International Journal of Minor Fruits, Medicinal and Aromatic Plants. Vol. 9 (2) : 52-61 , December 2023

Review article

Essential oils uses in post-harvest management of fruits and vegetables : A Review

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Received : 19.09.2023 ; Revised : 02.10.2023 Acceptance : 05.10.2023

DOI : 10.53552/ijmfmap.9.2.2023. 52-61

ABSTRACT

Fresh fruit and vegetable consumption is steadily rising because of their nutritional value. It is estimated that about 30 to 40 percent of fruits and vegetables spoiled after harvesting due to poor post harvest management. Presently, this sector is facing lots of challenges in storage and supply chain of fresh fruits and vegetables to the consumers. The majority of post-harvest losses of horticultural produce are managed by using synthetic chemicals that may have detrimental effect to human health and nutritional value of horticultural produce. Therefore, using natural resources to control its damage and post-harvest management has been emphasized in order to prevent the decay of fresh fruits and vegetables. One of the natural sources and alternatives to the synthetic chemicals for reducing post-harvest losses and to improve overall quality and extending the shelf-life of perishable goods through natural essential oils and its constituents. Essential oils are used as preservatives, fragrant & flavour, vapour and coating wax as post-harvest management of fresh fruits and vegetables. The post-harvest losses of fruits and vegetables can be reduced by using essential oils of various aromatic crops such as cinnamon, geranium, citronella, mint, eucalyptus, lavender, thyme, rosemary, citrus, lemongrass, and basil, among the others. The objective of this review is to gather and discuss up-to-date applications and effects of the essential oils in post harvest management.

***Keywords*:** Essential oil, horticultural produce, natural resources, post-harvest management, shelf-life,

INTRODUCTION

India is the world's largest producer and consumer of fruits and vegetables, producing approximately 12.40 and 13.30 percent of global production, respectively (Gajanana *et al.*, 2011). Fruits and vegetables are the richest sources of vitamins and minerals, both of which are essential in human diets. The recommended dose of fruits and vegetables are 120g and 300g, respectively per capita per day, but availability of fruits and vegetables are still around 104g fruits and 207g, respectably per day per person (Gajanana *et al.*, 2011). To prevent the various diseases and to provide nutrients for many people who are low in micronutrients, an average of 400 g of fruits and vegetables per person per day are required (World Health Organization 2003). It is estimated that 30 to 50% losses of fruits and vegetables occurred world-wide, which is the main reason for low availability to the people (Gajanana *et al.*, 2011). During post-harvest handling, about 20 to 30 percent of fresh fruits and vegetables are also damaged. Post-harvest losses of various fruits and vegetables are brought through fungi, such as brown rot and rhizopus rot that *Rhizopus stolonifer* and *Monilinia fructicola* induce in peach (Sholberg and Gaunce, 1996; El-Sheikh Ali and Baraka, 2000). Nectarine fruits exposed to *Botrytis cinerea* induced grey mould, Rhizopus rot caused by *Rhizopus stolonifer*, and *Penicillium expansum* generated blue mould (Zhang *et al.*, 2008). Fungicides are a first line of defense against post-harvest losses of fruits and vegetables. The majority of synthetic chemicals used to minimize post-harvest losses in fruits and vegetables which are bad for consumer safety, hence, the uses of natural compounds and natural goods should be prioritized (Alzoreky and Nakahara 2003). One of the healthiest and safest ways to prevent post-harvest infections is to utilize essential oils extracted from plant sources. Essential

oils include a variety of secondary metabolites, most of which have antibacterial, fungicidal, antioxidant, and bio-regulating activities (Asghari *et al.,* 2009). Utilizing essential oils offers an alternative strategy for preventing fruit and vegetable storage losses and post-harvest pathogen growth.

Reason of spoilage of horticultural produce

In horticulture production, there is a major problem to save the produce from various damages such as physiological disorders, insects, pests and diseases attack because maximum loss of these produce occurred by these factors at various stages from field to final consumption. Most of the spoilage of the produce occurs by fungal, bacteria, viruses and insects. Post-harvest diseases affect the production, mainly because of the lack of proper post-harvest storage facilities.

After harvesting of crops, storage should be proper because most of the fruits and vegetables have very short shelf-life and some of those started spoilage in between one to two days. Important pathogens responsible for damage of the horticultural produce are given in Table 1.

Essential oils and its properties

Aromatic plants are the richest sources of secondary metabolites which have a wide range of properties like antioxidant, analgesic, anti-inflammatory, antitumor activity, larvicidal, anticancer, antimicrobial, anti-parasitic, insecticidal, anti-fungal and antibacterial properties (Saranraj *et al*., 2017; Srivastava *et al.,* 2014). The volatile compounds of the essential oils have a wide range of properties such as eugenol- local aneasthetic, neuro- protective, anti-cancer (Pramod *et al.,* 2010), Linalool- Anti-hyperalgesic, anti-nociceptive (Kim *et al.*,2015), Limonene- anti-inflammatory, motor-relaxant (Vale *et al.,* 2002), 1,8-cineole- monoterpenoid wound healing, antiulcer (Rocha Caldas *et al.,* 2015), Menthol- Anaesthetic (Balakrishnan *et al.,* 2018), Camphor- Anti-pruritic, decongesting (Zuccarini, 2009), Chicoric Acid- Immuno-stimulatory, antioxidant (Kuban-Jankowska *et al.,* 2016), Farnesene- Anti-insecticidal, antioxidant (Sun *et al.,* 2011), β-cadinene- Anti-proliferative (Cascaes *et al.,* 2015), Menthyl acetate- Antioxidant, Antibacterial (Singh *et al.,* 2015), Germacrene- Anti-inflammatory, analgesic (Del-Vechio-Vieira *et al.,* 2009), Silv Erio *et al.,* 2013), α-bisabolol- Analgesic, Antibiotic, Anticancer (Queiroz and Cajaiba 2015; Kamatou and Viljoen 2010).

Skrinjar and Nemet (2009) reported antibacterial properties of various essential oils like rosemary, turmeric, clove, pepper, fennel, round cardamom, angelica root, etc. against *Escherichia coli*, *Listeria monocytogenes* and *Pseudomonas fluorescens* which are prevalent as spoilage pathogenic bacteria. The anti-pathogen properties of essential oil are shown in Table 2.

Uses of essential oils in post harvest management

Essential oils have been used in management of diseases and pests, minimizing post-harvest losses, the extension of shelf-life, and the addition of flavour & fragrance and nutritional value to foods. The essential oil from Mints, Lemongrass, Thyme, Rosemary, Lavender, Bergamot, Dill, and Coriander, etc. have the efficacy for enhancing the shelf-life and also maintaining the quality of fruits and vegetables (Serrano *et al.,* 2005).

Essential oils as enhancement of self-life

According to studies of Abd-AllA *et al.* (2011), lemongrass oil has antifungal, antibacterial, antioxidant, antiviral, and antimicrobial properties. It also reduces the incidence of diseases, weight loss and firmness loss of fruits. It also enhanced acceptable texture and has a higher acceptance rate overall when avocado fruits are stored in cold storage under market shelf conditions (Mpho *et al.,* 2013). Rosemary (*Rosmarinus officinalis* L.) oil is utilized as an antioxidant and has antibacterial effects (Almela *et al.,* 2006). Against several bacterial and fungal strains, the oils of lavender (*Lavandula hybrida*), dill (*Anethum graveolens* L.), and coriander (*Coriandrum sativum* L.) demonstrated strong antibacterial and antifungal action. During the six weeks in cold storage of Crimson seedless grape, bergamot (*Citrus bergamia*) oil used for delayed the changes in total soluble solids, anthocyanin content, firmness, vitamin C, respiration rate, titratable acidity, and also reduced decay and weight losses (Abd El wahab *et al.,* 2014). It also had positive effects on titrable acidity, total soluble solids, weight loss

Table 1: Food borne Pathogenic microorganism

S.N.	Pathogen	Associated foods	References
1.	*Escherichia coli*	Salads, Green beans, Apple pieces, Spinach leaves, Fresh Lettuce,	(Severino *et al.,* 2015)
2.	*Salmonella typhimurium*	Green beans, Fresh Lettuce,	(Bhargava *et al.,* 2015)
3.	*Salmonella enteric*	Spinach leaves	(Ruengvisesh *et al.,* 2015)
4.	*Penicillium digitatum*	Green mould (post-harvest)	(Abdolahi *et al.,* 2011)
5.	*Penicillium expansum*	Post-harvest mould (Apple)	(Znini *et al.,* 2013)

Table 2: Anti-microbial/Anti-pathogen properties of essential oils

S.N.	Name of the medicinal/ aromatic plants	Anti-microbial properties of essential oils	Inhibited Micro-organisms	References
1.	Basil	Antibacterial	*Escherichia coli, Pseudomonas aeruginosa (Positive gram), Bacillus cereus, Staphylococcus aureus (Nigative gram)*	(Moghaddam *et al.,* 2011)
		Antibacterial	*Saphylococcus aureus, Streptococcus mutans (Positive gram), Citrobacter freundii, Escherichia coli, Proteus mirabilis, Salmonella choleraesuis, Yersinia enterocolitica (Nigative gram), Enterococcus faecalis, Sarcina sp, Enterococcus faecalis, Acinetobacter sp., Proteus vulgaris, Shigella flexneri, Aeromonas sp., Serratia marcescens, Staphylococcus epidermidis, Klebsiella pneumonia*	(Gaio *et al.,* 2015)
		Anti-fungual	*Fusarium spp.*	(Antunes and Cavacob 2010)
		Anti-yeast	*Candida albicans*	(Adigozel *et al.,* 2005)
		Anti-Fungi	*Alternaria alternate, Aspergillus flavus, Fusarium oxysporum, Penicillium spp.*	(Adigozel *et al.,* 2005)
2.	Lemongrass	Anti-fungal	*Enteriobacteriacae, S. aureus*	(Grohs and Kunz, 2000)
			Rhizopus	(Antunes and Cavacob 2010)
			Alternaria spp.	(Antunes and Cavacob 2010)
			Aspergillus niger	
3.	Mentha		*S. typhimirium, Vibrio parahaemolyticus, S. aureus*	(Sokovic *et al.,* 2009)
4.	Eucalyptus		*Escherichia coli*	(Selim, 2011)
5.	Orange oil	Anti-fungal	*Stolonifer*	(Antunes and Cavacob 2010)
6.	Thyme		*Clostridium perfringens*	(Radaelli *et al*., 2016)
7.	Cinnamon		*Escherichia coli, Staphylococcus aureus*	(Zhang *et al.,* 2016)
8.	Salvia		*Enterococcus faecalis, P. aeruginosa, P. vulgaris, Klebsiella pneumoniae*	(Hassanshahian *et al.,*2014)

Table 3: Essential oils used as fumes to control postharvest diseases of fruits and vegetables

S.N.	Name of the plants used for essential oils	Diseases/pathogen causing post harvest loss	Infected crops	References
1.	Thyme (*Thymus* sp.)	*Botrytis cinerea* (Grey mould rot)	Sweet cherries	(Chu *et al.,* 1999)
		Monilinia fructicola (Brown rot)	Sweet cherries	(Chu *et al.,* 2001)
		Anthracnose (*Collectotrichum gloeosporioides*)	Avocado	(Sellamuthu *et al.,* 2013)
			Mango cv. Banganapalli & Totapuri	(Perumal *et al.,* 2017)
2.	Eucalyptus (*Eucalyptus globulous* L.*)*	Antimicrobial properties	Tomato, Strawberry	(Tzortzakis, 2007)
3.	Cinnamon *(Cinnamomum zeylanicum* Blume*)*	Antimicrobial properties	Tomato, Strawberry	(Tzortzakis, 2007)
4.	Lemongrass and cinnamon oils and combination of both	*Colletotrichum musae, Collectotrichum gloeosporioides*	Banana, Papaya	(Maqbool *et al.,* 2011)
5.	Oregano and lemongrass oils, vanillin	Psychrophilic microorganisms, yeasts, moulds, L. innocua	Fresh-cut 'Fuji' apples	(Rojas-Grau *et al.,* 2007)

Table 4: Properties of essential oil as preservative agents in fruits and vegetables

S.N.	Essential oils	Effect on produces	Remark	References
1.	Lemongrass Oil	Prepared formulation effective on minimized weight loss, total plate count, respiration rate, yeast, firmness and mold counts during low temperature storage of pineapple fruit.	Coated formulation prepared by using 0.5% (w/v) essential oil of lemongrass	(Azarakhsh *et al.,* 2014)
2.	Lemongrass Oil	After coating the formulation with wax on cut pieces of Fuji apple the activity of *E. coli* minimized	Activity of *E. coli* minimized after coating with formulation	(Via-Trujillo *et al.,* 2015)
3.	Chitosan–lemon essential oil	During the storage of Strawberry fruit mixture of chitosan and lemon oil maximize the antifungal activities and its respiration rate.	The combination of lemon and chitosan oil enhanced the shelf life of strawberry	(Perdones *et al.,* 2012)
4.	Gelatin-based edible coating incorporated with *Mentha pulegium* Essential Oil	The formulations reduced the effect of yeasts, mold and total flora on strawberry fruit	The rate of microbial activities on fruits was dependent on concentration of essential oil and method of application.	(Aitboulahsen *et al.,* 2018)
5.	Basil oil mixed with Beeswax	Application of prepared coat of basil oil with beeswax reduced the post harvest diseased, delayed ripening and enhance shelf life by reduction of weight loss of fruit	To control anthracnose was very significantly of 600 600µL L-1 with beeswax mixture coat	(Karunanayake *et al.,* 2020)

percentage, and the length of time in plum fruits for storage (Aminifard and Mohammad 2013).

3.2 Uses as fumigant

Few essential oils have been used as fumigants to reduce post-harvest diseases in fruits and vegetables because they have volatile compounds which evaporate easily in ambient temperature (Ding and Lee 2019). Table 3 shows essential oils used as fumes to control the diseases of fruit and vegetable.

Use as preservative

Some essential oils have been used as preservative because they have anti micro-organisms properties which inhibit the growth of

Table 5: Major volatile aroma compound available in fruits

S.No.	Fruits	Major volatile compounds	Reference
1.	Mango	ä-3-carene, ethyl butanoate, limonene, terpinolene, R-phellandrene	(Pino *et al.*, 2003)
2.	Banana	(E)-2-hexenal, acetoin, 2, 3-butanediol, solerol, hexanal, isoamyl acetate, 3-methylbutyl acetate, 3-methylbutyl butanoate	(Araguez *et al.*,2013; Nogueira *et al.*, 2003)
3.	Papaya	Methyl butanoate, ethyl butanoate, 3-methyl-1-butanol and 1-butanol	(Pino *et al.*, 2003)
4.	Guava	Acetic acid, 3-hydroxy-2-butanone, 3-methyl-1-butanol, 2,3-butanediol, 3-methylbutanoic acid, (Z)-3-hexen-1-ol, 6-methyl-5-hepten-2- one, limonene, octanol, ethyl octanoate, 3-phenylpropanol, cinnamyl alcohol, R-copaene	(Jordan *et al.*, 2003)
5.	Citrus	Limonene, â-myrcene, linalool, hexanal, ethyl butanoate	(Moufida *et al.*, 2003)
6.	Grape	Linalool, geraniol, (E)-2-hexenal, hexanal, phenylethyl alcohol, octanoic acid	(Rosillo *et al.*, 1999)
7.	Strawberry	Ethyl acetate, ethyl butanoate, butyl acetate, methyl hexanoate, ethyl hexanoate, hexenyl acetate, hexyl acetate, 2-hexenyl butanoate, benzyl acetate, phenylethyl acetate, 1-butanol, 1-hexanol and 2-heptanone	(Prat *et al.*, 2013)
8.	Apple	Acetaldehyde, ethyl butanoate, ethyl methyl propanoate, 2-methyl butanol, ethyl 2-methyl butanoate, 2-methyl butyl acetate, hexyl acetate, butyl acetate, hexyl butanoate, hexyl hexanoate, (E)-2-hexenal, (Z)-2-hexenal	(Araguez *et al.*, 2013)
9.	Pear	Hexanal, hexyl acetate, ethyl hexanoate, ethyl 2-methylbutanoate, ethyl butanoate	(Li *et al.*, 2012)
10.	Plum	(E)-2-hexenal, hexanol, hexanal, (E)-2-hexen-1-ol, (Z)-3-hexen-1-ol, hexyl acetate, (Z)-3-hexenyl acetate, ethyl acetate	(Bononi *et al.*, 2012)

Table 6: Essential oil components use in beverage and soft drink

S.N.	Name of the crops for essential oils used	Components of EOs in Soda (in % w/w)	Name of product
1.	Lemon	Lemonene 54.6, B-pinene 14.5, geranial 2.3, y-Terpinene 19.1, Myrcene 1.5 and a-pinene 3.9	Citrus Soda
2.	Orange	Lemonene 94.2, Myrcene 2.1-4.3, a-Pinene 0.7-1.4 and B-pinene 0.2-1.0	Citrus Soda
3.	Lime	Lemonene 74.8, Myrcene 7.1, B-pinene 1.4, a-pinene 0.3 and y-Terpinene 0.1	Citrus Soda
4.	Neroli Flower Oil (0.8-1 w/w)	Lemonene 27.5, a-Terpineol 14.0, Nerolidol 17.5, a-Terpinyl acetate 11.7 and B-Terpinyl acetate 1.7	Citrus Soda
5.	Cola Leaf Oil	Methyle salicylate 0.6-0.13,	Cola Soda
6.	Nutmeg seed oil (5-15w/w),	Sabinene 50, a-pinene 20, lemonin 8, linalool 6, borniol 6, geraniol 6,	Cola Soda
7.	Cinnamon bark oil,	Cinnameldehyde (65-80%), linalool, ethyl eugenol	Cola Soda
8.	Orange oil	Lemonene 94.2, b-Pinene 02-1.0, a-pinene 0.7-1.4, myrcene 2.1- 4.3	Orance Soda/Fanta

Resource: Ameh *et al.*, 2016

micro-organisms of the preserved materials and also protect from spoilage with enhance shelf-life. The essential oil of *Thymus capitates* L. has been used to prevent several diseases of fruit plants (Abd-AllA *et al.*, 2011). Table 4 shows the use of essential oils as a preservative.

Use as flavouring and fragrant agent

Essential oils are mainly used as flavouring agent compounds that are supplemental, enhanced, or modified in modest doses to the food of natural flavour or aroma without adding any of its own distinctive flavours or aromas. There are three

Table 7: Patents on use of essential oils in post-harvest technology

S.N.	Patent No.	Inventor	Title	Field date/Application no./ Publication date
1.	WO 93/06735	(Vassilis D and Panagiotis T 2017)	Post-Harvest fruit protection using components of natural essential oil in combination with coating waxes	Filed date: 09.10.92 Application No. PCT/GR92/ 0018 Publication date: 15.04.1993
2.	EP1106070A2	(Freire GM and Maria J 2001)	Natural source composition for the control of post-harvest pathologies and method of application	Filed date : 10.11.2000 Application No. 00500230.8 Publication date-13.06.2001
3.	US9,957,215 B2	Louis Perez, Camille Mol, Ronald C. Bakus, James Rogers, Gabriel Rodriguez (2018)	Plant extract compositions for forming protective coatings	Filed date: 18.08.2017 Application No.15 / 680, 541 Publication date-15.02.2018
4.	US10,517,310B2	Louis Perez, James Rogers, Ronald C. Bakus, Chance Holland, Jenny Du (2017)	Plant extract compositions and methods of preparation thereof	Filed date: 26.07.2017 Application No. 15 / 660,260 Publication date: 9.11.2017

categories of flavouring agents i.e. natural, nature-identical, and artificial, according to European Union law. There are so many volatile compounds show in Table 5, presented in fruits that are responsible for fragrance and flavour. The same volatile compounds are available in different essential oil (Table 6) extracted from different aromatic plants which are used in food industries for the preparation of natural flavour and fragrance.

Use of essential oils in beverage and soft drink

Methyl eugenol, which is found in many plants and vegetables, is another widely used flavoring agent to enhance the taste and aroma. The European Union establishes maximum levels for the use of this substance in food, and the permitted amount in nonalcoholic beverages is up to 1 mg/kg.

Available patent on minimizing post-harvest losses

Various studies are available on essential oil used for reducing post-harvest losses. Some patents (Table 7) are also assigned on the method which is related to coating wax used to reduce post-harvest losses.

CONCLUSION

Since last decade, a large number of studies have been conducted to demonstrate the benefits of essential oils in post-harvest handling of fruits and vegetables. In various studies, it has been found that the essential oils are used as coating wax, vapour, preservative, fragrant & flavour, beverages and soft drink to enhancement the overall quality and shelf-life of fruits and vegetables. The essential oils of some plants like lemongrass, mint, basil, rosemary, thyme, eucalyptus, salvia, cinnamon, etc. have properties against various diseases and plant pathogens, especially which are responsible for losses in horticultural produces. Recently, the use of natural essential oils increased because of it is safe and non-toxic for human health and environment. Hence, the demand and interest towards use of essential oils in post harvest handling has also enhanced in recent years. Although, various research works have been done on advantages of essential oils, but further research on effect and uses of essential oils in post harvest management needs to scientifically prove for reduction on the losses and improve the overall quality of horticulture crops.

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