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Effects of 1-methylcyclopropene and diphenylamine on changes in sensory properties of 'Granny Smith' apples during postharvest storage

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ABSTRACT

The objective of this study was to investigate and compare the effects of 1-methylcyclopropene (1-MCP) and diphenylamine (DPA) postharvest pre-storage treatments on changes in sensory properties of 'Granny Smith' apples during cold storage along with subsequent keeping of fruit at room temperature. Apples were stored in normal atmosphere (NA) at 0–1 °C/90–95 RH and evaluated after 3, 6 and 9 months (after removal from cold storage plus 1, 8 and 15 d at room temperature) by descriptive sensory analysis.

Fourteen of the 17 evaluated attributes, in the form of an unfolded data matrix, were subjected to principal component analysis (Tucker-1). The combination of 11 sensory attributes, which loaded heavily on PC-1, was referred to as 'Freshness' axis. Three-way analysis of variance was applied on PC-1 scores for samples (PC-ANOVA). 1-MCP samples showed relatively low rates of juiciness, cohesiveness, hardness, crunchiness, greenness and sourness reduction during the observed period of storage as compared to Control and DPA samples. All of the evaluated 1-MCP samples practically appeared on the positive side of 'Freshness' axis in principal component space. The highest level of freshness loss during the storage period was observed in Control samples, which suffered changes in quality after the 9 months of storage at such a level that the fruit ware decayed and not suitable for consumption. The most resistant to scald forming were 1-MCP treated apples. No scald was found after 9 months of cold storage.

The treatment of 'Granny Smith' apples with 1-MCP can extend the storage time in standard NA storage for at least 3 months without significantly losing freshness even two weeks after removal from cold storage, and is more effective in preserving sensory attributes related to apple freshness when compared with the DPA treatment.

1. Introduction

Apple fruit is the second most produced fruit in Serbia with annual production of over 266 thousand tons (Yearbook, 2012). The production of 'Granny Smith' apples is estimated to be at the level of less than 10% of total apple production in Serbia (no official data available). 'Granny Smith' is a late-ripening apple cultivar valued for its attractive appearance, bright green skin color, white to greenish-white flesh, crunchiness, juiciness, and specific tart flavor, although concentrations of aromatic flavor volatiles are low (Abbott et al., 2004).

Apple quality and sensory characteristics can be influenced by different factors, including maturity, storage conditions and postharvest treatments (Lu et al., 2012). During postharvest storage a series of physiological disorders can be developed in fruit influencing significant changes in sensory characteristics. 'Granny Smith' is an apple cultivar highly susceptible to disorders during medium to long-term postharvest storage, especially to skin color changes characterized by irregular brown discolorations called superficial scald (Golding, 2004; Whitaker, 2004). These color changes have a negative influence on consumer acceptability and may cause loss of market value (Zanella, 2003). Scald symptoms develop only slowly in cold storage but they rapidly increase in severity within a few days at normal air temperature (Golding, 2004). Typically, early-harvested and less-mature fruit are most susceptible (Ingle, 2010), but scald also may be developed on fully mature fruit (Watkins et al., 1995). Scald has been commercially controlled for years by the postharvest application of diphenylamine (DPA) (Anet, 1974; Huelin and Coggiola, 1970; Meir and Bramlage, 1988), but since this synthetic antioxidant is considered to be pollutant and health hazard (Drzyzga, 2003) the use of another ethylene inhibitor, 1-methylcyclopropene (1-MCP),

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as a means of improving postharvest life and maintaining quality of fruit, has gained more attention in recent years (Blankenship and Dole, 2003; Watkins, 2008). 1-MCP is absolutely volatile, not toxic and does not leave any harmful residue (Lafer, 2006) while extending the shelf-life of fresh fruit (DeEll et al., 2008). 1-MCP treatment can effectively suppress scald development when applied at the correct time and concentrations (DeEll et al., 2002; Golding, 2004; Lu et al., 2012; Moggia et al., 2009; Watkins et al., 2000). Beside scald, the application of 1-MCP may positively influence peel greasiness (Fan et al., 1999; Watkins and Nock, 2005), senescent breakdown (DeLong et al., 2004; Watkins et al., 2000) and firmness in apples (Lu et al., 2012; McArtney et al., 2011; Moggia et al., 2009) throughout the storage period.

Table fruit is usually held and displayed in the markets at room temperature for a certain period of time before sale. Long fruit storage and exposure to high temperatures in markets can cause fruit to ripen quickly, limiting their shelf life. Over-mature fruit are unsalable in retail outlets and are disposed of, usually at very low prices, representing a significant loss in the fruit value chain (McArtney et al., 2011).

Considering application of 1-MCP and DPA in fruit supply chain, the majority of published manuscripts provide instrumental sensory data such as firmness and objective color, as well as sensory data such as ground color and incidence and severity of scald (DeEll et al., 2008; DeEll and Ehsani-Moghaddam, 2010; Golding, 2004; Jung and Watkins, 2008; Lu et al., 2012; McArtney et al., 2011; Moggia et al., 2010; Zanella, 2003). A few authors performed descriptive sensory analysis in their experiments but did not apply multivariate statistical approach in analyzing and interpreting sensory data (Lurie et al., 2002; Pre-Aymard et al., 2005; Rizzolo et al., 2014). This study represents an attempt to provide a better view of the sensory dimensions of 'Granny Smith' apple fruit during postharvest life.

The objective of this study was to investigate and compare the effects of 1-MCP and DPA postharvest pre-storage treatments on changes in sensory properties of 'Granny Smith' apples during the long-term cold storage combined with post-storage keeping of fruit at room temperature in order to simulate the conditions that could be found throughout entire marketing supply chain.

2. Material and methods

2.1. Samples

Physiologically mature fruit of 'Granny Smith' apple cultivar were harvested from 6-year old trees (size-controlling rootstock M.9) planted at 3.2 × 0.8 m and grown in a commercial orchard near the city of Arandjelovac in the Republic of Serbia (44°12′N 20°25′E). The harvest date was 10 October 2012.

2.2. Experimental setup and sampling plan

After the harvest, apples were divided into three batches (macro-plastic harvest bins cca. 320 kg/bin) and tempered a couple of hours in a pre-chamber space at 15–17 °C. One of the batches was then submerged for 30 s in a 0.5% solution of diphenylamine (DPA), drained and placed in normal atmosphere (NA) cold storage at 0–1 °C and 90–95% relative humidity (RH). The second one was placed in the cold storage (previously described) for 2 d until the fruit had reached storage temperature and was then wrapped in polyethylene (PE) plastic bag (no less than 100 μm thick) and treated with 1-methylcyclopropene (1-MCP) using SmartFresh™ Research Tablet Generator [RTG (AgroFresh Inc.)]. 1-MCP was applied in a gaseous state by dissolving three Pink and one Blue SmartFresh™ tablets in the activator solution to provide concentration of 937 nL/L of 1-MCP (according to the instructions provided by AgroFresh Inc.). The bag was sealed within one minute. Duration of the application was between 20 and 21 h at 1 °C. The third batch was used as untreated control and was stored in the same storage conditions as the treated batches.

The apples were sampled for sensory evaluation after removal from the cold storage at room temperature (20–22 °C) plus 1, 8 and 15 days according to the sampling plan shown in Table 1.

2.3. Sensory evaluation

Descriptive analysis was conducted by a sensory panel that consisted of 7 members of the University of Belgrade—Faculty of Agriculture staff who were experienced in apple quality judging (3 men and 4 women). Over a period of 4 weeks, eight 2-h training sessions were performed using 'Granny Smith' apples of different levels of freshness together with some other apple cultivars. Different apple cultivars were used to help in both the training of panelists and the anchoring of minimum and maximum levels of individual sensory attributes. The list of 17 sensory attributes used in descriptive analysis was generated during the first two training sessions considering only 'Granny Smith'. The attributes with their definitions are presented in Table 2. During the rest of the training period the scales were calibrated and the panelists practiced in using them for the evaluation. Since the apples had been removed from the storage and evaluated basically in three separate periods of time (after 3, 6 and 9 months of storage), a 2-h training session was held each time a week before removing the apples from the storage.

The selected sensory attributes were scored with respect to their intensities using 15 cm line scales anchored with multiple reference points within paper ballots. The scales for skin odor, flesh odor, sourness, sweetness and apple flavor were anchored using reference standards (sucrose, citric acid and green-apple aroma

Table 1
The sampling plan for sensory evaluation of 1-methylcyclopropene (1-MCP) and diphenylamine (DPA) treated, and untreated (Control) 'Granny Smith' apples. The table also contains abbreviations for the experimental samples.

Cold storage	Duration at room T (20–22 °C) after the storage time	Sensory evaluation [Yes (+)/No (−)]/Abbreviations		
(0–1 °C, 90–95% RH)		Control[a]	DPA	1-MCP
3 months	1 d	(+)/Control-3m	(+)/DPA-3m	(+)/1MCP-3m
	8 d (1 week)	(+)/Control-3m-1w	(+)/DPA-3m-1w	(+)/1MCP-3m-1w
	15 d (2 weeks)	(+)/Control-3m-2w	(+)/DPA-3m-2w	(+)/1MCP-3m-2w
6 months	1 d	(+)/Control-6m	(+)/DPA-6m	(+)/1MCP-6m
	8 d (1 week)	(+)/Control-6m-1w	(+)/DPA-6m-1w	(+)/1MCP-6m-1w
	15 d (2 weeks)	(+)/Control-6m-2w	(+)/DPA-6m-2w	(+)/1MCP-6m-2w
9 months	1 d	(−)	(+)/DPA-9m	(+)/1MCP-9m
	8 d (1 week)	(−)	(+)/DPA-9m-1w	(+)/1MCP-9m-1w
	15 d (2 weeks)	(−)	(+)/DPA-9m-2w	(+)/1MCP-9m-2w

[a] Changes in sensory quality in Control samples after 9 months of storage were of such a level that apples were not suitable for sensory analysis.