

Effect of 1-methylcyclopropene treatment on sensory characteristics of apple fruit

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Abstract

Effect of an inhibitor of ethylene action, 1-methylcyclopropene (1-MCP), on sensory qualities of apple fruit of 15 common cultivars of Latvia was evaluated in this study. Taste, aroma, sourness, sweetness, juiciness and colour change of control and 1-MCP-treated apple fruit before and after six and nine months of storage were compared using two different methods of sensory evaluation. The evaluated parameters significantly changed during storage, but the results suggest that treatment with 1-MCP did not lead to significant change in sensory qualities of fruits. Experts admitted that treated fruit were juicier and had more distinctive colour even after nine months of storage, although they were slightly more sour than non-treated samples. However, control samples of all apple cultivars were somewhat tastier and sweeter than were 1-MCP-treated fruits.

Key words: apple fruit, 1-methylcyclopropene, sensory evaluation.

Abbreviations: 1-MCP, 1-methylcyclopropene.

Introduction

Apples are the second most popular and widely used fruit, and play a significant role in human nutrition through providing the human body with necessary nutrients and biologically active substances – vitamins, minerals, organic acids and fibres (Potter et al. 2007). The sensory quality of fruit is very important for consumers. One of the key attributes of fruit quality is favorable sensory evaluation. The choice of storage technology is essential for preservation of fruit freshness as long as possible.

Ethylene (C₂H₄), widely documented as a plant hormone, is synthesized from methionine in fruit tissues (McKeon et al. 1995). At a certain phase of ripening, ethylene binds with appropriate receptors in fruit cells, which promotes fruit ripening completion and beginning of cell degradation (Burg, Burg 1967; Sisler, Lallu 1994). Several artificial substances, which compete with ethylene binding, have been found to lead to reduction of ethylene effects. The substances 2,5-norbornadiene and diasocyclopropenadiene bind with ethylene receptors, thus decreasing ethylene activity or completely blocking the receptor. Blankenship and Sisler (1989; 1996) noticed that 2,5-norbornadiene and diasocyclopropenadiene delay softening and ripening of apples. Nevertheless,

none of these products can be used commercially due to their toxicity (Fan et al. 1999). Fruit treatment with 1-methylcyclopropene (1-MCP) has been broadly used worldwide in recent years (Watkins et al. 2010). This method is based on substitution of ethylene by 1-MCP gas, hindering attachment to receptors and ethylene function.

1-MCP is considered to be commercially efficient for preserving quality and increasing shelf-life of fruit and vegetables (Sisler, Serek 1997; Watkins 2002). Most importantly, it can be used on both climacteric and non-climacteric fruit, vegetables and flowers. The positive effects of 1-MCP include delay of ripening-related biochemical and physiological changes, decrease of intensity of rotting, as well as reduction of weight-loss and cooling damage during storage (Blankenship, Dole 2003). By binding with a sufficient number of receptors chemically and permanently, 1-MCP makes them insensitive to ethylene. The treated plants do not perceive ethylene, preventing ripening, wilting and other ethylene-related phenomena. As a result, prolongation of freshness of flowers and quality of fruit after harvest, extension of their shelf life, and, ultimately, benefits for producers and consumers (Pirrung et al. 2008) are among the main positive effects of treatment with 1-MCP.

It has been shown that shelf-life of apple fruit treated

with 1-MCP can last for up to 120 days without significant change of quality (Watkins et al. 2010). As structure of fruit changes minimally during storage consumers will buy good fruit for a longer period of time. The concentration of 1-MCP used for fruit treatment should not exceed 1 mL L⁻¹, as higher concentrations result in complete loss of characteristic apple aroma (Beaudry, Watkins 2003), meaning a decrease of quality. 1-MCP treatment not only delays aging of apples (Watkins et al. 2000; DeLong et al. 2004; Moran, McManus 2005), but it also significantly slows internal browning and seed cavity rotting (Fan, Mattheis 1999; Zanella, 2003). Consequently, there is a great overall potential for 1-MCP application in commercial fruit storage to provide customers with qualitative fruit for as long as possible, thus also decreasing storage expenses. The aim of the present study was to evaluate suitability of apple cultivars grown in Latvia for 1-MCP treatment. Evaluation was made using sensory characteristics assessed by panel evaluation.

Materials and methods

Samples and treatment

The research was conducted at the Latvia State Institute of Fruit Growing in Dobeles, Latvia. Fifteen apple tree (*Malus domestica* Borkh.) cultivars frequently grown in Latvia were tested: 'Auksis', 'Koričnoje Novoje', 'Saltana', 'Kovaļenkovskoje', 'Orlik', Rubin', 'Gita', 'Tina', 'Antej', 'Aļesja', 'Iedzēnu', 'Belorusskoje Maļinovoje', 'Spartan', 'Zarja Alatau', 'Sinap Orlovskij'. The trees were cultivated at the territory of the Institute. Harvest in 2011 was carried out in September for autumn cultivars and in October for winter cultivars. Average sample weight was 10 kg. Until treatment, the samples were stored in a refrigerator for approximately three days.

Treatment with 1-MCP was performed when fruit were ready for consumption. 1-MCP was obtained from Hangzhou Ruijiang Chemical Co., Ltd. 1-MCP was dissolved in warm water at ratio 1:30 in a sealed container. The container with 1-MCP was placed into a hermetically closed fruit processing cabinet; then the plug was opened and the treatment was performed for 12 h at 18 °C.

After treatment, fruit samples were stored in a cooling chamber at 2 ± 1 °C and 90% relative humidity. The overall duration of storage was 9 months; intermediate stage testing was performed after 6 months.

Sensory and taste evaluation by panelists

The attributes of samples were evaluated by 15 previously trained panelists (5 men and 10 women) aged from 26 to 56. The evaluation was performed by line scale evaluation and hedonic evaluation. Panelists tasted autumn cultivars in the morning and winter cultivars in the afternoon of the same day. All experts were employees of the Latvia State Institute of Fruit Growing.

Panelists and samples were prepared for sensory evaluation according to the method of Tragon Corp., Redwood City, CA, USA and Spectrum™ Analysis Method (Sensory Spectrum Inc., Chatam, NJ, USA).

Before tasting, apples were stored at 18 ± 2 °C for 3 h in order to match the temperature of the environment. Each panelist received three apples from each cultivar served on white trays; samples were coded with letters. Panelists then cut small pieces of the apples and evaluated the colour, aroma, taste, sourness, sweetness, and juiciness of all samples, first according to line scale evaluation, and then by hedonic evaluation. A glass of water was served together with the samples for panelists to wash their mouths after tasting of each sample.

Line scale evaluation

Estimated sensory attributes (colour, aroma, taste, sourness, sweetness, and juiciness) were evaluated based on ISO 4121:1987 (Sensory analysis – Methodology – Evaluation of food products by methods using scales). The distance of a mark given by a panelist was measured in centimetres. Samples were evaluated according a scale from 0 to 12 cm, where 0 cm indicated that the attribute was not pronounced, and 12 cm was an extremely pronounced attribute.

The obtained results were processed by PanelCheck software using principal component analysis (Næs et al. 2010). If a point of a particular attribute (as evaluated by the panelists) was located within a radius of 1.5 cm from a cultivar it was supposed that the attribute was a significant characteristic of the cultivar.

Hedonic evaluation

For hedonic evaluation of sensory attributes (colour, aroma, taste, sourness, sweetness, and juiciness) a structural scale from 9 to 0 was used where 9 reflected a maximum appreciation and 0 indicated a completely displeasing attribute.

Statistical analysis

The obtained sensory data were processed using the SPSS 15 software package (Harris 2001; Leech et al. 2005), PanelCheck software was used for analysis of panelist data (Næs et al. 2010). Storage effect on sensory qualities was analysed using multi-factor ANOVA analysis (MANOVA).

Results

Apple sensory evaluation using line scale

Fruit evaluation before storage using the line scale indicated that autumn cultivars 'Koričnoje Novoje' and 'Orlik' had distinctive ($p < 0.05$) aroma and taste, compared to other cultivars (Fig. 1 A). Cv. 'Orlik' had a harmonic sweet-and-sour taste, whereas cv. 'Gita' had pronounced sourness before storage.

Sensory evaluation of winter cultivars showed that cv.

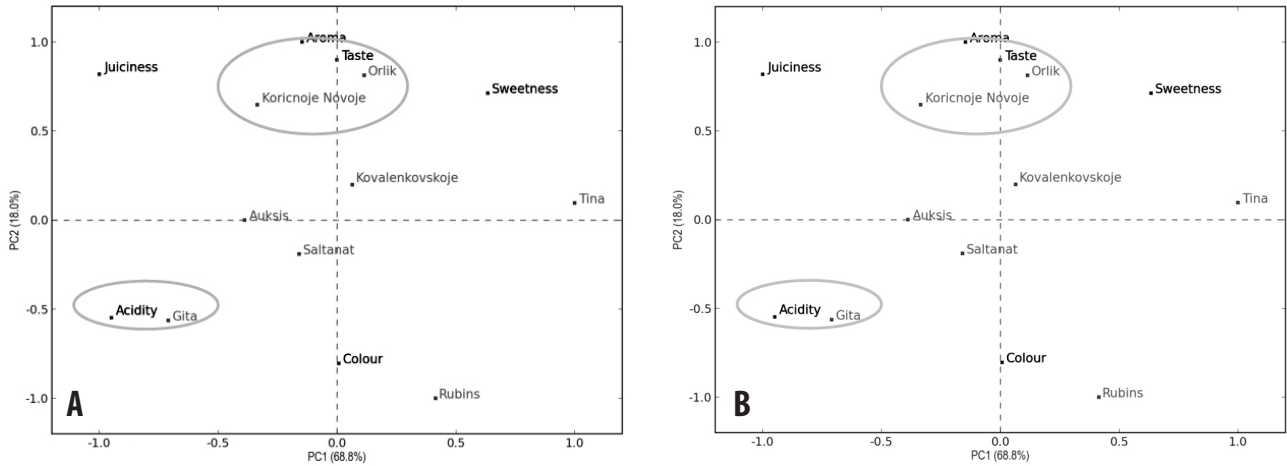


Fig. 1. Results of sensory parameters using a line scale for autumn (A) and winter (B) apple cultivars before storage.

'Tedzenu' was significantly sweeter than the other winter cultivars before storage (Fig. 1B). In addition, cv. 'Antej' was discriminated from the other cultivars by its explicit colour.

Storage of apple fruit resulted in pronounced changes

in sensory characteristics. After 6-month storage in control conditions, samples of cvs. 'Rubins', 'Saltanat', 'Auksis' were evaluated as sweet and cv. 'Koricnoje Novoje' was recognized as sour (Fig 2A). Storage of 1-MCP-treated

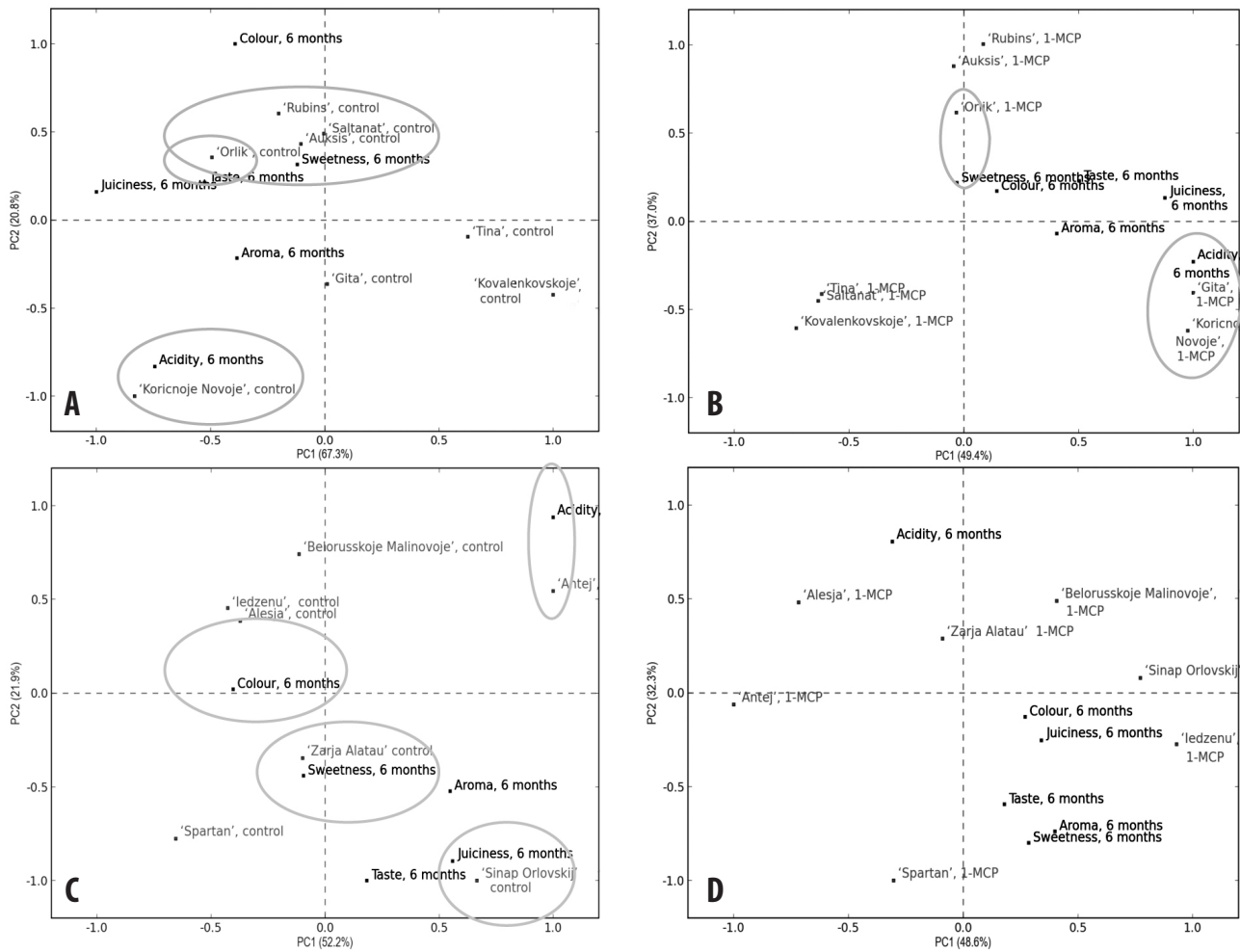


Fig. 2. Results of sensory parameters using a line scale for autumn (A, B) and winter (C, D) apple cultivars after storage during 6 months for control (A, C) or 1-MCP-treated fruit (B, D).

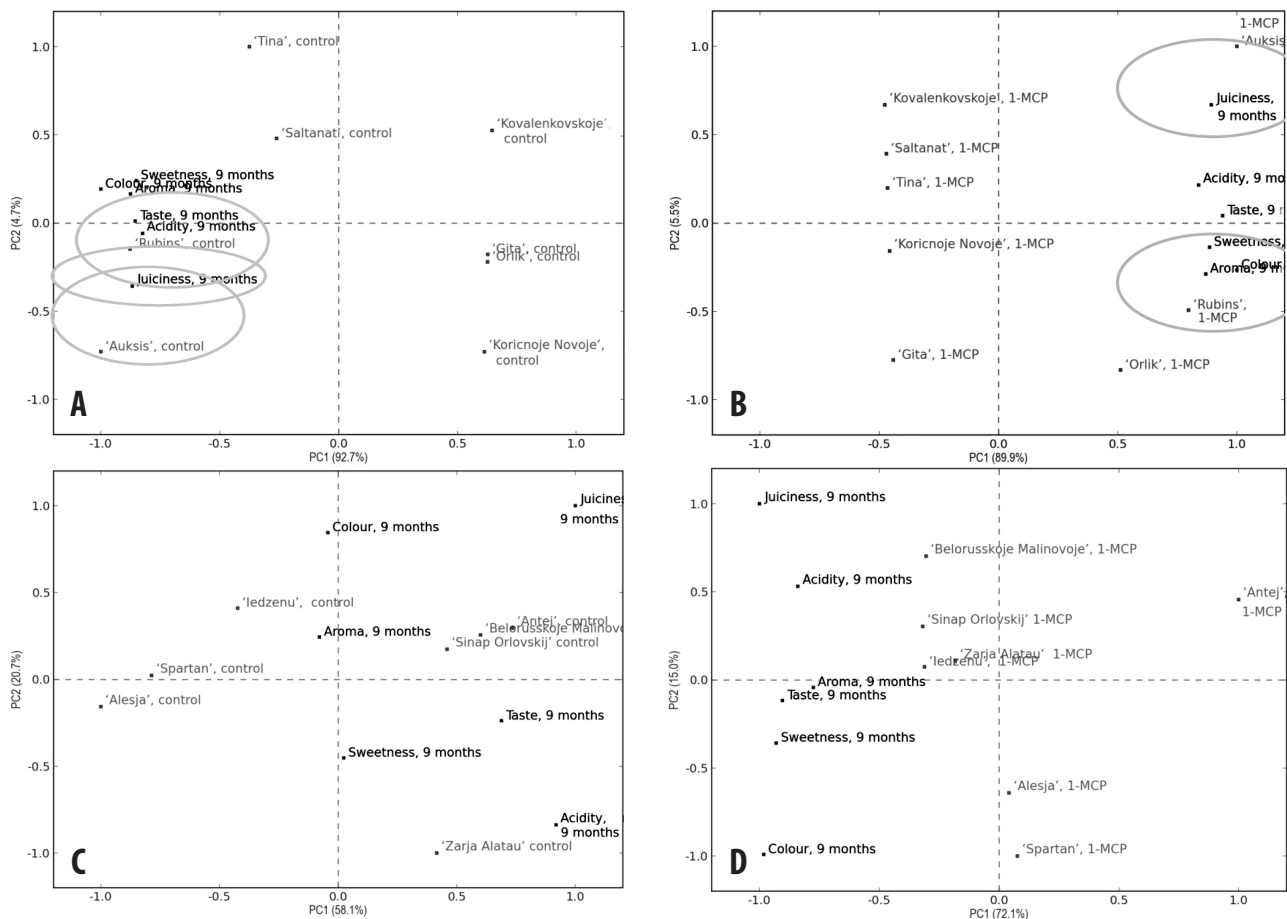


Fig. 3. Results of sensory parameters using a line scale for autumn (A, B) and winter (C, D) apple cultivars after storage during 9 months for control (A, C) or 1-MCP-treated fruit (B, D).

fruit caused significant changes of several characteristics that were not observed in control fruit. Thus, cv. 'Gita' treated with 1-MCP was evaluated as sour after storage (Fig. 2B), similarly as before storage; however, this cultivar in control conditions was not evaluated as sour (Fig. 2A). In contrast, cv. 'Korincnoje Novoje', which was not distinctively sour before storage, was evaluated as sour, irrespective of treatment, when stored for 6 months. Similarly, cv. 'Orlik' was regarded as distinctly sweet both in control and 1-MCP-treated samples (Fig. 2). No distinctive sensory qualities were found for the other autumn apple cultivars tested.

After six months of storage, apple cultivars differed in sensory evaluation results from those before storage. Winter cv. 'Alesja' was identified as having a distinctive colour, and cv. 'Antej' was evaluated as the sourest (Fig. 2C). Cv. 'Zarja Alatau' lost its sourness during storage in control conditions, and possibly the fruits had started to overripe. Cv. 'Sinap Orlovskij' was evaluated as being very juicy, showing that the fruits had reached the best ripeness stage.

No distinctive sensory characteristics were found for fruit samples of winter cultivars treated with 1-MCP and stored for 6 months (Fig. 2D).

Cv. 'Rubins' was evaluated as the best among non-treated samples of autumn apples after 9 months of storage, as only this cultivar had a favourable juiciness, sourness, taste and aroma (Fig. 3A). Treatment with 1-MCP did not change these important characteristics (Fig. 3B). Fruit of cv. 'Auksis' also had distinctive juiciness after 9 months of storage, irrespective of treatment with 1-MCP.

None of the sensory properties of control samples or treated samples of winter apple cultivars were found to be distinctive after nine months of storage (Fig. 3C, D). It is possible that control samples, which had some distinctive attributes after six months of storage, had started to overripe after nine months. In contrast, 1-MCP treated samples had not yet reached this ripeness stage. In general, autumn apple cultivars had more distinctive sensory attributes, even after nine months of storage, in comparison to winter cultivars.

Apple sensory evaluation using a hedonic scale

Hedonic evaluation showed that sensory properties of autumn apple cultivars were more distinctive before storage, the changes that occurred during storage were statistically significant ($p < 0.05$; Fig. 4). Fruit colour after six months of storage was more distinctive for 1-MCP treated

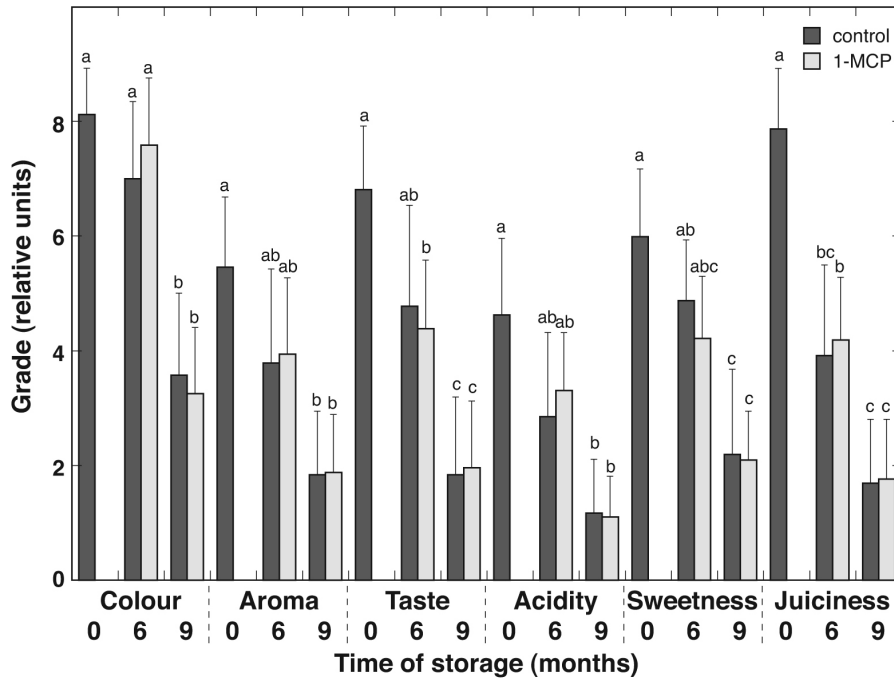


Fig. 4. Mean values of sensory parameters for autumn apple cultivars. Data are means from 15 replicates \pm SD. Different letters denote values that are significantly different at $p < 0.05$ by Tukey's test.

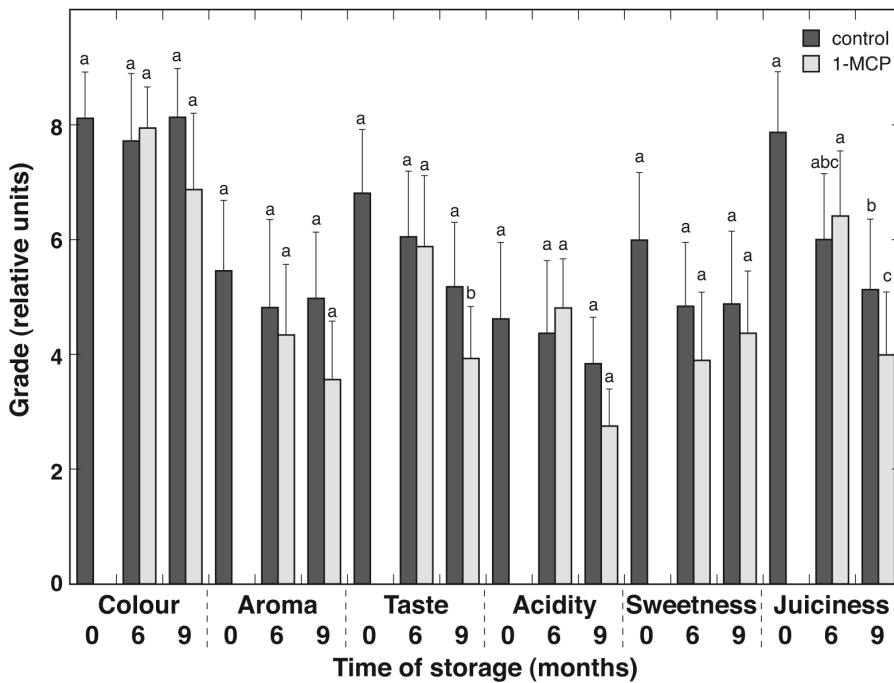


Fig. 5. Mean values of sensory parameters for winter apple cultivars. Data are means from 15 replicates \pm SD. Different letters denote values that are significantly different at $p < 0.05$ by Tukey's test.

samples, but after nine months for non-treated samples. Similar results were obtained for fruit aroma. Interestingly, apple samples appeared to be tastier after nine months of storage, in comparison with the same cultivars stored for six months. 1-MCP-treated fruit samples had distinctive acidity after six months of storage, which dramatically decreased after nine months. Also, 1-MCP treated apples

had lower sweetness, compared with control samples after both storage periods, but they appeared to be juicier.

The results of hedonic sensory evaluation of winter apple cultivars were similar to the results from autumn apple cultivars, with sensory properties appearing to be more distinctive before storage, compared to fruit stored for six or nine months (Fig. 5). Colour and aroma of control

samples did not change during storage. However, taste, acidity and sweetness tended to decrease during storage. Only fruit juiciness significantly decreased during storage. However, it should be noted that the effect of 1-MCP treatment was more pronounced, especially, after longer storage. Thus, colour, aroma, taste, acidity, sweetness and juiciness had a tendency to be lower in 1-MCP-treated fruit stored for nine months. However, the effect was statistically significant only for fruit taste and juiciness.

Discussion

The effectiveness of 1-MCP in decreasing the impact of aging on fruit physiology has been shown in a number of studies (Abdi et al. 1998; Golding et al. 1998; Fan, Mattheis 1999; Lurie et al. 2002; Defilippi et al. 2004; Kondo et al. 2005; Mattheis et al. 2005). One of the most important factors that needs to be considered for 1-MCP treatment is the initial stage of fruit ripeness before treatment. Apples have to be red-ripe before treatment with 1-MCP inhibitor (Marin et al. 2009; Zdunek et al. 2011). If they are not sufficiently ripe, panelists can miss the qualities that develop when ripe. This problem occurred in the present study with winter apple cultivars.

The present study suggests that fruit quality, with the exception of 'Koricnoje Novoje' and 'Gita', were not significantly influenced by 1-MCP treatment for six months of storage, as no sensory attributes were recognized to be distinctively expressed. Israeli scientists showed that 1-MCP treatment had no effect on taste (Pre-Aymard et al. 2005). Sensory parameters for 1-MCP-treated samples might even become more expressed over time, compared to these of control samples. This can explain the distinctive attributes (taste, sourness, sweetness) for control samples compared to treated samples.

As fruit ripens, firmness decreases and aroma and soluble dry matter in fruit increases (Watkins 2002). Volatile aroma compounds develop and peak in fruits during ripening. A number of studies have shown a close relationship between the amount of volatile compounds and ethylene activity, when application of ethylene inhibitors lowers the amount of volatile substances (Bauchot et al. 1998; Flores et al. 2002; Lurie et al. 2002; Defilippi et al. 2004). This also suggests a drawback of 1-MCP application, as it can result in decrease of volatile substances as much as by 70% (Salaun, Baird 1995; Golding et al. 1998; Fan, Mattheis 1999; Defilippi et al. 2004; Kondo et al. 2005; Mattheis et al. 2005). The concentration of aroma-producing compounds in turn influences fruit flavour, which plays a crucial role for consumers when considering buying fruits (Bai et al. 2002). Flavour of fruit depends on combination and concentration of volatile aroma compounds in fruit. Apples as well as pears and other fruit can produce a large number of different aroma compound combinations, which are responsible for flavour development (Chervin et al. 2001;

Lara et al. 2003).

Complex effect of some sensory attributes (external appearance, firmness, sweet and sour flavours) on overall fruit appreciation has been suggested (Watkins et al. 2004; Mitcham et al. 2006). Therefore, during fruit evaluation, the complex of these attributes needs to be assessed. Panelists preferred variety of colours; two-coloured cultivars like 'Gala,' 'Braeburn,' and 'McIntosh' are considered more preferable than single-coloured cultivars like 'Golden Delicious,' 'Granny Smith,' 'Red Delicious' (Watkins et al. 2004). In this respect, cultivar 'Antej' seemed to be more attractive, as it can be considered a two-coloured cultivar.

The study showed that treatment with 1-MCP in general did not result in significantly different sensory evaluation results of apple cultivars commonly grown in Latvia. According to expert panelist suggestion, fruits, even after nine months of storage, are juicier and have more distinctive colour, but are slightly sourer. However, all non-treated apples were somewhat tastier and sweeter, regardless of storage duration, in comparison with samples that were treated with 1-MCP.

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