# FACTORS INFLUENCING SUCCESSFUL USE OF 1-MCP

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The ethylene action inhibitor 1-methylcyclopropene (1-MCP) has been evaluated for use on fresh apples. All apple cultivars tested in our laboratory (i.e., Braeburn, Cameo, Delicious, Fuji, Gala, Ginger Gold, Golden Delicious, Granny Smith, Honeycrisp, Jonagold and Pink Lady® brand apples) have exhibited responses to 1-MCP that include reduced ethylene production and respiration rate, slower loss of firmness and titratable acidity, slower degreening and yellowing, inhibition or reduced incidence of superficial and soft scald, core flush, and greasiness, as well as delayed production of ripe aroma. The degree to which these processes of ripening are inhibited is dependent on several factors including maturity at harvest and at the time of 1-MCP treatment, the length of the delay between harvest and treatment, and storage environment after treatment.

'Gala' apples were harvested over a 4-week period to evaluate how maturity at harvest impacts 1-MCP response (Table 1). Based on firmness and starch index, fruit harvested August 20 were the most suitable for long-term storage. Treatment the day of harvest with 1 ppm 1-MCP resulted in delayed softening through 6 months storage for apples harvested at greater than 17 lbs (Table 2). Treatment with 1-MCP did not delay softening of apples harvested at 14.7 pounds with little starch remaining when apples were stored for 3 months or greater. The combination of 1-MCP treatment followed by CA storage can provide some delay of ripening for late harvest fruit; however, the range of fruit maturity over which benefits from 1-MCP and CA will be realized is not unlimited.

**Table 1.** Harvest values for 'Gala' apples. Fruit were held overnight at 70 ºF prior to analysis. Values are average of 20 apples.

| Harvest Date | Starch (1 to 6 scale) | Firmness (lbs) | Ethylene (ppm) |
|---|---|---|---|
| Aug. 20 | 2.9 | 19.0 | 2.6 |
| Aug. 27 | 4.3 | 17.6 | 3.0 |
| Sep. 3 | 5.1 | 17.3 | 3.4 |
| Sep. 17 | 5.9 | 14.7 | 8.6 |

**Table 2.** Firmness of 'Gala' apples after storage in air at 32 ºF, plus 7 days at 68 ºF.

| Harvest Date | 3 months | | 6 months | |
|---|---|---|---|---|
| | Control | 1-MCP | Control | 1-MCP |
| Aug. 20 | 12.7 | 17.3 | 13.0 | 16.5 |
| Aug. 27 | 12.5 | 15.8 | 12.2 | 14.9 |
| Sep. 3 | 12.4 | 14.3 | 11.4 | 13.3 |
| Sep. 17 | 11.4 | 12.2 | 9.7 | 11.0 |

Dissolution of watercore is an active metabolic process and treatment of watercored apples with 1-MCP can slow this process. Clearing of watercore in 'Delicious' apples stored in air can be delayed following treatment with 1-MCP (Table 3). Similar results have been observed for 'Fuji'. Storing apples in CA also delays clearing of watercore but previous treatment with 1-MCP does not appear to lengthen this delay due to the use of CA alone.

**Table 3.** Watercore in 'Delicious' apples. Fruit were harvested October 10, treated with 1 ppm 1-MCP the same day, and then stored at 32 ºF in air or CA (1% $O_2$, 2% $CO_2$).

| | % Incidence | Visual rating (1 to 4) |
|---|---|---|
| At harvest | 83 | 3.0 |
| 3 months: RA | 11 | 2.0 |
| RA 1-MCP | 61 | 2.4 |
| CA | 56 | 2.5 |
| CA 1-MCP | 44 | 2.9 |

The effectiveness of 1-MCP treatments can also be manipulated by delaying treatment after harvest. For cultivars where benefits of rapid CA are known, 1-MCP treatment should be applied as soon after harvest as possible. For these cultivars where quality loss can occur rapidly after harvest, prompt 1-MCP treatment is necessary to maximize benefits for quality retention as well as to prevent physiological disorders. For Granny Smith, development of superficial scald will increase as the delay between harvest and treatment increases (Table 4). Cultivars for which delayed CA is desirable can still benefit from 1-MCP even if treatment is delayed. Delayed CA is used primarily to avoid $CO_2$ injury and this type of injury is not prevented by 1-MCP. Storage protocols that utilize delayed establishment of CA and maintenance of low $CO_2$ set points should continue to be utilized with 1-MCP treatment occurring just prior to establishment of CA. Testing of this protocol using Fuji apples has demonstrated delaying 1-MCP treatment can still provide benefits for quality retention while greatly reducing the potential for $CO_2$ injury. If DPA is used, no delay of 1-MCP treatment is necessary.

**Table 4.** Impact of delayed 1-MCP treatment on development of Granny Smith superficial scald. Apples were stored in air at 32 ºF prior to and after treatment with 1-MCP. At 6 months after harvest, all apples were removed to 68 ºF from RA for 7 days.

| | Scald Incidence (%) |
|---|---|
| Untreated | 100 |
| Weeks 1-MCP delay: 0 | 0 |
| 2 | 10 |
| 4 | 100 |
| 8 | 100 |
| 12 | 100 |
| 16 | 100 |

Production of ripe aromas is stimulated by ethylene during apple fruit ripening. Fruit treated with 1-MCP have a delayed production of many compounds that impart ripe, fruity aromas and contribute to characteristic flavor. This effect of 1-MCP is similar in magnitude to that induced by long-term storage in CA. However, production of ripe aroma declines rapidly after 1-MCP treatment compared to the effect of CA, which takes several months to develop. Production of ripe aroma by 1-MCP treated apples recovers if fruit are stored in air, and the length of time required for recovery is dependent on maturity when treated with 1-MCP, post-treatment storage temperature and environment. Storing 1-MCP treated fruit in RA at 32 ºF delays production of ripe aroma for several months; however, this process does not resume if fruit with or without previous 1-MCP treatment are stored in CA for an extended period. Treatment with 1-MCP does not impact production of all volatile compounds. Volatiles that impart green, fresh aroma notes continue to be produced if fruit have been treated with 1-MCP. Although these effects of 1-MCP are consistent for all cultivars we have evaluated, the importance of ripe aroma to apple quality varies depending on cultivar. For example, the absence of ripe aroma is potentially more important for Gala than for Granny Smith. While the impact of 1-MCP on ripe aroma production is pronounced, it remains to be demonstrated how this impacts marketability on a cultivar-by-cultivar basis.

Postharvest technology currently used in the apple industry is utilized to address many of the same responses 1-MCP induces in apples. For example, refrigeration, CA and DPA help to slow ripening and reduce development of physiological disorders. An impact of 1-MCP that has been difficult to achieve with current methods is management of quality during shipping and display at retail. All apples that have excellent quality at the time of shipment will deteriorate if mishandled, particularly when displayed at retail without refrigeration. By inhibiting ethylene action, 1-MCP reduces the rate of ripening within the 32- to 70-ºF range. While the use of 1-MCP is not a replacement for refrigeration for prolonged storage, apple quality will deteriorate slower under sub-optimal temperature conditions if previously treated with 1-MCP.

Much remains to be learned regarding how 1-MCP can be most effectively utilized as a tool for postharvest management of apples. Just how much difference in 1-MCP response can be expected due to cultivar, fruit maturity, storage conditions and lot-to-lot variability is unknown. Long-term experience with existing cultivars and postharvest tools currently enables segregation at harvest for appropriate storage environment and duration. The addition of 1-MCP brings the potential for different choices for storability and marketing that will take time to realize. While there are likely to be problems unforeseen based on the limited pilot tests conducted to date, many potential benefits of 1-MCP have already been identified and the risks appear worth the payoff.