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Measuring consumer response to 'Gala' apples treated with 1-methylcyclopropene (1-MCP)

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ABSTRACT

Post-harvest apple treatment with 1-methylcyclopropene (1-MCP) was previously found to inhibit fruit ripening but also to inhibit the production of volatile compounds that contribute to apple flavor. The first objective of this study was to determine if consumers could distinguish 1-MCP treated and untreated Gala apples [*Malus sylvestris* L. (Mill.) var. *domestica* Borkh. Mansf.] following long-term storage. Chemical analysis showed 1-MCP treated fruit had reduced flavor volatiles compared to untreated fruit. Consumer difference tests showed they could distinguish between 1-MCP treated and untreated fruit. A second objective was to compare consumers' acceptance for 1-MCP treated to untreated apples. Both 1-MCP treated and untreated apples received high overall liking scores that were not significantly different. Equal numbers of consumers indicated preference for 1-MCP treated and untreated fruit and there was no difference in purchase intent. However, subsets of consumers who eat Gala, Fuji or Red Delicious apples showed preference for untreated over 1-MCP treated fruit compared to consumers who do not eat these varieties.

1. Introduction

The ethylene action inhibitor 1-methylcyclopropene (1-MCP) delays decay/ripening and has consistently displayed improved firmness retention (Fan et al., 1999; Fan and Mattheis, 2001; DeEll et al., 2002; Saftner et al., 2003). However, studies indicate reduced fruit production of volatile alcohols and esters (Saftner et al., 2003; Fan and Mattheis, 1999; Fan et al., 2001; Defilippi et al., 2004) compared to untreated apples stored in similar conditions. For example, several volatile esters and alcohols that are considered characteristic of the aroma of Gala apples, such as 2-methylbutyl acetate, butyl acetate, hexyl acetate, and butanol (Young et al., 1996), were found to be inhibited by 1-MCP treatment (Fan and Mattheis, 2001). No significant inhibitory effect of 1-MCP treatment on soluble solids concentration was found for varieties such as Gala, Fuji, Jonagold, Red Delicious, Cortland and Empire apples (Fan and Mattheis, 1999; DeEll et al., 2002). Findings on impact of 1-MCP on titratable acidity differed across studies and may be dependent upon the apple variety studied and the treatment protocol, such as 1-MCP concentration, duration of treatment and temperature (Fan and Mattheis, 1999; Fan and Mattheis, 2001; Mir et al., 2001).

Post-harvest storage, in regular atmosphere (RA) or controlled atmosphere (CA), with lower O_2 and higher CO_2 than air, also affects the apple quality. Smock (Smock, 1979) reported that apples retained firmness and acidity under CA storage. CA storage was found to reduce volatile production in Cox's Orange Pippin, Golden Delicious (Patterson et al., 1974) and Gala apples (Mattheis et al., 1998; Boylston et al., 1994). Results by Boylston et al. (1994) suggest that RA Gala apples are more acceptable than their counterparts stored in CA or in CA-then-RA sequence for 1, 2, and 3 months. Saftner et al. (2003) found that after 2.5 and 5 months of storage at 0 °C, 1-MCP treated Golden Delicious apples retained their firmness, and titratable acidity of 1-MCP treated and CA apples was similar.

While the impact of 1-MCP treatment on physiological/chemical properties of apples has been established analytically, little research has investigated sensory characteristics of 1-MCP treated apples. In one study (Lurie et al., 2002), sensory assessment from a trained descriptive panel of 10 judges was conducted on only the aroma of Anna apples at harvest, as well as on untreated and 1-MCP treated apples stored in RA under various conditions: (A) 6 or 12 days at 20 °C, or (B) 5 weeks at 0 °C then 6 or 12 days at 20 °C. For both conditions A and B, judges were able to distinguish aroma dif-

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ferences between apples treated with 1 $\mu L L^{-1}$ 1-MCP and control fruit; giving lower ratings of overall aroma intensity and fruity and ripe aromas to the treated apples. Hedonic ratings were conducted only on the short-term storage fruit (condition A) with preference for fruit treated with 1 $\mu L L^{-1}$ 1-MCP, as judges preferred "green" or harvest-like aroma more than the ripe and fruity aroma. These hedonic data should be considered with caution, though, as one of the principles of sensory evaluation is that a descriptive panel should adopt an analytical frame of mind and set aside personal preferences and hedonic reactions (Lawless and Heymann, 1999; O'Mahony, 1979).

In a recent study, (Moya-Leon et al., 2007), CA and 1-MCP treatment were found to depress volatile production of Gala apples but retain fruit firmness. There was a good correlation between measured fruit volatiles and aroma intensity perceived by taste panelists and also between ethylene levels and many of the odor-active volatiles. Even so, consumers preferred 1-MCP treated and CA-stored fruit, largely attributed to maintained fruit textural properties.

Given that both 1-MCP treatment and CA storage result in better firmness retention (as measured by instruments) than in absence of treatment, and perceived firmness is one of the main drivers of consumer acceptance of apples (Williams, 1979; Daillant-Spinnler et al., 1996), controlling firmness levels will permit the exploration of other sensory characteristics that affect consumers. The first goal of the present study is thus to investigate whether consumers perceive a difference between 1-MCP treated Gala apples and their untreated counterparts when matched for firmness. Then, if consumers can distinguish untreated apples from 1-MCP treated fruit, to measure and compare consumer acceptance for 1-MCP treated and untreated Gala apples. In this series of experiments, 1-MCP treated apples, stored in RA or CA for more than 6 months, were compared with untreated apples stored in CA. 1-MCP treated apples stored in CA were also compared with Chilean Gala apples. The Chilean fruit, being from the Southern hemisphere, represented minimally stored Gala apples closer to fresh harvest and that are found in the market at the same time as the US stored fruit.

2. Materials and methods

2.1. Apple treatment

On day 1 Extra Fancy Size 100 Gala apples were purchased from a commercial orchard in the state of Washington and were divided into two groups. Core temperature of apples was brought down to below 10 °C by holding in 0 °C conditions prior to any treatment. One subset of apples was treated with 1 $\mu L L^{-1}$ 1-MCP (SmartFresh™; Agro-Fresh, Inc., Philadelphia, PA) for 24 h at 0 °C in a commercial apple processing facility. The other group of apples (control) was placed in cold storage at 0 °C.

On day 5, instrumental measurements of firmness, internal ethylene and skin color were taken prior to long-term storage on 25 apples from each treatment (1-MCP and control). Starch content was evaluated on 10 apples from each treatment. Non-destructive measurements of firmness collected were Sinclair Internal Quality (SIQ) (Sinclair International, Norwich, United Kingdom). Destructive firmness readings (FTA) were collected using a Fruit Texture Analyzer (Guss Manufacturing, Strand, South Africa). Internal ethylene (in $ng L^{-1}$) was measured by drawing a 0.5 mL gas sample through a hypodermic needle inserted into the calyx end of the fruit. The sample was injected into a gas chromatograph (HP5890; Hewlett-Packard, Palo Alto, CA) calibrated to measure ethylene. The glass column used was packed with Porapak Q (80/100 mesh). Gas chromatographic operating conditions were injector temperature 100 °C; column temperature 60 °C; flame ionization detector (FID) temperature 250 °C. Gas flow rates for N_2 carrier, H_2, and air were 100, 125, and 1750 $\mu L s^{-1}$, respectively. A CTIFL (Centre Technique Interprofessionnel des Fruits et Légumes) color chart on a 1 (green) to 5 (yellow) scale was used for assessment of apple background color, while a CTIFL color chart on a 1 (pale red with background color showing through) to 5 (dark red with no background color showing through) scale was used for assessment of intensity of red color. Starch content was determined on fruit cut in half perpendicularly to the core. A 0.0904 $mol L^{-1}$ potassium iodine 0.0236 $mol L^{-1}$ iodine solution was applied on the cut surface and the resulting color was compared to the Cornell University starch chart, which measures starch content on a 1 (100% starch) to 8 (0% starch) scale.

On day 6, 10 boxes or half of the 1-MCP treated apples and 14 boxes of control fruit were placed in controlled atmosphere (CA) storage with 2.0% CO_2 and 2.0% O_2 at 0 °C for 178 days. Each box of apples was lined with plastic to reduce fruit shrivel. This resulted in three fruit treatment groups which will be denoted as 1-MCP-CA (1-MCP treated fruit held in CA storage), 1-MCP-RA (1-MCP treated fruit held in RA storage) and Control-CA (untreated fruit held in CA storage).

On day 184, 1-MCP-CA and Control-CA apples were removed from CA storage and stored in RA at 0 °C. A sample of 20 apples from each treatment was stored at 20 °C for 7 days before a profile analysis of volatile compounds was conducted using the gas chromatographic apparatus and methods described in (Fan and Mattheis, 1999). Volatile profiles for each apple treatment were collected using headspace sampling of 1 kg apples, and were replicated four times (three replicates collected for 1-MCP-CA).

On day 204, apples across treatment groups were matched according to SIQ values into eight categories (from 28 to 35 SIQ units). The next day, boxes were transported to Portland, Oregon and kept in a cold room at 0 °C. Apples were brought to ambient temperature (12–18 °C) before serving to consumers. Five apples from each box of fruit were sampled (one slice per apple) and pooled to yield approximately 25 mL of juice for measurements of soluble solids concentration (Pallette Digital Refractometer; Atago, Tokyo, Japan) and titratable acidity (Titrino Automatic Titrator; Metrohm, Herisau, Switzerland).

Chilean apples were purchased from a packinghouse in the state of Washington the week before the consumer test. They were not treated with 1-MCP and were stored in RA at 0 °C.

2.2. Participants

More than 600 individuals were screened for participation in the taste tests. Criteria for participation were no allergies to apples and consuming apples once a month or more often. Taste tests and consumer recruitment were at the Portland Saturday Market, a public venue open over both weekend days, in downtown Portland, Oregon. Participants were offered a complimentary apple at the end of the test as a token of appreciation.

2.3. Experimental design

Three separate tests were run, with the target number of 120 consumers for each test. Consumers were invited to participate during a 4–6 h test time interval. Each test involved a blind taste evaluation of a 1-MCP treated apple against a untreated fruit of similar firmness. The apples served in each test were (1) 1-MCP-RA vs. Control-CA, (2) 1-MCP-CA vs. Control-CA, or (3) 1-MCP-CA vs. Chilean.

Within each test, a difference test first determined whether a consumer could distinguish the 1-MCP treated fruit from the

Table 1
Mean[a] % titratable acidity and % soluble solids characteristics of post-storage Gala apples

Quality measure	Test 1		Test 2		Test 3	
	1-MCP-RA	Control-CA	1-MCP-CA	Control-CA	1-MCP-CA	Chilean RA
% Acidity	0.2969	**0.3363***	0.3358	0.3294	0.3427	0.3207
% Soluble solids	11.67	13.17	12.32	**13.40***	12.87	**13.60***

[a] Means marked with an asterisk within a given test are significantly different (independent samples *t*-test, $p < 0.05$). Bold font denotes the larger mean within a test.

untreated fruit. Individuals who were able to make the correct distinction were then administered a separate preference test but with slices from the same fruit as in the difference test. Aggregate results from the difference test were periodically monitored during the test period. Once the sample size and proportion of correct responses indicated that consumers could distinguish control vs. 1-MCP treated fruit at a 95% confidence level, all subsequent incoming panelists were administered the preference test directly.

2.3.1. Difference test

The difference test method was a duo-trio test (O'Mahony, 1979). Each consumer was presented with three samples, each consisting of two slices of unpeeled apple: a labeled reference sample and two coded samples. The reference sample and one of the coded samples were taken from the same fruit, while the other coded sample was from a different fruit. The participants' task was to taste the slices and indicate which coded sample was the same as the reference.

1-MCP treated fruit was used as the reference for half of the respondents, while untreated fruit was used as reference for the other half of consumers. Apples presented to a given consumer were matched according to SIQ values in order to control for firmness differences between 1-MCP treated and untreated apples.

2.3.2. Preference test

Consumers were presented with two coded samples consisting of two unpeeled slices each. Participants received slices from the same apples as the ones tasted in the difference test but with different blinding codes and at a different test station. Participants were asked to taste each fruit sample and provide ratings for overall liking and purchase intent. Overall liking was measured using a 10-cm line scale with three anchors (0 = Dislike Extremely, 5 = Neither Like nor Dislike, 10 = Like Extremely), with scores corresponding to the distance (in cm) of the consumer's marked response from the left end of the line. For purchase intent, consumers indicated their answer among five choices presented: "Would definitely not buy", "Would probably not buy", "Might not buy/Might buy", "Would probably buy", and "Would definitely buy".

Next, they indicated which sample they preferred, as well as the reasons why they liked the preferred sample and disliked the not-preferred sample: respondents were allowed to select one or more options among texture, juiciness, apple flavor, sweetness, and sourness/tartness.

They also reported which apple varieties they regularly like to eat as fresh eating quality apples. Choices were Braeburn, Fuji, Gala, Golden Delicious, Granny Smith, McIntosh, Pink Lady, and Red Delicious. Finally, they indicated how often they ate Gala apples ("Frequently", "Sometimes", or "Never").

2.4. Data analysis

Consumer data was collected on tablet and laptop computers using ballots presented in Compusense® five (Version 4.2; Compusense Inc., Guelph, Ontario) data collection software. All of the resulting data was analyzed with Statistical Analysis System for Windows, Version 8e (SAS, Cary, NC). For the difference tests, in order to determine the probability of obtaining the given result on the null hypothesis, that there is no difference between the two samples, both an established table (Roessler et al., 1978) and Compusense® results were used with significance evaluated at 95% confidence or $\alpha = 0.05$. For the preference tests and demographic questions, descriptive statistics were used to determine the percentages of subjects in various subcategories. Preference test results were evaluated for significance using χ^2 tests evaluated at 95% confidence or $\alpha = 0.05$ (Lawless and Heymann, 1999). Overall liking scores were compared using paired *t*-tests and evaluated for significant difference at 95% confidence or $\alpha = 0.05$ (Lawless and Heymann, 1999).

3. Results

3.1. Storage characteristics of Gala apples

Pre-storage tests showed that 1-MCP treated and control apples were of similar firmness (17.3–18.0 lbs FTA), starch content (4.6–5.1%) and peel color (3.3). Ethylene biosynthesis had been suppressed by 1-MCP treatment (Control: 17 $\mu L\,L^{-1}$, 1-MCP: 0.89 $\mu L\,L^{-1}$). No pre-storage measurements were conducted on Chilean apples.

Post-storage apple measures showed that titratable acidity of 1-MCP-RA fruit was significantly lower than that of Control-CA apples ($p < 0.05$) in Test 1, whereas titratable acidity measures were similar for Control-CA and 1-MCP-CA and treated fruit for Test 2. The lower levels of titratable acidity for 1-MCP-RA differ from those reported by Moya-Leon et al. (2007). They found no difference in titratable acid levels between 1-MCP treated and Control-CA Gala apples during 6 months storage, but the original 1-MCP dose in their study was lower (625 $nL\,L^{-1}$ 1-MCP) than used in this study (1 $\mu L\,L^{-1}$ 1-MCP).

The 1-MCP-CA fruit used in Tests 2 and 3 had a lower soluble solid content than untreated fruit ($p < 0.05$; Table 1), and the concentrations measured in 1-MCP-RA fruit for test 1 tended to be lower than Control fruit, but were not significantly different statistically. The results comparing 1-MCP-RA fruit to CA fruit are similar to those reported by Moya-Leon et al. (2007). Results showing lower SSC levels in treated than in Control CA fruit suggest that that 1-MCP treatment followed by long-term storage in CA may have impacted carbohydrate metabolism in these Gala apples.

3.2. Gala apple volatiles analysis

Table 2 summarizes and compares key volatiles for each apple treatment for all three tests. For all three tests, control fruit or fruit not treated with 1-MCP had more total esters than their 1-MCP-treated counterparts. 1-MCP treatment also significantly inhibited the production of alcohols in fruits compared in Tests 1 and 3. A similar reduction in alcohol production was seen in Test 2 but the difference was not statistically significant. Though alcohols have not been reported as contributing significantly to apple aroma when analyzed by GC-olfactometery methods, (Plotto et al., 2000) their concentrations are worth considering since they are the metabolic precursors to esters, which are key contributors to aroma. Also, Young et al. (1996) reported a solution of 1-butanol in combination with 2-methyl butyl acetate and hexyl acetate most closely

Table 2
Comparison of volatile compound concentrations (ng L^{-1})[a] produced by 1-MCP treated and untreated stored Gala and Chilean fruit used for each of three consumer tests

Volatiles (ng L^{-1})	Test 1		Test 2		Test 3	
	1-MCP-RA	Control-CA	1-MCP-CA	Control-CA	1-MCP-CA	Chilean-RA
Butyl acetate	2.73 ± 1.71	**35.4*** ± 6.92	1.13 ± 0.25	**35.4*** ± 6.92	1.13 ± 0.25	**321*** ± 69.1
Hexyl acetate	9.52 ± 2.09	**39.0*** ± 5.05	9.69 ± 1.05	**39.0*** ± 5.05	9.69 ± 1.05	**142*** ± 12.2
2-Methylbutylacetate	7.33 ± 1.90	**43.9*** ± 6.07	3.29 ± 0.30	**43.9*** ± 6.07	3.29 ± 0.30	**57.2*** ± 9.65
Methyl 2-methylbutyrate	0.00	**1.96*** ± **1.63**	0.00	**1.96*** ± **1.63**	0.00	**3.38*** ± **1.02**
4-Allylanisole	0.162 ± 0.79	**0.788*** ± **0.12**	0.714 ± 0.33	0.788 ± 0.12	0.714 ± 0.33	0.753 ± 0.24
Hexanal	0.298 ± 0.10	0.155 ± 0.26	0.203 ± 0.22	0.155 ± 0.26	0.203 ± 0.22	**0.722*** ± **0.22**
Hexanol	2.17 ± 0.16	1.88 ± 0.63	3.18 ± 1.10	1.88 ± 0.63	3.18 ± 1.10	**7.25*** ± **1.86**
1-Butanol	2.31 ± 1.18	**7.71*** ± 2.45	1.58 ± 0.41	**7.71*** ± 2.45	1.58 ± 0.41	**60.8*** ± 13.6
Total esters	34.3 ± 7.21	**203*** ± 33.9	44.2 ± 6.41	**203*** ± 33.9	44.2 ± 6.41	**699*** ± 108
Total alcohols	9.93 ± 1.34	**21.2*** ± 7.47	9.40 ± 3.02	21.2 ± 7.47	9.40 ± 3.02	**101*** ± 17.6
Total aldehydes	0.88 ± 0.40	2.34 ± 1.95	1.79 ± 2.40	2.34 ± 1.95	1.79 ± 2.40	**20.9*** ± 11.6
Total ketones	1.29 ± 0.24	**4.12*** ± 1.32	2.45 ± 1.00	4.12 ± 1.32	2.45 ± 1.00	8.25 ± 4.09

[a] (*)Indicates mean volatile concentrations that are significantly different ($p < 0.05$) within that test. Bold font denotes the higher concentration for that apple volatile for that sample within a test.

Table 3
Number of participants (n) in each test and gender (M = male, F = female) of participants in the preference tests

	Test 1 (1-MCP-RA vs. Control-CA)		Test 2 (1-MCP-CA vs. Control-CA)		Test 3 (1-MCP-CA vs. Chilean)	
Difference (n)	137		90		119	
Preference (n)	186		202		81	
Gender	M	F	M	F	M	F
n (%)	102 (55%)	84 (45%)	111 (55%)	91 (45%)	36 (44%)	45 (56%)

Table 4
Age categories and percent of participants in each test

	Age category in years						
	10–17	18–24	25–34	35–44	45–54	55–64	65+
Test 1	4%	19%	26%	23%	20%	5%	2%
Test 2	4%	23%	27%	25%	16%	4%	1%
Test 3	7%	16%	26%	15%	21%	9%	6%

resembled the red apple character in Gala apples. So the alcohols may contribute to aroma in combination with other compounds, rather than as odor-active components themselves. Likewise, Plotto et al. (1998) reported hexanal as important to the aroma of solution mixtures simulating Gala apple aroma, even though it was not isolated as a contributing odor-active volatile in GC-olfactometery. Aldehydes were significantly inhibited in 1-MCP-CA apples relative to Chilean-RA fruit, but concentrations were not significantly different in 1-MCP-treated fruit vs. control. Plotto et al. (2000) reported that the compound 4-allylanisole contributed to Gala aroma and was affected by storage, with lower concentrations found in CA-stored Gala apples stored 20 weeks. This is different than the results reported here where the 1-MCP treated RA fruit had significantly lower concentrations of this compound than the Control-CA fruit. The length of storage and 1-MCP treatment could contribute to this difference. 1-MCP-RA fruit displayed a significantly lower ketone production than Control-CA apples. More importantly, in all tests the concentration of volatile compounds reported as odor-active and characteristic to Gala apples (butyl acetate, hexyl acetate, 2-methylbutyl acetate, and methyl 2-methylbutyrate, Plotto et al., 2000, and Moya-Leon et al., 2007) were significantly lower in 1-MCP-treated fruit.

3.3. Participants demographics and apple eating habits

Demographic characteristics of the participants, number and gender of participants, in the three tests are given in Table 3, and age distribution of participants in Table 4.

Participants' responses to which apple cultivars they regularly eat as fresh eating quality apples are given in Table 5. The table gives the percent of all consumers in each test who indicated they eat that apple variety fresh. The four varieties most consumers eat are in bold print, with Fuji being the variety selected by most consumers in all tests.

Table 5
Apple varieties regularly eaten as fresh apples by participants in the preference tests

Apple variety	Test 1 (n = 186)	Test 2 (n = 202)	Test 3 (n = 81)	Total (n = 469)
Fuji	**47%**	**44%**	**53%**	**46%**
Red Delicious	**40%**	**36%**	**36%**	**38%**
Granny Smith	**39%**	**37%**	33%	**37%**
Gala	**34%**	31%	**44%**	**35%**
Golden Delicious	33%	**37%**	28%	34%
Braeburn	26%	25%	**44%**	29%
McIntosh	13%	14%	25%	16%
Pink Lady	17%	16%	21%	17%

The four top ranked varieties for each test are listed in bold type face.

Table 6
Preference test participants' frequency for eating Gala apples as fresh eating quality fruit

Eating frequency	Test 1 ($n = 186$) (1-MCP-RA vs. Control-CA)	Test 2 ($n = 202$) (1-MCP-CA vs. Control-CA)	Test 3 ($n = 81$) (1-MCP-CA vs. Chilean)
Never	27%	23%	25%
Sometimes	50%	58%	58%
Frequently	23%	19%	17%

Table 7
Difference test results

	Test 1 ($n = 137$) (1-MCP-RA vs. Control-CA)	Test 2 ($n = 90$) (1-MCP-CA vs. Control-CA)	Test 3 ($n = 119$) (1-MCP-CA vs. Chilean)
# and % of consumers who correctly detected a difference between apple treatments	83 (60.6%) $p < 0.001$	67 (74.4%) $p < 0.01$	84 (70.6%) $p < 0.001$

Table 8
Overall liking scores and preference patterns for 1-MCP treated and untreated Gala apples

	Test 1 ($n = 186$)		Test 2 ($n = 202$)		Test 3 ($n = 81$)	
	1-MCP-RA	Control-CA	1-MCP-CA	Control-CA	1-MCP-CA	Chilean-RA
Mean overall liking score	6.85	6.92	6.88	7.01	6.36	6.62
# and % of consumers who preferred	93 (50.0%)	73 (39.2%)	104 (51.5%)	86 (42.5%)	44 (54.3%)	34 (42.0%)
# and % of consumers with no preference	20 (10.8%)		12 (6.0%)		3 (3.7%)	

Participants in the preference tests all responded to how often they eat Gala apples as fresh eating quality fruit. More than 70% of participants reported eating Galas at least sometimes. Results for each test are given in Table 6.

3.4. Difference test

A total of 346 individuals completed the three difference tests. Table 7 shows the number of respondents who correctly matched a coded apple sample with the reference sample. Consumers could distinguish untreated apples (control-CA and Chilean) from 1-MCP treated apples stored either under controlled or regular atmosphere, at the 0.01 significance level or better (Roessler et al., 1978).

3.5. Preference test

3.5.1. Overall liking and preference ratings

Table 8 compares the overall liking scores and number of consumers indicating preference for each fruit treatment. Overall liking scores for all consumers indicated that 1-MCP treated and untreated fruit were both well liked with average scores well above 5.0—"neither like nor dislike". Within each test, mean liking scores did not differ significantly from each other ($p > 0.10$). Similarly, for consumers who expressed a preference, similar numbers of consumers preferred untreated fruit as those preferring 1-MCP treated apples within each test (chi-square test, d.f. = 1, $p > 0.10$). Also, preference patterns for consumers of different gender, age categories or with different Gala consumption frequencies were compared for each test with no significant differences found (all chi-square tests, $p > 0.10$). Consumers' reasons for liking the fruit they preferred or disliking the fruit they did not prefer were tabulated, but significance tests could not be applied due to incomplete ranking for reasons chosen. However, tabulated reasons for liking indicated the main reason for liking the fruit they chose as preferred, apple flavor, was the same regardless of sample for each of the three tests. Similarly, consumers chose texture, then apple flavor as the reasons they disliked the fruit not chosen as preferred. Since consumers' interpretation for such general terms as "apple flavor" and "texture" are personal and can vary widely between individuals, responses to reasons for liking or disliking questions in these tests were only considered as possible indicators for more in depth research direction in future.

3.5.2. Purchase intent

For purchase intent, consumers were given five answer choices based on their degree of certainty: "Would definitely not buy", "Would probably not buy", "Might not buy/Might buy", "Would probably buy", and "Would definitely buy". For analysis purposes, "Definitely" and "Probably" purchase categories were combined for both "Buy" and "Not Buy" responses, and the "Might Buy/Might Not Buy" responses were pooled with the "Not Buy" responses. This left two purchase intent categories: "Would probably or definitely buy" and "Would definitely or probably NOT buy". Purchase intent results for all three tests are given in Table 9. Over 58% of consumers tested said they would probably or definitely buy either the 1-MCP treated or untreated fruit. For Tests 1 and 2, the proportion of buyers was significantly greater than the proportion of those who would not buy the fruit, (chi-square tests, $p < 0.01$) and is consistent with the high mean liking scores for these apples. For Test 3, the proportion of buyers to those who would not buy was not significantly different, however the trend was for more people to say they would buy than not buy, similar to the other test results. In addition, the distribution of purchase intent responses for 1-MCP treated apples does not differ significantly from that for untreated apples within each test (McNemar tests, $p > 0.10$). This is consis-

Table 9
Consumers' willingness to buy 1-MCP treated and untreated Gala apples

	Test 1 ($n = 186$)		Test 2 ($n = 202$)		Test 3 ($n = 81$)	
	1-MCP-RA	Control	1-MCP-CA	Control	1-MCP-CA	Chilean
Would probably or definitely buy	61.3%	62.4%	62.9%	64.4%	58.0%	60.5%
Would definitely or probably NOT buy	38.7%	37.6%	37.1%	35.6%	42.0%	39.5%
Chi-square (d.f. = 1) within treatment	**9.48** ($p <$ **0.01**)	**11.38** ($p <$ **0.01**)	**13.39** ($p <$ **0.001**)	**16.65** ($p <$ **0.001**)	2.09 ($p > 0.10$)	3.57 ($p > 0.05$)

Table 10
Preference, overall liking and purchase intent patterns for consumers who regularly eat Gala apples (Yes) and those who do not (No) in Test 2: MCP-CA vs. Control-CA (Mean overall liking scores with different letters are significantly different, $p < 0.05$. significantly higher values in bold)

Acceptance measure	Gala consumption			
	Gala (Yes) ($n = 64$)		Gala (No) ($n = 138$)	
Preference				
# and % preferring Control-CA	**40 (62.5%)**		63 (45.6%)	
# and % preferring 1-MCP-CA	23 (35.9%)		64 (46.4%)	
No preference	1		11	
Overall liking				
Control-CA	**7.70 a**		6.69 c	
1-MCP-CA	6.33 b		7.13 c	
Purchase intent	No	Yes	No	Yes
# and % for Control-CA	15 (23.4%)	**49 (76.6%)**	57 (41.3%)	**81 (58.7%)**
# and % for 1-MCP-CA	29 (45.3%)	35 (54.7%)	46 (33.3%)	**92 (66.7%)**

Table 11
Preference, overall liking and purchase intent patterns for consumers who regularly eat Fuji apples (Yes) and those who do not (No) in Test 2 (Mean overall liking scores with different letters are significantly different, $p < 0.05$. significantly higher values in bold)

Acceptance measure	Fuji consumption			
	Fuji (Yes) ($n = 89$)		Fuji (No) ($n = 113$)	
Preference				
# and % preferring Control-CA	**52 (58.4%)**		52 (46.9%)	
# and % preferring 1-MCP-CA	33 (37.1%)		53 (46.0%)	
No preference	4		8	
Overall liking				
Control-CA	**7.25 a**		6.72 ac	
1-MCP-CA	6.58 b		7.25 c	
Purchase intent	No	Yes	No	Yes
# and % for Control-CA	32 (36.0%)	**57 (64.0%)**	40 (35.4%)	**73 (64.6%)**
# and % for 1-MCP-CA	41 (46.1%)	48 (53.9%)	34 (30.1%)	**79 (69.9%)**

tent with consumers' similar overall liking scores and preference patterns for control and 1-MCP treated fruit.

3.5.3. Consumer acceptance patterns for given apple cultivars

Acceptance responses for 1-MCP treated fruit did not significantly differ from those for untreated apples when considering all consumers. However, when the variety of apples consumers eat was taken into consideration, there were different preferences observed for consumers who eat Gala, Fuji and Red Delicious apples. Consumers of other apple varieties, listed in Table 5, did not differ from that of the participants as a whole.

Results for Gala consumers and non-consumers in Test 2, 1-MCP-CA vs. Control-CA, are given in Table 10 for three acceptance measures: indicated preference, overall liking and purchase intent. More Gala consumers preferred Control-CA fruit ($\chi^2 = 4.59$, $p < 0.05$), and gave higher overall liking scores ($t = 3.02$, $p < 0.05$) to Control-CA fruit than to 1-MCP-CA apples than those consumers who do not eat Galas. Gala consumers also gave lower overall liking ratings ($t = 2.27$, $p < 0.05$) to 1-MCP treated fruit than consumers who do not eat Galas. Also, more Gala consumers were willing to purchase the Control-CA fruit than not buy it ($\chi^2 = 18.06$, $p < 0.001$), while they were divided regarding purchase intent for 1-MCP-CA. This purchase behavior was different than consumers that do not eat Galas who were more willing to purchase than not purchase both Control-CA fruit ($\chi^2 = 4.17$, $p < 0.05$) and 1-MCP treated fruit ($\chi^2 = 15.33$, $p < 0.001$).

Similar results for the three acceptance measures are given in Table 11 for Fuji consumers and non-consumers in Test 2. Similar to Gala consumers, more Fuji consumers preferred Control-CA fruit ($\chi^2 = 4.25$, $p < 0.05$) and gave higher overall liking scores ($t = 2.36$, $p < 0.05$) to Control-CA fruit than 1-MCP treated apples than non-Fuji consumers. Fuji consumers also gave lower overall liking scores ($t = 2.03$, $p < 0.05$) to 1-MCP treated fruit than non-Fuji consumers. More consumers indicated they would buy Control-CA fruit than not buy it for both Fuji consumers ($\chi^2 = 7.02$, $p < 0.01$) and non-consumers ($\chi^2 = 9.64$, $p < 0.005$), while Fuji consumers were divided regarding purchase intent for 1-MCP-CA, but Fuji non-consumers were more willing to buy than not buy the 1-MCP treated fruit ($\chi^2 = 17.92$, $p < 0.001$).

In Test 3, there were 29 consumers (36%) who ate Red Delicious and who followed some similar preference patterns to the Gala and Fuji consumers in Test 2. For those who consume Red Delicious, more prefer the Chilean fruit (69%, $\chi^2 = 4.18$, $p < 0.05$) to 1-MCP-CA (28%) but liking scores for Chilean fruit (average 6.89) and 1-MCP-CA (average 5.78) were not significantly different ($t = 1.53$, $p > 0.10$). Also, more Red Delicious consumers were willing to buy Chilean fruit (75.9%) than not buy them (24.1%, $\chi^2 = 7.68$, $p < 0.01$) while they were divided in terms of purchase intent of 1-MCP-CA apples. Although the results for the Red Delicious consumers were statistically significant, they were based on a relatively small number of people and should be considered a trend perhaps worthy of further investigation.

4. Conclusion

Since the 1-MCP treated and control fruit in these tests were matched for firmness, the most significant effect of 1-MCP treatment and long-term storage on the physiological/chemical properties of Gala apples for these tests was the inhibited production of total esters as well as that of volatile compounds that characterize Gala apples. Also, for fruit in this study, 1-MCP treatment resulted in lower SSC content of apples stored in controlled atmosphere, and in lower titratable acidity in apples stored in regular atmosphere, compared with Control-CA fruit.

From a sensory viewpoint, when Gala apples were matched for firmness, this study showed that consumers could distinguish 1-MCP treated from untreated fruit. However, consumers gave relatively high liking scores to both 1-MCP treated and untreated apples. The present findings also indicate there are consumers that like and will buy 1-MCP treated fruit and other consumers who prefer untreated fruit, and the size of those groups is similar. Further examination of acceptance patterns for some consumers of Gala, Fuji and Red Delicious apple varieties, however, indicated they have a preference and are more willing to buy Control-CA compared to 1-MCP-CA apples. This preference trend should be examined further since the preference for untreated fruit was only observed for about 40% of the consumers that eat Galas or Fujis and only 16% of consumers that eat Red Delicious. A potential preference for untreated fruit may be very important to validate for Gala consumers since there may be potential market share loss if 1-MCP-CA treated Galas are not as acceptable to consumers that normally eat that variety. Also, Gala consumers did not show preference for Control fruit in Test 1 when the fruit compared was 1-MCP-RA or in Test 3 when 1-MCP-CA apples were compared to untreated Chilean fruit. This indicates 1-MCP treatment under different storage conditions, RA or CA, may affect the Gala apple flavor in different ways that Gala consumers, who are more familiar with the fruit, may detect and be basis for their preference. The higher SSC concentration and concentration of volatiles characteristic to Galas in untreated fruit may be more familiar and important to consumers that normally eat Galas, thus a possible reason for their preference for untreated vs. 1-MCP treated fruit in Test 2.

Further studies are needed to determine whether 1-MCP treatment has similar physiological or chemical effects on other apple varieties, and if any potential quality effects from treatment would be perceived and impact consumers' acceptance and buying behavior, especially for consumers that regularly eat those varieties.

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