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journal homepage: www.elsevier.com/locate/lwtEffect of 1-MCP treatment on the apple (*Malus domestica* L. Borkh.) allergen Mal d 1 during long-term storageDaniela Kiewning^{a,*}, Gerhard Baab^b, Michaela Schmitz-Eiberger^a^a Institute of Crop Science and Resource Conservation, Horticultural Science, University of Bonn, Auf dem Hugel 6, D-53121 Bonn, Germany^b Dienstleistungszentrum Ländlicher Raum Rheinpfalz – Klein-Altendorf, Meckenheimer Str. 40, D-53359 Rheinbach, Germany

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ABSTRACT

The consumption of apple fruits can induce allergic reactions. The major allergen responsible for these allergic reactions in Central Europe and North America is the apple allergen Mal d 1, the synthesis of which depends on the apple cultivar and increases during storage time. Several studies have investigated the impact of the cultivar and storage conditions on the Mal d 1 content in apple fruits. However, there are few data available on the impact of 1-methylcyclopropene (1-MCP) on Mal d 1 synthesis during long-term storage. In this study, the Mal d 1 content of seven different apple cultivars was analyzed. Half of the fruits were treated with 1-MCP (Smart Fresh™, Agro Fresh Inc. Spring House, PA, USA). After treatment, the fruits were stored for 12, 20, 28 and 36 weeks in a cold chamber at 2 °C as well as for 12, 20, 28, 36 and 44 weeks under controlled atmosphere (CA-storage, 1.5% CO₂, 1.5% O₂, 2 °C). The Mal d 1 contents of all apple cultivars increased during storage. With the exception of 'Boskoop', Mal d 1 contents of all of the fruits treated with 1-MCP were significantly lower than those of the fruits in the untreated control group.

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1. Introduction

Except for citrus fruits, apples are the most consumed fruit in the EU (Martinez-Palou & Rohner-Thielen, 2008). Due to the availability of the fruit throughout the year, apples are a very important source of secondary plant metabolites such as polyphenols. A high intake of secondary plant metabolites is reported to be beneficial to human health and to play a role in the prevention of cardiovascular diseases, cancer, stroke and osteoporosis (Boyer & Liu, 2004; Scalbert, Manach, Morand, Rémésy, & Jiménez, 2005). On the other hand, apples can also cause severe allergic reactions; 0.4–6.6% of adults and 2.2–11.5% of children aged 0–6 years report perceived fruit allergies. In the latter group, 8.5% of children perceived reactions against apples particularly (Zuidmeer et al., 2008). Up to 70% of birch-pollen-pollinosis patients develop food allergies, most frequently to apples (Eriksson, Formgren, & Svenonius, 1982; Geroldinger-Simic et al., 2011).

Four main classes of apple allergens have been identified: Mal d 1, Mal d 2, Mal d 3 and Mal d 4 (Botton et al., 2008). In Central Europe and North America the most important apple allergen is Mal d 1, a protein that belongs to pathogenesis-related proteins (PRP) subgroup 10 (Breiteneder & Ebner, 2000; Pühringer et al.,

2000). The allergic reaction against Mal d 1 is based on an immunologic cross-reactivity between the major birch-pollen allergen Bet v 1 and the major apple allergen Mal d 1 (Björkstén, Halmepuro, Hannuksela, & Lathi, 1980; Ebner et al., 1991). Mal d 1 is a labile protein that is sensitive to heat, pepsin digestion and oxidation (Asero, Marzban, Martinelli, Zaccarini, & Laimer da Câmara Machado, 2006; Hsieh, Moos, & Lin, 1995). Due to these properties, allergic reactions to apples are normally mild oral symptoms such as itching in the oral cavity or swelling of the lips. These symptoms are called oral allergy syndrome (OAS) (Mari, Ballmer-Weber, & Vieths, 2005).

Currently, the biological function of Mal d 1 is unknown. It is suspected that it may be involved in the binding and transport of plant steroids (Markovic-Housley et al., 2003). The Mal d 1 content depends on the cultivar. Apple cultivars are classified in groups with high, moderate and low allergenic potentials (Bolhaar et al., 2005; Marzban et al., 2005; Matthes & Schmitz-Eiberger, 2009). The highest amounts of Mal d 1 generally are found in the fruits of the 'Golden Delicious' cultivar (Asero et al., 2006; Bolhaar et al., 2005; Gao et al., 2008). Furthermore, different authors have reported that the Mal d 1 content increases significantly during storage (Bolhaar et al., 2005; Matthes & Schmitz-Eiberger, 2009; Sancho et al., 2006). Thus, slowing the maturation process during storage could be a possibility for reducing the Mal d 1 content in apples.

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Ethylene is known to play an important role in the ripening and senescence processes of climacteric fruits, such as apples, and regulates many aspects of these fruits, such as seed germination, root initiation, flower development, fruit ripening and senescence (Lin, Zhong, & Grierson, 2009). Furthermore, ethylene is induced under biotic and abiotic stress conditions (Bleecker & Kende, 2000).

Synthetic cyclopropenes can inhibit ethylene action. One effective inhibitor is 1-methylcyclopropene (1-MCP). 1-MCP is a hydrocarbon compound that is gaseous at standard temperature and pressure. It binds irreversibly to ethylene receptors and blocks them, consequently inhibiting the effects of ethylene. 1-MCP has 10-times the affinity for the ethylene receptor than ethylene itself (Blankenship & Dole, 2003). Recent studies have examined the differences in the impact of 1-MCP on fruits and ornamentals. The results indicate that 1-MCP has the ability to maintain apple quality during storage. Treatment with 1-MCP effectively inhibits ethylene production by repressing the expression of the ethylene biosynthesis genes (Blankenship & Dole, 2003; Rupasinghe, Murr, Paliyath, & Skog, 2000). Thus, 1-MCP is able to irreversibly stop the autocatalytic synthesis of ethylene (Sisler, Dupille, & Serek, 1996). Due to the reduction in ethylene production and respiration rates, the maturation process of the fruits can be decelerated (Baritelle, Hyde, Fellman, & Varith, 2001). Furthermore, 1-MCP treatment inhibits the incidence of postharvest disorders and diseases, such as superficial scald, core flush and greasiness (Fan, Mattheis, & Blankenship, 1999; Rupasinghe et al., 2000).

The relationship between fruit ripening and the synthesis of allergens has been described above, however, little is known about the impact of 1-MCP treatment on Mal d 1 synthesis. The aim of this study was to evaluate the impact of 1-MCP treatment on the apple allergen Mal d 1 during long-term storage. To compare the effect of 1-MCP under different storage conditions, apples were stored in cold- and CA-storage.

2. Material and methods

2.1. Materials

Fruits of the apple cultivars 'Boskoop', 'Elstar', 'Gala', 'Golden Delicious', 'Jonagold', 'Santana' and 'Topaz' were cultivated at the Campus Klein-Altendorf – University of Bonn, Germany. Fruits were harvested in 2010 at the optimal harvest date, according to the Streif-Index (DeLong, Prange, Harrison, Schofield, & DeEll, 1999). They were picked from a defined position so that high variability among the individual apple fruits might be avoided. After harvest, half of the fruits were treated with Smart Fresh™ (Agro Fresh Inc. Spring House, PA, USA). The treatment was conducted by the Agro fresh company which used 1 mg kg⁻¹ 1-MCP at 2 °C for 24 h. After treatment, the fruits were stored for 12, 20, 28 and 36 weeks in a cold chamber at 2 °C at Klein-Altendorf as well as for 12, 20, 28, 36 and 44 weeks in CA (1.5% CO₂, 1.5% O₂, 2 °C) in Karlsruhe, Max-Rubner Institute, Federal Research Centre for Nutrition and Food, Germany—Department for the Safety and Quality of Fruit and Vegetables.

2.2. Preparation of extracts

The extraction of the proteins was carried out according to the method of Björkstén et al. (1980). For the extracts from every cultivar, a mixed sample of five fruits, including peel and pulp, were homogenized with potassium phosphate buffer (2.2833 g L⁻¹ K₂HPO₄, 1.36 g L⁻¹ KH₂PO₄, pH 7) containing 0.0225 g L⁻¹ sodium diethyldithiocarbamate trihydrate, 0.0074 g L⁻¹ ethylenediaminetetraacetic acid and 0.2 g L⁻¹ polyvinylpyrrolidone. Afterward the homogenates were incubated on a shaker for 4 h at room

temperature and, finally, were centrifuged at 4 °C for 15 min at 4000 g. The supernatants were collected and frozen at –80 °C. For each cultivar, extracts were prepared in three replicates.

2.3. Quantification of Mal d 1

The quantification of Mal d 1 was performed using a sandwich enzyme-linked immunosorbent assay (ELISA). Microtiter plates (F96 Maxisorp Nunc-Immuno-Plate, Nunc A/S, Roskilde, Denmark) were coated with 1:1000 sheep anti-mouse Ig AP 302 (Chemicon, Merk Millipore, Darmstadt, Germany) diluted in a phosphate-buffered saline buffer, pH 7 (PBS). After incubation for 1 h at room temperature, the plates were washed (TECAN Columbus Washer) four times with PBS-T (v/v 0.05% Tween 20 in PBS). This washing step was conducted after every incubation step. Afterward a monoclonal antibody specific for Mal d 1, provided by the Paul-Ehrlich Institute (Division of Allergology, Langen, Germany) and diluted in PBS-T (1:100) was incubated at 4 °C overnight. On the next day, the plates were incubated with dilutions of the extracts (1:4–1:512 in PBS-T in dual steps) in triplicate and with dilutions of recombinant Mal d 1 (Biomay AG, Vienna, Austria) (2000–2.4 ng mL⁻¹) as a reference. After incubation for 1 h at room temperature the plates were coated with a polyclonal rabbit serum with specificity for Bet v 1 diluted in PBS-T (1:1000) for 1 h at room temperature. For detection, the plates were incubated for 1 h at room temperature with goat anti-rabbit IgG (Sigma, A0545, Germany) labeled with a peroxidase (diluted 1:20,000 in PBS-T). Finally, the plates were incubated for 20 min with the substrate 3,3',5,5'-tetramethylbenzidine (citrate buffer, pH 3.95). The reaction was stopped with sulfuric acid (25%, v/v). Photometric detection was performed at 450 nm in a microplate reader (Lab-systems Multiskan®). Recombinant Mal d 1 was used as the standard. The total Mal d 1 content was calculated using a four-parametric calibration curve (SigmaPlot 11).

2.4. Statistical analysis

Experimental data were analyzed using the statistic program SPSS 20 for Windows (Munich, Germany). Statistical analysis was performed using a *t*-test for independent samples, with a significance level of $\alpha = 0.05$.

3. Results

Apple fruits of every cultivar were harvested at the optimal harvest date according to the Streif-Index. The Streif-Index mainly determines the maturities of fruit harvests. Tables 1 and 2 show the Streif-Indices of studied apple cultivars depending on the treatment group, storage time and storage conditions. After 12 weeks under cold storage, in most cases, Streif-Indices of fruits treated with 1-MCP were higher than those of untreated control. These results indicate that the 1-MCP-treated fruits had higher firmness and titratable acidity, as well as a slower loss of starch compared to the untreated fruits.

Mal d 1 contents were measured at the harvest and at 12, 20, 28, 36 and 44 weeks after the harvest. The ELISA-analysis showed that Mal d 1 content of the different apple cultivars differed significantly. The lowest Mal d 1 contents were observed in the fruits of the cultivar 'Santana' (Table 3). Nevertheless, 'Santana' has a short storage life. It was not possible to store the fruits longer than 12 weeks in a CA and 20 weeks in a cold chamber. Thus, there were less data to compare the Mal d 1 contents of treated and untreated fruits with the other cultivars. The highest Mal d 1 content was found in the fruits of the cultivar 'Golden Delicious,' followed by 'Gala' and 'Jonagold' (Fig. 1).

Table 1
Streif-Indices of the different apple cultivars stored in a cold chamber.^a

	T	Harvest	12 weeks	20 weeks	28 weeks	36 weeks
Boskoop	–	0.19a	0.047a	0.035a	0.033a	0.029a
	+	0.19a	0.05a	0.036a	0.032a	0.029a
Elstar	–	0.25a	0.50a	0.027b	0.028a	0.026a
	+	0.25a	0.048a	0.036a	0.030a	0.027a
Gala	–	0.26a	0.059b	0.044b	0.044b	0.047b
	+	0.26a	0.074a	0.059a	0.060a	0.056a
Golden Delicious	–	0.1a	0.054a	0.032a	0.033a	0.030a
	+	0.1a	0.050a	0.034a	0.033a	0.026a
Jonagold	–	0.06a	0.048b	0.033a	0.031a	0.030a
	+	0.06a	0.058a	0.039a	0.030a	0.031a
Santana	–	0.27a	0.048b	n.d.	n.d.	n.d.
	+	0.27a	0.061a	n.d.	n.d.	n.d.
Topaz	–	0.14a	0.064a	0.045a	0.083a	0.041a
	+	0.14a	0.057b	0.059a	0.044a	0.040a

^a T = treatment, – “without 1-MCP,” + “with 1-MCP”, different letters indicate significant differences between the treatments (Students *t*-test, $p \leq 0.05$); mean, $n = 6$.

The Mal d 1 content increased in all cultivars during storage, compared to the Mal d 1 content at the harvest. In every cultivar we noted at least one date where the Mal d 1 content slightly decreased before increasing directly afterward. This could be noticed, for example, in the treated fruits of the cultivar ‘Boskoop’ after 20 weeks stored in a CA as well as in the treated fruits of ‘Topaz,’ after 28 weeks of being stored in a cold chamber (Fig. 1A and F). After this decrease, the Mal d 1 content increased over the next few weeks. Another decrease was observed after 36 weeks of cold storage or 44 weeks in a CA. Due to the initial onset of senescence, the fruits were no longer acceptable for sale at that time.

With the exception of the cultivar ‘Boskoop,’ the Mal d 1 content of all variants was lower in fruits treated with 1-MCP compared to that in the untreated (Fig. 1). For ‘Boskoop’ fruits (Fig. 1A), we found after 12 weeks in a cold chamber and in a CA as well as after 28 weeks in a CA there were higher Mal d 1 contents in the treated variants than in the untreated samples. After 36 weeks of storage in the cold chamber, the Mal d 1 content was very low in both variants. After 44 weeks in a CA, the Mal d 1 content decreased significantly.

The impact of 1-MCP treatment on the Mal d 1 content in apples seemed to depend on the apple cultivar and type of storage. There was no large difference between the treated and untreated fruits of the cultivar ‘Boskoop’. In contrast, the Mal d 1 contents of the 1-MCP treated ‘Elstar’ fruits stored under cold conditions were up to 3.5-times lower than the untreated ones (Fig. 1B). Similar results

Table 2
Streif-Indices of the different apple cultivars stored under controlled atmosphere.^a

	T	Harvest	12 weeks	20 weeks	28 weeks	36 weeks	44 weeks
Boskoop	–	0.19a	0.059a	0.057a	0.043a	0.041a	0.042a
	+	0.19a	0.058a	0.045b	0.042a	0.039a	0.045a
Elstar	–	0.25a	0.072a	0.046a	0.044a	0.033a	0.041a
	+	0.25a	0.068a	0.044a	0.040a	0.039a	0.042a
Gala	–	0.26a	0.079a	0.062a	0.062a	0.054a	0.063a
	+	0.26a	0.078a	0.067a	0.063a	0.061a	0.070a
Golden Delicious	–	0.1a	0.061a	0.044a	0.035b	0.035a	0.035a
	+	0.1a	0.061a	0.046a	0.049a	0.044a	0.043a
Jonagold	–	0.06a	0.064b	0.055a	0.045a	0.043a	0.040b
	+	0.06a	0.076a	0.055a	0.054a	0.055a	0.057a
Santana	–	0.27a	n.d.	n.d.	n.d.	n.d.	n.d.
	+	0.27a	n.d.	n.d.	n.d.	n.d.	n.d.
Topaz	–	0.14a	0.087a	0.061a	0.058a	0.063a	0.056a
	+	0.14a	0.062b	0.059a	0.062a	0.056a	0.052a

^a T = treatment, – “without 1-MCP,” + “with 1-MCP”, different letters indicate significant differences between the treatments (Students *t*-test, $p \leq 0.05$); mean, $n = 6$.

Table 3
Mal d 1 contents in $\mu\text{g g}^{-1}$ FW of ‘Santana’ apple fruits, mean, $n = 3$.

	Harvest	After 12 weeks		After 20 weeks	
		Cold chamber	CA	Cold chamber	CA
Without 1-MCP	0.291	1.752	1.518	n.d.	n.d.
With 1-MCP	0.249	n.d.	n.d.	0.855	n.d.

were established for fruits of ‘Jonagold’, ‘Gala’ and ‘Golden Delicious’. The Mal d 1 content of ‘Gala’ fruits stored for 20 weeks in air was 4.7-times higher in untreated fruits than in the 1-MCP fruits. Additionally, treated fruits stored 28 weeks in a CA showed a 4.3-fold lower Mal d 1 content than the control fruits (Fig. 1C). The greatest effect of the 1-MCP treatment was investigated within the cultivar ‘Golden Delicious,’ in which the Mal d 1 content was up to 6.8-times lower in the 1-MCP treated fruits than in the untreated control fruits. However, these great differences were only detectable in the fruits stored in CA. For the fruits stored under cold conditions, the impact of 1-MCP was marginal (Fig. 1D).

Regarding storage conditions, there were hardly any differences in the Mal d 1 contents for the treated fruits of the cultivars ‘Gala’ and ‘Topaz’. Significantly higher amounts of Mal d 1 were measured in treated fruits of the cultivars ‘Boskoop’ and ‘Elstar’ stored in a CA compared to fruits stored in a cold chamber. Finally, the Mal d 1 contents of the treated fruits stored in a CA of the cultivars ‘Golden Delicious’ and ‘Jonagold’ were considerably lower than the Mal d 1 level of the fruits stored in a cold chamber.

4. Discussion

In this study, apples of the ‘Golden Delicious’ cultivar had the highest amounts of Mal d 1. The second highest Mal d 1 content in the examined varieties was found in the fruits of the ‘Gala’ cultivar. The lowest Mal d 1 content in our study was determined to be in the fruits of the ‘Topaz’ cultivar. A low Mal d 1 level was also found for the fruits of the ‘Santana’ cultivar. These results are consistent with the findings of previous studies, which have shown that the Mal d 1 contents of apples depend on the cultivar (Kiewning & Schmitz-Eiberger, 2012; Matthes & Schmitz-Eiberger, 2009; Schmitz-Eiberger & Matthes, 2011).

Furthermore, we noted, that Mal d 1 content increased during senescence. The increase of Mal d 1 content during storage has also been shown by other authors (Matthes & Schmitz-Eiberger, 2009; Sancho et al., 2006; Schmitz-Eiberger & Matthes, 2011), but only for fruits stored between 3 and 5 months. In this study, Mal d 1 synthesis was observed during long-term storage up to 44 weeks. At the harvest date, only low levels of Mal d 1 were detectable in some variants, such as ‘Boskoop,’ in the treatment group, or ‘Elstar,’ in both the treatment group and the control group. In the latter variants, the Mal d 1 content was under the detection limit. From harvest to the 28th week of storage, the Mal d 1 content increased continuously in all variants. After 36 weeks of storage, a decrease in the Mal d 1 levels could be observed for ‘Boskoop’ (cold chamber, both variants), ‘Elstar’ (CA, both variants), ‘Gala’ (CA, control), ‘Golden Delicious’ (CA, control) and ‘Topaz’ (cold chamber, treated). For fruits stored in the cold chamber, this decrease could be explained by advanced senescence processes. For example, the fruits of the cultivar ‘Boskoop’ had a very low firmness (data not shown) and were no longer consumable. The senescence progress is characterized by the degradation and loss of proteins (Huffaker, 1990). Therefore, the decrease of Mal d 1 in ‘Boskoop’ fruits after 36 weeks of storage in the cold chamber and after 44 weeks in a CA could be explained by advanced senescence. Another explanation

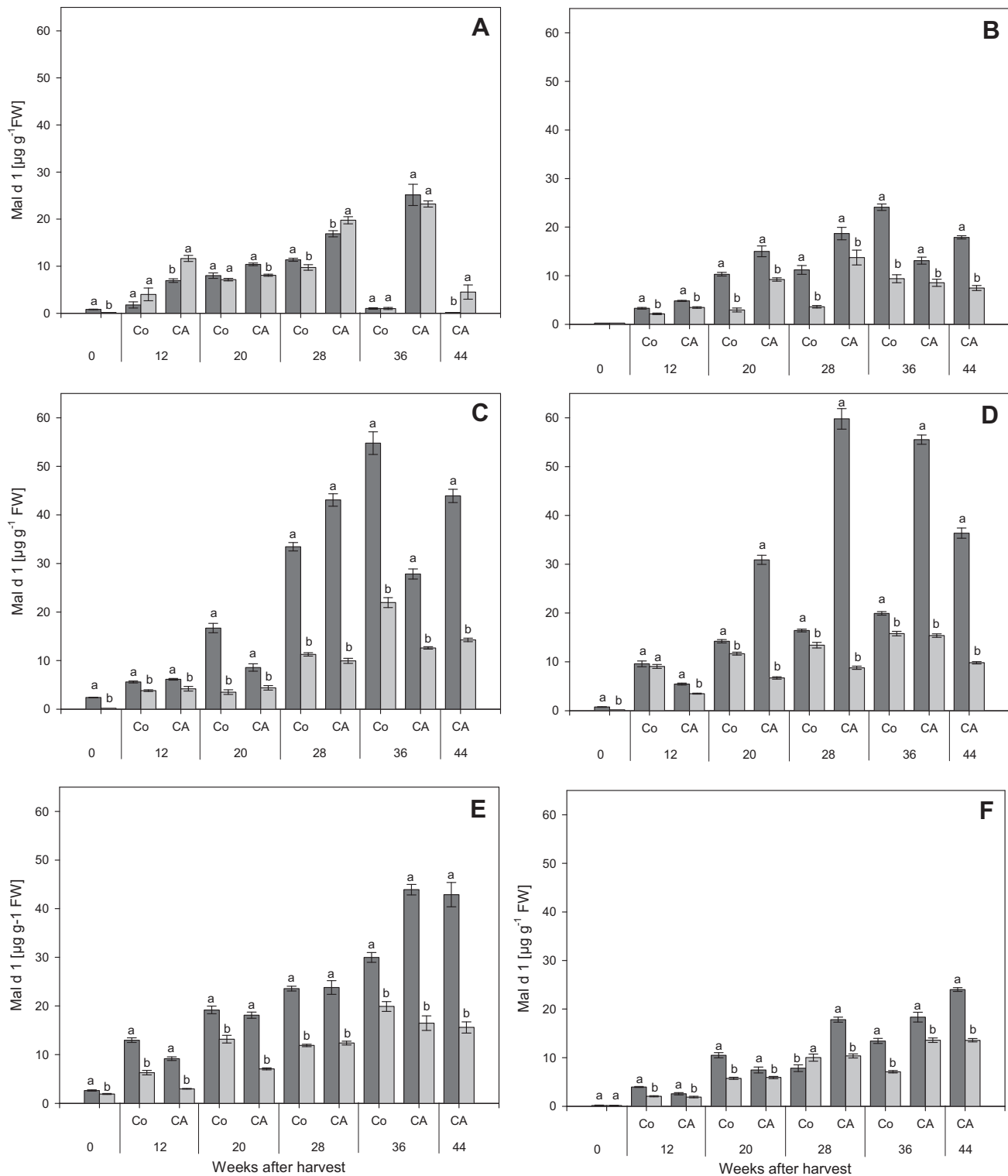


Fig. 1. Mal d 1 contents of 'Boskoop' (A), 'Elstar' (B), 'Gala' (C), 'Golden Delicious' (D), 'Jonagold' (E) and 'Topaz' (F) in ng g⁻¹ FW depending on storage time, storage conditions and 1-MCP treatment. Dark gray bars: without 1-MCP, light gray bars: with 1-MCP; mean $\pm$ SE, $n = 3$.

for the decreasing contents of Mal d 1 could be a down-regulation at the translational level. Sancho et al. (2006) found that Mal d 1 expression decreased after 3 months of storage time, followed by another increase after 5 months of storage time. They hypothesized a feedback mechanism in which Mal d 1 regulates its own gene expression.

There have been different studies about the impact of storage conditions on Mal d 1 synthesis and the changes in the Mal d 1 content during storage. Moreover, many experiments have been conducted to analyze the effect of postharvest treatment with 1-MCP on apples. However, there are less data on the impact of 1-MCP on the Mal d 1 content of apples. This is the first published

study that shows the results of the influence of 1-MCP on the Mal d 1 content in seven different apple cultivars treated with 1-MCP during long-term storage in comparison with untreated control fruits. The results show that the Mal d 1 content of nearly all cultivars was reduced by 1-MCP, compared to the controls, at the same sampling time. The sole exception is 'Boskoop', for which the results were very different. In some cases, the Mal d 1 content in control fruits was significantly higher than in the treated ones (e.g., cold chamber 28 weeks or CA 20 weeks); in other cases, the amount of Mal d 1 in the treated fruits was higher compared to control fruits (e.g., CA 12, 28 and 44 weeks). Due to this, the impact of 1-MCP treatment on the allergenicity of the fruits of the cultivar 'Boskoop' is ambiguous. Nevertheless, 'Boskoop' is a cultivar with a low Mal d 1 content that could still be tolerated by patients who were allergic to apples. On the other hand, the results of the Mal d 1 analysis for the other apple cultivars in this study showed lower Mal d 1 amounts in 1-MCP-treated fruits compared to control fruits. In particular, the differences in the Mal d 1 contents of the treated and control fruits of the cultivars 'Gala' and 'Jonagold' were substantial. Furthermore, the Mal d 1 synthesis of the treated fruits of the cultivar 'Golden Delicious' could be clearly reduced during storage, but only when stored in a CA. The fruits stored in the cold chamber also had lower Mal d 1 contents when treated with 1-MCP, but the differences between the treated and control fruits were not as high as in those stored in a CA. For 'Elstar' fruits the differences in the Mal d 1 contents between treated and control fruits were higher when the fruits were stored in a cold chamber. It is worth mentioning that cultivars with a high Mal d 1 content (for example, 'Gala') showed greater differences between the treated and the control groups than the cultivars with lower Mal d 1 contents did (for example, 'Topaz'). These results indicate that the impact of 1-MCP treatment on the allergenicity of apples depends on the cultivar and the storage conditions. Furthermore, it seems that treatment with 1-MCP affects cultivars with a high Mal d 1 content more than those cultivars that already have a low Mal d 1 level. Unfortunately, there are no data in the literature to compare our results.

Our results show that the synthesis of Mal d 1 in apples could be reduced by treating with 1-MCP. This effect arises from the fact that the treatment with 1-MCP slows the ripening, and senescence processes and increases the postharvest life (Asif, Pathak, Solomos, & Trivedi, 2009; Rupasinghe et al., 2000). Furthermore, it is well known that Mal d 1 is enhanced by fruit ripening (Atkinson, Perry, Matsui, Ross, & Macrae, 1996; Sancho et al., 2006). The deceleration of ripening and senescence in treated fruits was shown by Streif-Indices. Fruits treated with 1-MCP had generally higher Streif-Indices compared to control fruits, indicating a minorly advanced ripening process. Yang, Song, Campell-Palmer, Walker, and Zhang (2012) analyzed the effect of ethylene treatment and 1-MCP treatment, respectively, on the expression of Mal d 1 in the fruits of the cultivar 'Golden Delicious' during a storage time of 22 days at room-temperature (20 °C). They discovered that the expression of Mal d 1 was up-regulated when fruits were treated with ethylene. In contrast, treatment with 1-MCP caused a down-regulation of Mal d 1 expression, which indicates that the expression of Mal d 1 is correlated with the process of ripening (Yang et al., 2012). However, we analyzed seven different apple cultivars, with different Mal d 1 contents. They were stored over a period of 44 weeks, not for only 22 days. Our results demonstrate that this described correlation also exist on the protein-level for different cultivars in long-term storage. Accordingly, 1-MCP seems to reduce the process of ripening and senescence so that the treatment affects the Mal d 1 content of fruits positively.

In conclusion, we have demonstrated, for the first time, that the application of 1-MCP can reduce Mal d 1 synthesis in different cultivars effectively during long-term storage. The fruits of the

treatment groups had significant lower Mal d 1 contents for all sampling dates, with the exception of 'Boskoop'. We recommend the treatment with 1-MCP to reduce allergenicity and to make apple consumption for allergic people more tolerable.

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