1-MCP: How Useful Can It Be on New England Apples?

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Fruit ripening is initiated by ethylene, and to some extent, the rate at which ripening proceeds is regulated by its concentration in the fruit. Fruit generally soften faster at high ethylene levels, but ethylene is also needed to stimulate formation of flavor producing volatiles in the fruit. Low temperature air storage slows the progress of ripening but does not prevent the changes it produces. Controlled atmosphere (CA) storage, however, can interfere with ethylene actions and alter the quality of ripened fruit.

For ethylene to have an effect, it must first be bound on the surface of the cells. 1-Methylcyclopropene (1-MCP) is a new compound that can block this ethylene binding and prevent or seriously interfere with ethylene induced fruit ripening and its effects on fruit quality. Recent studies of 1-MCP treatment of apples have produced some exciting results, including substantial retention of firmness and dramatic reduction of superficial scald. However, effects have not been entirely consistent, especially on McIntosh, and further tests to characterize responses to 1-MCP are clearly needed.

1-MCP is obtained as a powder that is used to generate 1-MCP gas within a closed area containing harvested fruit. Following treatment the fruit can be placed into air or CA storage and will require no follow-up 1-MCP treatment. The material is not yet commercially available, but since it does not leave any residue on the fruit and is incorporated into the fruit in minute concentrations, no health issues have arisen to our knowledge, so its labeling might occur soon

There are many questions surrounding potential use of 1-MCP. Results do not appear to be uniform across cultivars. If ripening has begun before a fruit is treated, presumably it will continue despite treatment, making time of harvest a crucial concern. If ripening is blocked, will a fruit recover sufficiently to develop quality attributes, especially flavor? For these reasons, in Fall 2001 we initiated experiments to evaluate 1-MCP effects on apples under New England conditions.

We surveyed 1-MCP effects on a range of cultivars from early- to late-maturing, and at different harvest times for individual cultivars. Cultivars reported here are Ginger Gold, Gala, McIntosh, Delicious, and Spigold. All fruit were stored in 32F air following treatment, the durations of storage varying among cultivars. For all cultivars, internal ethylene concentration and fruit firmness were evaluated. Occurrence of storage disorders was recorded, and, for Delicious, fruit weight loss was determined since there is some evidence that 1-MCP reduces it during and following storage.

Application

The 1-MCP is provided as a powder. When mixed with water, 1-MCP is released as a gas. This is not an instantaneous reaction. Apples were harvested and cooled overnight at 32F. A sample of approximately one bushel was then removed from the cold storage and placed in a 33 gallon plastic trash barrel. A petri dish with 200 mg of the 1-MCP powder was then placed on top of the apples and was mixed with 5 ml of warm water. The barrel was immediately covered with plexiglass and sealed with silicon vacuum grease. This procedure was to produce a concentration of 1 part per million 1-MCP in the barrel. The barrel was then returned to cold storage. After 24 hours the barrel was removed from cold storage, the apples were removed, returned to conventional boxes, and put back into cold storage.

We looked at only some of the known effects of 1-MCP on fruit. Internal ethylene and fruit firmness were measured at harvest and following storage. Some fruit were weighed at these times as well, as it had been reported that 1-MCP could influence weight loss in apple. Background color was recorded for Royal Gala.

Table 1. Effects of 1-MCP on ethylene content and firmness GingerGold apples after 32F air storage for 3 or 8 weeks, each followed by a week at 70F to evaluate shelf life.

Treatment	Harvest date	At harvest	After 3 wks at 32F	Plus 1 wk at 70F	After 8 wks at 32F	Plus 1 wk at 70F
			Internal ethylene concentration (ppm)			
Check	8/20	0	101	710	109	483
	8/27	7		474	335	663
1-MCP	8/20	0	0.4	1.1	1.4	4.4
	8/27	7		1.5	3.3	13.2
			Firmness (pounds pressure)			
Check	8/20	19.8	16.3	11.6	15.4	13.8
	8/27	18.9	15.0	11.1	14.3	12.0
1-MCP	8/20	19.8	17.9	19.7	16.6	17.9
	8/27	18.9	17.9	18.2	16.3	15.6

Table 2. Effects of 1-MCP on internal ethylene concentration, firmness, and background color of Royal Gala apples after 32F air storage for 90 or 150 days, each followed by 1 week at 70F to evaluate shelf life.

Treatment	Harvest date	At harvest	After 90 days at 32F	Plus 1 wk at 70F	After 150 days at 32F	Plus 1 wk at 70F
			Internal ethylene concentration (ppm)			
	9/4	0.8	62	195	65	169
Check	9/11	2.3	48	169	32	215
1-MCP	9/4	0.8	0.3	0.7	0.5	0.4
	9/11	2.3	0.8	0.6	0.3	0.4
			Firmness (pounds pressure)			
Check	9/4	20.4	17.5	16.4	16.1	15.3
	9/11	19.4	16.9	14.9	15.1	14.9
1-MCP	9/4	20.4	18.9	18.8	17.9	17.3
	9/11	19.4	17.1	17.2	16.5	16.6
			Background color[z]			
Check	9/4		6.5	7.4	7.8	7.7
	9/11	6.4	7.8	8.3	8.1	8.1
1-MCP	9/4		6.0	6.8	7.2	7.2
	9/11	6.4	7.1	6.5	7.9	7.9

[z] Background color ratings of 1-10 move from green (1) through white-green to yellow (10). The dividing line between green/white-green and yellow was between 6 and 7.

Results by Cultivar

Ginger Gold. Ginger Gold is not a cultivar normally associated with long storage. We tested it primarily to test the application method, but results were striking (Table 1). Fruit were stored for either three or eight weeks in 32F air, after which half the fruit were evaluated and the rest were kept at room temperature for a week before being evaluated.

1-MCP greatly suppressed ethylene levels in the fruit. In fact, for the August 27 harvest it caused the ethylene present at harvest to drop sharply during and following storage. However, over time, both in storage and after storage, the ethylene gradually rose as the fruit slowly overcame the 1-MCP effect.

Firmness of untreated fruit predictably dropped rapidly during and following storage, producing unacceptably soft apples. 1-MCP treated fruit also softened during storage, but far less. In particular, little additional softening occurred at room temperature following storage, whereas untreated fruit softened greatly after storage.

Table 3. Effects of 1-MCP on ethylene concentration, fruit firmness, and superficial scald development of McIntosh apples in two experiments. Data were collected after 7 days at 70F following each air storage period at 32F to evaluate shelf life.

Treatment	Days in 32F storage	After 7 days at 70F		
		Ethylene (ppm)	Firmness (lbs)	Scald (%)
	Mean of three strains harvested 9/10			
Check	0	0.04	17.2	0
	90	743	10.7	3
	175	972	9.2	100
1-MCP	0	0.04	17.2	0
	90	52	12.4	3
	175	816	11.6	0
	Retain[tm]-treated fruit harvested 10/1			
Check	0	2.2	14.4	0
	90	381	10.1	0
	150	649	9.1	0
1-MCP	0	2.2	14.4	0
	90	1	12.3	0
	150	35	10.8	0

Ginger Gold apples treated with 1-MCP were still firm and appealing after eight weeks in air storage plus one week at room temperature, whereas untreated fruit were unacceptable.

Royal Gala. Royal Gala were harvested on two dates, treated with 1-MCP like Ginger Gold, and stored in 32F air, but for longer times, i.e., 90 and 150 days. Untreated fruit increased in ethylene content during and following storage, but their maximum levels were only about one-third the maximum levels in Ginger Gold (Table 2). 1-MCP treatment severely suppressed ethylene levels in Royal Gala. Again, at second harvest 1-MCP suppressed the ethylene levels in treated frui to below what was there at harvest, but in this cultivar, ethylene levels never gave any indication of increasing following treatment.

Untreated fruit softened during and following storage, and also developed a progressively yellower background color. Treated fruit also softened during storage, but like Ginger Gold, did not soften at room temperature following storage and were substantially firmer than the untreated ones at all evaluations. Treated fruit also became yellower with time, but were generally less yellow than the controls. Harvest date did not influence the effect of 1-MCP; harvest differences were retained, but not changed.

McIntosh. McIntosh is of particular interest in New England and two experiments were conducted. In the first, three strains (Rogers, Morspur, and SpurMac) were harvested on September 10 when the fruit were just beginning to produce ethylene. The strains were all treated as described above, and stored at 32F in air for 90 or 175 days, plus 7 days at 70F prior to evaluation. In the second experiment, some Retain[tm] treated fruit were harvested on October 1, and treated and stored the same as the strains, except for a maximum of 150 rather than 175 days. This is a late harvest date, and fruit averaged over 2 ppm internal ethylene at harvest.

The three strains all responded similarly to 1-MCP so only their averages are presented in Table 3. (Note that Rogers were about 3/4 pound softer than the

others, but this was true across time and treatment and was not treatment-related). Untreated fruit accumulated very high ethylene concentrations, and 1-MCP only delayed the rise, the fruit eventually reaching about the same level as the untreated ones. Untreated ones softened excessively, although it should be noted that they were stored beyond the normal limits for McIntosh. 1-MCP-treated fruit also softened, but much less, and were still acceptably firm after the longer storage time. The untreated fruit also scalded during the longer storage time, whereas 1-MCP treatment prevented this from happening.

Table 4. Effects of 1 -MCP on internal ethylene concentration, fruit firmness, and weight loss of Redchief Delicious apples after 32F air storage for 90 or 150 days, each followed by 1 week at 70F to evaluate shelf life.

Treatment	Storage time (days)	Ethylene (ppm)	Firmness (lbs)	Fruit weight (grams)	Weight loss (%)
Check	0	32	17.4	164	
	90	159	14.8	158	3.2
	90+7	309	13.9	156	4.6
	150	266	13.2		
	150+7	401	12.7		
1-MCP	0	32	17.4	166	
	90	12	15.9	162	2.7
	90+7	62	16.1	159	4.0
	150	41	15.4		
	150+7	93	15.2		

The Retain[tm] treated fruit harvested three weeks later responded much the same as the three strains, except that ethylene increased far less and no scald developed. These differences are not likely associated with 1-MCP, but rather occurred because Retain[tm] has the effect of reducing ethylene, and late harvest reduces scald.

Delicious. Redchief Delicious were harvested on October 1 and October 11, treated with 1-MCP, and stored in 32F air for 90 or 150 days, and then for 7 more days at 70F. Subsamples were weighed at harvest, placed in paper bags, and stored like the others, and reweighed at removal from storage and again after 7 days at room temperature.

Fruit from the two harvests responded the same to treatment and storage, so in Table 4 the means of the two harvests are presented. Ethylene content of untreated fruit increased substantially with storage time and after transfer to 70F. 1-MCP again caused ethylene content during storage to fall below that at harvest, but it rose over time and during fruit warming, although it never approached the ethylene levels of untreated fruit. Untreated fruit softened greatly during storage and at room temperature. 1-MCP treated fruit also softened, but not nearly as much as the untreated fruit. Both treated and untreated Delicious lost weight during and following storage, but 1-MCP reduced the size of this loss.

Spigold. In order to determine if 1-MCP could inhibit ethylene production even if fruit were already producing substantial ethylene, Spigold were harvested October 22 (very late!) with average Starch Index of 7.6 (Cornell generic chart) and average internal ethylene concentration of 31 ppm. Fruit were treated like the other cultivars, and stored for 90 or 150 days in 32F air, plus 7 days at 70F. Table 5 shows that the ability of 1-MCP to reduce ethylene production was significant despite the fact that the fruit were already producing a substantial amount of ethylene prior to the 1-MCP treatment. 1-MCP treated fruit were firmer, too, although there was substantial fruit-to-fruit variation in firmness due to very large fruit sizes.

Discussion

Treatment with 1-MCP consistently resulted in firmer fruit following cold storage. This firmness advantage remained or was enhanced after fruit were left at room temperature for a week. 1-MCP-treated fruit did, however, soften over time, just not as much as did the untreated fruit. Ethylene production was suppressed well into the storage period. The duration of this suppression was cultivar dependent. Ethylene production was essentially shut down by 1-MCP

Table 5. Effects of 1-MCP on internal ethylene concentration and fruit firmness on Spigold apples harvested October 22 following 32F air storage for 90 or 150 days, each followed by 1 week at 70F to evaluate shelf life.

		90 days cold storage		150 days cold storage	
1-MCP applied	At harvest	1 day warm	7 days warm	1 day warm	7 days warm
		Internal ethylene concentration (ppm)			
Check	31	180	359	209	384
1-MCP		49	39	64	185
		Firmness (pounds)			
Check	14.6	10.2	10.0	9.4	9.1
1-MCP		11.0	11.8	10.6	10.0

treatment for at least 150 days in Gala. Ethylene production in 1-MCP treated McIntosh reached levels of control fruit by 175 days of cold storage in fruit which had not been treated with Retain[tm]. Weight loss during cold storage was significantly reduced in Delicious, and weight loss during a week at room temperature following cold storage was reduced by 1-MCP treatment of McIntosh (data not shown) and Delicious. A very significant result was that all cultivars harvested on different dates showed the same results between harvest dates, except that changes that occurred before harvest were not reversed. Thus, 1-MCP had some benefit regardless of ripeness at harvest. Two important effects were not measured. We did not measure volatile production (or aroma), although we did observe that aroma was lacking in the 1-MCP-treated Gala following storage. We did not do taste tests, as the product is not registered for use. The only 1-MCP-treated fruit which fully recovered ethylene production were the non-Retain[tm] McIntosh harvested on September 10 and stored for 175 days in 32F air. Even these fruit retained their firmness advantage over untreated fruit and did not develop superficial scald as the other fruit did. The Ginger Gold, Retain[tm]-treated McIntosh, Delicious, and Spigold which had been treated with 1-MCP all started producing more ethylene after a time in storage, but did not come close to catching up with their untreated counterparts.

Based on this preliminary investigation, 1-MCP treatment appears promising for increased firmness retention in a broad spectrum of apple cultivars, including McIntosh as well as for scald control. We observed scald only on McIntosh in this study, but others have observed similar results on other cultivars, so a general response may exist although further tests are essential. Since maximum 1-MCP effect may depend on early harvest, at least in some cultivars, scald protection would be an extremely valuable benefit. Combining 1-MCP treatment with CA might enhance the effect of either one alone. Taste tests will be essential to determine if the firmness advantage is offset by losses in flavor or aroma. If so, this is likely to be cultivar dependent. Seasonal variation in effectiveness of 1-MCP has been reported, so we need to determine how repeatable these results are. Finally it remains to be determined how 1-MCP can be applied efficiently on a commercial scale. Nevertheless, despite these issues, this is an extremely interesting new material.

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