



EFFECT OF 1-MCP TREATMENT ON STORAGE POTENTIAL OF TOMATO FRUIT

Anna WRZODAK^{1*}, Marek GAJEWSKI²

¹Research Institute of Horticulture, Konstytucji 3 Maja 1/3, 96-100 Skierniewice, Poland

²Warsaw University of Life Sciences – SGGW, Department of Vegetable and Medicinal Plants,
Nowoursynowska 159, 02-776 Warszawa, Poland

Received: September 2015; Accepted: November 2015

ABSTRACT

Tomato fruit cv. 'Faustine' F₁ were harvested at mature green and full-red stages and treated with 1 or 2 $\mu\text{l}\cdot\text{l}^{-1}$ of 1-methylcyclopropene (1-MCP) at 20 °C and 85-90% RH, for 21 hours to investigate the ability to delay ripening. Treated and control fruit were stored at 12.5 and 20 °C and 85-90% RH. Ethylene production, rate of respiration, weight loss, market value and storage life were determined after 4-week storage. Exposure of tomato fruit to 1-MCP reduced ethylene production and respiration rate of the fruit harvested at mature-green and full-red stages of maturity. Storage life and market value of tomato fruit depended on the treatment with 1-MCP, stage of maturity and storage temperature. Untreated fruits were characterized by the shortest storage life in comparison with the fruit treated with 1-MCP. The lowest market value was observed for tomato fruit harvested as a mature green, untreated with 1-MCP and stored at 20 °C. Treatment of tomato fruit with 1-MCP resulted in the reduction of natural weight loss during storage. These results suggest that 1-MCP treatment can be used in a commercial storage and trading system for tomatoes due to its ability to delay fruit ripening.

Key words: tomato fruit, 1-methylcyclopropene, ethylene, storage potential

INTRODUCTION

Quality of tomato fruit during storage depends on many factors such as cultivation methods, post-harvest handling, cultivar, stage of maturity at harvest. In Poland, in commercial field production of tomatoes for consumption during summer and autumn, interest in growing tomato plants at stakes has been increasing (Suszyna 2006).

Storage temperature is the most important factor for the post-harvest life of the fruit (Mostofi & Toivonen 2006). The most appropriate temperature for storage of tomato fruit harvested at the mature-green stage is 12.5-13 °C (Adamicki 1991; Castro et al. 2005; Gajewski 2001). Red tomatoes can be stored at temperature of 6-8 °C, but considerably shorter than the mature-green ones.

1-Methylcyclopropene (1-MCP) radically inhibits ripening of tomato fruit. The increase in ethylene production and internal ethylene concentration associated with the climacteric stage of ripening are delayed by 1-MCP treatment (Hoeberichts et al. 2002; Krammes et al. 2003; Opiyo & Ying 2005). Other ripening processes that are inhibited include respiration (Colleli et al. 2003; Wills & Ku 2002), color change and softening (Mir et al. 2004; Mostofi et al. 2003; Opiyo & Ying 2005). Generally, 1-MCP treatment influences physicochemical changes of tomato fruit, as well as a reduction in decay, weight loss and extends storage life of the fruit (Blankenship & Dole 2003).

The objective of the present study was to examine the effects of 1-MCP treatment on ethylene production, rate of respiration and storage life of tomato fruit stored at two temperatures – 12.5 °C and 20 °C.

*Corresponding author:
e-mail: anna.wrzodak@inhort.pl

MATERIALS AND METHODS

In the experiment conducted in the two growing seasons (2008 and 2009), tomato fruit (*Lycopersicon esculentum* Mill.) cv. Faustine F₁ (Syngenta Seeds, Ltd., Holland; TmVF₂N) were used. The cultivar has a commercial value, recommended for growing at stakes in the open field production. Standard cultivation practices, such a soil preparing, planting and plant protection, were applied for the crop in vegetation periods.

The fruit for the experiment were harvested at mature green (MG) and full-red (R) stages (1st and 6th maturity stages, according to USDA classification). Fruit of the same size and shape without defects or diseases, without a calyx, were selected for the experiment. Prior to storage, the fruit were washed in water, then dipped in an aqueous solution of sodium hypochlorite (0.03%) for disinfection and subsequently dried before being placed in storage boxes. Each treatment was made up in four replications, consisting of 20 fruit in each. Three-way analysis of variance in a completely randomized design was carried out.

Gaseous 1-MCP was prepared from SmartFresh™ (AgroFresh Inc.) commercial powder (0.14% of active ingredient). SmartFresh™ was applied on the day of harvest for each stage of maturity, in special air-tight steel containers (capacity of 1 m³) applying 1.0 and 2.0 µl·l⁻¹ of 1-MCP for 21 h, at the temperature of 20 °C and 85-90% RH. Control fruit were kept under similar conditions, but without 1-MCP treatment. After treatment, the fruit were stored for 4 weeks at 12.5 °C or 20 °C, and 85-90% RH in air in the dark.

After the storage, the following quality attributes were determined: weight loss (in %); fruit market value in 1-9 point grading scale, according to Adamicki (1991), Getinet et al. (2008) and Telefera et al. (2007); where 9 = the highest quality, 7 = good, 5 = satisfactory, 3 = poor (i.e. no market and consumption value), 1 = very bad. The observations concerning the market value of the fruit were carried out at three-day intervals, while removing fruit with diseases symptoms. Storage potential was determined as the number of days from the time of reaching full maturity until obtaining the market value score of 5 (limit of marketability) and the market value 3 (poor).

Respiration rate was determined on the basis of CO₂ production. Tomato fruit (samples of 1 kg) were put to glass jars (volume of 5 L each) with lids, equipped with valves enabling taking small air samples from the jars to analyze. After 3 hours of keeping the fruit at the temperature of 20 °C, the CO₂ concentration (in v.v. %) in the jars was measured using gas analyzer COMBO 280 (David Bishop Instr., UK). The measurements were done in a laboratory, at room temperature (20 °C), in three replicates. The data obtained were used to calculate CO₂ production, which was expressed in ml CO₂·kg⁻¹·h⁻¹.

To determine ethylene production, the same method as above was applied. Ethylene concentration in the jars (in ppm) was measured with ICA 56 ethylene analyzer (ICA Instruments, USA) and expressed as µl C₂H₄·kg⁻¹·h⁻¹.

For the analysis of variance, Statistica ver. 10 software with three-factor ANOVA was applied (factor A - stage of maturity, B – treatment with 1-MCP, C – storage temperature). Mean values were compared using the Tukey's HSD test at the significance level of p = 0.05.

RESULTS AND DISCUSSION

If we compare the respiration rate for the tomato fruit before and after storage, it can be seen that the rate decreased markedly for the fruit kept at 20 °C (Fig. 1). However, for the fruit stored at 12.5 °C only small changes in respiration rate was observed, in general. This phenomenon could be explained by faster ripening of the fruit kept at the higher temperature, which caused faster entry into the lower point on a climacteric curve. As the confirmation of this statement, we can point out that fruit of a non-climacteric tomato cultivar LSL showed quite different reaction of storage temperature on respiration rate, and the respiration at 20 °C was higher than at 12 °C (our own data, unpublished yet). The other reason can be due to thermal shock – as the fruit stored for a long period at 12.5 °C in storage chamber were transferred for the measurement to the laboratory condition (20 °C). Respiration rate of the fruit during the storage period differed in relation to the treatment. Generally, the control tomatoes produced more CO₂ compared to the 1-MCP treated samples. As it can be seen in Fig. 1,

the highest respiration rate was noted before storage for the control fruit of both stages of maturity (12.2 and 13.6 ml CO₂·kg⁻¹·h⁻¹) and after storage at 12.5 °C (10.9 and 10.4 ml CO₂·kg⁻¹·h⁻¹). The rate of respiration was mainly dependent on 1-MCP treatment. However, stage of maturity and storage temperature also showed a significant influence on the rate of respiration. Pangaribuan & Irving (2010) showed that tomato slices at the pink maturity stage treated with 1-MCP at 1.0 µl·l⁻¹ concentration were characterized by reduced res-

piration rate after one day of storage compared with the control fruit. As it was already pointed out above, our results showed that the mature-green and full-red tomatoes stored at 12.5 °C were characterized by a higher production of CO₂ compared with the fruit stored at 20 °C. The lowest rate of respiration was observed for the untreated tomato fruit after storage at 20 °C, regardless of the stage of maturity (4.9 ml CO₂·kg⁻¹·h⁻¹ for mature-green and 4.6 ml CO₂·kg⁻¹·h⁻¹ for full-red fruit).

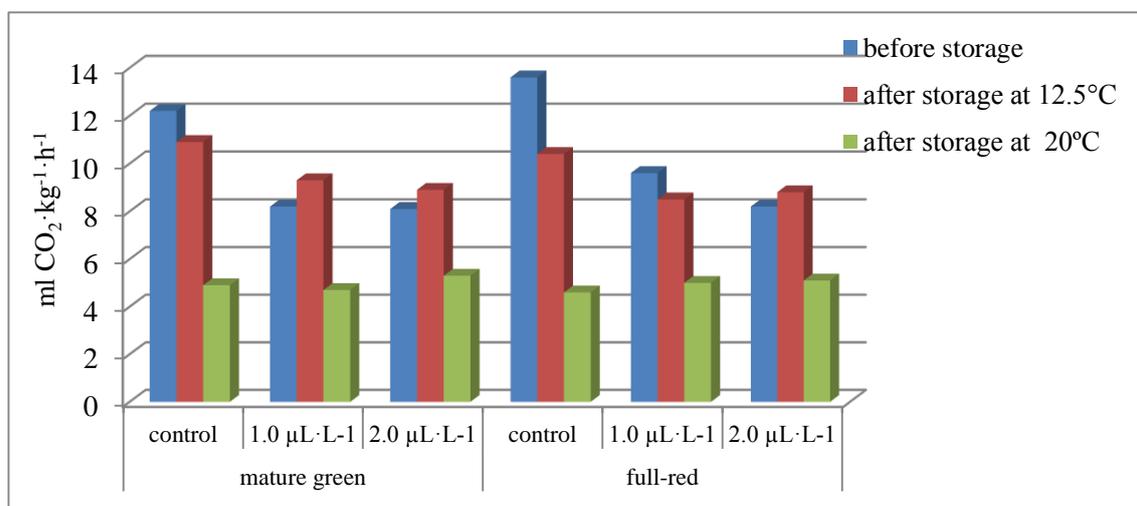


Fig. 1. Effect of treatment with 1-MCP on rate of respiration for tomato fruit cv. Faustine F₁ during storage at 12.5 and 20 °C in 2009 (ml CO₂·kg⁻¹·h⁻¹). LSD_{0.05} A×B×C = 1.9

Tomato, as well as other climacteric fruits, is characterized by a rise in ethylene production, reaching the climacteric peak (Lelièvre et al. 1997). Low temperature during the storage is not sufficient to inhibit ethylene production and the related ripening processes, so there is consequently a need to have new tools to inhibit and/or to delay ethylene production.

In our experiment, the treatment with 1-MCP resulted in decrease of ethylene production of the tomato fruit harvested at both stages of maturity (Fig. 2). Initial ethylene production of the mature-green harvested fruit was lower than for the full-red fruit. After 4 weeks of storage of the tomato fruit at both temperatures, ethylene production for the mature-green ones was still lower than for the full-red fruit. The results showed lower production of ethy-

lene for the fruit stored at 20 °C than at 12.5 °C. The reasons of this phenomenon could be the same as for respiration rate relationship, which is explained above. The highest ethylene production at 12.5 °C was noted for the mature-green tomato fruit untreated with 1-MCP (3.5 µl C₂H₄·kg⁻¹·h⁻¹), and the lowest for the mature-green fruit treated with 1-MCP after storage at 20 °C (0.9 µl C₂H₄·kg⁻¹·h⁻¹). This is in agreement with Wills & Ku (2002) report. The authors observed a positive effect of the treatment with 1-MCP for fully ripe tomato fruit cv. 'Clarion' after storage for 5 days at 20 °C on reduction of ethylene production. However, Hoerberichts et al. (2002) found no effect of 1-MCP treatment on ethylene production for full-red tomato fruit cv. 'Prisca' during storage at 20 °C.

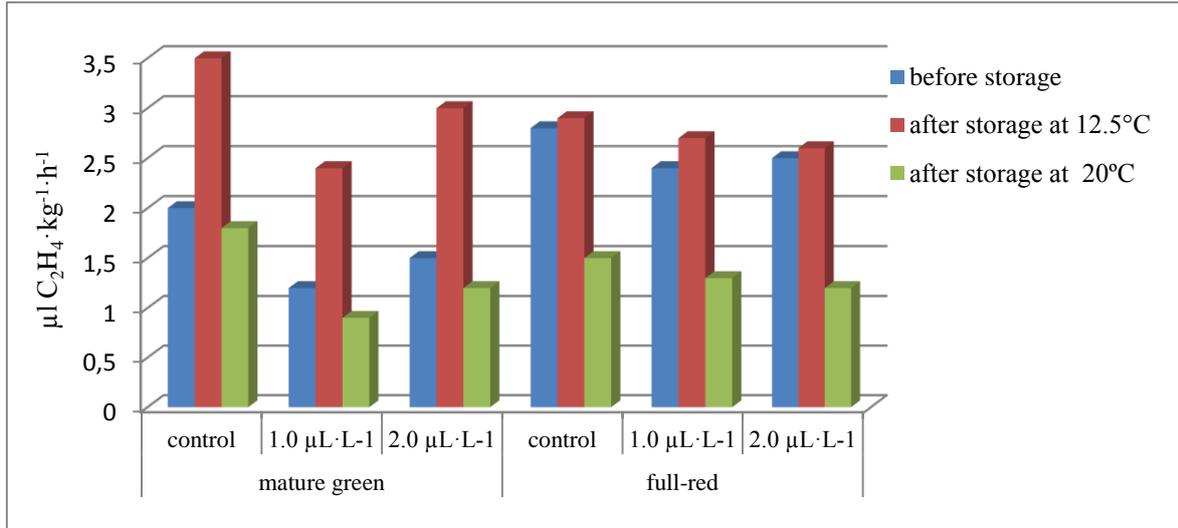


Fig. 2. Effect of treatment with 1-MCP on ethylene production for tomato fruit cv. Faustine F₁ during storage at 12.5 and 20 °C in 2009 (µl C₂H₄ · kg⁻¹ · h⁻¹). LSD_{0.05} A × B × C = 0.4

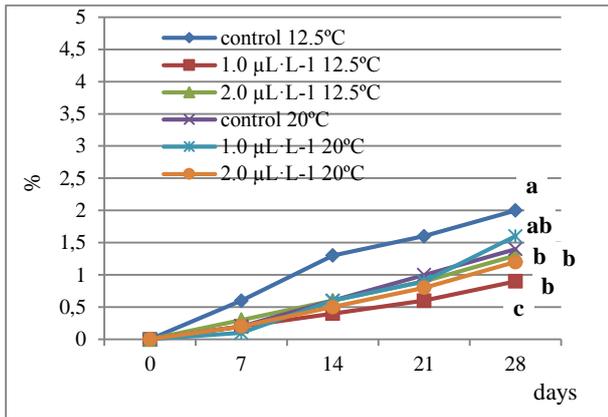


Fig. 3. Effect of 1-MCP on weight loss (%) for mature-green tomato fruit during storage in 2008

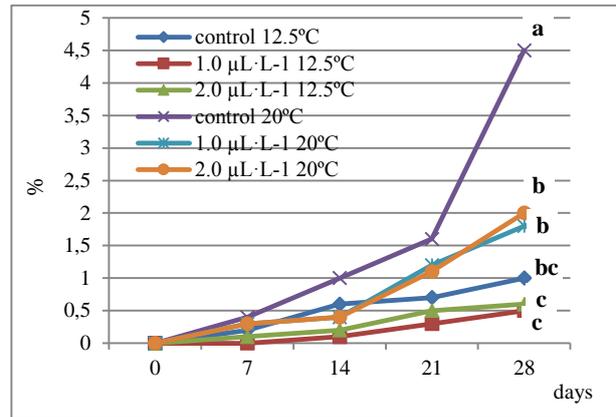


Fig. 4. Effect of 1-MCP on weight loss (%) for mature-green tomato fruit during storage in 2009

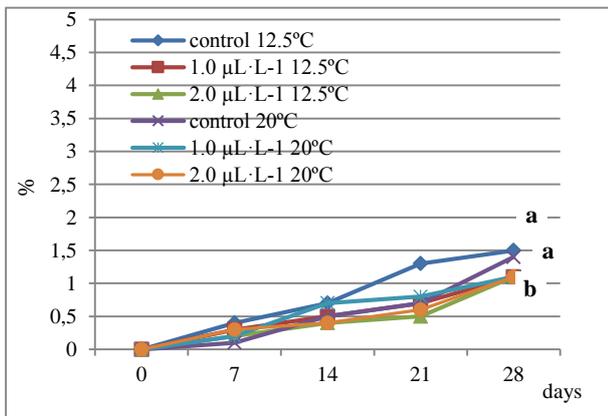


Fig. 5. Effect of 1-MCP treatment on weight loss (%) for full-red tomato fruits during storage in 2008

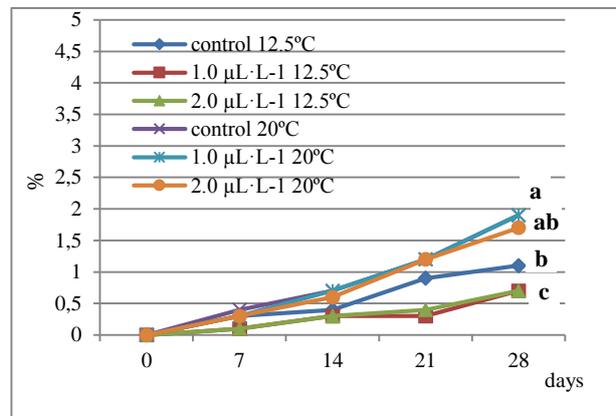


Fig. 6. Effect of 1-MCP treatment on weight loss (%) for full-red tomato fruit during storage in 2009

Result of the studies shows the significant differences in the market value and storage potential of tomato fruit depending on the year of cultivation (Table 1). We found better market value for the tomato fruit treated with 1-MCP versus untreated fruit. Treatment of the mature-green and full-red fruit with 1-MCP, as well as storage temperature, significantly affected market value of the fruit. In 2008, the best market quality was obtained for the mature-green fruit treated with 1-MCP, after storage at 12.5 °C and 20 °C (8.9 and 8.8 points, respectively). Compared to the results from 2009, the best market value was recorded for full-red fruit treated with 1-MCP after storage at 20 °C (8.3 points). The lowest fruit quality in the two years was obtained in 2009 for the control fruit harvested at both stages of maturity, after storage at 20 °C and 12.5 °C (6.2 points). Guillen et al. (2007) and Adamicki & Badelek (2006) obtained similar results. Sun et al. (2003) and Ergun et al. (2006) noted that tomato fruit treated with 1-MCP were

firmer at the end of marketable life comparable with the untreated fruit.

Fruit storage potential in 2008, determined as the number of days from the time of reaching full maturity until obtaining the market value score of 5 (limit of marketability), was on average 41 days at 12.5 °C and 33 days at 20 °C (mature-green) and for full-red fruit – 41 days at 12.5 °C and 38 days at 20 °C (Table 1). Treatment with 1-MCP of the mature-green and full-red tomato fruit significantly extended storage potential of the fruit by 11 and 16 days respectively, compared to the untreated fruit. The best storage potential was found for full-red fruit treated with 1-MCP. These tomato fruit still had satisfactory market value (score of 5) after 48 days of storage at 12.5 °C. According to Adamicki & Badelek (2003) 1-MCP is the most effective in delaying ripening of mature-green tomatoes, when they are stored at 12.5 °C, and is considered as a potential commercial treatment of field grown tomato destined for prolonged storage.

Table 1. Influence of 1-MCP treatment, and storage temperature on the market value in tomato fruit cv. Faustine F₁, harvested in two stages of maturity

Year	Stage of maturity (A)	Temperature (C)	Market value after 4 weeks of storage				Number of days to reach market value 5			
			1-MCP treatment (B)			\bar{x}	1-MCP treatment (B)			\bar{x}
			control	1.0 $\mu\text{l}\cdot\text{l}^{-1}$	2.0 $\mu\text{l}\cdot\text{l}^{-1}$		control	1.0 $\mu\text{l}\cdot\text{l}^{-1}$	2.0 $\mu\text{l}\cdot\text{l}^{-1}$	
2008	Mature-green	12.5 °C	7.4	8.9	8.7	8.3	35	46	43	41
		20 °C	7.0	8.8	8.1	7.8	30	33	35	33
		\bar{x}	7.2	8.8	8.4	8.1	32	39	39	37
	Full-red	12.5 °C	6.5	7.7	8.1	7.4	33	42	48	41
		20 °C	6.6	7.6	7.8	7.3	29	40	46	38
		\bar{x}	6.5	7.6	7.9	7.3	31	41	47	40
		12.5 °C	6.9	8.3	8.4	7.9	34	44	45	41
		20 °C	6.8	8.2	7.9	7.6	29	36	40	35
		\bar{x}	6.8	8.2	8.1	7.7	31	40	42	38
		LSD _{0.05}	A – 0.34, B – 0.5, C – ns, A × B – ns, A × C – ns, B × C – ns, A × B × C – ns				A – ns, B – 4.08, C – 2.74, A × B – 5.76, A × C – 3.87, B × C – ns, A × B × C – ns			
2009	Mature-green	12.5 °C	7.7	8.1	8.1	7.9	35	39	41	38
		20 °C	6.2	7.2	7.9	7.1	28	30	31	30
		\bar{x}	6.9	7.6	8.0	7.5	31	34	36	34
	Full-red	12.5 °C	6.2	8.0	8.1	7.4	28	42	41	37
		20 °C	6.9	7.7	8.3	7.6	31	40	40	37
		\bar{x}	6.5	7.8	8.2	7.5	29	41	40	37
		12.5 °C	6.9	8.0	8.1	7.7	31	40	41	37
		20 °C	6.5	7.4	8.1	7.3	29	35	35	33
		\bar{x}	6.7	7.7	8.1	7.5	30	37	38	35
		LSD _{0.05}	A – ns, B – 0.37, C – 0.25, A × B – ns, A × C – 0.35, B × C – ns, A × B × C – 0.75				A – 1.37, B – 2.04, C – 1.37, A × B – 2.88, A × C – 1.94, B × C – ns, A × B × C – ns			

CONCLUSIONS

1. 1-MCP treatment of tomato fruit cv. Faustine F₁ significantly reduced respiration rate and ethylene production during storage.
2. Treatment of tomato fruit with 1-MCP reduced natural weight loss during the storage period compared to the untreated fruit.
3. Storage potential and market value of tomato fruit depended on the treatment with 1-MCP, stage of maturity and storage temperature.
4. The lowest market value was observed for tomato fruit harvested as a mature-green, untreated with 1-MCP and stored at 20 °C.

REFERENCES

- Adamicki F. 1991. Wpływ temperatury i kontrolowanej atmosfery na przechowywanie, dojrzewanie i jakość owoców pomidorów. Praca habilitacyjna, Instytut Warzywnictwa w Skierniewicach. (in Polish)
- Adamicki F., Badełek E. 2006. The studies on new technologies for storage prolongation and maintaining the high quality of vegetables. *Vegetable Crops Research Bulletin* 65: 63-72.
- Blankenship S.M., Dole J.M. 2003. 1-Methylcyclopropene: a review. *Postharvest Biology and Technology* 28: 1-25. DOI: 10.1016/S0925-5214(02)00246-6.
- Castro L.R., Vigneault C., Charles M.T., Cortez L.A.B. 2005. Effect of cooling delay and cold-chain breakage on 'Santa Clara' tomato. *Journal Food Agriculture and Environment* 3: 49-54.
- Colelli G., Sánchez M.T., Torralbo F.J., 2003. Effects of treatment with 1-methylcyclopropene (1-MCP) on tomato. *Alimentaria* 342: 930-934.
- Ergun M., Sargent S.A., Huber D. 2006. Postharvest quality of grape tomatoes treated with 1-methylcyclopropene at advanced ripeness stages. *HortScience* 41(1): 183-187.
- Gajewski M. 2001. Przechowalnictwo warzyw. Wydawnictwo SGGW. (in Polish)
- Getinet H., Seyoum T., Woldetsadik K. 2008. The effect of cultivar, maturity stage and storage environment on quality of tomatoes. *Journal of Food Engineering* 87: 467-478. DOI: 10.5897/AJB11.652.
- Guillén F., Castillo S., Zapata P.J, Martínez-Romero D., Serrano M., Valero D. 2007. Efficacy of 1-MCP treatment in tomato fruit. Duration and concentration of 1-MCP treatment to gain an effective delay of postharvest ripening. *Postharvest Biology and Technology* 43: 23-27. DOI: 10.1016/j.postharvbio.2006.07.004.
- Hoerberichts F.A., van der Plas L.H.W., Woltering E.J. 2002. Ethylene perception is required for the expression of tomato ripening-related genes and associated physiological changes even at advanced stages of ripening. *Postharvest Biology and Technology* 26: 125-133. DOI: 10.1016/S0925-5214(02)00012-1.
- Krammes J.G., Megguer C.A., Argenta L.C., Amarante C.V.T., Grossi D. 2003. Use of 1-methylcyclopropene to delay fruit ripening of tomato. *Horticulture of Brasilia* 21: 611-614. (in Portuguese with English abstract)
- Lelièvre J.M., Latché A., Jones B., Bouzayen M., Pech J.C. 1997. Ethylene and fruit ripening. *Physiology Plantarum* 101: 727-739.
- Mir N.A., Canoles M., Beaudry R., Baldwin E., Pal Mehla C. 2004. Inhibiting tomato ripening with 1-methylcyclopropene. *Journal of the American Society for the Horticultural Science* 129: 112-120.
- Mostofi Y., Toivonen P.M.A. 2006. Effects of storage conditions and 1-Methylcyclopropene on some qualitative characteristics of tomato fruits. *International Journal Agriculture and Biology* 8: 93-96.
- Mostofi Y., Toivonen P.M.A., Lessani H., Babalar M., Lu C.W. 2003. Effects of 1-methylcyclopropene on ripening of greenhouse tomatoes at three storage temperatures. *Postharvest Biology and Technology* 27: 285-292. DOI: 10.1016/S0925-5214(02)00113-8.
- Opiyo A.M., Ying T.J. 2005. The effects of 1-methylcyclopropene treatment on the shelf life and quality of cherry tomato (*Lycopersicon esculentum* var. cerasiforme) fruit. *International Journal Food Science Technology* 40: 665-673. DOI: 10.1111/j.1365-2621.2005.00977.x.
- Pangaribuan D.H., Irving D.E. 2010. The effect of 1-MCP in maintaining the quality of tomato slices. *Jurnal Teknologi dan Industri Pangan* 21(1): 80-85.
- Sun X., Wang Z., Li Z., Wang W., Zhang Z. 2003. Effects of 1-MCP on postharvest physiology of tomato. *Agricultural Sciences in China* 2(6): 663-669.
- Suszyna J. 2006. Influence of extreme moisture conditions on yielding of tomato in field cultivation. *Folia Horticulturae Suppl.* 2: 181-185.
- Telefera A., Seyoum T., Woldetsadik K. 2007. Effect of disinfection, packaging and storage environment on the shelf life of mango. *Biosystems Engineering* 96(2): 1537-1550. DOI: 10.1016/j.biosystemseng.2006.10.006.
- Wills R.B.H., Ku V.V.V. 2002. Use of 1-MCP to extend the time to ripen of green tomatoes and postharvest life of ripe tomatoes. *Postharvest Biology and Technology* 26: 85-90. DOI: 10.1016/S0925-5214(01)00201-0.
- Žnidarčič D., Požrl T. 2006. Comparative study of quality changes in tomato cv. 'Malike' (*Lycopersicon esculentum* Mill.) whilst stored at different temperatures. *Acta Agriculture Slovenica* 87-2: 235-243.