Postharvest Quality and Sensory Characteristics of 'Granny Smith' Apple Treated with SmartFresh™ (1-MCP)

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Summary

Apple fruit of cv 'Granny Smith' was treated with 0.625 µl/L SmartFresh™ (1-MCP) and stored in NA (90% RH, 1 °C) for 16 weeks. After storage, fruits were left for four days at room temperature to simulate market display period (SMP) before analysis. Fruit treated with 1-MCP retained firmness on values very similar to harvest, while control fruit had significantly lower values. No significant differences were observed in the amount of soluble solid concentration (SSC), titratable acidity (TA) and maturity index (SSC/TA).

Fruit colour was significantly affected with SmartFresh™ (1-MCP treatment). After storage, b value and Chroma were significantly lower in SmartFresh™ (1-MCP) treated fruit. After SMP, significance of differences in b and Chroma values increased to as high as $P \leq 0.001$ and differences in L and Hue values became significant. Colour differences (ΔEab and ΔHab) between storage and SMP were not significant, but difference in L value (ΔL) was significantly higher in control fruit.

Control fruit had scald index of 2.27, while SmartFresh™ (1-MCP) treated fruit had scald index of only 0.27.

Female panelist scores showed the lower quality of control sample in all characteristics, except aroma, while male panelists noticed difference only in colour.

The results showed that SmartFresh™ (1-MCP) treatment significantly affects fruit quality of apple cv. 'Granny Smith'. Subtle changes in sensory characteristics caused by this treatment are more easily recognized by female panelists.

Key words

Malus x *domestica* Borkh, SmartFresh™, 1-MCP, storage, superficial scald, fruit quality, sensory analysis

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Received: July 16, 2012 | Accepted: October 29, 2012

Introduction

The active compound of SmartFresh™, 1-methylcyclopropene (1-MCP) blocks the response of plants to exo- and endogenous ethylene at very low concentrations after a short-time exposure (Sisler and Serek, 1997; Sisler and Serek, 1999). Since its discovery, there has been a rapid expansion of research on its effects on fruits and vegetables (Watkins, 2006). The effect of 1-MCP has been extensively reviewed by several authors (Blankenship and Dole, 2003; Sozzy and Beaudry, 2007; Watkins, 2006; Watkins, 2008). Although other compounds that interact with ethylene receptor are studied, 1-MCP will be a primary mean of controlling ethylene responses for the immediate future (Sisler, 2006).

Although the 1-MCP is effective in many fruits and vegetables (Watkins and Miller, 2005; Watkins, 2006; Sozzy and Beaudry, 2007), it is the most widely applied on apples. Of 27 countries where this compound is registered, in 22 countries registration is for apple (Sozzy and Beaudry, 2007). Apples treated with 1-MCP retain its firmness (Jeziorek et al., 2010; Pre-Aymard et al., 2005; Zanella, 2003), even in retail market conditions (McArtney et al., 2011). Other quality parameters affected by this compound include titratable acidity (Jeziorek et al., 2010; Pre-Aymard et al., 2005), sensory properties (Pre-Aymard et al., 2005), and physiological disorders such as superficial scald (Magazin et al., 2010; Lurie and Watkins, 2012; Sabban-Amin et al., 2011; Zanella, 2003).

Many factors may change the efficacy of 1-MCP, such as cultivar, harvest date, storage conditions, treatment temperature and duration, fruit maturity, and length of time after harvest (Magazin et al., 2010; Tatsuki et al., 2011; Zanella, 2003; Watkins, 2008).

'Granny Smith' is important apple cultivar in Croatia. Since it is late-maturing cultivar, it can be easily damaged by physiological disorders such as superficial scald when harvested earlier due to the unfavorable temperature conditions in some years or due to the effort of growers to avoid development of red blush in some warmer regions. 1-MCP is effective against scald in relatively wider harvest window (Magazin et al., 2010; Zanella, 2003), which is not the case for some other postharvest treatments, such as hot-water dipping (Jemric et al., 2006). Therefore, 1-MCP treatment offers good solution against this physiological disorder. In 2011, SmartFresh™ (1-MCP) is registered in Croatia (AgroFresh, personal communication), and objective of this study is to evaluate the effect of SmartFresh™ (1-MCP) on the quality of apple cv. 'Granny Smith' grown in Croatia. This study is the first report on the application of this compound in Croatia.

Material and methods

Harvest date has been determined according to the standard method (Streif, 1995) and fruit were harvested on 21th of October, 2011 with firmness of 7.99 kg cm^{-2}. Fruit was divided into two samples consisting of 30 fruit each. One sample was treated with 0.625 µl/L of active ingredient of SmartFresh™ (1-MCP) according to the official instructions given by producer. Another sample was used as control. Fruit were stored in normal atmosphere (NA) cold storage (90% RH, 1°C) for 16 weeks.

After storage, fruit samples were transported to the laboratory of Department of Pomology, Faculty of Agriculture and inspected for damage and other defects. Then they were left for four days at room temperature to simulate market display period (SMP) before analysis

Colour was measured according to CIE Lab system by colourimeter (Colourtec PCM, USA) one each fruit on previously marked place. The colourimeter calibration was done with black and white plates supplied with the instrument and the fruit colour was represented with Hue angle (H°) (McGuire, 1992). Colour differences (ΔE_{ab}) and hue differences (ΔH_{ab}) between storage and SMP for the same fruit were calculated according to Sève, 1991, where C*1 and C*2 represent the chroma value of fruit after storage and SMP, respectively, and ΔH is the hue angle difference between the storage and SMP, respectively. For each fruit, difference in L value (ΔL) was calculated from corresponding values for the same fruit after storage and after SMP.

Firmness was measured using Effegi FT 327 penetrometer with 11 mm probe as an average value from four measurements made at opposite fruit sides at equatorial fruit zone with fruit skin removed.

The juice from each fruit was extracted with electric juicer and was used for determination of soluble solids content (SSC) with refractometer (ATAGO PAL-1, Japan), and titratable acidity (TA) by titration with 0.1 N NaOH and expressed in percent of malic acid per 100 ml of juice (Mitcham et al., 1996).

After SMP, fruits showing superficial scald symptoms were sorted into three categories based on their scalded surface. A scores of 0 = no scald (0% scalded surface), 1 = slight scald (0–30% scalded surface), 2 = medium scald (31–60% scalded surface) and 3 = severe scald (61–100% scalded surface) were used. Scald index was calculated according to Jemric et al. (2006).

Sensory analysis was performed according to Miller et al. (2005). Crispness, texture, juiciness, sugar/acid ratio, aroma, flavour richness and general impression were scored using a bipolar 5-point (1 to 5) hedonic scale. On the scale the 1-unit intervals were considered: dislike, dislike slightly, like, like very much, and like extremely.

Data analysis was conducted with SAS software, version 9.2 (SAS Institute, Cary, NC, USA) using one way ANOVA and LSD test at $P \leq 0.05$ level.

Results

Fruit quality and colour

Fruit treated with 1-MCP retained firmness on values very similar to harvest, while control fruit had significantly lower values (Table 1). Despite the tendency that fruit treated with 1-MCP had higher content of soluble solid concentration (SSC), titratable acidity (TA) and maturity index (SSC/TA), the difference was not significant.

Fruit colour was significantly affected with 1-MCP treatment (Tables 2 and 3). After storage, b value and Chroma were significantly lower in 1-MCP treated fruit. After SMP, significance of differences in b and Chroma values increased to as high as $P \leq 0.001$ and differences in L and Hue values became significant (Table 2). Colour differences (ΔE_{ab} and ΔH_{ab}) between storage and SMP were not significant (Table 3), but difference in L value (ΔL) was significantly higher in control fruit.

Table 1. The quality of apple fruit 'Granny Smith' treated with 1-MCP after 16 weeks of storage and four days of simulated market period

Treatment	Firmness (kg cm^{-2})	SSC (%)	TA (as malic) (%)	SSC/TA
1-MCP	7.89±0.23	14.64±0.67	0.61±0.06	24.41±2.58
Control	6.74±0.58	14.14±0.90	0.56±0.05	23.08±5.56
t-test	**	n.s.	n.s.	n.s.

Note: n.s.,** - nonsignificant or significant at P≤0.01, respectively

Table 2. Colour of apple fruit 'Granny Smith' treated with 1-MCP after 16 weeks of storage and four days of simulated market period

Treatment	Lightness (L)	a - value	b - value	Chroma	Hue angle (°)
			Storage		
1-MCP	58.50±3.90	-9.57±0.72	32.93±3.50	34.31±3.45	106.33±1.57
Control	57.60±1.56	-9.54±0.97	35.38± 3.54	36.65 ±3.53	105.12±0.92
	n.s.	n.s.	**	*	n.s.
			Simulated market period		
1-MCP	57.74±2.62	-9.19±1.08	29.85±4.22	31.25±4.24	107.24± 1.85
Control	56.34±1.84	-8.95±1.94	36.19±4.01	37.33±4.01	103.97±3.16
t-test	*	n.s.	***	***	*

Note: n.s.,*,**, *** - nonsignificant or significant at P≤0.05, 0.01, and 0.001, respectively

Table 3. Colour change of apple fruit 'Granny Smith' treated with 1-MCP after 16 weeks of storage and four days of simulated market period

Treatment	Colour difference (ΔE_{ab})	Hue difference (ΔH_{ab})	Lightness difference (ΔL)
1-MCP	4.33±2.45	3.86±8.99	-0.33±2.30
Control	4.4 1± 3.11	-0.41±11.59	-1.08±1.82
t-test	n.s.	n.s.	***

Note: n.s., *** - nonsignificant or significant at P≤ 0.001

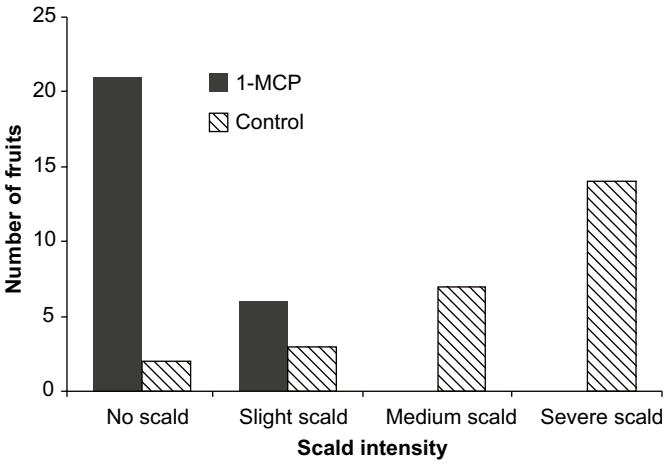

Figure 1. Scald intensity on 'Granny Smith' apples treated with 1-MCP after 16 weeks of storage and four days of simulated market period

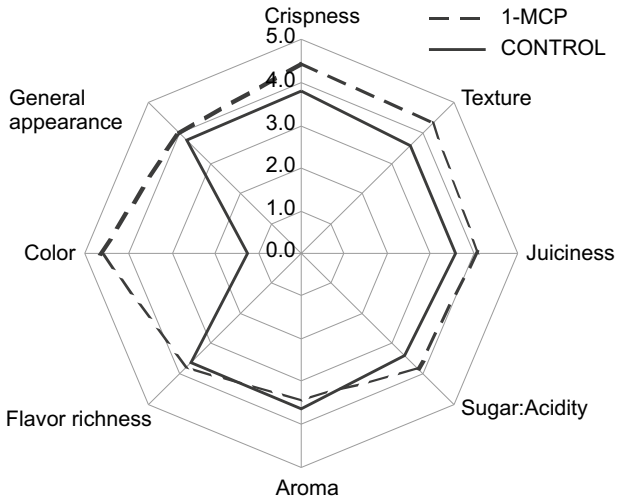

Figure 2. Sensory analysis of 'Granny Smith' apples treated with 1-MCP after 16 weeks of storage and four days of simulated market period

Scald intensity

Control fruit had scald index of 2.27, while 1-MCP treated fruit had scald index of only 0.27. Only two fruits remained without superficial scald symptoms in control sample (Fig. 1), while in 1-MCP treated sample 21 fruit showed no superficial scald symptoms.

Sensory analysis

Average panelist scores (Fig. 2) showed that 1-MCP treated fruit received better scores for all characteristics, except aroma. The most significant difference was in scores for colour. Colour scores for control fruit were below the level of acceptance due to the intensive scald damage (Fig 1). On the contrary, 1-MCP treated fruit received maximum scores for colour.

Panelist scores were analized separately for women and men (Fig. 3 and Fig. 4). Female panelist scores showed the lower quality of control sample in all characteristics, except aroma (Fig. 3), while male panelists noticed difference only in colour (Fig. 4).

Discussion

Fruit quality and colour

Fruit treated with 1-MCP had significantly higher firmness (Table 1). This is in accordance with numerous previous studies. 1-MCP treated fruit retain its firmness for four weeks in retail market conditions in comparison with non-treated fruit (McArtney et al., 2011). This compound significantly affected fruit firmness of cv. 'Granny Smith' across different storage regimes, including normal atmosphere, ultra low oxygen and initial low oxygen stress (Zanella, 2003). Magazin et al. (2010) also reported increased firmness on 1-MCP – treated apples cv. 'Granny Smith'.

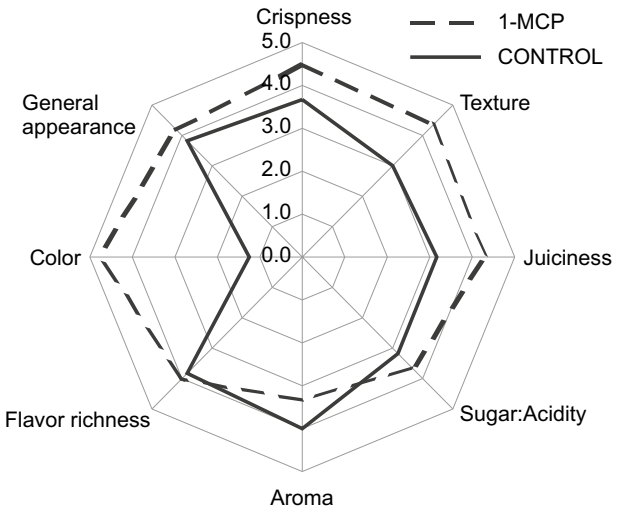

Figure 3. Sensory analysis of 'Granny Smith' apples treated with 1-MCP after 16 weeks of storage and four days of simulated market period made by females

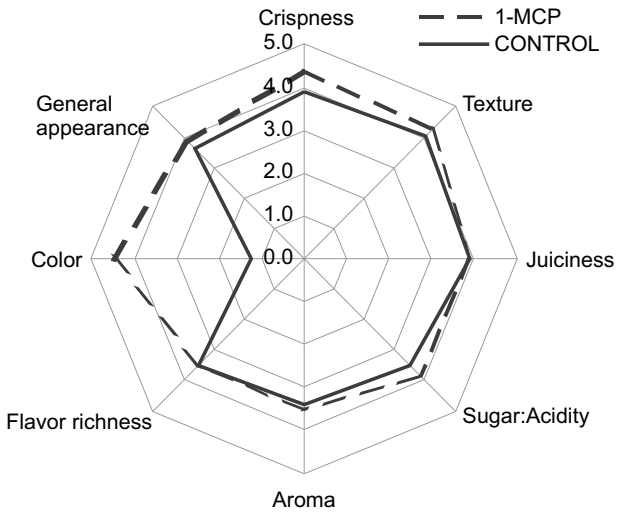

Figure 4. Sensory analysis of 'Granny Smith' apples treated with 1-MCP after 16 weeks of storage and four days of simulated market period made by males

SSC and titratable acidity have not been affected by 1-MCP treatment. SSC remained unaffected by 1-MCP treatment, but this compound significantly affected titratable acidity that was higher in treated fruit (Zanella, 2003). The similar results were reported by other authors (Jeziorek et al., 2010; Magazin et al., 2010; Pre-Aymard et al., 2005). This can be explained by increased 1-MCP concentration, cultivar and environmental effect.

Fruit colour was significantly affected by 1-MCP treatment. Treated fruit retained green colour even after SMP, although there were no significant difference in colour and hue differences between treated and control fruit (Tables 2 and 3). 1-MCP significantly affects colour development on fruits of cv. 'Granny Smith' after long term storage in normal atmosphere, but some loss of colour still occurs after ripening at 20°C for seven days (Zanella, 2003). Maintaining green colour is very important for cultivars such as 'Granny Smith' since its degrading is associated with loss of market value.

Scald intensity

Treatment with 1 MCP effectively controlled scald (Fig. 1). Such result was expected since the effect of 1-MCP in controlling superficial scald in 'Granny Smith' was well documented in the literature (Lurie and Watkins, 2012; Magazin et al., 2010; Zanella, 2003).

Superficial scald is important physiological disorder of apples in Croatia (Jemrić and Ilić, 2012), even in controlled atmosphere (CA) storage which is known to suppress superficial scald development. Since sintetic antioxidants are not allowed, until registration of Agrofresh™, hot water dips have been shown to have potential of decreasing superficial scald in this cultivar (Jemric et al., 2006), but only if fruits are harvested at optimal harvest date. 1-MCP is effective against scald in both early and late harvested fruit (Magazin et al., 2010; Zanella, 2003)

Sensory analysis

Sensory analysis helps in the evaluation of the level of acceptance and of the perception capacity of the distinctive traits of the fruit by the consumer (Bignami, 2003). Consumers indicated that flavour, taste and texture were the main reason for purchasing apples (Harker, 2002). Taste, aroma and freshness were in this order the three most important attributes taken into account by consumers when choosing an apple (Péneau et al., 2006). Beside taste, flavour and crispness are also important traits, ranking above appearance in importance among apple characteristics (Redalen, 1988).

1-MCP treated fruit received maximum scores for colour, due to the fact that in this sample, most of the fruit remained without superficial scald symptoms (Fig. 1) and they retained their green colour (Table 2). Sensory scores for other properties were similar between treated and non-treated fruits when panelist scores are analyzed irrespective of panelist gender.

However, when panelist scores were analyzed separately for female and male panelists (Fig. 3 and 4), differences occurred between 1-MCP treated and control fruit in female panelist scores (Fig. 3). Control fruit received lower scores for all characteristics, except aroma, which was scored better than in 1-MCP treated fruit. This is not surprising since 1-MCP affects aroma development (Kondo et al., 2005). Male panelist observed significant difference only in colour (Fig. 4). This shows that female panellists more easily recognized the subtle differences in the quality of fruit as affected by 1-MCP treatment. Ship and Weiffenbach (1993) showed that females have better smell identification; therefore such result is not surprising. The difference in sensory scores between untreated fruit and 1-MCP treated fruit exists only at higher concentration of 1 µl/L (Pre-Aymard et al., 2005). Since in our study 1-MCP was applied at lower concentration (0.625 µl/L), the less recognizable effect on sensory properties is to be expected. Magazin et al. (2010) also noticed differences in sensory properties of control and 1-MCP treated 'Granny Smith' apples.

Conclusion

The results showed that SmartFresh™ (1-MCP) treatment effectively maintains the quality of 'Granny Smith' apples stored in normal atmosphere. However it may suppress aroma development which might be recognized by female panelists. Further studies must be focused on the effect of SmartFresh™ (1-MCP) on other apple cultivars grown in Croatia to check its full potential.

References

Bignami C., Scossa A. Vagnoni G. (2003). Evaluation of old Italian apple cultivars by means of sensory analysis. Acta Hortic 598: 85–90

Blankenship S. M., Dole J. M. (2003). 1-Methylcyclopropene: a review. Postharvest Biol Tec 28: 1-25

Harker R. (2002). Improve fruit quality to increase demand. Good Fruit Grower 53: 27

Jemrić T., Ilić Z. (2012). Present state of cold chain and postharvest loss of fruits and vegetables in Croatia and Serbia. Agric conspec sci 77: 1-4

Jemric T., Lurie S., Dumija L., Pavicic N., Hribar J. (2006). Heat treatment and harvest date interact in their effect on superficial scald of 'Granny Smith' apple. Sci Hort 107: 155-16

Jeziorek K., Wozniak M., Tomala K (2010). Response of 'golden delicious' apples to postharvest application of 1-methylcyclopropene (1-MCP) in conditions of normal and controlled atmosphere. Journal of Fruit and Ornamental Plant Research 18: 223-237

Kondo S., Setha S., Rudell D.R., Buchanan D.A., Mattheis J.P. (2005). Aroma volatile biosynthesis in apples affected by 1-MCP and methyl jasmonate. Postharvest Biol Tec 36: 61–68

Magazin N., Gvozdenovic, D., Keserovic, Z., Milic, B., 2010. Fruit quality of Granny Smith apples picked at different harvest times and treated with 1-MCP. Fruits 65: 191–197

McArtney S., Parker M., Obermiller J., Hoyt T. (2011). Effects of 1-Methylcyclopropene on Firmness Loss and the Development of Rots in Apple Fruit Kept in Farm Markets or at Elevated Temperatures. HortTechnology 21: 494-499

McGuire R.G. (1992). Reporting of objective colour measurements. HortScience 27: 1254-1255

Miller S., Hampson C., McNew R., Berkett L., Brown S., Clements J., Crassweller R., Garcia E., Greene D., Greene G. (2005). Performance of Apple Cultivars in the 1995 NE-183 Regional Project Planting: III. Fruit Sensory Characteristics. J Amer Pomolog Soc 59: 28–43

Mitcham B., Cantwell M., Kader A. (1996). Methods for determining quality of fresh commodities. Perishables Handling Newsletter Issue No. 85: 1-6

Lurie S., Watkins, C.B. (2012). Superficial scald, its etiology and control. Postharvest Biol Tec 65: 44-60

Péneau S., Hoehn H., Roth H.R., Escher F, Nuessli J. (2006). Importance and consumer perception of freshness of apples. Food Qual Prefer 17: 9–19

Pre-Aymard C., Fallik E., Weksler A., Lurie S. (2005). Sensory analysis and instrumental measurements of 'Anna' apples treated with 1-methylcyclopropene. Postharvest Biol Tec 36: 135-142

Redalen G. 1988. Quality assessment of apple cultivars and selections. Acta Hort 224: 441–447

Sabban-Amin R., Feygenberg O., Belausov E., Pesis E. (2011). Low oxygen and 1-MCP pretreatments delay superficial scald development by reducing reactive oxygen species (ROS) accumulation in stored 'Granny Smith'apples. Postharvest Biol Tec 62: 295-304

Sève R. (1991). New formula for the computation of CIE 1976 hue difference. Color Res Appl 16:217–218

Sisler E.C., Serek M. (1997). Inhibitors of ethylene responses in plants at the receptor level: recent developments. Physiol Plantarum 100: 577-582

Sisler E.C., Serek M. (1999). Compounds controlling the ethylene receptor. Bot Bull Acad Sinica 40:1-7

Sisler E.C. (2006). The discovery and development of compounds counteracting ethylene at the receptor level. Biotechnol Adv 24: 357-367

Sozzi G.O., Beaudry R.M. (2007). Current perspectives on the use of 1-methylcyclopropene in tree fruit crops: an international survey. Stewart Postharvest Rev 3: 1–16

Streif J. (1995). Optimum harvest date for different apple cultivars in the 'Bodensee' area. In: The postharvest treatment of fruit and vegetables. European Commission, Louxemburg: 15–20

Ship J.A., Weiffenbach J.M. (1993). Age, Gender, Medical Treatment, and Medication Effects on Smell Identification. J Gerontol 48: M26-M32

Tatsuki M., Hayama H., Yoshioka H., Nakamura Y. (2011). Cold pre-treatment is effective for 1-MCP efficacy in 'Tsugaru' apple fruit. Postharvest Biol Tec 62: 282-287

Watkins C.B. (2006). The use of 1-methylcyclopropene (1-MCP) on fruits and vegetables. Biotechnol Adv 24: 389–409

Watkins C.B. (2008). Overview of 1-Methylcyclopropene Trials and Uses for Edible Horticultural Crops. HortScience 43: 86-94

Watkins C.B., Miller W.B. (2005). A summary of physiological processes or disorders in fruits, vegetables and ornamental products that are delayed or decreased, increased, or unaffected by application of 1-methylcyclopropene (1-MCP). [http://www.hort.cornell.edu/mcp/]

Zanella A. (2003). Control of apple superficial scald and ripening - a comparison between 1-methylcyclopropene and diphenylamine postharvest treatments, initial low oxygen stress and ultra low oxygen storage. Postharvest Biol Tec 27: 69-78

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