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Review

Use of essential oils for prolonging postharvest life of fresh fruits and vegetables

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Abstract

Fresh fruits and vegetables are perishable commodities which play vital roles in humans' diet and health. Unfortunately, the losses along the supply chain of fresh fruits and vegetables are high especially due to the decay caused by pathogens during poor postharvest handling. During postharvest, attempts have been made to combat microbial decay in fresh horticultural industry by avoiding the use of fungicides which threaten consumers' health. Among those attempts, essential oils extracted from plants have been used as antimicrobial in postharvest and proven to be efficient in prolonging shelf life of fruits and vegetables without affecting their sensory properties. The glandular trichomes of plants are the important site for biosynthesis of essential oils and they act as defence system against herbivores and pathogens. Since essential oils are volatile aromatic compounds, the easily vaporised property has been exploited in postharvest application as fumigants. In addition, essential oils have also been incorporated into chitosan and alginate-based materials as edible coatings. Research in the use of essential oils as antimicrobial in Malaysia is however still lacking.

Introduction

Fresh fruits and vegetables contain a lot of phytochemicals, vitamins and minerals that are essential to humans' health. A minimum of 400 g of fruits and vegetables per day is needed for the prevention of chronic diseases (such as heart disease, cancer, diabetes and obesity), and alleviation of several micronutrient deficiencies (World Health Organization, 2003). With the global population approaching 9 billion people, 70-100% more food is needed to feed mankind (Godfray *et al*., 2010). As such, reducing the losses along the supply chain of fresh fruits and vegetables is necessary to ensure its availability. However, fresh fruits and vegetables are naturally perishable with short postharvest life. These horticultural produces are vulnerable to mechanical injury, fluctuation in handling temperatures and humidity, and contamination during handling which eventually lead to postharvest decay. It is estimated that about 20–25% of the harvested fruits and vegetables are decayed by pathogens during postharvest handling (Droby, 2006; Zhu, 2006; Singh and Sharma, 2007). In order to prevent this, preventive measurements are being explored.

Among these, chemical means by using authorised fungicides are the most commonly practiced due to ease and cheap application. However, their side-effects such as residues and long degradation period towards consumers' health have attracted great attention from consumers, manufacturers and handlers. This is because the interval between fungicidal application and consumption is short, and the effect might be more devastating than those applied in pre-harvest stage (Amin *et al*., 2012). Therefore, it is important to develop safe, effective and eco-friendly strategies to avoid the limitations of fungicides in reducing postharvest losses. Essential oils extracted from plants have shown antimicrobial property (Bosquez-Molina *et al*., 2010), low mammalian toxicity, less environmental effects (Burt, 2004), eco-friendly and biodegradable properties (Tzortzakis and Economakis, 2007). As such, using essential oils in postharvest is a useful strategy. This paper thus reviews the use of essential oils extracted from different plants and plant parts in prolonging postharvest life of fresh fruits and vegetables.

What is essential oil?

The history of essential oils usage dated as far back as 3000 B.C. when the Egyptians used aromatic plants for the embalming of the deceased

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as well as for medicinal and cosmetic purposes in their daily life. Basically, essential oils are plant secondary metabolites which consist of complex and volatile compounds (Bakkali *et al*., 2008). The molecular weights of secondary metabolites found in essential oils are ranging from 50 to 200 Da with four major chemical groups, i.e. terpenes, terpenoids, polypropenes and other aromatic compounds (Lee and Ding, 2016). Plants that release strong odour and aroma contain high amounts of essential oils, and these can be extracted from any part of the plants including buds, flowers, leaves, stems, branches, seeds, fruits, roots, wood or bark (Bakkali *et al*., 2008).

In plants, these essential oils play vital role in allelopathy, help in adapting to abiotic stresses, intra- and inter-plant signalling, and defence system against herbivores and pathogens (Sharifi-Rad *et al*., 2017). It is generally known that essential oils are synthesised and secreted in a specialised plant organ known as glandular trichome (Werker, 1993). Botanically, glandular trichomes are modified epidermal hairs that form boundary between the plant and the external environment. The morphology of glandular trichomes varies in term of forms, sizes, secretion abilities and its contents (Werker, 2000). Furthermore, the chemical contents synthesised in the glandular trichomes are often associated with various biological activities such as antimicrobial, antifungal and antioxidant (Hyldgaard *et al*., 2012). However, until today, scientists are still not clear on the relationships between glandular trichomes forms, types, distributions and essential oils' chemical groups.

Application of essential oil in fresh fruits and vegetables

Essential oil vapour

By nature, essential oils are volatile aromatic compounds. As such, essential oils have been applied as fumigants to control postharvest diseases in fresh fruits and vegetables. The vapour of thyme oil (extracted from *Thymus* plants of the Lamiaceae (mint) family) was used to fumigate sweet cherries and showed effective control of grey mould rot (*Botrytis cinerea*) (Chu *et al*., 1999) and brown rot (*Monilinia fructicola*) (Chu *et al*., 2001). Similarly, thyme oil also effectively controlled anthracnose (*Colletotrichum gloeosporioides*) in avocados (Sellamuthu *et al*., 2013) and mango (cv. Banganapalli and Totapuri) (Perumal *et al*., 2017). Liu *et al*. (2002) found out fumigation using thyme oil vapour was able to retard mycelial growth and conidial germination of *M. fructicola* in apricot and plums. However, this fumigation caused higher surface browning and firmer fruit in apricot while total soluble solids and titratable acidity was not affected. For plum, fumigation using thyme oil caused higher total soluble solids, but firmness and titratable acidity was not affected. It seems that the effects of same essential oil vary with different type of fruits.

On top of thyme oil, essential oil vapours of eucalyptus (*Eucalyptus globulus L.*) and cinnamon (*Cinnamomum zeylanicum Blume*) were also proven to have antimicrobial property by reducing tomato and strawberry fruit decay (Tzortzakis, 2007). However, in a study using thyme and cinnamon oil vapours to treat 'Spring Princess' and 'Sonnet' peaches, it was found out that the efficacy of cinnamon oil was weaker than thyme oil in controlling brown rot (*M. laxa*) (Cindi *et al*., 2016).

Fumigation using essential oil of cinnamaldehyde extracted from cinnamon, clove (*Syzygium aromaticum*) and thyme showed positive effects in improving the quality of button mushrooms (*Agaricus bisporus*) by slowing down the browning process and cap opening, and reducing the microbial counts (Gao *et al*., 2014). In another essential oil fumigation study using clove, cinnamaldehyde and thyme oils, the treated shiitake mushrooms (*Lentinula edodes*) showed lower sensory deterioration, higher antioxidant activity and flavonoid content as compared to control (Jiang *et al*., 2015). In both studies, it was found that cinnamaldehyde yielded the highest result among the three essential oils tested.

Besides the commonly used plant extracts, essential oil of *Solidago canadensis* L. was also used as fumigant in inhibiting growth of postharvest pathogens (Liu *et al*., 2016). *Solidago canadensis* is a herbaceous perennial of the family Asteraceae and one of the most destructive invasive weeds in south-eastern China. Since the leaves possess antimicrobial property, it was extracted and used as fumigants during postharvest. It was proven that essential oil vapour of *S. canadensis* could inhibit B. cinerea growth and preserve postharvest quality of strawberry. Another less known herb, *Origanum dictamnus* L. (Cretan dittany), which is a local endemic in the island of Crete, Greece, has been extracted to obtain its essential oil (Stavropoulou *et al*., 2014). The oil vapour of *O. dictamnus* was able to suppress *B. cinerea* conidial production in eggplants (*Solanum melongena*).

Essential oil in edible coatings

Naturally, fruits have protective waxy coatings on its surface. However, this quickly diminishes or gets thinner during postharvest handling. As such, edible coatings are applied to the fruit surface in addition to or as a replacement to the natural protective wax by using thin layers of edible material (Misir *et al*., 2014). Edible coatings have proven to provide an aesthetic appearance, to prevent the escape of favourable volatiles and moisture, as well as to protect products from mechanical and microbial damage (Arnon *et al*., 2015). This is because edible coatings can carry essential oils that have antimicrobial properties and then the vapour phases of essential oils are being released slowly. With this property, essential oils have been incorporated in edible coatings to protect coated products from microbial damage.

Chitosan has been applied to coat fruits and vegetables. Coating fresh blueberries using chitosan with combination of 0.1% carvacrol or 0.2% trans-cinnamaldehyde has reduced fruit softening and decay by inhibiting microbial growth (Sun *et al*., 2014). Carvacrol is the major component in essential oils of oregano (*Origanum vulgare L.*) and thyme, while cinnamaldehyde is the major component in essential oil of cinnamon (Yuan *et al*., 2016). Similarly, chitosan and cinnamon oil coating reduced the weight loss and decay of jujube fruits during 60 days of storage at 4°C (Xing *et al*., 2015). In vegetables, chitosan and lemon essential oil coating was able to prolong the shelf life of rocket salad (*Eruca sativa* Mill.) leaves from three to seven days as compared to control (Sessa *et al*., 2015). In another study using sweet pepper (*Capsicum annum* L.), it was revealed that chitosan and cinnamon oil coating could control decay (below 5%) and maintained sensory acceptability of sweet pepper for 35 days at 8°C (Xing *et al*., 2011).

Besides applying directly to intact fruits and vegetables, essential oils have also been applied to fresh-cut produces. Lemongrass (*Cymbopogon citratus* L.) essential oil (0.3% w/v) incorporated in alginate-based edible coating showed positive result on fresh-cut pineapple where respiration rate, weight loss and yeast and mould counts were reduced while firmness, colour and sensory characteristics were maintained (Azarakhsh *et al*., 2014). In another fresh-cut study, 'Bravo de Esmolfe' apple could be stored for seven days at 4°C with good attractive appearance, sensory and nutritional quality when the essential oils of eugenol and citral were incorporated into coatings which had sodium alginate or pectin as base (Guerreiro *et al*., 2016).

Conclusion

Essential oils extracted from plant species that are either well-known or not to mankind are good substitutes to fungicides during postharvest. The oil is not only able to retard microbial growth; it can also maintain the sensory acceptability when applied to fresh fruits and vegetables. These are the properties needed by the industry. Unfortunately, not many attempts have been explored to use essential oils in reducing postharvest losses.

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