricosane was detected only in *P. tricornutum* extract. Further, cyclopropanecaronic acid,-2-phenyl, ethyl ester (E-), molybdenum, bis[(1,2,3,4,5-eta)-1,3-bis(1,1-dimethylethyl)-2,4-cyclopentadien-1-yl]di-mu-carbonyldicarbonyldi-, (mo-mo), 9-octadecenoic acid (Z)-, methyl ester and 9-octadecenoic acid, methyl ester (CAS) methyl octadec-9-enoate were detected only in *M. aeruginosa* extract. Acetic acid 3-isopropyl-8,10,14-trimethyl-16-phenyl-1,2,3,5,6,7,8,9,10,11,12,14- and 2,6-dihydroxybenzoic acid 3TMS were detected only in *N. oculata* extract.

2.2 EOs from other plants

So many researches inquired into the chemical composition of the EOs obtained from various sources including *Thymus ulgaris, Nigella sativa, Achillea millefolium, Curcuma zedoaria*, *Rosmarinus officinalis* etc. A summary of these investigations is reported in **Table 1**. In an outstanding study, the essential oil composition of thyme (*Thymus ulgaris* L.) was investigated by capillary GC/MS evaluation method. The effect of vegetative cycle on the variation of EOs chemical composition was looked over, as well. Generally, the oil was had high amounts of monoterpene

EOs sources	Major components	References
A. taxiformis	Bromine and iodine-containing haloforms	[15]
L. obtusa and *L. obtusa* var. pyramidata	2,6-Dimethyl-4-oxa-endo-tricyclo decane	[16]
S. lomentaria	Crown ether (18-crown-6-ether)	[17]
C. sinuosa	Dihexylsulfide	[17]
D. salina	Octadecanoic acid, methyl ester, hexadecanoic acid, methyl ester (Cas) methyl palmitate, 9,12,15-octadecatrienoic acid, ethyl ester	[18]
N. oculata	Acetic acid 3-isopropyl-8,10,14-trimethyl-16-phenyl-1,2,3,5,6,7,8,9,10,11,12,14- and 2,6-dihydroxybenzoic acid 3TMS	[6]
Thyme (*Thymus ulgaris* L.)	Carvacrol, thymol, *p*-cymene, and γ-terpinene	[19]
Flowering Thyme (*Thymis vulgaris* L.)	Camphor, camphene, α-pinene, 1, 8-cineole, borneol, and β-pinene	[20]
Nigella sativa	Thymoquinone, *p*-cymene, carvacrol, 4-terpineol, t-anethole, and sesquiterpene longifolene	[21]
Turmeric (*Curcuma longa* L.)	*ar*-turmerone, turmerone, and curlone	[22]
Rosemary (*Rosmarinus officinalis* L.)	1,8-cineole, α-pinene, camphor, and camphene	[24]

Table 1.
Some investigations performed to investigate the chemical composition of EOs.

phenols (carvacrol and thymol) and their related monoterpene hydrocarbon precursors (*p*-cymene and γ-terpinene), that demonstrated integrated effects of the different collection periods and seasons on the chemical composition of EOs. The EOs obtained from old plant included much lower quantities of monoterpene hydrocarbones (mostly γ-terpinene) and the highest quantities of the oxygenated monoterpenes (linalool and borneol), monoterpene phenols (mostly thymol) and their derivatives (mostly carvacrol methyl ether), sesquiterpenes (mostly β-caryophyllene) and their oxygenated derivatives (e.g., caryophyllene oxide). A characteristic presence of camphor and thymodihydroquinone was also discovered in the old plant EOs [19].

The EOs obtained by hydrodistillation from flowering Thyme (*Thymis vulgaris* L.) was investigated by GC/FID and GC/MS. The yield of extraction in this study was reported as 1%, in which 43 chemical compounds (97.85% of total constituents) were identified. The EOs extracted from flowering Thyme were mainly consisted of camphor (38.54%), camphene (17.19%), α-pinene (9.35%), 1, 8-cineole (5.44%), borneol (4.91%) and β-pinene (3.90%) [20].

In an another research, seven EOs of *N. sativa*, which were all extracted by soxhlet extraction and steam distillation, were analyzed by GC/MS. A total of 32 compounds were identified. The major fraction of every EOs was a mixture of monoterpenes. The major components were thymoquinone (30–48%), *p*-cymene (7–15%), carvacrol (6–12%), 4-terpineol (2–7%), t-anethole (1–4%) and the sesquiterpene longifolene (1–8%). Very small quantities of the esters of special un/saturated fatty acids were also detected [21].

Curcumin, the yellowish pigment of turmeric, is generated from turmeric oleoresin. In a study performed in order to investigate the antibacterial activity of turmeric oil extracted by hexane and fractionated by silica gel column chromatography, GC/MS analysis identified 13 major components in turmeric oil, fraction I, and fraction II. *ar*-turmerone (62.0%), *trans-â*-farnesene (6.6%), turmerone (5.1%), and curlone (3.9%) were found to be the major compounds in turmeric oil whereas fraction II contained *ar*-turmerone (77.9%), curlone (5.3%), and turmerone (5.2%) [22].

Rosemary (*Rosmarinus officinalis* L.), a member of mint family, is an ordinary aromatic shrub grown in various places around the world [23]. Some researchers has assessed the chemical composition of rosemary EOs to understand the reason of biological activities such as antimicrobial activity. In an experimentation 22 components were identified from this plant by GC/MS. The major constituents were 1,8-cineole (26.54%), α-pinene (20.14%), Camphor (12.88%), and camphene (11.38%) [24].

3. Antioxidant activity of EOs

There are many EOs which have antioxidant activity, and their application as natural antioxidants has been increasingly interested due to harmful effects to human health that some synthetic antioxidants (e.g., BHA and BHT) are faced. The antioxidant activity of EOs is due to their potential ability to cease or suspend the oxidation reaction of organic materials in the presence of oxygen which is a result of some special components including phenols. There are EOs which lack of phenolic compounds also show antioxidant activity. Some constituents including terpenoids and other volatile constituents (such as sulfur-containing components) have special radical chemistry which capable them to express antioxidant activity [25, 26].

As it was discussed earlier (Section 2.2), the major constituents of many EOs can be categorized in two specific structural families: terpenoids (monoterpene, sesquiterpene, and diterpene) and phenylpropanoids, which both comprise phenolic compounds. Some phenolic compounds are demonstrated in **Figure 1**.

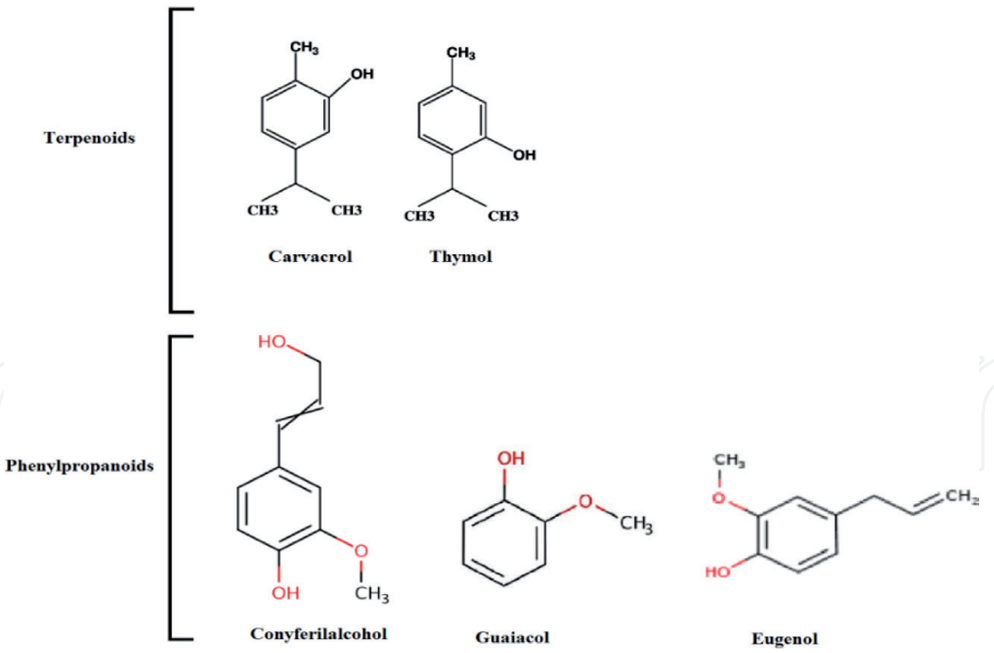

Figure 1.
Some phenolic compounds present in EOs.

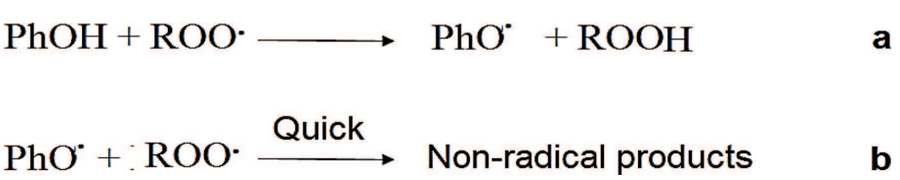

Figure 2.
Mechanism of antioxidant activity of phenolic compounds. The reaction between phenolic compounds and peroxyl radicals (a), quenching the second peroxyl group by phenoxyl radical (b).

Generally, phenolic compounds can potentially react with peroxyl radicals and transfer the H atom (**Figure 2a**). Due to the stability of phenoxyl radical, it will not continue the radical chain reactions. Instead it will quench the second peroxyl radical quickly (**Figure 2b**).

In contrast with phenolic compounds present in EOs, unsaturated non-phenolic terpenoids such as α-pinene (**Figure 3**) can autoxidize similarly to unsaturated lipids [27].

Many researchers have investigated the antioxidant activity of EOs. A potential antioxidant essential oil was extracted from *Achillea millefolium subsp. millefolium* Afan, which significantly reduced DPPH radical (IC50 = 1.56 μg/ml) and showed lipid peroxidation (IC50 = 13.5 g/ml). The authors demonstrated that the polar phase of the extract exhibited antioxidant activity [28]. The essential oil extracted from dried rhizome *Curcuma zedoaria* (Berg.) Rosc. (Zingiberaceae) showed a moderate to good antioxidant activity at 20 mg/ml. This activity was measured by three different methods, reducing power (good activity), DPPH radical scavenging (excellent activity), and ferrous ion chelating (low activity) [29]. In another research, the antioxidant activity of *Rosmarinus officinalis* essential oil were determined against gastric injury caused by ethanol. Results showed that the *R. officinalis* essential oil (50 mg/kg) ingestion can make gastro-protective influences by reducing the ethanol induced ulcers. The resultant data suggested possible antioxidant mechanism induced by *R. officinalis* essential oil. The major components of chemical composition of this essential oil were cineole (28.5%), camphor (27.7%), and α-pinene (21.3%).

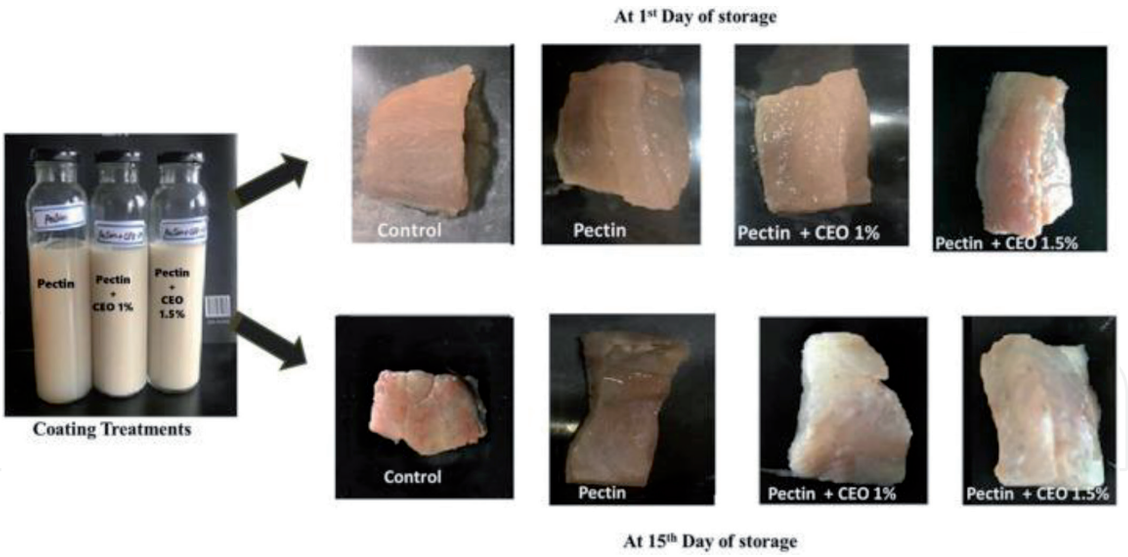

Figure 3.
The effect of pectin-CEO coating on the bream fillets at day 1 and day 15 of the storage (adopted from Nisar et al. [42]).

The lipid oxidation is one of the most important limiting factors for the shelf-life seafood products. For this purpose the antioxidant activity of the EOs of five Mediterranean spices (*Origanum vulgare*, *Thymus vulgaris*, *Rosmarinus officinalis*, *Salvia officinalis*, and *Syzygium aromaticum*) was analyzed. The *S. aromaticum* essential oil, which comprised the highest level of total phenols (898.89 mg/l GAE), demonstrated the highest antioxidant activity (98.74% for DPPH radical inhibition and 1.47 TEAC for FRAP value). The EOs extracted from *T. vulgaris* and *R. officinalis* showed the highest TBARS inhibition (89.84%) and iron (II) chelating (76.06%) activities, respectively [30].

4. Antimicrobial activity of EOs

The antimicrobial effect of essential oils is attributed to actions including alteration of the permeability, and disruption of lipophilic cell membrane. The antimicrobial potential of essential oils can be completely associated with their constituents. Phenolic compounds with their hydrophobicity inherent, breakdown the lipid of cell membrane and mitochondria and enhance the permeability [31, 32]. The inherent of cellular energy generation system (ATP) and damage of proton motive force is a result of changing cell and cytoplasmic membrane permeability [33]. In addition, leakage of internal contents of the cell during the disruption of the membrane is another mechanism which causes cell death [32]. It is generally believed that Gram-negative bacteria are more resistance to essential oils because of their outer hydrophilic cell wall which exhibits inhibitory activity against the penetration of phenolic components [34].

Algae extracts and their components have displayed antimicrobial activity against organisms found in foods. Algae extracts and their components have displayed antimicrobial activity against organisms found in foods. The antibacterial activities of essential oils from two red seaweed *Laurencia obtuse* and *L. obtusa* var. *Pyramidata* showed that the essential oils from Laurencia obtuse exhibited the strong antimicrobial effect against Gram-positive (*Bacillus subtilis*, *Staphylococcus aureus*, methicillin-oxacillin resistant *Staphylococcus aureus*, *Enterococcus faecalis* and *Staphylococcus epidermidis*), Gram-negative bacteria (*Enterobacter cloaceae*) and yeast (*Candida albicans*) [16].

Terpenoids, thymol, carvacrol, β-cubebene, β-eudesmol, β-ionone, dactylol and pachydictol A are the usual volatile compounds in seaweeds and it is known that there is correlation between β-ionone and antibacterial and antifungal activity of seaweeds [17]. However, two known sesquiterpenes (1R*,2S*,3R*,5S*,8S*,9R*)-2,3,5,9-tetramethyltricyclo(6.3.0.$0^{1,5}$)undecan-2-ol and (1S*,2S*,3S*,5S*,8S*,9S*)-2,3,5,9-tetramethyltricyclo-(6.3.0.$0^{1,5}$)undecan-2-ol were isolated from the red macroalgae *Laurencia dendroidea* had no antibacterial effect on eight bacteria strains (*Staphylococcus aureus*, *Bacillus subtilis*, *Enterococcus faecalis*, *Streptococcus pneumonia*, *Klebsiella pneumoniae*, *Salmonella typhi*, *Escherichia coli* and *Pseudomonas aeruginosa*) and the yeast *Candida albicans* [5].

5. Shelf-life extension of seafood products

The short shelf-life of fresh seafood is a practical issue in the industries and distribution chain systems. Short shelf-life caused by chemical and microbial spoilage reactions can be stopped by traditional preservation methods but there is increasing interest in natural preservation methods. EOs are natural antioxidants and antimicrobials by which the shelf-life of seafood can be extended alone or in combination with other techniques. However, the reduction of antimicrobial effect of EOs in a food system due to some components of food and also the reverse action of EOs as antioxidant agents in some cases, has slowed down the use of them in practical systems.

Combination of EOs exhibit the synergistic antimicrobial activity. Thus, using of EOs into packaging can be the safe approach for food preservation technology [35]. The antimicrobial activity of gelatin-chitosan films incorporated with organo essential oil exhibited the great inhibitory effect through reducing the *E. coli*, *S. aureus*, *B. subtilis* and *B. entritidis* growth. Its inhibition zone was larger for Gram-positive bacteria compared with Gram-negative bacteria. Furthermore, the lower total aerobic plate count and total volatile basic nitrogen values that can extend the shelf life of grass carp muscle was recorded in fish muscle packed with film containing the 4% organo essential oil. It seems the high percentage of carvacrol, eugenol, and thymol as phenolic components are responsible for this antimicrobial activity by damaging the cell membrane or interfere the enzyme functionality located on the cell wall. Moreover, the TVB-N value of sample packaged with gelatin-chitosan-EOs film was lower compared with control and the shelf life of grass carp muscle packaged with the film containing EOs was extended to 12 days [36]. The same observation was gained from the gelatin-chitosan film incorporated with other EOs including clove, fennel, cypress, lavender, thyme, herb-of-cross, pine and rosemary for cod fillet preservation. Among all EOs, the high antimicrobial effect was obtained from clove against a wide range of food pathogen and spoilage bacteria such as *Salmonella*, *Lactobacillus*, *Listeria*, *Citrobacter*, *Escherichia*, *Yersinia*, *Brochothrix*, *Staphylococcus*, *Bacillus*, *Listeria*, *Clostridium*, *Aeromonas*, *Shewanella*, *Vibrio* and *Photobacterium*. In addition, the film containing the clove essential oil used for preservation of cod fillets, lowered the microorganisms in particular, *Entrobacteria*. Further, by delaying the formation of TVB-N, can extend the shelf life of chilled stored fish [37].

Immersion of salmon in marinade solution containing 1 w/w% essential oil from organo, cinnamon and thyme revealed that the antimicrobial effect, however, organo and cinnamon essential oil caused to enhance the shelf life of salmon and scampi. In addition, reduction of yeast and mold was observed by cinnamon (1%) addition in marinade for 6 days. Moreover, salmon treated with marinade containing 1% essential oil, shoed appropriate sensorial properties and high hedonic score

rather than 5% essential oil [38]. Combination of EOs with different types of packaging is another approach for enhancement of shelf life. For instance, the combination of cinnamon essential oil (1 w/w%) and MAP/vacuum packaging extend the shelf life of salmon. However, the MAP+ cinnamon had a better effect on salmon shelf life and the microbial shelf life reach nine or more days. While it was 6 days for vacuum packaged salmon treated with cinnamon. Moreover, cinnamon had no additional antimicrobial effect on LAB, when salmon stored vacuum or MAP [12].

Furthermore, the vacuum packaged common carp (*Cyprinus carpio*) stored 4°C had high quality with the combination of cinnamon essential oil. In addition, cinnamon essential oil inhibited the *Aeromonas* and *Lactococcus* on day 10. *Pseudomonas* and H2S-producing bacteria count was lower in treated fillets and did not exceed the microbial level of 7 log CFU/g at the end of the fillet's shelf life. Moreover, was effective in inhibition the increase of TVB-N and the accumulation of biogenic amines. TVB-N value fluctuated in 6.21 and 9.90 mg/100 g before 12 days treated sample contained and the highest value (15.15 mg/100 g) occurred at day 14. Moreover, crap fillets treated with cinnamon essential oil exhibited the acceptance longer sensorial shelf life (14 days) [39]. The Flounder fillet covered with clove essential oil agar films (0.5 g clove essential oil/g agar) had high low microbial count because of the great antimicrobial activity of clove essential oil against pathogens such as *Staphylococcus aureus*, *Yersinia enterocolitica*, *Aeromonas hydrophila*, *Debaryomyces hansenii* and *Listeria innocua*. The chemical indicators such as TVB-N was 25.83 mg TVB-N/100 g after 15 days of storage. The low total volatile bases and pH values and inhibitory effect on H_2S producing microorganisms suggested clove essential oil could be suitable biopreservative for the flour fillet shelf life extension [40].

In another study, the active films accommodated by poly lactic acid enriched with ZnO nanoparticles (1.5%w/w) and *Zataria multiflora* Boiss (0.5, 1, 1.5%w/w) and the effect of this film on shelf-life extension of refrigerated *Otolithes ruber* fillet during 16 days was investigated. One aspect of shelf-life extension effect is the antibacterial activity of the films which in this case was conducted against *Escherichia coli*, *Salmonella enterica*, *Pseudomonas aeruginosa*, *Bacillus cereus* and *Staphylococcus aureus* by disc diffusion procedure. PLA/ZnO/ZEO and PLA/ZnO/MEO [*Zataria multiflora* Boiss. essential oil (ZEO) and *Menta piperita* L. essential oil] films demonstrated magnified antibacterial (691 and 513.33 mm^2, respectively, against *S. aureus*). The authors expressed that according to the microbial count, the active film remarkably enhanced the shelf-life extension from 8 to 16 days. Chemical factors such as TBARS and TVB-N were also determined. The fillet wrapped with PLA/ZnO containing 1.5% ZEO, showed the lowest TBARS (0.8 mg MA/kg muscle) and TVB-N (21.23 mg/100 g muscle). GC/MS analysis of EOs showed that the carvacrol and menthone were the major components of ZEO and MEO, respectively [41].

A new edible coating of pectin containing clove essential oil (CEO), was assessed to extension of bream (*Megalobrama ambycephala*) fillets shelf-life during 15 days. Physicochemical (pH, PV, TBA and TVB-N), microbiological (Total viable count, Psychrophilic bacteria, Lactic acid bacteria, *Enterobacteriaceae*, *Pseudomonas* spp., H_2S producing bacteria) and organoleptic characteristics were analyzed to determine the influences of the pectin-CEO coating. Physicochemical analysis revealed that lipid oxidation decreased. Some other factors such as weight loss, water holding capacity, color, and texture of the fillets were improved as a result of coating with pectin-CEO (**Figure 3**). During 15 days, lactic acid bacteria were not affected by coating. However, the effects of coating on bacterial growth, especially on Gram-negative bacteria, was observed [42].

The effect of chitosan, thyme essential oil and their combination, on the shelf-life of vacuum packaged smoked eel fillets at 4°C, was investigated and according to sensory odor analysis the shelf-life of chitosan/thyme and chitosan-thyme

combination treated samples extended 1 and >2 weeks, respectively, compared with than control sample (35 days for control). The control sample showed a significantly higher thiobarbituric acid value compared chitosan-thyme combination treated sample. Control, thyme, chitosan, and chitosan-thyme combination treated samples showed TVB-N values below the maximum permissible level (35 mg N/100 g) in fish and fishery products which was 31.5, 18.1, 14.9, and 13.1 mg N/100 g in 35 and 42, 49 days of storage, respectively [43]. The maximum permissible level of TVB-N in fish and fishery products is 35 mg N/100 g [44].

6. Conclusions

During the past decades, EOs have achieved great attention due to their food preservation effects, particularly for the antimicrobial and antioxidant effects.

The EOs of different sources from land and the seas, have variety of phenolic and non-phenolic components which the most actives are low molecular weight terpenoids, terpenes, and aliphatic chemicals (obtained data from analysis by GC-MS and GC/FID in literature). These EOs have shown significant antioxidant, antimicrobial activities which can extent the shelf-life of seafood products. However, it is still mandatory to inquire into cytotoxicity and toxicity of these EOs.

Conflict of interest

The authors declare no conflict of interest.

Author details

Marzieh Moosavi-Nasab[1,2*], Armin Mirzapour-Kouhdasht[1,2] and Najme Oliyaei[1,2]

1 Department of Food Science and Technology, School of Agriculture, Shiraz University, Shiraz, Iran

2 Seafood Processing Research Group, School of Agriculture, Shiraz University, Shiraz, Iran

*Address all correspondence to: marzieh.moosavi-nasab@mail.mcgill.ca

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