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A REVIEW OF HOW TO OPTIMIZE STORAGE AND SHELF LIFE EXTENDING TECHNOLOGIE OF KIWIFRUIT (*ACTINIDIA* SP.) BY USING 1-METHYLCYCLOPROPENE TO MEASURABLY REDUCE FRUIT WASTE

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Abstract

Kiwifruit (Actinidia deliciosa) are capable of long term storage only if carefully protected against deterioration prior to and during storage. They are harvested when mature but unripe and must ripen before eating. They are extremely sensitive to ethylene gas, which causes rapid flesh softening during storage, starch depletions to reduced sugars, increased susceptibility to spread of fruit rotting organisms and physiological breakdown. Hardy kiwifruit/Baby kiwi (Actinidia arguta) have smooth, edible skins and are smaller in size than 'Hayward' kiwifruit. Unlike A. deliciosa, baby kiwi fruits are very sensitive to dryness because of their smooth peels that lack hair. This phenotype characteristic is the main reason for the short-storage time and fast loss of postharvest quality. Fruits are not picked vine ripe, as they would be too soft to package and ship, instead they are picked when physiologically mature and firm, and are stored under refrigeration (0˚C, 90–95% RH). Limited information exists regarding the ripening physiology of hardy kiwifruit or the ideal packaging and storage conditions for optimum quality, storage and shelf life. The objectives of this paper is to integrate existing knowledge and findings about applying technologies developed to suppress ethylene content and its effects degrading the kiwifruit post-harvest by applying 1-methylcyclopropene and periodically reviewing its effects and changes in kiwifruit quality, thereby improving storage technologies and extend the shelf life. The paper is an overview of how to optimize storage technologies of kiwifruit, managing fruit ripening by controlling naturally occurring ethylene during storage for optimal market value and more efficient harvest management, while maintaining excellent quality fruit and reduce losses and findings reveal the importance for assessing the marketing performance of the retail wine stores and the limits that generated lack of adoption on a large scale.

***Key words**: kiwifruit, 1-methylcyclopropene, shelf life, short-storage.*

INTRODUCTION

The inhibitor of ethylene, 1-methylcyclopropene (1-MCP), is a new technology that is increasingly being used to improve storage potential and maintain quality of fruit and vegetables. 1-MCP is a synthetic cyclic olefin capable of inhibiting ethylene action. 1-MCP is a cycloalkene with the molecular formula C4H6 (Figure 1). It is a volatile gas at standard temperature and pressure with a boiling point of ~12°C. It acts as a competitor of ethylene, blocking its access to the ethylene-binding receptors (Sisler and Serek, 1997). The affinity of 1-MCP for the receptors is approximately 10-times greater than that of ethylene and, therefore, compared with ethylene, thus it is active at much lower concentrations.

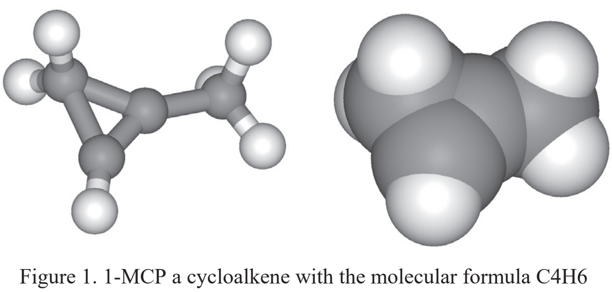

Figure 1. 1-MCP a cycloalkene with the molecular formula C4H6

1-MCP is a gaseous nontoxic product that delays softening and improves post-storage quality of several climacteric fruits (Blankenship and Dole, 2003) and it is applied to extend their postharvest life. To maintain the market position of the fruit, it is very important that techniques of storage and ripening retardant applications be used, which reduce the effect of ethylene (Watkins, 2008) and conserve a longer postharvest quality (Magaña et al., 2004; Andrade et al., 2006). Ethylene is a natural gaseous hormone (Martínez-Romero et al., 2007) that regulates the processes related to fruit ripening and senescence (Binder, 2008). The action of ethylene results from the binding of molecules to receptors located in the cell membrane of the endoplasmic reticulum (Serek et al., 2006). This binding activates the receptors, which send transduction signals, generating a gene expression and physiological response (Pereira et al., 2008). For this reason, the endogenous and/or exogenous presence of this hormone accelerates ripening and creates desirable senescence effects (fast, uniform ripening) or undesirable effects, such as reductions in the fruit's life (Giovannoni, 2004). There is a group of compounds called analogues of ethylene that competes for membrane receptors and inhibits the effect of this hormone, within which 1-methylcyclopropene (1-MCP) is notable, which has been widely used in various fruits and vegetables (Nanthachai et al., 2007; Watkins, 2008), generating changes in multiple metabolic processes, such as decreases in respiratory rates, ethylene production and volatile degradation of chlorophylls, changes of color, sugars, acidity and softening, which vary depending on the fruit, concentration and exposure time (Watkins, 2006). Sooyeon et al. (2015) used the 1-MCP treatment to inhibite hardy kiwifruits (*Actinidia arguta*) ripening by reducing respiration and ethylene production; the hardy kiwifruits could be stored for up to 5 weeks by maintaining higher fruit firmness, ascorbic acid and total phenolic contents, reducing changes in acidity, respiratory rate and color. In this sense, the employment of technologies such as 1-MCP applications has a potential use in the reduction of changes associated with quality losses during postharvest, which would extend the shelf-life of fruits and vegetables (Vilas-Boas and Kader, 2007); so the greater exposure time of the product, the lower the needed concentration will be in order to obtain the desired effect (Bassetto, 2002). Extensive literature about the effects of 1-MCP on fruit, vegetables, and ornamental products exists, and by 2007, results for over 50 fruit and vegetables, both whole and fresh-cut, as well as ornamental products, were available (Watkins and Miller, 2006). Other studies shows that the effect of 1-MCP on fruit considers the effects on factors that influence product quality using several fruit that have received the most attention in the literature, and that highlight some of the challenges that exist in commercialization of 1-MCP-based technology.

THE EFFECTS OF 1-MCP POSTHARVEST TREATMENT

For *Actinidia aruguta* (Seib. et Zucc.) Planch. Ex Miq., known as 'hardy kiwifruit' or 'baby kiwifruit' the recommended storage period of hardy kiwifruits is one to two weeks and an additional two or three days for shelf life. The main reasons for the short storage life are fruit softening, skin wrinkling due to water loss (dryness) and fruit decay. Fruit softening rapidly increases at the room-temperature ripening period, after harvest or cold storage (Krupa et al., 2011). Unlike *A. deliciosa*, the hardy kiwifruits are very sensitive to dryness because of their smooth peels that lack hair. This phenotype characteristic is the main reason for the short-storage time and fast loss of postharvest quality (Strik, 2005).

In various climacteric fruit including kiwifruit, preclimacteric application of 1-methylcyclopropene (1-MCP), a potent inhibitor of ethylene perception due to its largely irreversible binding to ethylene receptors, has been reported to delay ripening and senescence significantly, and consequently to lead to a prolonged storage life and/or shelf life (Watkins, 2006).

To extend the storage life of hardy kiwifruits different edible coating materials were used in past, consisting of mixtures of various formulas, such as calcium caseinate, chitosan, Prima Fresh 50-V and Semperfresh (Fisk et al.

(2008). Krupa et al. (2011) reported that hardy kiwifruits stored in common cold storage gradually lost physicochemical quality over 4 weeks due to decreases in ascorbic. Contrary to the fruit of *A. deliciosa*, which can be stored in cool conditions for up to 5 months, the storage time of hardy kiwifruits is usually no longer than 10–12 weeks and varies from year to year (Strik, 2005).

In Asiche et al. (2016) study, the application of 1-MCP after propylene treatment delayed the initiation and progression of ethylene biosynthesis and overall fruit ripening. 1-MCP extended the "eating window"of kiwifruit, especially in fruit treated with propylene for 48 h that had started ethylene biosynthesis. This suggests that, in kiwifruit, immediately after the commencement of propylene treatment, even before ethylene production is initiated, synthesis of cell-wall degrading enzymes isinitiated, which induces subsequent fruit softening, whereas the application of 1-MCP delayed fruit softening induced by propylene. Similar effects of 1-MCP in delaying fruit softening after ethylene or propylene treatment have also been observed in melon (Nishiyama et al., 2007) and 'La France' pear (Kubo et al., 2003).

In his study Park et. Al., (2015), provides dates where flesh firmness decreased gradually with storage time and reached lower levels at the end stage of storage in 1-MCP treatments. Fruits treated with 1-MCP enhanced firmness, about 20 % higher than control fruits. Application of 1 ppm of 1-MCP was sufficient to delay kiwi fruit softening during cold storage. In Park's experiment it has been shown that flesh firmness enhanced by 1-MCP treatment changes with increasing of starch content during storage. Several explanations are available for the tendency of firmness in correlation with starch content when the treatment was carried out. 1-MCP treated kiwi fruits showed the lesser decrease of the starch content. The relatively high content of starch is related to the enhanced kiwi fruit firmness.

In his study, Kwanhong et. al. (2017), shows that 1-MCP treatment effectively delayed the rate of fruit softening in red-fleshed kiwifruit by suppressing ethylene biosynthesis during storage at all temperatures. The application of 1-MCP was very effective in delaying fruit ripening and senescence, especially at higher storage temperatures above 10°C, according to his study.

As shown in Hwanhong et al. study, 1-MCP treatment also influenced both SSC and TA of red-fleshed kiwifruit. The fruit reached full ripeness when the SSC level increased to 15 Brix. His study demonstrates that application of 1-MCP could delay the increase of SSC and decrease acidity. Fruit treated with 1-MCP had lower SSC and higher TA than untreated fruit during storage at all temperatures, similar to previous studies on 'Hayward'(Koukounaras and Sfakiotakis, 2007) and 'Allison' kiwifruit (Sharma et al., 2012). In which sensory evaluation regards, storage had a measurable effect on the quality of the fruit. The results show that 1-MCP-treated fruit were harder, sourer, and less juicy than untreated fruit, especially for fruit stored at 20°C. This suggests that 1-MCP treatment could delay softening and sourness in fruit stored at all temperatures. However, the 1-MCP treatment did not affect the juiciness of the fruit, except for fruit stored at 20°C which were less juicy.

Boquete et al. (2004) and Kim et al. (2001) determined that application of 1-MCP in kiwi fruits reduces ethylene production and softening during cold storage and subsequently exposed to 20 °C. Low concentrations of 1-MCP from 2.5 ppm to 1 ppm in most commodity are the most effective, but this depends also on temperature treatment. The most commonly applied is 20–25°C, but lower temperatures can be used in some commodities (Mir et al. 2001). Generally, optimal treatment durations of 12–24 h in fruits were sufficient to achieve a full response (Ku and Wills, 1999b). It was shown that 1-MCP effectiveness in fruits and vegetables were influenced by the cultivar, developmental stage, time from harvest to treatment and its concentration (Wills and Ku, 2002).

1- MCP is being used as a powerful tool to gain insights into fundamental processes that are involved in ripening and senescence, as well as to understand ethylene's action and responses (Watkins, 2006). The effects of 1-MCP in fruits are variable depending on the fruit. For example, 1-MCP induced an increase in sugars (expressed as soluble solids) in papaya (Hofman et al., 2001) and pineapple

(Selvarajah et al., 2001), but reduced sugars in kiwifruit (Boquete et al., 2004) and nectarines (Bregoli et al., 2005). Furthermore, 1-MCP had no effect on soluble solid contents of plums (Menniti et al., 2004) and mamey sapote (Ergun et al., 2005). Organic acids such as citric acid were reduced in 1-MCP-treated apple (Defilippi et al., 2004) and were increased in guava (Bassetto et al., 2005); malic acid in apple did not change due to 1-MCP treatment (Defilippi et al., 2004; Kondo et al., 2005).

Respiration rates and ethylene production are reduced in fruits treated with 1-MCP most of the time (Jiang et al., 2001; Dong et al., 2002; Mwaniki et al., 2005). Exposure of kiwifruits to exogenous ethylene (ethephon) accelerates maturation, which generates metabolic processes that reduce postharvest fruit life. The 1-MCP treatment extended the postharvest life of the kiwifruits, slowing the metabolic processes and loss of firmness and likewise decreased the respiration rate. The main method used to prolong the storage life of fruit is through reducing the fruit temperature to slow metabolism. Refrigerated storage slows the rate of ripening and senescence of the fruit, and also slows the development of any rots.

The way in which temperature management is implemented after harvest can significantly affect the quality of the fruit at the end of storage, both in the amount of ripening retardation and also the presence or absence of disorders. The basic effect of refrigerated storage on fruit can be supplemented by modification of the atmosphere in the coolstore, by reducing oxygen and increasing carbon dioxide concentrations. The application of the inhibitor of ethylene action 1-methylcyclopropene (1-MCP) has become common to slow the ripening of a range of fruit. The technologies impact on the fruit is dependent on the physiological state, or maturity, of the fruit at harvest and may differ dependent on the commercial requirements of the fruit, i.e. a short or long storage period.

Ultimately, the target for good storage is for the fruit to remain in good condition, to ripen properly, have an acceptable flavour and not to have any disorders at the end of storage and when it reaches the consumer. For commercial practice it is needed to be taken into consideration the cultivar, the maturity and ripening stage, the time between harvest and treatment, the temperature.

In **summary**, this review supports previous research on the beneficial effects of 1-MCP application in delaying ripening and postharvest quality loss of kiwifruit, and can extend its storage life.

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