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Role of 1-MCP on post-harvest quality of fruits and vegetables

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Abstract
The rapid rate of ripening of fruits and senescence of fruits, vegetables and flowers due to the plant hormone ethylene has direct implications on their biology, shelf-life, durability, processability, postharvest losses and management practices. An average of one -third of harvested edible product is wasted worldwide after harvest. Energy, vitamins, minerals, fiber, phenolics (anthocyanins, flavonoids, etc.), pigments (carotenes, betacyanin's, etc.) and other phytochemicals are all found in fruits and vegetables. Due to the nutraceutical functions of these bioactive compounds in fruits and vegetables are classified as functional foods in the human diet. One of the most popular techniques for delaying the ripening of fruits and vegetables is the use of 1-methylcyclopropene (1-MCP). 1-methylcyclopropene is an odorless gas that biologically resembles ethylene and can bind to the ethylene receptors in fruits, inhibiting the normal action of ethylene and extending the storage life of fruit. 1-MCP is an inhibitor of ethylene that can significantly affect the ripening and senescence of many agricultural commodities because the binding of 1-MCP to the ethylene receptor allows the ethylene sequence to be inactivated and protects. In some commodities, 1-MCP may be sprayed at lower temperatures, however it is most frequently used between 68 – 77 °F (20 – 25 °C). Usually, treatments lasting 12 to 24 hours were enough to produce a complete response. In order to prolong the shelf life of fruits, vegetables and ornamentals, 1-MCP shows better performance. Other benefits of 1-MCP includes non-toxicity, safety, low volume, excellent efficiency and no environmental pollution.

Keywords: 1-Methylcyclopropene, ethylene inhibitor, ethylene receptors, shelf life, ripening, senescence

1. Introduction
Harvested fruits, vegetables and flowers are highly perishable agricultural products that spoil quickly. Poor post-harvest handling and subsequent transport procedures might result in significant overall losses. In our everyday lives, fruits and vegetables safety and freshness are crucial. Moreover, fresh fruit and vegetable deterioration will result in the production of pathogenic bacteria that are harmful to human health [1]. For a long time, storage the preservation of harvested fruits and vegetables largely has relied on synthetic chemical fumigation, controlled storage and modified temperature storage. Paper goods are frequently used in the retail of fruits and vegetables for transportation, wrapping and decorating. These paper products can serve purposes more than simply packaging when they are altered with active ingredients. Thus, adding 1-MCP to paper products can provide fruits and vegetables a preservation function. 1-MCP is an excellent and eco-friendly inhibitor of ethylene that can effectively slow down the ripening of fruits and vegetables and extended their shelf life [2]. One of the many plant growth regulators, ethylene influences growth and developmental processes, especially ripening and senescence. Simple alkene- or olefin-based hydrocarbon ethylene may diffuse into and out of plant cells from both endogenous and external sources. Ethylene affects the post-harvest quality of horticultural crops and depending on the type of fruits and vegetables its stage of ripening and the intended use, it may be beneficial or harmful. For example, ethylene initiates uniform ripening and colour change during banana ripening and de-greening of citrus fruits [3]. Fruit and vegetable quality is significantly related to the physical and biological features that change as they mature. Although ripening is necessary for the best edible quality but uncontrolled ripening accelerates ageing and reduces quality. Fruits quickly change as they mature because of ethylene. Vegetable browning and flowers ageing rapidly are caused by it [4]. Several strategies have been developed in recent years to control the impact of ethylene activity.

A variety of chemicals are effective ethylene inhibitors, including silver thiosulfate (STS), carbon dioxide, aminoethyoxyvinylglycine (AVG), 1-methyl Cyclopropene (1-MCP), diazocyclopentadiene (DACP) and 2,5-norbornadiene (2,5-NBD). Among all these inhibitors the most potent ethylene antagonist chemical is 1-MCP, which binds to ethylene receptors, hence inhibiting its eliciting effect [4, 5]. 1-MCP was discovered by Sisler in 1994 and patented by Sisler and Blankenship in 1996. For usage on ornamental crops, they obtained a license from Floralife. The United States Environmental Protection Agency (EPA) allowed Floralife commercial use in ornamental crops in 1999. It was manufactured as -cyclodextrin (-CD)/1-MCP and sold under the trademark name EthylBloc (Waterboro, SC, USA). When dissolved in water, it emits 1-MCP gas. Rohm and Haas company was first to acquire non- floral right for 1-MCP in December 1999 [6]. After the Strict inspection by US Environmental Protection Agency, 1-MCP has excellent safety, non- toxic, no residues can be detected for fruits, vegetables and flowers after 1-MCP treatment therefore it is safe for humans, animals, fruits, vegetables and environment. It is approved for use on a broad range of fruits and vegetables, including tomato, chili pepper, apple, avocado, banana, broccoli, baby squash, cucumber, date, kiwifruit, mango, melon, nectarine, papaya, peach, gerbera and pear [4, 6].

2. Commercialization of 1-MCP

The product was approved under the trade names EthylBloc and SmartFresh by the US Environmental Protection Agency (EPA) in 1999 for ornamentals [6].

The sugar-based powder formulation SmartFresh™, while dissolved in tap water, it releases 1-MCP in the store room. Till the fruit is taken from storage or the refrigerator, it penetrates the air and interacts with the ethylene receptors and effectively blocking them. By controlling naturally occurring ethylene during both storage and transportation, it successfully controls the ripening of fruits and vegetables. It reduces post-harvest losses and preserves fruits' texture, firmness, flavour, and appearance consistent [4, 7].

EthylBloc™ is also known as ethylene inhibitor, naturally maintains the freshness of the flowers and plants during transportation and distribution. Cut flowers, potted flowers, bedding, nursery, and foliage plants all can be utilized with it. The natural ripening process is slowed down by Harvista™ technology, preserving optimum fruit quality and price from harvest to storage and packing. By preserving fruits in their original colour, size and firmness, it gives a longer harvesting time for farmers [7].

3. Applications of 1-MCP

3.1 Pre-Harvest Applications

Testing of 1-MCP pre-harvest treatment on a variety of crops, including pears, apples, and roses. Application of 1-MCP prior to harvest has been shown to be effective in reducing fruit drop, delaying colour development, softening, ethylene emission and ripening. By pre-harvest spraying with 10µ L-1 1-MCP, enhanced the storage life of cut rose flowers to up to 6 days [8].

In case of apples pre-harvest application 1-MCP before 21 days of harvest showed reduced starch hydrolysis, internal ethylene, pre-harvest drops and maintain firmness during storage [9].

3.2 Post-Harvest Applications

It is used for decrease the rate of respiration in fruits, vegetables and ornamentals, thus delaying the ripening processes. Post-harvest application used to inhibit the yellowing of vegetables. 1-MCP can be used in consolidation with controlled atmosphere is very effective method [10]. Approximately 20 to 30 minutes at 20 ºC are required for the aqueous dissolution of -CD powder to create 1-MCP in a gaseous state; at lower temperatures, complete release may take more time. The most common 1-MCP application forms used nowadays is the 1-MCP/CD form. Even though innovative forms like tablets and packing materials have been created. In the latter, 1-MCP is packaged as an encapsulated paper product that releases slowly over time [1]. A weekly dosage of 1-MCP prevented apples from softening during 20 °C storage more than at 0 °C storage. It was discovered that at low temperatures, the ability to produce new ethylene receptors was severely limited [11]. 1-methylcyclopropene is used at a temperature between 0-1 °C and relative humidity is 90-95%, it shows no weight loss, firmness and quality but the effect of 1-MCP is affected by temperature fluctuation, involvement of non-target elements and co_2 that affect the storage of food product [12].

4. Preservation Mechanism of 1-MCP (C_4H_6)

By engaging with the receptor and outcompeting ethylene for binding in the receptor sites,

1-MCP inhibits ethylene-induced respiration process. The ethylene receptor is coupled by 1-MCP, which prevents the development of ethylene receptor complexes. In order to prevent the immediate precursor in the ethylene biosynthesis pathway, S-AdoMet, from being transformed to ACC, 1-MCP binds to an ACC synthase enzyme and inhibits the signal transduction caused by ethylene [13]. 1-MCP functions as a "key" that enters the "lock," but it does not activate the "lock." There is no way for the ethylene "key" to enter the "lock" when the 1-MCP "key" is inside [14].

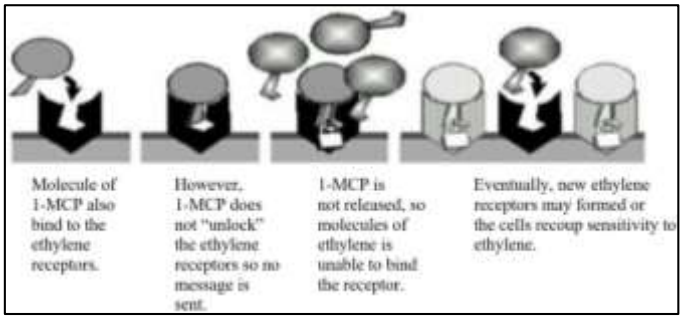

Fig 1: When 1-methylcyclopropene binds with ethylene receptor, it remnants sealed the receptor inhibits the tying of ethylene and the chain reaction does not arise [14].

5. Effect of 1-MCP at controlled atmosphere storage

Controlled atmosphere storage based on increasing carbon dioxide and decreasing oxygen during transportation or storage. By inhibiting the enzyme activity of 1-aminocylpropane carboxylic acid oxidase (ACO), which acts as a catalyst an important step in the formation of ethylene, these changes have an impact on the synthesis of ethylene. There are a variety of benefits depending on the concentrations of both gases, including a reduction in the rate of softening and physiological diseases, a delay in colour development, and a decreased risk of decay [15].

6. Physiological and biochemical effects of 1-MCP on horticultural crops (Table)

Table 1: Physiological and biochemical effects of 1-MCP on horticultural crops

S. No.	Crop	Physiological and biochemical effects
1.	Chinese Cabbage	1-MCP @ 3 µL L−1 extended the shelf life, ascorbic acid, soluble protein, total chlorophyll content, total soluble sugar and reduce weight loss till 20 days of storage [16].
2.	Banana (*Musa* spp.)	The treatment of 1-MCP @ 450 nL L-1 influenced the biosynthesis of aroma volatiles up to 18 days of storage [17].
3.	Apple (*Malus domestica*)	The application of 1-MCP @ 625 nL L-1 reduced internal ethylene emission (IEE) till 7 days storage [10].
4.	Citrus (*Citrus spp.*)	1-MCP @ 1.5 µL L-1 retarded the activities of fruit softening enzymes up to 75 days of storage [18].
5.	Eggplant	1-MCP @ 1 µL/L decreased weight loss and extended firmness up to 23 days of storage [19].
6.	Tomato (*Solanum lycopersicon* L.)	The application of 1-MCP @ 2.0 µL L-1 that inhibits ethylene production and fruit ripening during storage up to 12 days [12].
7.	Persimmon (*Diospyros kaki* L.)	The application of 1-MCP @ 1.0 µL L-1 delayed ethylene production and fruit softening up to 90 days storage [20].
8.	Kiwifruit (*Actinidia deliciosa* L.)	The formulation of 1-MCP @ 625 ppb maintained better sensory attributes during storage up to 11 days of storage [21].
9.	Potato	Extend the shelf life and inhibit rooting, sprouting, prohibit ethylene induced sugar accretion at @ 1µL [22].
10.	Broccoli	@ 2 µL that delay the senescence of florets maintain higher chlorophyll content and sugar content [23].

7. Impact of 1-MCP on physiological disorders

The chemical pathway is affected by 1-MCP, which function like competitive inhibition. Binding and blocking the physiological or chemical transport system. 1-Methylcyclopropene reduces the occurrence of many physiological disorders and associated with senescence. Disorders such as bitter pit, superficial scald, internal browning and soft scald [24]. A preharvest formulation of 1-methylcyclopropene on apple fruit shows delayed maturation, ripening and reduces the incidence of internal browning [24, 25].

8. Conclusion

1-MCP has shown a significant impact in horticultural crops which effectively delays the ripening of fruits or vegetables and extend their shelf life. There are several opportunities for combining 1-MCP with modern technology to supply consumers high-quality horticultural products and to lower post-harvest losses, especially for perishable fruits, vegetables, and ornamental crops. 1- MCP also provides the scientific community a tool to investigate at the biochemical and physiological reactions of agricultural product to ethylene. In order to ensure safe utilization of the technology, ongoing research is also required to understand the various responses within various horticulture crops.

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