

## RESPONSES OF PACIFIC NORTHWEST APPLES TO 1-METHYLCYCLOPROPENE (MCP)

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The ethylene action inhibitor 1-methylcyclopropene (MCP) effectively delays ripening of climacteric fruit including apples. This synthetic compound is applied as a gas and has activity at very low concentrations (100 ppb to 1 ppm). There are a number of factors that influence treatment success including fruit maturity at the time of treatment, treatment concentration and duration, and post-treatment storage conditions. While the use of this synthetic compound is, at this time, restricted to experimental purposes, an application for commercial use is pending with the U.S. Environmental Protection Agency. To our knowledge, all apple cultivars tested to date have shown some similar responses including reduced ethylene production and respiration rate, slower loss of firmness and titratable acidity, and reduced incidence of superficial scald in susceptible cultivars. The benefits of storing apples treated with MCP in long-term CA are also becoming evident. However, these positive effects are accompanied by delayed production of compounds contributing to aroma and, in some cultivars, an increased risk of internal browning. These two areas require additional research to develop alternative protocols to optimize use of MCP.

Fruit maturity at the time of treatment influences the duration of apple fruit responses to MCP. The potential to delay harvest to allow additional color development is possible with postharvest use of MCP; however, there is a limit to how far fruit development can progress after which MCP use will not compensate. An experiment using 'Redchief Delicious' apples indicated fruit harvested after the optimum maturity for long-term storage (starch 3.2 on a 1 to 6 scale, 15 lb) then treated with MCP had acceptable quality after 3 months, but not after 6 months in RA



**Figure 1.** Red color “brightness” is preserved with MCP treatment (apple on right).

storage. While treatment of overmature apples with MCP is unlikely to allow these fruit to be acceptable after long-term storage, there is an extension of storage life that provides a wider marketing window provided fruit quality is monitored during storage. In particular, loss of titratable acidity, a critical component of fruit quality, may occur at a faster rate compared to firmness loss; therefore, careful monitoring is critical.

In addition to the benefits to fruit eating quality, treatment with MCP can delay or prevent development of cosmetic disorders. Treatment with

MCP has been consistently effective for preventing development of superficial scald during the postharvest period over which fruit quality is commercially acceptable. We have also observed that MCP treatment tends to preserve brightness in the red color of Delicious and Gala apples (Figure 1). These positive effects of MCP treatment on apple appearance are accompanied by a delay in the loss of peel chlorophyll and green color, desirable for 'Granny Smith' but not for 'Golden Delicious'.

Another factor that is a critical determinant of MCP response is the duration between harvest and application of the material. Maximal response is achieved by treatment as soon after harvest as possible. For example, Granny Smith apples treated with 1 ppm MCP the day after harvest did not develop superficial scald through 6 months in RA storage (Figure 2). Delaying the treatment 2 weeks resulted in 10% of the fruit developing scald after 6 months, while 100% of the fruit developed scald if the treatment was delayed 4 weeks or more. There are situations where maximal response may not be desirable; e.g., Fuji apples with watercore treated the day after harvest were more likely to develop internal browning during CA storage than apples treated after a 2-week delay. These results along with similar experiments conducted using other cultivars indicate similarities in protocols for CA establishment and use of MCP. Cultivars that respond favorably to rapid CA will respond maximally when MCP treatment is conducted soon after harvest. For cultivars that are intolerant of rapid CA under some conditions, for example Braeburn or Fuji with moderate to severe watercore, a delay after harvest prior to MCP treatment may be beneficial to reduce the risk of internal browning during storage.



**Figure 2.** MCP treatment one day after harvest prevents scald in Granny Smith apples in RA.

The combination of MCP treatment then storage in CA can provide benefits in excess of either treatment alone. Trials comparing fruit with or without MCP treatment stored in air or CA have shown the benefits of the combination treatment are typically realized over longer storage durations. Results for some cultivars including Delicious, Gala and Jonagold have been particularly impressive when fruit was treated at the optimum maturity for long-term storage. While MCP is a powerful tool to manage fruit quality during storage, it is not a substitute for attention to fruit maturity at harvest that has served the industry so well since the advent of CA storage.

Production of volatile compounds that contribute to apple fruit aroma is closely regulated by ethylene, the colorless, odorless gas produced by fruit that stimulates ripening. Treatment with MCP delays the increase in production of these compounds for several months. While this effect potentially alters fruit aroma and flavor, our results indicate the MCP effect on volatile production is similar to that induced by CA storage. The difference is that MCP treatment

induces this effect in a much shorter period (days) compared to low oxygen CA storage (months). Reduced volatile production following MCP application may be most important during the first several months after harvest when non-treated fruit will also be marketed. For some cultivars, Gala for example, it may be advantageous to exploit the slower impact of CA conditions on volatile production by delaying MCP treatment. We have found Gala apples treated with MCP after 2 months CA storage had firmness and titratable acidity after an additional 5 months storage in air that was similar to that of fruit stored continuously in CA. This would allow marketing in the early season with less potential for reduced volatile production but still realize the benefits of the use of MCP.

In some cultivars there are reports of injury developing related to MCP use. We have observed what appears to be carbon dioxide (CO<sub>2</sub>) injury in MCP-treated Braeburn and Golden Delicious apples after storage. The injury in Braeburn apples was slight browning near the coreline for fruit stored in air or CA. For Golden Delicious, peel bronzing as well as internal browning and cavities developed in fruit treated at harvest with 1 ppm MCP then stored in CA at 1% O<sub>2</sub> and 2% CO<sub>2</sub>. Further research is necessary to determine if lower MCP application rates and/or low storage CO<sub>2</sub> concentrations are a means to avoid these types of injury.

Many of the practices utilized for storing apples are effective in part due their impact on ethylene production and action. Low temperature, low oxygen and high CO<sub>2</sub> all contribute to reduced ethylene activity in apples during storage. The addition of MCP as another tool to manipulate fruit ripening may provide alternatives and enhancements to current practices to achieve the industry's goal of providing consistent, high quality fruit to a competitive world market.