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REVIEW ARTICLE

1-methyl cyclopropene (1-MCP) for quality preservation of fresh fruits and vegetables

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ABSTRACT

The use of 1-methyl cyclopropene (1-MCP) is a commercial strategy commonly used for handling of several fruits and vegetables, as pre and postharvest application extends their shelf life. Ethylene promotes rapid ripening, softening and early senescence of fruits and vegetables. It binds with receptors present in fruit tissues and elicits functions.1-MCP binds with ethylene receptors and blocks ethylene mediated responses in fruits and vegetables. Its efficacy depends on various factors such as cultivar, harvesting and maturity stage, concentration, exposure duration, time, etc. It delays many physiological disorders and chilling injury development in several commodities. This review explores the role of 1-MCP for quality preservation of fruits and vegetables.

Keywords: 1-MCP, ethylene action, ethylene management, shelf life, senescence

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INTRODUCTION

The quality of fruits and vegetables is closely associated with their physical and biochemical characteristics that are associated changes occur during ripening. Although ripening is important for optimum edible quality, but uncontrolled ripening causes senescence and deterioration of quality. Ethylene is responsible for rapid ripening changes in fruits. It is responsible for the discoloration of vegetables and rapid senescence in flowers. Thus, it is important to control the effect of ethylene and the ripening process during postharvest handling, in order to provide the best possible quality produce to the consumers (Hamzah et al., 2013). In recent years, several techniques have been developed to regulate the effect of ethylene action (Razzaq et al., 2014; Cao et al., 2015). Compounds such as carbon dioxide, silver thiosulfate (STS), aminoethyoxyvinylglycine (AVG), 1-methyl cyclopropene (1-MCP) 2,5-norbornadiene (2,5-NBD) and diazocyclopentadiene (DACP) are effective ethylene inhibitors. Among all these compounds 1-MCPis most effective ethylene antagonist (Serek et al., 1994a) which binds with ethylene receptors and inhibit its elicit action. 1-mcp has several characteristics that results its rapid approval by regulatory authority around the world. It is a gaseous molecule which is easily applied and has an excellent safety profile without any residual effect in treated produce. The safety, toxicity and environmental profiles of 1-MCP in regard to humans, animals and the environment are extremely favorable (Environmental Protection Agency, 2002). Recently, more than 40 countries had been got approval for the use of 1-MCP by regulatory bodies. It is registered for use on a wide variety of fruits and vegetables,

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including apple, avocado, banana, broccoli, cucumber, date, kiwifruit, mango, melon, nectarine, papaya, peach, pear, pepper, persimon, pineapple, plantain, plum, squash and tomato (Watkins, 2015).

APPLICATION OF 1-MCP

The concentration required for inhibition of ethylene action depends on various factors of fruits and vegetable like species, cultivar, maturation stage, temperature and exposure time, and the production of new ethylene receptors on the cell membranes (Pereira et al., 2013). Many studies reveal that 1-MCP has been applied at temperature ranging from 20^{o}C to 25^{o}C and active at very low concentrations normally in ppb range (Table 1). Low temperature application is not more effective but gives positive results for some fruit crops such as pear cv. Bartlett (Wang and Sugar, 2015), loquat cv. Claudia (Liguori et al., 2017).

COMMERCIAL FORMULATIONS OF 1-MCP

Commercial application of 1-MCP to edible crops was undertaken by AgroFresh, Inc., a subsidiary of Rohm and Haas (Spring House, PA), under the trade name SmartFresh. Commercialization of 1-MCP as the Smart Fresh^{TM} has led to rapid adoption of this technology for many horticultural industries. Use of SmartFresh technology in CA storage mostly occur in apples (Mattheis, 2008; Watkins, 2008) due to its large volume kept in CA storage for periods up to 12 months, depending on the cultivar and growing region.

SmartFresh^{TM} is a sugar-based powder formulation which is dissolved in tap water and release 1-MCP in the storage room. It permeates the air and interacts with the ethylene receptors, blocks them temporarily until the fruit comes out of the storage or the refrigerated environment. It successfully manages fruit and vegetable ripening by controlling naturally occurring ethylene during storage and transport. It reduces postharvest losses and maintains the texture, firmness, taste and appearance of fruits (Rebeaud and Gasser, 2015).

EthylBloc^{TM} is an ethylene action inhibitor, which naturally keeps the flowers and plants fresh during shipping and distribution. It can be used with cut flowers, potted flowers, bedding, nursery and foliage plants.

Ripelock^{TM} is an innovative complete ethylene control packaging system used for bananas. This offers flexibility and consistency to distributors, ripeners, retailers and consumers to handle and purchase bananas at their preferred ripening stages.

Harvista^{TM} technology slows the natural ripening process, maintaining superior fruit quality and value from harvest to storage and packing. It provides a longer harvesting period for growers by keeping fruits in optimum color, size and firmness.

EFFECT OF 1-MCP ON FRUITS AND VEGETABLES

Researchers have been reported that 1-MCP delays the ripening process and extends the storage life of many fruits and vegetables (Table 1).

Table 1: Physiological and biochecmical effects of 1-MCP application in different fruits and vegetables

Crop	Concentration & Temperature	Physiological and biochemical Effects	Reference
Avocado cv. Pollock	300nl/L, 27±2°C	extend the shelf life up to 9 days, delay the decline of antifungal activity	Daulagala and Daundasekera (2015)
Bitter melon	5µl/L, 20°C	inhibit ethylene production, maintain antioxidant enzymes, improve fruit quality	Han et al.(2015)
Cape gooseberry	1µl/L, 20°C	delay maturity and ripening, extend postharvest shelf life	Balaguera- lopez et al. (2016)
Papaya cv. Solo	1µl/L,	reduce respiration rate and ethylene production, delay ripening, retention of green peel colour	Ohashi et al. (2015)
Durian fruit	300nl/L, 25°C	inhibit ethylene production by decreasing ACO activity	Amornputti et al. (2016)
Pear cv. Barlett	500µg/L	delay rise in respiration rate ethylene production, softening and ripening for a minimum of 6 days	Escribano et al. (2017)
Orange cv Pera	0.1µl/L , 20°C	delay the onset of peak value of phenolic compounds and increase in antioxidant activity	Rosa et al. (2016
Peach cv Yahualu	5 µl/L	delay the onset of peak value of phenolic compounds and increase in antioxidant activity	Liu et al. (2015)
Mango cv. Kensington Pride	1ml/L, 20±1°C	inhibit the activities of softening enzymes, delay ripening and ripening related changes	Razzaq et al. (2016)
Loquat cv. Claudia	5 µl/L	slow fruit softening, delay internal browning index and chilling injury development	Liguory et al. (2017)
Pithaya fruit	600mg/L	reduce respiration rate, maintain quality, decrease chlorophyll degradation	Alvarez- Herrera et al. (2016)
Mango cv. Maha Chanok	1500nl/L 1000nl/L	retain high chlorophyll content, lowest fruit decay, longer Shelf life up to 12 days	Chutichudet et al. (2016)
Ornamental Pepper	1µl/L	delay senescence and abscission of leaves, good shelf life up to 6 days	Lima et al. (2017)
Persimon cv.Fuyu	150mg/L	reduce premature flesh softening, postharvest translucent strain Disorder	Vieira et al. (2016)
Meldar fruit cv. Istanbul	0.4µl/L & 0.6µl/L	delay softening, reduce weight loss, extend storage life	Selcuk and Erkan (2015)
Apple	5µl/L	decrease blue mould disease Severity, suppress the mycelia growth and spore germination of P.expansum	Li et al. (2017)
Gynura bicolour	500µl/L	delay senescence, protect leaf chloroplast and cells by enhancing stress response and defence mechanism	Jiang et al. (2015)
Hardy kiwi Fruit	20µl/L, 10°C	delay ripening, maintain fruit quality and nutritional value regulate the expression of ripening and senescence genes (AcACO, AcACS and AcLOX)	Lim et al. (2016)
Feijoa cv.Unique	1000nl/L, 20°C	delay ripening of early harvested fruits, suppress respiration rate, softening and loss of flesh colour	Rupavatharam et al. (2015)
Table grapes	2µl/L, 15°C	improve shelf life, reduce rachis, browning, lower respiration rate	Li et al. (2015

Pear cv. Nanguo	0.5µl/L , 20°C	effectively enhance chilling tolerance and alleviate chilling Injury	Cheng et al. (2015)
Yali pear	1µl/L	reduces oxidative damage, inhibit oxidation of phenols and development of core browning.	Dong et al. (2015)
Potato	1µl/L	prolong storage life and suppress sprouting, prevent ethylene induced sugar accumulation	Foukaraki et al. (2016)
Broccoli	2µl/L, 20°C	delay senescence of florets maintain higher chlorophyll content and sugar content	Xu et al. (2016)
Apricot cv Xiaobai	1µl/L, 20±1°C	delay ripening, softening and decay development, maintain quality and extend shelf life	Wu et al. (2015)

Effect of 1-MCP on ripening and senescence

1-MCP shows a positive effect on delaying of ripening and senescence. It binds to copper metal present in the ethylene receptors and blocks the normal as well as system II of ethylene production (Paul and Pandey, 2010). As a result, I-MCP provides protection of produce from ethylene related undesirable responses for a longer period than any other potential inhibitor compounds. Accumulation of ACC-synthase as well as ACC-oxidase is also reduced by 1-MCP which inhibits ethylene production (Zhu et al., 2015). It also induced the activities of antioxidant enzymes (CAT, SOD and POD) which are very important for scavenging ROS to protect cell membranes of produce and delay senescence (Wu et al., 2015).

Effect of 1-MCP on physiological disorders

In general, 1-MCP decreases the incidence of many disorder associated with senescence, e.g. superficial scald, soft scald, internal breakdown and internal browning in 'Abate Fetel' pears (Vanoli et al., 2016) and also reduces or aggravates chilling injury in several commodities such as Japanese plum cv. Sungold (Velardo-Micharet, 2016).

CONCLUSION

1-methylcyclopropene (1-MCP) is a new method which effectively delays the ripening of fruits and maintains their quality with no toxicity or damage. It responds very well to several horticultural produce. Recently it is gaining popularity as an ethylene antagonist and adopted by dozens of countries. Two important directions need to continue further postharvest research on 1-MCP and ethylene in. The first one is to learn how we effectively use 1-MCP to maximize profits for agricultural business and provide a quality consumer product. The second is to use 1-MCP as a research tool to understand the role of ethylene in plant development.

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