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EFFECTS OF 1-METHYLCYCLOPROPENE TREATMENT ON POSTHARVEST LIFE AND QUALITY IN FOUR TOMATOES CULTIVARS

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ABSTRACT

The effects of 1-methylcyclopropene (1-MCP) on postharvest quality in four tomato cultivars ('601', '602', '603' and 'Target') were determined during storage. Tomatoes were harvested at pink stages and divided into two lots per each cultivar. One of the lots was exposed to 1000nl l^{-1} 1-MCP doses for 24 h at 20°C while untreated fruits were considered as control. Thereafter, fruits were stored at 10°C and 90% RH for 21 days. During storage weight loss, elasticity, skin color, soluble solid content (SSC), titratable acidity (TA), ripening index (SSC/TA), lycopene and ascorbic acid were measured. The results indicated that in all of the four cultivars, 1-MCP treatment significantly delayed the development of skin color, inhibited the increase of lycopene synthesis and ripening index (SSC/TA) corresponds to tomato fruit ripening. 1-MCP treatment provided better results across all the tested cultivars. Especially, Target cultivar was more responsive to 1-MCP in terms of quality maintenance and storage life extension.

Key words: Tomato, 1-MCP, postharvest quality, lycopene.

INTRODUCTION

Tomato is one of the most important vegetable crops grown in Turkey. According to statistical data, 10 052 000 tons of tomatoes are produced in Turkey, which corresponds to approx. 7% of the total world production (145 million tons) (Anonymous 2010). Tomato fruit contain carotenes (mostly lycopene and β-carotene), vitamin C and several phenolic compounds such as flavonoids and hydroxycinnamic acid derivaties, which are believed to be beneficial to human health (Gautier *et al.* 2008).

Tomatoes are climacteric fruits which have a relatively short postharvest life due to high ethylene production. Inhibition of ethylene production delays the fruit ripening process, and increases the shelf life of the fruit for the consumer (Madhavi and Salunkhe 1998). 1-methylcyclopropene (1-MCP) blocks ethylene receptors and prevent ethylene effects in harvested fruit and vegetable plant tissues (Blankenship and Dole, 2003; Watkins, 2006). Tomato fruits treated with 1-MCP indicate lower respiration rate, ethylene production and weight loss, slower rates of lycopene accumulation, external color development and ripening index (SSC/TA) and prolonged postharvest life than untreated fruits (Hoeberichts *et al.*, 2002; Wills and Ku 2002; Fernandez-Trujillo and Sanchez, 2003; Mostofi *et al.*, 2003; Opiyo and Ying, 2005;Guillén *et al.*, 2006; Wang *et al.*, 2010). Cultivar, ripening stage and storage temperature significantly affect postharvest life and quality of tomatoes, as well as the treatment dose and duration of 1-MCP (Hoeberichts *et al*., 2002; Guillén *et al*., 2006; Lee *et al*., 2010).

The objective of this experiment was to investigate the effects of 1-MCP (1000 nl l^{-1}) on postharvest life and quality of four tomato cultivars ('601', '602', '603' and 'Target') during storage.

MATERIALS AND METHODS

Plant Material and Treatments: Tomato (*Solanum lycopersicum*) fruit cv 601, 602, 603 and Target were harvested at pink stage of ripening using USDA tomato ripeness color classification chart (USDA, 1991) from a research greenhouse of Cukurova University, and immediately transferred to Postharvest Laboratory of Horticulture Department after harvest. Fruits were selected for unity and freedom from defects and blemishes. For each cultivar, fruits were randomly divided into two equal lots. Fruits of the first lot were placed in 65 L volume air tight plastic container and subjected to 1000 nl l^{-1} of 1-MCP. For this purpose, SmartFresh™ powder (0.14% active ingredient) weighed and placed in a 2 ml tube and afterwards warm distilled water (40°C) was added to release the 1-MCP gas. After shaking, the tube was placed into the container. The container was then immediately sealed and stored at 20°C for 24h. After the application the container was opened and ventilated. The second lot fruits represented the control group which was kept under the same conditions without any application.

After the treatments, all fruits were stored at 10°C and 90% RH for 21 days. Stored fruit was analyzed weekly for weight loss (%), skin color (hue angle), elasticity (shore), lycopene (mg kg^{-1}), ascorbic acid (mg $100g^{-1}$), soluble solid content (SSC, %), titratable acidity (TA, %) and SSC/TA.

Fruit Quality Parameters: Weight loss was determined by weighing before storage and at weekly intervals during storage period and results are represent as percentage. Surface color was determined using a colorimeter (Model CR300, Minolta, Osaka, Japan) after calibration with white tile. Three measurements were made on fruit equatorial axes and results were calculated as hue angle using equations described by McGuire (1992). Elasticity of fruit was measured using a Durometer (Non-Destructive Penetrometer, Model 53210, TR Turoni srl, Italy). Ten fruit, in each replication, were pressed at opposite sides of their equatorial axes. Results are expressed as shore. Squeezed tomato juice was analyzed for SSC using a refractometer (Atago, Tokyo, Japan) and results are expressed as %. Titratable acidity (TA) was determined by titration of 5 ml juice with 0.1 N sodium hydroxide to an endpoint of pH 8.1, results are presented as % citric acid. The ratio between SSC and TA was also calculated as a ripening index.

Lycopene content of tomatoes was performed as previously described by Sharma and Maguer (1996) and Rao *et al*. (1998) with slight modifications. Pericarp tissue of tomatoes was grounded and 1 g homogeneous tissue with 50 ml of hexane-ethanol-acetone (2:1:1, vol/vol) were shaked for 30 minutes in 100 ml flax wrapped with aluminum foil to prevent light-induced lycopene oxidation. Afterward, 10 ml of distilled water were added and shaked for 5 minutes again. The solution was then placed in a separator funnel and after phase separation, the lower phase was discarded. Extract was filtered via Whatman 42 and lycopene concentration was determined by measuring the absorbance of the solution at 502 nm using a UV-Vis spectrophotometer (UV-1201, Shimadzu, Kyoto, Japan). Results are expressed as mg kg^{-1} fresh weight.

For ascorbic acid content, tomatoes were ground with a warring blender and 5 g sample was mixed with 45 ml 0.4% oxalic acid and then filtered. One ml filtrate and 9 ml 2,6-Dichlorophenolindophenol sodium salt solution ($C_{12}H_6Cl_2NO_2$-Na) mixed and then transmittance values 520 nm in a spectrophotometer. Results are expressed as mg $100g^{-1}$ (Ozdemir and Dundar, 2006).

Statistical Analysis: The experiment was performed according to a factorial design and data were subjected to ANOVA analysis using SPSS statistical software, version 17.0. For each cultivar, sources of variation were treatments, storage time and their interactions. Means were compared by HSD Tukey's test at $p \leq 0.05$.

RESULTS AND DISCUSSION

Weight loss: The percentage weight loss increased during storage to varying degrees depending on the treatments for all the cultivars. The 1-MCP treatment had a reduced weight loss compared to control (Fig. 1). The restrictive effect was statistically significant in 603 cultivar ($p \leq 0.05$) however its effect were insignificant for other cultivars. At the end of 21 days storage, the least weight loss value was obtained from 1-MCP-treated tomatoes of Target (3.37%), followed by 601 (4.98%), 603 (5.60%) and 602 (5.80%), respectively. Weight loss values for tomatoes of control groups ranged from 4.60% (Target) to 7.10% (603). Nunes (2008) reported that maximum acceptable weight loss values before a tomato becomes unsalable range from 6 to 7%. In this study, the weight loss values of 1-MCP-treated tomatoes for all cultivars used were found lower than those suggested by Nunes (2008). This indicates that there is a protective effect of 1-MCP on weight loss of tomatoes in storage as stated by Guillen *et al*. (2006) previously. However, separate studies by different researchers such as Wills and Ku (2002) and Lee (2003), are present in literature on weight loss changes of tomatoes after 1-MCP treatment. Considering the findings of present study where the effect of 1-MCP on weight loss was insignificant for most of the cultivars and significant for one cultivar, it could be explained that tomato cultivar markedly varies in response to 1-MCP.

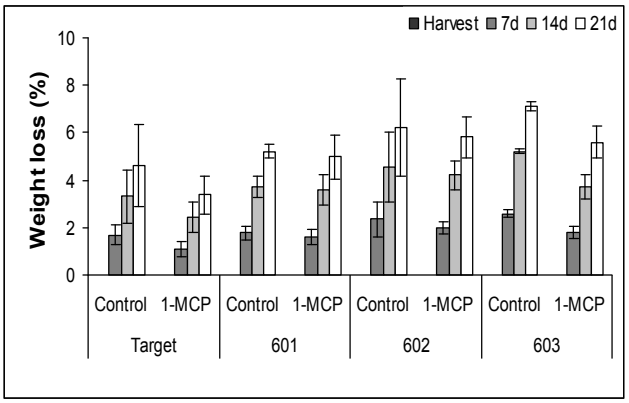

Fig. 1 Effects of 1-MCP treatment on weight loss (%) of four tomato cultivars. Each bar represents the mean of three replicates. Error bars represent the standard deviation of that mean

SSC, TA and SSC/TA (ripening index): At harvest, SSC contents of fruits were 4.5, 4.8, 4.5 and 4.9 % in 601, 602, 603 and Target tomatoes, respectively. These values gradually increased during the storage regardless of the treatments. Similar results were also stated by Wills and Ku (2002), Krammes *et al*. (2003), Opiyo and Ying (2005), using different tomato cultivars.

Titratable acidity (TA) values tended to reduce during storage across all the cultivars, the extent depending on the response of the cultivar. At harvest, TA values were0.429, 0.412, 0.439 and 0.447% in cv 601, 602, 603 and Target, respectively. At the end of the storage period, TA values of 1-MCP-treated tomatoes were higher than those of control groups for all cultivars although such differences were statistically significant for cv 602 and cv Target. TA values of 1-MCP-treated tomatoes were between 0.428% (cv Target) and 0.378% (cv 601). Among control groups the least TA value was 0.362% (cv 601). The response of cv 601 to treatment in terms of TA change is more pronounced than those of other cultivars. General findings on TA change in this study were similar to the findings of Krammes *et al*., (2003), Fernandez-Trujillo and Sanchez (2003), Opiyo and Ying (2005) on tomatoes, Fan and Mattheis (2000) on carrots and Dong *et al.*, (2002) on plums.

SSC / TA value (maturity index) increased with prolonged storage across the cultivars although the magnitudes of such increments were more pronounced in control tomatoes (Table 1). 1-MCP treatments resulted in lower SSC/TA values, protecting the TA contents. SSC/TA values at harvest varied from 10.2 (cv 603) to 11.7 (cv 602) whereas, at the end of the storage, they were 11.5, 11.6, 11.7 and 11.9 (for cv Target, 602, 601 and 603, respectively) for 1-MCP treated groups and were 12.2, 13.0, 13.1 and 13.3 (for cv 602, 601, Target and 603, respectively) for control groups. These findings are in accordance with the reports of Guillén *et al*., (2005), Guillén *et al*., (2007) and Sabir and Agar (2011) who indicated the obvious influence of 1-MCP on SSC/TA value.

Elasticity: The elasticity values of four tomatoes cultivars decreased with prolonged storage. The initial elasticity values of 601, 602, 603 and Target cultivars were 74.72 shore, 78.25 shore, 75.39 shore and 76.22 shore, respectively. 1-MCP treatment significantly ($p \leq 0.05$) inhibited the loss of elasticity value in 603 and Target cultivars while no significant effect was found for the other cultivars. The elasticity values of 1-MCP treated 603 and Target cultivars were found as 54.89 shore and 64.78 shore while the untreated control fruits of the same cultivars were 46.61 shore and 52.83 shore, respectively. At the end of the storage period, the lowest elasticity value was observed in control fruits of 603 cultivar. For fresh market tomatoes, the two quality attributes that are the most important to buyers and consumers are texture and skin color Texture is influenced by flesh firmness and skin strength (Batu, 2004). Reduction in firmness and elasticity during storage, shorten the shelf life of horticultural commodities. Texture softening takes place with degradation of pectic substances on cell wall and lamels between the cells (Lee, 2003). 1-MCP slows down the degradation of pectin substances by hindering the ethylene synthesis and therefore helps the maintenance of the intact firmness of commodities. According to the most recent studies, 1-MCP was effective in delaying fruit softening in various horticultural products such as tomatoes (Moretti *et al*., 2005; Mostofi *et al*., 2003; Krammes *et al*., 2003; Guillén *et al*., 2007), apples (Mir *et al*., 2001; Pre-Aymard *et al*., 2005; Jung and Watkins 2009) and apricots (Fan *et al*., 2000; Cao *et al*., 2009).

Table 1. Effects of 1-MCP treatment on SSC, TA and SSC/TA (Maturity Index) of four tomato cultivars

Cultivars		Storage (d)			
		Harvest	Day 7	Day 14	Day 21
Target	**SSC (%)**				
	Control	4.9^{a}	5.0^{a}	4.9^{a}	5.1^{a}
	1-MCP	4.9^{a}	4.9^{a}	4.9^{a}	4.9^{a}
	TA (%)				
	Control	0.447^{a}	0.423^{c}	0.384^{d}	0.390^{d}
	1-MCP	0.447^{a}	0.438^{ab}	0.430^{bc}	0.428^{b}
	SSC/TA				
	Control	10.9^{d}	12.2^{b}	12.9^{a}	13.1^{a}
	1-MCP	10.9^{d}	11.1^{cd}	11.4^{c}	11.5^{bc}
601	**SSC (%)**				
	Control	4.5^{a}	4.5^{a}	4.4^{a}	4.7^{a}
	1-MCP	4.5^{a}	4.5^{a}	4.2^{a}	4.4^{a}
	TA (%)				
	Control	0.429^{a}	0.413^{a}	0.402^{a}	0.362^{a}
	1-MCP	0.429^{a}	0.421^{a}	0.394^{a}	0.378 ^{a}
	SSC/TA				
	Control	10.5^{c}	10.9^{c}	11.1bc	13.0^{a}
	1-MCP	10.5^{c}	10.7^{c}	10.8^{c}	11.6^{b}
602	**SSC (%)**				
	Control	4.8^{a}	4.5^{a}	4.5^{a}	4.9^{a}
	1-MCP	4.8^{a}	4.7^{a}	4.9^{a}	4.9^{a}
	TA (%)				
	Control	0.412^{bc}	0.391^{d}	0.389^{d}	0.403^{cd}
	1-MCP	0.412^{bc}	0.412^{bc}	0.433^{a}	0.420^{ab}
	SSC/TA				
	Control	11.7^{a}	11.5^{a}	11.6^{a}	12.2^{a}
	1-MCP	11.7^{a}	11.5^{a}	11.4^{a}	11.7^{a}
603	**SSC (%)**				
	Control	4.5^{a}	4.9^{a}	5.1^{a}	5.2^{a}
	1-MCP	4.5 ^{a}	4.7^{a}	4.9^{a}	4.9^{a}
	TA (%)				
	Control	0.439^{a}	0.387^{a}	0.389^{a}	0.395^{a}
	1-MCP	0.439^{a}	0.410^{a}	0.413^{a}	0.409^{a}
	SSC/TA				
	Control	10.2^{a}	12.6^{a}	13.1^{a}	13.3^{a}
	1-MCP	10.2^{a}	11.5^{a}	11.9^{a}	11.9^{a}

Each value represents the mean of three replicates. For each parameter of each cultivar different letters are significantly different at $p \leq 0.05$ according to Student's t test.

Surface Color: 1-MCP treatment significantly affected surface color of tomatoes during storage. At harvest, hue angle values for cv 601, 602, 603 and Target were 88.26°, 94.39°, 88.08° and 89.13°, respectively (Fig. 3). Hue angle value of untreated control tomatoes decreased

faster than those of treated ones, indicating the role of 1-MCP in surface color maintenance. At the end of storage period, hue angle values was the highest in 1-MCP treated cv Target (81.26°), followed by cv 602 (74.19°), cv 603 (72.36°) and cv 601 (71.30°). The lowest value was observed in control group of cv 603 (69.09°). Surface color changes involve loss of chlorophyll, and synthesis of other pigments, such as carotenoids and lycopene, during the ripening period. Thus, color change is often used as an index of the degree of ripeness, and provides primary information about physiological condition of the fruits (Lee, 2003). The results of the present and the previous studies conducted on different commodities such as tomatoes (Moretti *et al*., 2002; Fernandez-Trujillo and Sanchez, 2003; Guillen *et al*., 2006), broccoli (Ku and Wills, 1999), and plum (Valero *et al*., 2004; Luo *et al*., 2009) prove that 1-MCP apparently restrict the decrease in hue angle and help to retard the senescence.

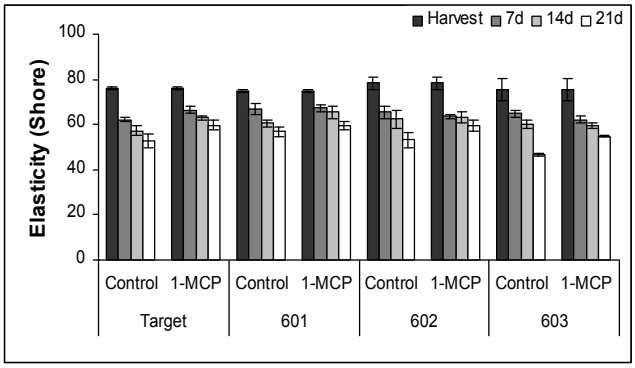

Fig. 2 Effects of 1-MCP treatment on elasticity (shore) of four tomato cultivars. Each bar represents the mean of three replicates. Error bars represent the standard deviation of that mean.

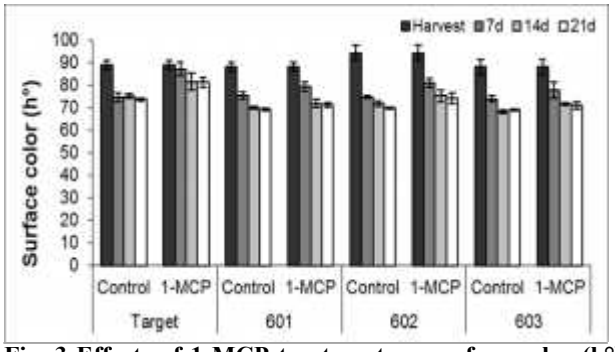

Fig. 3 Effects of 1-MCP treatment on surface color (h°) of four tomato cultivars. Each bar represents the mean of three replicates. Error bars represent the standard deviation of that mean

Lycopene: 1-MCP treatment in all the tested four cultivars had significant effects on lycopene compared with control. Initial lycopene content of the cvs 601, 602, 603 and Target were 2.17 mg kg^{-1}, 2.66 mg kg^{-1}, 2.23 mg kg^{-1} and 1.14 mg kg^{-1}, respectively. During storage, lycopene values increased in both treatments, but this increase of control fruits was faster than 1-MCP treated fruits (Fig. 4). Generally, 1-MCP treatment commenced to delay the synthesis of lycopene after one week storage, except for Target. At the end of storage, restrictive effect of 1-MCP treatment on lycopene synthesis was obvious in all cultivars. At this stage, the lowest lycopene content was obtained in 1- MCP treated Target tomatoes (8.86 mg kg^{-1}), followed by cv 602 (13.63 mg kg^{-1}), cv 603 (15.94 mg kg^{-1}) and cv 601 (17.00 mg kg^{-1}). In contrary, the highest value was obtained from control group of cv 601 (23.85 mg kg^{-1}). Lycopene synthesis, increases as maturity progresses, is affected by storage conditions and postharvest operations (Javanmardi and Kubota, 2006; Gautier *et al*., 2008). Furthermore, there is linear correlation between lycopene synthesis and ethylene production (Kucukbasmaci-Sabir, 2008). 1-MCP retards the lycopene synthesis by blocking the ethylene receptors. Such restrictive effect of 1-MCP revealed in this study confirms the previous reports of Mostofi *et al*. (2003) and Opiyo and Ying (2005).

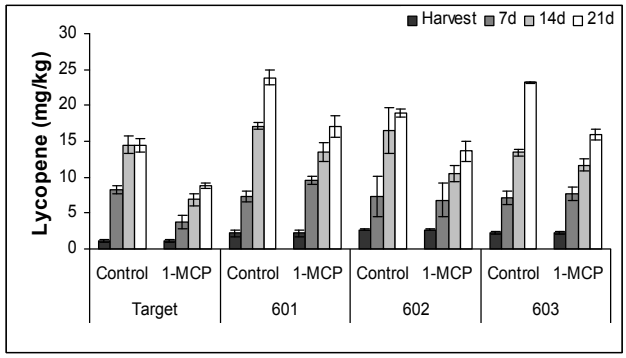

Fig. 4 Effects of 1-MCP treatment on lycopene (mg kg^{-1}) of four tomato cultivars. Each bar represents the mean of three replicates. Error bars represent the standard deviation of that mean

Ascorbic Acid: The ascorbic acid changes of tomatoes during storage were presented in Fig. 5. At harvest, ascorbic acid contents of cultivars were 5.71 mg $100g^{-1}$, 6.60 mg $100g^{-1}$, 5.07 mg $100g^{-1}$ and 2.80 mg $100g^{-1}$ (for cvs 601, 602, 603 and Target, respectively). Ascorbic acid content of control tomatoes was found higher than those of 1-MCP treated ones. Treatments had significant effects on ascorbic acid contents of 603 and Targ*et al*though the response of others was insignificant. At the end of storage period, the highest ascorbic acid amount was found in control group of cv Target (9.11 mg $100g^{-1}$), followed by the control groups of cv 602 (9.04 mg $100g^{-1}$), cv 601 (8.23 mg $100g^{-1}$) and cv 603 (7.87 mg $100g^{-1}$). The lowest ascorbic acid amount was detected in 1-MCP

treated cv Target tomatoes (6.38 mg $100g^{-1}$). Considering the overall results, the increment of ascorbic acid in control tomatoes was higher than those of 1-MCP treated tomatoes. This demonstrates that the maturity in control tomatoes progresses faster than the treated tomatoes as previously indicated by Madhavi and Salunkhe (1998) and Lee and Kader (2000).

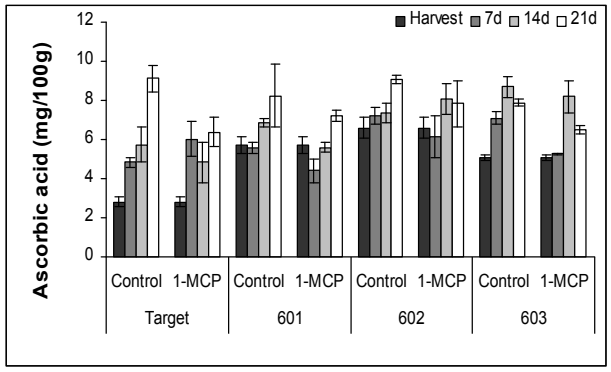

Fig. 5 Effects of 1-MCP treatment on ascorbic acid (mg $100g^{-1}$) of four tomato cultivars. Each bar represents the mean of three replicates. Error bars represent the standard deviation of that mean.

Conclusion: Ethylene stimulates or regulates various processes such as flowering and especially ripening of climacteric fruits. From this physiological perspective, postharvest quality maintenance of tomatoes, as a climacteric vegetable, highly depend on blocking the effect of ethylene. 1-MCP, a cyclopropane derivative which tightly binds to the ethylene receptor, has been used commercially to slow down the ripening of horticultural commodities. In the present study, 1-MCP retarded lycopene synthesis and hue angle value during the 21 d storage across the cultivars. Especially, Target tomato cultivar responded more positively to the 1-MCP treatment. Among the cultivars, postharvest quality of Target was found considerably better than the other tomato cultivars. SSC/TA (maturity index) values were found lower in 1-MCP-treated tomatoes than those of control group. Similarly, 1-MCP was significantly capable of preserving of tomatoes fruit texture and inhibition weight loss. From this study, 1-MCP could be seen as an effective tool in delaying of postharvest senescence. Finally, 1-MCP in 1000 nl/l dose was found more effective in 601, 602, 603 and Target cultivars.

REFERENCES

Anonymous. (2010). FAO. Statistical database. http://faostat.fao.org/site/567/DesktopDefault.aspx?PageID=567#ancor.

Batu, A. (2004). Determination of acceptable firmness and colour values of tomatoes. J. Food. Eng. 61: 471–475.

Blankenship, S. M. and J. M. Dole (2003). 1-methylcyclopropene: A review. Postharvest. Biol. Technol. 28: 1-25.

Cao, J. K., Y. M. Zhao, M. Wang, H. Y. Lu and W. B. Jiang (2009). Effects of 1-methylcycloproepene on apricot fruit quality, decay and on physiological and biochemical metabolism during shelf-life following long-term cold storage. J. Hortic. Sci. Biotech. 84: 672-676.

Dong, L., S. Lurie and H. W. Zhou (2002). Effect of 1-methylcyclopropene on ripening of 'Canino' apricot and 'Royal Zee' plums. Postharvest. Biol. Technol. 24: 135–145.

Fan, X., J. P. and Mattheis (2000). Reduction of ethylene-induced physiological disorders of carrots and iceberg lettuce by 1-methylcyclopropene. HortScience 35: 1312-1314.

Fan, X., L. Argenta and J.P. Mattheis (2000). Inhibition of ethylene action by 1-methylcyclopropene prolongs storage life of apricots. Postharvest. Biol. Technol. 20: 135–142.

Fernandez-Trujillo, J. P. and C. Sanchez (2003). Postharvest quality of fruit from a long-life cultivar of tomato treated with 1-methylcyclopropene. Acta Hort. 628: 233-238.

Gautier, H., V. Diakou-Verdiri, C. Benard, M. Reich, M. Buret, F. Bourgaud, J. L. Poessel, C. Caris-Veyrat and M. Generd (2008). How does tomato quality (Sugar, acid and nutritional quality) vary with ripening stage, temperature and irradiance? J. Agric. Food. Chem. 56: 1241-1250.

Guillén, F., J. M. Valvarde, D. Martinez-Romero, S. Castillo, D. Valero and M. Serrano (2005). Tomato fruit quality retention during storage by 1-MCP treatment as affected by cultivar and ripening stage at harvest. Acta. Hort. 682: 1069-1075.

Guillén, F., S. Castillo, P. J. Zapata, D. Martinez-Romero, D. Valero and M. Serrano (2006). Efficacy of 1-MCP treatment in tomato fruit 2. Effect of cultivar and ripening stage at harvest. Postharvest. Biol. Technol. 42: 235-242.

Guillén, F., S. Castillo, P. J. Zapata, D. Martinez-Romero, M. Serrano and D. Valero (2007). Efficacy of 1-MCP treatment in tomato fruit 1. Duration and concentration of 1-MCP treatment to gain an effective delay of postharvest ripening. Postharvest. Biol. Technol. 43: 23-27.

Hoeberichts, F. A., L. H. W. Van Der Plas and E. J. Woltering (2002). Ethylene perception is required for the expression of tomato ripening-related genes and associated physiological changes even at advanced stage of ripening. Postharvest. Biol. Technol. 26: 125-133.

Javanmardi, J. and C. Kubota (2006). Variation of lycopene, antioxidant activity, total soluble

solids and weight loss of tomato during postharvest storage. Postharvest. Biol. Technol. 41: 151-155.

Jung, S. K. and C. B. Watkins (2009). 1-methylcyclopropene treatment and bruising of different apple cultivars during storage. J. Hortic. Sci. Biotech. 84: 143-148.

Krammes, J. G., C. A. Megguer, L. C. Argenta, C. V. T. Amarante and D. Grossi (2003). Uso do 1-metilciclopropeno para retardar a maturação de tomate. Hortic. Bras. 21: 611-614.

Ku, V. V. V. and R. B. H. Wills (1999). Effect of 1-methylcyclopropene on the storage life of broccoli. Postharvest. Biol. Tech. 17: 127–132.

Kucukbasmaci-Sabir, F. (2008). Effects of different postharvest applications on storage period and quality of whole and fresh-cut tomatoes. PhD thesis (unpublished). Depart. of Hort. University of Cukurova, Turkey.

Lee, S. K. and A. A. Kader (2000) Preharvest and postharvest factors influencing vitamin C content of horticultural crops. Postharvest. Biol. Technol. 20: 207-220.

Lee, Y., D. S. Chung, B. R. Harte and J. Shin (2010). Effect of 1-methylcyclopropene (1-MCP) treatment on the quality characteristics and pigmentation of tomato fruit (Lycopersicon esculentum mill.). Kor. J. Hort. Sci. Technol. 28: 600-608.

Lee, Y. S. (2003). Development of 1-methylcyclopropene package delivery system to control tomato ripening. PhD thesis (unpublished). Michigan State University, USA.

Luo, Z., J. Xie, T. Xu and L. Zhang (2009). Delay ripening of 'Qingnai' plum (Prunus salicina Lindl.) with 1-methylcyclopropene. Plant. Sci. 177: 705–709.

Madhavi, D. L. and D. L. Salunke (1998). Tomato. In Handbook of vegetable science and technology: production, storage and processing (Salunkhe D.K. & Kadam S.S., ed). Marcel Dekker, New York, pp. 171-201.

McGuire, R. G. (1992). Reporting of objective color measurements. HortScience. 27: 1254-1255.

Mir, N. A., E.Curell, N. Khan, M. Whitaker and R. M. Beaudry (2001). Harvest maturity, storage temperature and 1-MCP application frequency alter firmness retention and chlorophyll fluorescence of 'Redchief Delicious' apples. J. Am. Soc. Hortic. Sci. 126: 618-624.

Moretti, C. L., L. M. Mattos, F. L. N. Berg and J. Z. Santos (2005). Quality attributes of tomatoes submitted to different postharvest treatments. Acta. Hort. 682: 1029-1035.

Mostofi, Y., P. M. A. Toivonen, H. Lessani, M. Babalar and C. Lu (2003). Effects of 1-methylcyclopropene on ripening of greenhouse tomatoes at three storage temperatures. Postharvest. Biol. Technol. 27: 285-292.

Nunes, M. C. N. (2008). Color atlas of postharvest quality of fruits and vegetables. John Wiley & Sons, INC., pp 239-243.

Opiyo, A. M. and T. Ying (2005). The effects of 1-methylcyclopropene treatment on the shelf life and quality of cherry tomato (*Lycopersicon esculentum* var. Cerasiforme) fruit. Int. J. Food Sci. Tech. 40: 665-673.

Ozdemir, A. E. and O. Dundar (2006). The effects of fungicide and hot water treatments on the internal quality parameters of Valencia oranges. Asian. J. Plant. Sci. 5: 142-146.

Pre-Aymard, C., E. Fallik, A. Weksler and S. Lurie (2005). Sensory analysis and instrumental measurements of 'Anna' apples treated with 1-methylcyclopropene. Postharvest. Biol. Technol. 36: 135-142.

Rao, A. V., Z. Waseem and S. Agarwal (1998). Lycopene content of tomatoes and tomato products and their contribution to dietary lycopene. Food. Res. Int. 31: 737-741.

Sabir F. K. and I. T. Agar (2011). Effects of 1-methylcyclopropene and modified atmosphere packing on postharvest life and quality in tomatoes. J. Food. Quality. 34: 111-118.

Sharma, S. K. and M. L. Maguer (1996). Kinetics of lycopene degradation in tomato pulp solids under different processing and storage conditions. Food. Res. Int. 29: 309-315.

USDA (1991). United Stages standards for grade for fresh tomatoes. United States Department of Agriculture, Agricultural Marketing Service, pp13.

Valero, D., D. Mart´inez-Romero, J. M. Valverde, F. Guillén, S. Castillo and M. Serrano (2004). Could the 1-MCP treatment effectiveness in plum be affected by packaging? Postharvest. Biol. Technol. 34: 295–303.

Wang, M., C. Jiankang, L. Lin, J. Sun, W. Jiang (2010). Effect of 1-methylcyclopropene on nutritional quality and antioxidant activity of tomato fruit (*Solanum Lycopersicon* L.) during storage. J. Food Quality 33:150-164.

Watkins, C. B. (2006). The use of 1-methlcyclopropene (1-MCP) on fruits and vegetables. Biotechnol. Adv. 24: 389-409.

Wills, R. B. H. and V. V. V. Ku (2002). Use of 1-MCP to extend the time to ripen of green tomatoes and postharvest life of ripe tomatoes. Postharvest. Biol. Technol. 26: 85-90.