RESPONSE OF 'GOLDEN DELICIOUS' APPLES TO POSTHARVEST APPLICATION OF 1-METHYLCYCLOPROPENE (1-MCP) IN CONDITIONS OF NORMAL AND CONTROLLED ATMOSPHERE

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(Received September 29, 2010/Accepted December 6, 2010)

A B S T R A C T

The investigation aimed at assessing the quality and storability of 'Golden Delicious' apples. The experiment was performed in two storage seasons (2006/2007 and 2007/2008). Fruit treated with 1-methylcyclopropene (1-MCP) and untreated fruit were stored at 1°C in normal atmosphere (NA), and in three combinations of controlled atmosphere (CA) with the gaseous composition of CO_2:O_2 – 1.5:1.5; 3.0:3.0; and 5.0:3.0. Fruit quality was assessed after 2, 4 and 6 months of storage; both immediately after storage and after 7 days of being kept at room temperature. In the experiment a drastic inhibition of the intensity of ethylene production in apples treated with 1-MCP was noted, regardless of the conditions and the length of storage time. Treating fruit with 1-MCP as well as their storage in controlled atmosphere conditions resulted in higher flesh firmness of apples, both directly after storage and after 7 days at room temperature. In the first 4 months of storage the effect of 1-MCP treatment on fruit quality was clearly more visible in NA than in CA.

With the prolongation of storage time a constant decrease of titratable acidity in apples was observed. The rate of this process was significantly slower in the case of fruits stored in controlled atmosphere than in normal atmosphere. The differences between these storage technologies were even more visible after the shelf life than directly after storage. The post-harvest treatment of apples with 1-MCP, substantially limited the decrease of apple titratable acidity, especially under the NA conditions.

Fungal diseases (grey mould rot, bull's eye rot and blue mould rot) occurred mostly on fruits stored in normal atmosphere. Treating apples with 1-MCP usually decreased the percentage of rotten fruits both directly after storage and after the shelf life period.

Key words: apples, storage, firmness, titratable acidity, 1-MCP

INTRODUCTION

In the age of globalization, consumers expect that their favourite apple cultivars will be accessible on the market nearly the entire year. The most popular among consumers are apples with firm and juicy flesh (Harker et al., 2008). In order to meet those expectations, the produced fruit should be of the highest quality and should be delivered to the consumer in an unchanged or only slightly changed state. On the basis of consumer tests, Hoehn et al. (2003) decided that the minimal firmness value for apples of 'Golden Delicious' cv. should amount to 44 N. On the other hand, the firmness of 'Gala', which is counted among firm cultivars, should amount to about 56 N. Preserving the high quality of fruits for a long time is possible by creating optimum storage conditions, i.e. lowering the concentration of oxygen and increasing the carbon dioxide level. Such storage conditions significantly slow down the metabolic processes, including ethylene production. Due to this process apples do not excessively lose either firmness or taste (Konopacka and Płocharski, 2004). However, despite the fact that the conditions of controlled atmosphere in storage inhibit the ethylene production, and thus the ripening of apples, it is still difficult to preserve high apple quality after a few months of storage when the autocatalytic ethylene production begins. For a long time, in the world, a search was underway to find a means for delaying the appearance of climacterium. Lately, there appeared a possibility of inhibiting ethylene production in fruit and thus the later initiation of fruit ripening by the post-harvest treatment of apples with 1-methylcyclopropene (1-MCP). This compound enters into the interaction with ethylene receptors to which it has a ten-fold higher affinity than ethylene. As a result 1-MCP effectively stops ethylene synthesis (Sisler and Serek, 2003). Apart from preserving higher flesh firmness, 1-MCP also delays the decrease in fruit titratable acidity (Zanella, 2003).

MATERIAL AND METHODS

The investigation was performed on 'Golden Delicious' apples in two storage seasons (2006/2007 and 2007/2008). The harvest date was determined on the basis of a starch test and the induced ethylene method (stages of apple maturity at harvest are presented in Table 1). Fruits were stored at 1 ˚C in normal atmosphere and in three gaseous compositions of controlled atmosphere (CA) – CO_2 : O_2 – 1.5:1.5; 3.0:3.0; and 5.0:3.0. Directly after harvest, half of the apples from each combination were treated with the SmartFresh preparation containing 1-MCP. In order to do this, apples were put for 24 h into hermetic containers in the presence of 1-MCP (0.65 $\mu l \cdot l^{-1}$). Fruit quality was assessed immediately after 2, 4 and 6 months of storage, both directly and after keeping them at room temperature (20 ℃) for 7 days. At each date the following measurements were taken: the intensity of

Table 1. Traits of apple physiological status directly after harvest

Internal fruit quality traits	Year	
	2006	2007
Internal ethylene content (μl C_2H_4 l^{-1})	2.01	1.12
Firmness [N]	79.8	74.6
Soluble solids content [%]	14.6	16.2
Titratable acidity [% of malic acid]	0.51	0.70
Streif's index (IS)	0.067	0.063
Starch test (1-10)	8.1	7.2

ethylene production (with the help of gas chromatograph by Hewlett Packard type HP 5890 II, equipped with a column and flame ionization detector), flesh firmness (using the Instron penetrometer with a tip of the diameter of 11 mm) and titratable acidity (by titration 0.1 N NaOH to pH 8.1, expressed as malic acid equivalents). The evaluation of apple storability was also determined according to the occurrence of diseases and physiological disorders.

The investigation results of the quality and storability of 'Golden Delicious' apples were subjected to three-factor analysis of variance. The investigated factors included: storage period, postharvest treatment of apples with 1-MCP, and the conditions of apple storage. The assessment of the significance of experimental factors was performed on the basis of the F-Fisher-Snedecor test. To compare means, the Tukey's test was applied with the significance level $\alpha = 0.05$. However, while assessing the significance of the 1-MCP treatment effect on apples, two reliability levels were used: $\alpha = 0.05$ (marked with *) and $\alpha = 0.01$ (marked with **).

RESULTS

The experiment revealed a drastic inhibition of the intensity of ethylene production by apples of the 'Golden Delicious' cultivar treated with 1-MCP, during the whole period of their storage. In the first storage season, apples treated with 1-MCP slightly increased ethylene production after only 6 months of storage in normal atmosphere (results are not presented). However, in the second year of the investigations, fruits kept in the same conditions started ethylene production after 4 months of storage (Fig. 1). Apples of 'Golden Delicious' cultivar turned out to be very susceptible to the 1-MCP action – in CA conditions, for the entire period of storage, they produced less than 1 μl $C_2H_4 \cdot kg^{-1} \cdot h^{-1}$. On the other hand, apples untreated with 1-MCP and kept in the same conditions

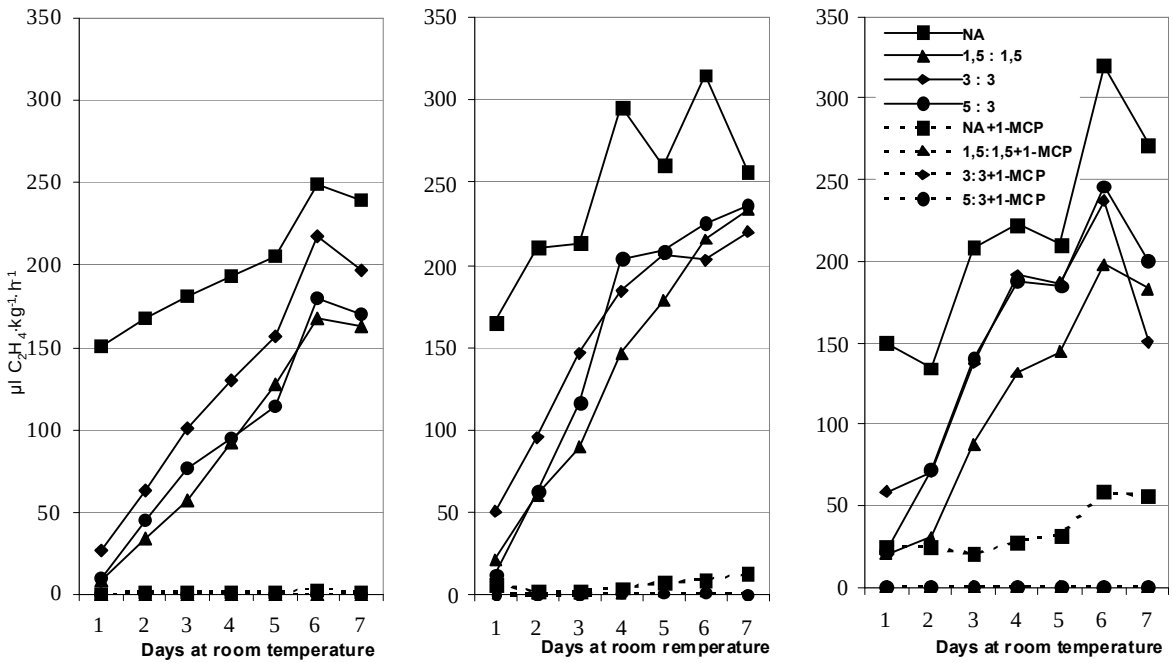

Figure 1. Effect of 1-MCP and storage conditions on ethylene production after (from the left) 2, 4 and 6 months of storage, 2007/2008

produced over 100 µl $C_2H_4 \cdot kg^{-1} \cdot h^{-1}$. It is worth mentioning that apples treated with 1-MCP and stored in NA produced less ethylene than apples untreated with 1-MCP and stored in NA and CA. The least ethylene production, among apples untreated with 1-MCP, was observed in fruits stored in atmosphere containing 1.5% of oxygen as well as carbon dioxide. It was noted in the present experiment, that apples whose ethylene production was more intensive were also characterized by less firmness and titratable acidity.

On the basis of firmness measurements, higher firmness was obtained directly after storage and after 7 days of keeping apples at room temperature, by treating fruits with 1-MCP and storing them in a controlled atmosphere. It can be assumed that the storage of 'Golden Delicious' apples in NA conditions without being treated earlier with 1-MCP, should be completed before

Table 2. The effect of 1-MCP in interaction with conditions and time of storage, on the firmness of apples (N) determined directly after storage; 'Golden Delicious', 2006/2007

1-MCP-treatments	Storage conditions (%CO_2 : %O_2)			
	0:21 (NA)	1.5:1.5	3:3	5:3
After 2 months of storage				
Non-treated with 1-MCP	B 44.5 a	B 71.1 b	B 67.7 b	C 67.7 b
Treated with 1-MCP	A 73.8 a	A 79.3 a	A 76.5 a	A 78.3 a
1-MCP effect	29.3**	8.2**	8.8**	10.6**
After 4 months of storage				
Non-treated with 1-MCP	A 40.6 a	A 58.5 b	A 55.0 b	B 57.0 b
Treated with 1-MCP	A 68.5 a	A 76.3 b	A 75.5 b	A 75.8 b
1-MCP effect	27.9**	17.8**	20.5**	18.8**
After 6 months of storage				
Non-treated with 1-MCP	A 38.7 a	A 57.1 c	A 50.9 b	A 50.6 b
Treated with 1-MCP	A 66.0 a	A 75.1 b	A 74.9 b	A 75.4 b
1-MCP effect	27.3**	18.0**	24.0**	24.8**

Explanation: small letters in the line allow the comparison of the effect of storage conditions; capital letters in a column mark the effect of the storage period within the same 1-MCP combination; *effect proved at $\alpha = 0.05$; **effect proved at $\alpha = 0.01$; ns – effect not significant statistically

the end of 4 months. In those conditions, fruit firmness determined directly after 4 months of storage, did not exceed 45 N, thus it was below the threshold of consumer acceptability (Tab. 2 and 3). Additionally the value of that index decreased when apples were kept at room temperature (Tab. 4 and 5). Flesh softening progression, along the climacteric increase with ethylene production in normal atmosphere, after subjecting apples to the 1-MCP treatment, could be delayed for at least two months. Results showed that fruits stored for 6 months in normal atmosphere after the 1-MCP treatment had similar firmness as apples stored in controlled atmosphere and untreated with 1-MCP. Apart from the above results, in apples stored up to 4 months in normal atmosphere, the effect of the 1-MCP treatment was clearly greater than in CA.

Table 3. The effect of 1-MCP in interaction with conditions and time of storage, on the firmness of apples (N) determined directly after storage; 'Golden Delicious', 2007/2008

1-MCP-treatments	Storage conditions (%CO_2 : %O_2)			
	0:21 (NA)	1.5:1.5	3:3	5:3
After 2 months of storage				
Non-treated with 1-MCP	B 47.5 a	C 65.6 bc	C 67.7 c	B 62.1 b
Treated with 1-MCP	B 61.4 a	A 71.9 b	A 70.7 b	A 69.8 b
1-MCP effect	13.9**	6.3**	3.0 ns	7.7**
After 4 months of storage				
Non-treated with 1-MCP	A 42.4 a	B 55.6 bc	B 52.7 b	B 59.3 c
Treated with 1-MCP	A 51.1 a	A 72.6 b	A 70.6 b	A 69.7 b
1-MCP effect	8.7 **	17.0 **	17.9 **	10.4 **
After 6 months of storage				
Non-treated with 1-MCP	A 42.7 a	A 48.5 b	A 48.6 b	A 51.3 b
Treated with 1-MCP	A 49.7 a	A 71.6 c	A 66.7 b	A 68.2 bc
1-MCP effect	7.0**	21.1**	18.1**	16.9**

Explanation, see Table 1

Table 4. The effect of 1-MCP in interaction with the condition and time of storage, on the firmness of apples (N) determined after shelf-life conditions; 'Golden Delicious', 2006/2007

1-MCP-treatments	Storage conditions (%CO_2 : %O_2)			
	0:21 (NA)	1.5:1.5	3:3	5:3
After 2 months of storage				
Non-treated with 1-MCP	B 45.5 a	B 56.4 b	B 58.5 b	B 55.3 b
Treated with 1-MCP	B 70.0 a	A 74.7 b	A 75.2 b	A 74.5 ab
1-MCP effect	24.5**	18.3**	16.7**	19.2**
After 4 months of storage				
Non-treated with 1-MCP	A 40.9 a	A 51.0 b	A 49.2 b	B 51.6 b
Treated with 1-MCP	A 66.2 a	A 74.5 b	A 74.3 b	A 74.2 b
1-MCP effect	25.3**	23.5**	25.1**	22.6**
After 6 months of storage				
Non-treated with 1-MCP	A 37.0 a	A 46.6 b	A 44.4 b	A 46.2 b
Treated with 1-MCP	A 65.3 a	A 74.3 b	A 73.2 b	A 74.0 b
1-MCP effect	28.3**	27.7**	28.8**	27.8**

Explanation, see Table 1

On the other hand, it may be noted that fruits treated with 1-MCP and stored in CA had similar firmness, despite the time of storage. In the case of a combination without 1-MCP, apples stored in normal atmosphere always had significantly lower firmness compared to apples stored in CA. On the other hand, in 2006/2007, in the conditions of CA the differences between combinations were noted only after 6 months of storage (Tab. 2). In the 2007/2008 season, some differences between CA conditions were also noted, but those differences were not the clean influence of atmosphere composition on fruit firmness (Tab. 3).

In the experiment on the quality of 'Golden Delicious' apples, a decrease of the titratable acidity with the prolongation of the storage time was observed. However, the rate of that process was significantly slower in the case of fruits stored in controlled atmosphere than normal atmosphere. The differences between those two storage technologies were even more visible after 7 days of simulated shelf life. After 6 months

Table 5. The effect of 1-MCP in interaction with the condition and time of storage, on the firmness of apples (N) determined after simulated shelf-life conditions; 'Golden Delicious', 2007/2008

1-MCP-treatments	Storage conditions (%CO_2 : %O_2)			
	0:21 (NA)	1.5:1.5	3:3	5:3
After 2 months of storage				
Non-treated with 1-MCP	B 47.8 a	B 56.0 b	B 57.2 b	B 53.3 b
Treated with 1-MCP	C 61.3 a	A 72.6 b	A 70.1 b	A 70.1 b
1-MCP effect	13.5**	16.6**	12.9**	16.8**
After 4 months of storage				
Non-treated with 1-MCP	A 41.8 a	A 49.8 b	A 49.2 b	B 50.8 b
Treated with 1-MCP	B 52.1 a	A 70.3 c	A 69.7 bc	A 66.1 b
1-MCP effect	10.3**	20.5**	20.5**	15.3**
After 6 months of storage				
Non-treated with 1-MCP	A 40.1 a	A 48.2 b	A 46.1 b	A 47.6 b
Treated with 1-MCP	A 44.4 a	A 70.8 c	A 69.9 c	A 65.6 b
1-MCP effect	4.3 *	22.6 **	23.8 **	18.0 **

Explanation, see Table 1

of storage in NA the titratable acidity of apples directly after storage amounted to, 0.16 and 0.26 %, depending on the season (Tab. 6 and 7). The postharvest treatment of apples with 1-MCP, significantly limited the drop in titratable acidity content. At the same time and in the same conditions of storage, the titratable acidity of apples treated with 1-MCP was much higher and amounted to 0.33 in 2006 and 0.48% in 2007. The effect of apple storage in NA, after the earlier treatment with 1-MCP and after 7 days of being kept at room temperature, was often very similar as in CA, without the use of 1-MCP (Tab. 8 and 9). However, the drop of titratable acidity was most effectively inhibited in the case of apples stored in CA after their treatment with 1-MCP. After 6 months of fruit storage according to that technology and depending on the atmosphere composition, titratable acidity of apples varied from 0.37 to 0.40% in the season 2006/2007 and from 0.49 to 0.56% in the season 2007/2008. In many cases titratable acidity was significantly higher compared to

Table 6. The effect of 1-MCP in interaction with the conditions and time of storage, on the titratable acidity determined directly after fruit storage; 'Golden Delicious', 2006/2007

1-MCP-treatments	Storage conditions (%CO_2 : %O_2)			
	0:21 (NA)	1.5:1.5	3:3	5:3
After 2 months of storage				
Non-treated with 1-MCP	C 0.40 a	B 0.46 a	C 0.46 a	C 0.47 a
Treated with 1-MCP	B 0.51 b	B 0.46 ab	A 0.46 ab	A 0.42 a
1-MCP effect	0.11**	0.00 ns	0.00 ns	-0.05 ns
After 4 months of storage				
Non-treated with 1-MCP	B 0.25 a	B 0.42 b	B 0.37 b	B 0.38 b
Treated with 1-MCP	B 0.47 a	B 0.44 a	A 0.41 a	A 0.41 a
1-MCP effect	0.22**	0.02 ns	0.04 ns	0.03 ns
After 6 months of storage				
Non-treated with 1-MCP	A 0.16 a	A 0.30 b	A 0.31 b	A 0.31 b
Treated with 1-MCP	A 0.33 a	A 0.37 a	A 0.40 a	A 0.38 a
1-MCP effect	0.17**	0.07*	0.09**	0.07*

Explanation, see Table 1

Table 7. The effect of 1-MCP in interaction with the conditions and time of storage, on the titratable acidity determined directly after fruit storage; 'Golden Delicious', 2007/2008

1-MCP-treatments	Storage conditions (%CO_2 : %O_2)			
	0:21 (NA)	1.5:1.5	3:3	5:3
After 2 months of storage				
Non-treated with 1-MCP	C 0.54 a	B 0.61 a	B 0.54 a	B 0.58 ab
Treated with 1-MCP	C 0.60 a	B 0.60 a	B 0.62 a	B 0.61 a
1-MCP effect	0.06*	-0.01 ns	0.08 **	0.03 ns
After 4 months of storage				
Non-treated with 1-MCP	B 0.37 a	A 0.53 b	B 0.53 b	B 0.54 b
Treated with 1-MCP	B 0.52 a	B 0.56 a	A 0.55 a	B 0.56 a
1-MCP effect	0.15**	0.03 ns	0.02 ns	0.02 ns
After 6 months of storage				
Non-treated with 1-MCP	A 0.26 a	A 0.54 c	A 0.47 b	A 0.47 b
Treated with 1-MCP	A 0.48 a	A 0.51 a	A 0.56 b	A 0.49 a
1-MCP effect	0.22**	-0.03 ns	0.09**	0.02 ns

Explanation, see Table 1

Table 8. The effect of 1-MCP in interaction with the conditions and time of storage, on the titratable acidity determined after 7 days of simulated shelf life; 'Golden Delicious', 2006/2007

1-MCP-treatments	Storage conditions (%CO_2 : %O_2)			
	0:21 (NA)	1.5:1.5	3:3	5:3
After 2 months of storage				
Non-treated with 1-MCP	B 0.29 a	B 0.40 b	A 0.33 ab	A 0.36 b
Treated with 1-MCP	B 0.45 a	B 0.45 a	C 0.44 a	B 0.41 a
1-MCP effect	0.16**	0.05*	0.11**	0.05*
After 4 months of storage				
Non-treated with 1-MCP	B 0.25 a	A 0.33 b	A 0.31 ab	A 0.33 b
Treated with 1-MCP	B 0.43 b	A 0.36 a	B 0.38 ab	B 0.40 ab
1-MCP effect	0.18**	0.03 ns	0.07**	0.07**
After 6 months of storage				
Non-treated with 1-MCP	A 0.16 a	A 0.29 b	A 0.27 b	B 0.31 b
Treated with 1-MCP	A 0.30 a	A 0.33 a	A 0.32 a	A 0.30a
1-MCP effect	0.14**	0.04 ns	0.05*	0.01 ns

Explanation, see Table 1

Table 9. The effect of 1-MCP in interaction with the conditions and time of storage, on the titratable acidity determined after 7 days of simulated shelf life; 'Golden Delicious', 2007/2008

1-MCP-treatments	Storage conditions (%CO_2 : %O_2)			
	0:21 (NA)	1.5:1.5	3:3	5:3
After 2 months of storage				
Non-treated with 1-MCP	C 0.46 a	B 0.54 b	B 0.49 ab	B 0.53 b
Treated with 1-MCP	C 0.59 a	B 0.59 a	B 0.62 a	B 0.59 a
1-MCP effect	0.13**	0.05*	0.13**	0.06**
After 4 months of storage				
Non-treated with 1-MCP	B 0.33 a	A 0.47 b	A 0.54 b	A 0.44 b
Treated with 1-MCP	B 0.50 a	A 0.54 ab	A 0.54 ab	B 0.55 b
1-MCP effect	0.17**	0.07**	0.0 ns	0.11**
After 6 months of storage				
Non-treated with 1-MCP	A 0.24 a	A 0.46 c	A 0.43 bc	A 0.41 b
Treated with 1-MCP	A 0.42 a	A 0.55 c	A 0.59 c	A 0.48 b
1-MCP effect	0.18**	0.09**	0.16**	0.07**

Explanation, see Table 1

apples untreated with 1-MCP, which was even more clear in the case of apples kept at room temperature. However, no bigger differences were noted in the titratable acidity of apples after apples were stored in various CA compositions. The value of that quality trait was also subject to some fluctuation on the successive assessment dates.

In both storage seasons, a small percent of apple losses were caused by fungal decay. The losses were mainly due to grey mould rot, bull's eye rot and blue mould rot. Fungal decay mostly appeared in apples stored in NA. Treating apples with 1-MCP usually decreased the per cent of rotten fruits (results not presented).

DISCUSSION

Storage quality of the majority of apple cultivars decreases with the increase of ethylene production – phytohormone inevitably connected with the process of fruit senescence. In the present experiment, 'Golden Delicious' apples after storage in controlled atmosphere produced much less ethylene than fruits stored in NA. Our results, thus confirmed the reports that the decrease of temperature and O_2 concentration and the increase of CO_2 concentration in the atmosphere surrounding fruits, limit the activity of enzymes responsible for respiration and also inhibit the ethylene production. It is known that the decrease of oxygen concentration decreases the activity of ACC oxidase responsible for oxidation of 1-aminocyclopropano-1-carboxylic acid to ethylene. Even lower ethylene production was characteristic for apples treated with 1-MCP, no matter what the storage technology. On all assessment dates (in both storage technologies), fruits treated with 1-MCP were characterized by a very low ethylene production. Similar dependencies were also observed by other researchers (Curry, 2008: Asif et al., 2009). In the present experiment, better results were obtained in the case of fruits which were treated with 1-MCP and stored in CA rather than in NA. Apples which more intensively produced ethylene were also characterized by less firmness and titratable acidity. The fact that an increase in ethylene production leads to the worsening of the overall apple quality, especially fruit flesh texture, is also stressed in literature. The results of the investigations reveal that apple softening in normal atmosphere could be delayed by 2-4 months whereas in CA could be nearly totally inhibited by at least 6 months in the conditions of the 1-MCP postharvest treatment. The obtained results confirm the opinion of many researchers concerning a very positive reaction of apples to 1-MCP, no matter what the storage conditions (McArtney et al., 2008; Akbudak et al., 2009).

A decrease in fruit firmness along with an increase in storage time was observed in the experiment. Depending on the storage conditions, that decrease in fruit firmness proceeded at different rates. According to expectations, the softening was quicker in NA, espe-

cially after 7 days of simulated shelf life, apples from NA were characterized by significantly higher decrease of firmness than fruits from CA. There is a lot of data in literature pointing to a significant limitation of the firmness decrease in the CA conditions as compared to the normal atmosphere (Róth et al., 2007). Treating fruit with 1-MCP, very favourably affected the preservation of high flesh firmness. Under the effect of 1-MCP apple firmness assessed both immediately after storage as well as after 7 days of simulated shelf life was significantly higher compared to fruits not treated with 1-MCP. The obtained results confirm the opinion expressed by Zanella (2003), that fruits treated with 1-MCP ripen more slowly not only during storage but also at the temperature 20-24 °C.

With the elongation of the storage time, a systematic decrease of fruit titratable acidity was observed. However, the rate of that process directly depended on the storage conditions and was significantly lower in the case of fruits stored in controlled atmosphere than in normal atmosphere. The differences between those two technologies were even more visible after 7 days of simulated shelf life. It should be stressed, however, that the differences in the titratable acidity of apples after their storage in various CA combinations were usually slight. The results of the present experiment agree with the opinion of other researchers, who report that a high CO_2 concentration together with lower concentrations of O_2, as compared to NA, inhibit the decrease of fruit titratable acidity (Aaby et al., 2002).

Apple postharvest treatment with 1-MCP significantly limited a fall in titratable acidity which is also reported by Fan and Mattheis (2001). In the present experiment in the season 2007/2008 the effect of 1-MCP on the titratable acidity of apples was more visible after 7 days of simulated shelf life than directly after storage. In this way the report by Mir et al. (2001) who did not observe changes in the titratable acidity of fruits after the treatment with 1-methylcyclopropene was not confirmed. The smallest decrease of titratable acidity was noted in the case of apples treated with 1-MCP and stored in CA conditions. The differences in the decrease of the titratable acidity in various storage conditions and 1-MCP treatment, may be explained by the differentiated rate of physiological processes including respiration intensity, which is pointed out in literature (Akbudak et al., 2009).

The quality of apples both during storage and during the simulated shelf life, to a great degree depends on the cultivar and the time of storage (Kazuhiro et al., 2001). In the experiment a small percentage of fruit with fungal diseases were observed. It mainly concerned fruits stored in normal atmosphere. Even less susceptibility to fungal diseases was noted in fruits treated with 1-MCP, which agrees with the report by Mitcham et al. (2001).

CONCLUSIONS

1. Storage of 'Golden Delicious' apples in normal atmosphere should stop, before the end of four months. Longer storage causes excessive loss of firmness. Flesh softening may be delayed up to six months after harvest if the apples are stored in controlled atmosphere.
2. As far as the apple storage quality is concerned, the treatment with 1-MCP is desirable as it inhibits the climacteric ethylene production and thus the ripening initiated by ethylene. Treatment with 1-MCP also inhibits the decreasing tendency of flesh firmness and titratable acidity.
3. The positive effect of 1-MCP on apple quality lasts much longer in conditions of CA than in normal atmosphere. Due to slower metabolic processes in fruits, apples are characterized by better quality not only directly after storage but also after shelf life.

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REAKCJA JABŁEK 'GOLDEN DELICIOUS' NA 1-MCP W CZASIE PRZECHOWYWANIA W WARUNKACH CHŁODNI ZWYKŁEJ I KONTROLOWANEJ ATMOSFERY

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S T R E S Z C Z E N I E

W pracy zajmowano się oceną jakości i zdolności przechowalniczej jabłek 'Golden Delicious'. Doświadczenie prowadzono w dwóch sezonach (2006/2007, 2007/2008). Owoce traktowane i nietraktowane przechowywano w temperaturze 1 °C w chłodni zwykłej oraz w trzech kombinacjach KA o składach gazowych (CO_2 : O_2): 1,5:1,5; 3,0:3,0 i 5,0:3,0. Jakość owoców oceniano po 2, 4 i 6 miesiącach przechowywania, zarówno bezpośrednio po przechowywaniu, jak i po 7 dniach przetrzymywania w temperaturze pokojowej. W doświadczeniu odnotowano drastyczny spadek intensywności wydzielania etylenu przez jabłka poddane działaniu 1-MCP, niezależnie od warunków i długości przechowywania. Traktowanie owoców 1-MCP, a także

przechowywanie w warunkach kontrolowanej atmosfery sprzyjało wyższej jędrności jabłek zarówno bezpośrednio po przechowywaniu, jak i po 7 dniach przetrzymywania w temperaturze pokojowej.

Wraz z wydłużaniem okresu przechowywania notowano stały spadek kwasowości jabłek. Tempo tego procesu było istotnie wolniejsze w przypadku owoców przechowywanych w kontrolowanej atmosferze niż w chłodni zwykłej. Różnice między tymi technologiami przechowywania były bardziej wyraźne po symulowanym obrocie niż bezpośrednio po przechowywaniu. Pozbiorcze traktowanie jabłek 1-MCP istotnie ograniczało spadek kwasowości jabłek, zwłaszcza w warunkach chłodni zwykłej.

Choroby grzybowe (szara pleśń, gorzka zgnilizna i mokra zgnilizna) występowały głównie na owocach przechowywanych w chłodni zwykłej. Traktowanie jabłek z użyciem 1-MCP na ogół zmniejszało odsetek owoców zgniłych zarówno bezpośrednio po przechowywaniu, jak i po okresie symulowanego obrotu.

Słowa kluczowe: jabłka, przechowywanie, jędrność, kwasowość, 1-MCP