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THE EFFECT OF 1-MCP TREATMENT AND CA STORAGE ON SOME PHYSICAL TRAITS OF "CHERRY" TOMATOES

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ABSTRACT

The objective of the study was to determine the effects of 1-methylcyclopropene (1-MCP) treatment and controlled atmosphere (CA) storage on some physical traits of 'cherry' tomato fruits. Plants of 'Dasher F_1' cv. were grown in a greenhouse in rockwool slabs. 1-MCP was applied directly after harvest at two stages of fruit maturity (pink and light red fruit, i.e. at 3rd and 5th stages, according to USDA classification) in the concentration of 1.0 $\mu L \cdot L^{-1}$, for 12 hours at 18°C. In the case of the experiment with CA storage, untreated pink fruits were stored under gas compositions: 3% CO_2 + 3% O_2, 3% CO_2 + 1.5% O_2 and under regular atmosphere (control). All fruits in both experiments were stored at the temperature of 12°C, 85% RH. The following physical traits of the fruits were determined before storage and after 2, 3 and 4 weeks of storage: colour in CIE L*a*b* system (L* – lightness, a* – redness, b* – yellowness) and flesh firmness with HPE scale, ranged from 0 to 100. Also C* colour parameter (chroma value) was calculated. 1-MCP treatment significantly reduced the decreasing of fruits firmness during storage, as well as changes of colour parameters. The effectiveness of CA in both gas compositions was not so high. Particularly, the CA storage did not delay the firmness decrease so effectively as 1-MCP treatment. It can be concluded that 1-MCP treatment is an effective method in delaying ripening of 'cherry' tomato fruits by keeping their firmness and colour and can be used to extend their storage period.

Key words: "cherry" tomato, storage, 1-MCP, controlled atmosphere, fruit quality.

INTRODUCTION

Tomato, one of the most popular vegetables worldwide, is consumed for its sensory value, attractive appearance and nutritional value. Recently, 'cherry' type tomatoes (*Solanum lycopersicum* L. var. *cerasiforme*) characterized by small fruits have become popular in Europe. Due to low storage ability of 'cherry' tomatoes, various methods of prolonging storage period for the fruits are investigated. In general, tomato fruits are chilling sensitive, so the optimum temperature for storage of the fruits harvested at mature green or breaker stages of maturity is 12.5–13°C [6, 19]. Tomato is a climacteric fruit, so its ripening process is influenced by ethylene. Therefore 1-MCP (1-methylcyclopropene) treatment of the fruits can be applied to delay their ripening and to prolong 'shelf life'. For vegetables and fruits 1-MCP is used as SmartFreshTM formulation. 1-MCP is safe for humans, because it quickly diffuses from the plant tissue after the treatment [2, 24]. It is believed that 1-MCP blocks ethylene receptors in plant cells. It results in delaying fruits and vegetables ripening or senescence and therefore extends their storage ability [24, 25]. The effect depends on 1-MCP concentration and time of the treatment. It was reported that 1-MCP reduced production of ethylene, cell respiration, restrained fruit colour changes, softening, taste and aroma degradation as well as diseases development [4, 16, 25]. There are reports that 1-MCP treatment markedly affects ripening of tomato fruits [17, 20, 21, 24], significantly reduces respiration in the fruits [7], delays change of fruits colour and reduces softening and decay of stored fruits [8]. Between 1-MCP treated and untreated ripe tomato fruits no differences in titratable acidity, soluble solids, fructose and glucose contents were reported [5, 8, 17]. Treatment with 1-MCP prolonged ripening of both breaker and pink tomato fruits for 4 to 6 days and delayed loss of firmness of the fruits [14]. Tomatoes should be treated with 1-MCP when the fruits started to ripe, what results in their better quality [9, 10]. However, literature data on the effectiveness of 1-MCP treatment of tomato in different stages of maturity are insufficient, especially as regards 'cherry' type tomatoes.

Controlled atmosphere (CA) storage is an effective method for prolonging storage ability of many crops and can be used also for tomato fruits [18, 22]. Standard gas composition recommended for CA storage of tomato is 5% CO_2 and 3% O_2 [19]. The effect of CA storage on quality of 'cherry' type tomato is not fully explained in literature.

The objective of the study was to determine the effects of 1-MCP treatment and controlled atmosphere (CA) on changes of some physical traits of 'cherry' type tomatoes during their storage.

MATERIALS AND METHODS

The work was carried out at Warsaw University of Life Sciences in 2011–2013. The cultivar used in the study was 'Dasher F1' (De Ruiter Seeds). This cultivar is a popular 'cherry' type cultivar and is characterized by small (15–17 g weight) red fruits, which are slightly elongated in shape. The fruits were obtained from tomato plants grown in the University experimental greenhouse with controlled atmosphere conditions (temperature and humidity). Standard coconut slabs were used as the growing medium. Tomato seeds were sown at the beginning of January, then the seedlings were transplanted to their final places in February, at the density of 2.7 plants per m^2. Drop irrigation system was applied in the greenhouse for watering and fertilizing the plants. Nutrients concentrations ($mg \cdot dm^{-3}$) in the feeding solution were kept at the optimal level for tomato plants, and were as follows: $N\text{-}NO_3$ – 210, P – 60, K – 340, Mg – 50, Ca – 200, Fe – 2.0, Mn – 0.6, B – 0.3, Cu – 0.15, Zn – 0.3, Mo – 0.05. The fruits for the experiment were harvested at pink fruit and light red fruit stages (3rd and 5th maturity stages, according to USDA classification) and selected in respect of uniformity.

All fruits were stored for up to 4 weeks at the experimental cold store, at the temperature of 12°C and 85% RH. 1-MCP was applied in the form of SmartFreshTM (Agrofresh Inc.) formulation directly after harvest, in special air-tight steel chambers (capacity of 1 m^3) in concentration of 1 $\mu L \cdot L^{-1}$, for 12 hours at 18°C. The conditions of the treatment were chosen according to previous own experiments and literature data [24, 25].

In the case of CA conditions, the pink fruits were stored in airtight steel containers (volume of 1 m^3) under gas compositions: 3% CO_2 + 3% O_2, 3% CO_2 + 1.5% O_2 (remaining – nitrogen) and under regular atmosphere (control). Gas composition of atmosphere was measured with the gas analyzer (David Bishop Instruments Ltd., England) and was kept at the settled level with accuracy of ±0.5%. Nitrogen and carbon dioxide were injected, when necessary, to the containers from bottles. Excessive amounts of CO_2 were absorbed by calcium lime scrubbers, working in closed-air circulation system. The complete computerized CA-storage system was made and assembled by COOLEX (Warsaw–Karczew, Poland). The fruits were put for storage into small open plastic (LDPE) containers used in retail for 'cherry' tomatoes (about 300 g of fruits in each) and for each combination four such containers were used as replicates.

The following physical traits of the fruits were determined before storage and after 2, 3 and 4-week storage periods. Fruit skin colour was measured in CIE L*a*b* system (with HunterLab MiniScan XE colorimeter, HunterLab, USA) with D65 standard light, and the following colour coordinates were determined: L* – lightness, a* – red colour intensity and b* – yellow colour intensity. Fruit flesh firmness was determined using HPE scale, ranged from 0 to 100 (with HPE II apparatus, Bareiss, Germany, equipped with 0.5 cm diameter probe, dedicated to tomato fruit measurements). Also C* colour parameter value (chroma) was calculated, based on colour coordinates (a* and b*) for the fruit skin. The measurements of colour and firmness were done at two equatorial points of the fruit and the mean value for the fruit was calculated.

For statistical analysis Anova was applied (StatgraphicsPlus 4.1TM software) to compare results for each storage period (2, 3 and 4 weeks) for fruits of the two maturity stages separately, and to compare the influence of storage durations. Values which differ significantly at $\alpha = 0.05$ are marked with different letters, as it is explained in Table 1.

Table 1. Colour parameter L* (lightness) for tomato fruits in relation to 1-MCP treatment and storage duration (means of 2011–2013)

Maturity stage at harvest	Treatment	Storage duration [weeks]			
		0	2	3	4
Red	Untreated	34.7	35.1 a	31.0 a	30.5 a
	1-MCP	34.7	34.9 a	34.0 b	33.5 b
	Means	34.7 B	35.0 B	32.5 A	32.0 A
Pink	Untreated	40.6	37.8 a	35.2 a	36.1 a
	1-MCP	40.6	38.1 a	39.7 b	37.5 b
	Means	40.6 B	37.9 A	37.5 A	36.8 A

Explaination to Tables 1–10: values in the columns for each of maturity stages marked with different small letters differ significantly at $\alpha = 0.05$. Values in the rows marked with different capital letters differ significantly at $\alpha = 0.05$

RESULTS AND DISCUSSION

Tomato fruits of 'cherry' type are a perishable product, but there is a demand for prolonging their storage period in retail or transport in keeping high quality of the fruits. In our study we applied storage conditions for the fruits in accordance with

recommendations of other authors for not fully ripen regular tomatoes [19]. These conditions enabled slow ripening of the fruits during the storage to obtain consumption ripeness for the pink fruits. In all the years of the study similar tendencies for changes of measured traits of fruits were observed.

Colour of tomato fruits is one of most important quality parameters and reflects their maturity stage. The CIE L*a*b* system uses three colour coordinates and is often used to evaluate colour of horticultural products. The results of colour measurements concerning L* parameter in relation to 1-MCP treatment and storage duration for red and pink fruits are given in Table 1. During storage of the fruits L* values decreased, what reflects in the darkening of the fruit skin. We found that L* values for both red and pink fruits were significantly influenced by 1-MCP treatment and as a result of the treatment the decrease of L* value was slowed down compared to the untreated fruits.

In the case of a* parameter (redness), there were consistent significant effects of 1-MCP treatment for both stages of maturity (Tab. 2). The increase of a* value was effectively slowed down by the treatment with 1-MCP. According to literature data, a* parameter is closely correlated with lycopene accumulation [3], so it is evident that the treatment inhibits the lycopene synthesis. We found the lowest a* value after 4-week storage for the pink tomato fruits treated with 1-MCP. This is in agreement with another report [23]. The researchers showed that 1-MCP treatment inhibited the lycopene accumulation in tomato fruits at all stages of maturity. The changes of b* parameter (yellowness) during storage were not as big as for a* parameter, but in the case of the pink fruits higher values of b* were detected, especially after 3 weeks of storage (Tab. 3). Parameter C* (chroma) reflects colour intensity of the fruit. Significant changes for C* values during storage of both red and pink fruits were detected, but the influence of 1-MCP treatment on chroma value was insignificant (Tab. 4).

Table 2. Colour parameter a* (redness) for tomato fruits in relation to 1-MCP treatment and storage duration (means of 2011–2013)

Maturity stage at harvest	Treatment	Storage duration [weeks]			
		0	2	3	4
Red	Untreated	24.6	26.3 a	29.5 b	30.4 b
	1-MCP	24.6	26.7 a	27.6 a	27.9 a
	Means	24.6 A	26.5 AB	28.5 B	29.2 B
Pink	Untreated	20.8	27.1 b	27.9 b	28.5 b
	1-MCP	20.8	23.4 a	25.8 a	26.4 a
	Means	20.8 A	25.3 B	26.9 C	27.5 C

Table 3. Colour parameter b* (yellowness) for tomato fruits in relation to 1-MCP treatment and storage duration (means of 2011–2013)

Maturity stage at harvest	Treatment	Storage duration [weeks]			
		0	2	3	4
Red	Untreated	21.2	22.7 a	22.7 a	21.1 a
	1-MCP	21.2	22.6 a	22.9 a	23.5 b
	Means	21.2 A	22.7 A	22.8 A	22.3 A
Pink	Untreated	23.2	22.3 a	22.7 a	24.2 a
	1-MCP	23.2	24.6 b	29.2 b	25.1 a
	Means	23.2 A	23.5 A	26.0 B	24.7 AB

Table 4. Colour parameter C* (chroma) for tomato fruits in relation to 1-MCP treatment and storage duration (means of 2011–2013)

Maturity stage at harvest	Treatment	Storage duration [weeks]			
		0	2	3	4
Red	Untreated	32.5	34.7 a	37.2 b	37.0 a
	1-MCP	32.5	35.0 a	35.9 a	36.5 a
	Means	32.5 A	34.9 B	36.5 B	36.7 B
Pink	Untreated	31.2	35.1 b	36.0 a	37.4 a
	1-MCP	31.2	34.0 a	39.0 b	36.4 a
	Means	31.2 A	34.5 B	37.5 C	36.9 C

Softening of the flesh is also an apparent quality change that occurs during ripening of tomato fruits. Previous studies had shown that 1-MCP treatment inhibited the softening of tomato fruit during storage [4, 24]. Objective measurements of firmness can be useful for assessing fruit durability in transport and in short-term storage [12]. The non-destructive method of firmness measurement with durometer used in our study reflects the fruit characteristics as it is perceived by consumers [11]. The firmness of stored ‘cherry’ tomato fruits affects their sensory characteristics [13]. Generally, after 4 weeks of storage the highest firmness was detected for pink fruits treated with 1-MCP (Tab. 5). In the case of red fruits, the treatment with 1-MCP also delayed their softening, but from lower start point. Our results are in accordance with another report [15], where the author observed higher firmness of 1-MCP treated tomato fruits than for the control. The trend of maintaining firmness in response to 1-MCP is also

reported for breaker Roma-type tomatoes [14]. In contrary, there is a report [16] that 1-MCP treatment delays tomato ripening, but does not significantly alter the firmness.

Table 5. Firmness of tomato fruits (in HPE units) in relation to 1-MCP treatment and storage duration (means of 2011–2013)

Maturity stage at harvest	Treatment	Storage duration [weeks]			
		0	2	3	4
Red	Untreated	39.6	34.7 a	31.0 a	25.7 a
	1-MCP	39.6	36.4 b	35.6 b	32.3 b
	Means	39.6 D	35.6 C	33.3 B	29.0 A
Pink	Untreated	44.1	39.3 a	37.7 a	38.7 a
	1-MCP	44.1	44.1 b	44.3 b	44.0 b
	Means	44.1 B	41.7 A	41.0 A	41.4 A

Controlled atmosphere storage is the effective method for prolonging storage period of many horticultural crops, including tomatoes [1, 26]. Gas compositions of atmosphere applied in our study were chosen according to recommendation for tomato fruits [19]. In the case of colour parameters of the fruits, decrease of L* (lightness) value was detected, and for control fruits the changes were the biggest compared to the fruits stored under both CA compositions (Tab. 6). The parameter a* (redness) increased markedly during storage of control fruits, but in the case of CA stored ones the increase was very low (Tab. 7). For the parameter b*, the changes resulted from storage were on average insignificant, but a slight decrease was detected for the fruits stored under normal atmosphere (Tab. 8). The C* parameter values increased during storage, especially under normal atmosphere (Tab. 9). There was found a significant effect of CA storage on the decrease of tomato fruits firmness compared to the control, and both CA variants showed similar influence on fruit firmness (Tab. 10). Since colour and firmness are the main indices of tomato fruits ripening, the results of our experiment showed that CA storage of 'cherry' tomatoes delays the fruits ripening and can extend their storage period.

Table 5. Firmness of tomato fruits (in HPE units) in relation to 1-MCP treatment and storage duration (means of 2011–2013)

Maturity stage at harvest	Treatment	Storage duration [weeks]			
		0	2	3	4
Red	Untreated	39.6	34.7 a	31.0 a	25.7 a
	1-MCP	39.6	36.4 b	35.6 b	32.3 b
	Means	39.6 D	35.6 C	33.3 B	29.0 A
Pink	Untreated	44.1	39.3 a	37.7 a	38.7 a
	1-MCP	44.1	44.1 b	44.3 b	44.0 b
	Means	44.1 B	41.7 A	41.0 A	41.4 A

Table 6. Colour parameter L* (lightness) for tomato fruits harvested at pink stage in relation to composition of atmosphere and storage duration (means of 2011–2013)

Gas composition of atmosphere	Storage duration [weeks]			
	0	2	3	4
Normal atmosphere	41.9	39.9 a	36.0 a	35.8 a
3% CO_2 + 3% O_2	41.9	40.6 a	37.4 ab	37.2 b
3% CO_2 + 1.5% O_2	41.9	40.7 a	39.1 c	38.5 b
Means	41.9 B	40.4 B	37.5 A	37.2 A

Table 7. Colour parameter a* (redness) for tomato fruits in relation to composition of atmosphere and storage duration (means of 2011–2013)

Gas composition of atmosphere	Storage duration [weeks]			
	0	2	3	4
Normal atmosphere	19.7	22.5 b	26.0 b	27.8 b
3% CO_2 + 3% O_2	19.7	20.5 a	21.2 a	22.5 a
3% CO_2 + 1.5% O_2	19.7	20.2 a	20.6 a	21.2 a
Means	19.7 A	21.1 B	22.6 C	23.8 D

Table 8. Colour parameter b* (yellowness) for tomato fruits in relation to composition of atmosphere and storage duration (means of 2011–2013)

Gas composition of atmosphere	Storage duration [weeks]			
	0	2	3	4
Normal atmosphere	25.8	25.2 a	23.3 a	23.6 a

3% CO_2 + 3% O_2	25.8	26.4 ab	26.6 b	26.2 b
3% CO_2 + 1.5% O_2	25.8	27.6 b	27.7 b	26.4 b
Means	25.8 AB	26.4 B	25.9 AB	25.4 A

Table 9. Colour parameter C* (chroma) for tomato fruits in relation to composition of atmosphere and storage duration (means of 2011–2013)

Gas composition of atmosphere	Storage duration [weeks]			
	0	2	3	4
Normal atmosphere	32.5	33.8 a	34.9 a	36.5 b
3% CO_2 + 3% O_2	32.5	33.4 a	34.0 a	34.5 ab
3% CO_2 + 1.5% O_2	32.5	34.2 a	34.5 a	33.9 a
Means	32.5 A	33.8 B	34.5 BC	35.0 C

Table 10. Firmness of tomato fruits (in HPE units) in relation to composition of atmosphere and storage duration (means of 2011–2013)

Gas composition of atmosphere	Storage duration [weeks]			
	0	2	3	4
Normal atmosphere	44.5	42.7 a	40.0 a	36.5 a
3% CO_2 + 3% O_2	44.5	43.8 b	41.5 ab	40.9 b
3% CO_2 + 1.5% O_2	44.5	43.6 b	42.5 b	41.5 b
Means	44.5 D	43.4 C	41.3 B	39.6 A

CONCLUSIONS

The results showed that 1-MCP treatment significantly reduced the decreasing of fruits firmness during storage, as well as changes of their colour parameters in CIE L*a*b* system. The effectiveness of both CA variants used in the study (CO_2 : O_2 as 3 : 3 and 3 : 1.5) was no as high as the effect of 1-MCP treatment, and it was especially evident in the case of keeping the fruit firmness. It can be concluded that both 1-MCP treatment and CA storage are effective methods in delaying ripening of the 'cherry' tomato fruits by keeping their firmness and colour, but 1-MCP treatment seems to be a more effective method for prolonging storage of the fruits.

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