

1-Methylcyclopropene delays tomato fruit ripening

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ABSTRACT

Tomato (*Lycopersicon esculentum* Mill.) fruits, cv. Santa Clara, were harvested at the breaker stage from commercial fields in Brazlândia, Brazil, to investigate the ability of 1-methylcyclopropene (1-MCP) to retard tomato fruit ripening. Fruit without external blemishes were graded for size (diameter = 80±5 mm) and mass (m = 130±10 g), placed inside hermetically sealed boxes, and 1-MCP was applied for 12 hours (T = 22±1°C; RH = 80-85%) at four different concentrations: 0 (control), 250, 500 and 1000 mL.L⁻¹. Fruits were held at ambient conditions (T = 23±2°C; RH 80-85%) for 2 days and then stored inside a cold room (T = 20±1°C; RH = 85-95%). Every 3 days, during a 15-day period, fruits were analyzed for firmness, total soluble solids, titratable acidity, external color, and total carotenoids. Firmness of fruit treated with 1000 mL.L⁻¹ was about 88% higher than control fruits after 17 days. The a*/b* ratio, an indicator of skin color, for fruit treated with 1000 mL.L⁻¹ of 1-MCP was 38% lower than control fruits at the end of the storage period. Treatments with higher concentrations of 1-MCP delayed total carotenoids synthesis and color development. Control fruits stored for 17 days had about 190% more total carotenoids than fruits treated with 1000 mL.L⁻¹ of 1-MCP. Postharvest application of 1-MCP was an efficient method to delay tomato fruit ripening. As 1-MCP concentration increased, ripening was further delayed. Tomatoes treated with 250, 500, and 1000 mL.L⁻¹ of 1-MCP were delayed by 8 to 11, 11 to 13 and 15 to 17 days, respectively.

Keywords: *Lycopersicon esculentum*, acidity, color, carotenoids, ethylene, firmness, postharvest.

RESUMO

Retardamento do amadurecimento de tomates com 1-metilciclopropeno

Tomates (*Lycopersicon esculentum* Mill.), 'Santa Clara', foram colhidos no estádio verde-rosado em campos de produção comercial em Brazlândia (DF) com o objetivo de investigar a capacidade do 1-metilciclopropeno (1-MCP) em retardar o amadurecimento de tomates. Frutos sem danos mecânicos externos aparentes foram selecionados para tamanho (diâmetro = 80±5 mm) e massa (m = 130±10 g), foram colocados em câmaras herméticas, e 1-MCP foi aplicado por um período de 12 horas (T = 22±1°C; RH = 80-85%), em quatro concentrações diferentes: 0 (controle), 250, 500 e 1000 mL.L⁻¹. Os frutos foram mantidos por dois dias em condições ambiente (T = 23±2°C; RH 80-85%) e posteriormente armazenados em câmara fria (T = 20±1°C; RH = 85-95%). A cada 3 dias, durante um período de 15 dias, os frutos foram analisados para firmeza, sólidos solúveis totais, acidez total titulável, coloração externa e teor de carotenóides totais. Frutos tratados com 1000 mL.L⁻¹ possuíam firmeza 88% maior do que frutos do tratamento controle após dezessete dias de armazenamento. A relação a*/b*, um indicativo da coloração da casca, foi 38% menor em tomates tratados com 1000 mL.L⁻¹ quando comparados com frutos do tratamento controle ao final do experimento. Frutos tratados com as maiores dosagens de 1-MCP apresentaram o maior retardamento da síntese e revelação dos pigmentos carotenóides. Tomates provenientes do tratamento controle possuíam ao redor de 190% mais pigmentos carotenóides do que frutos tratados com 1000 mL.L⁻¹ de 1-MCP ao final do experimento. A aplicação pós-colheita de 1-MCP foi um método eficiente em retardar o amadurecimento de tomates. À medida que aumentou-se a concentração do produto, observou-se um maior retardamento do amadurecimento. Tomates tratados com 250, 500, e 1000 mL.L⁻¹ de 1-MCP tiveram o amadurecimento retardado em 8 a 11, 11 a 13 e 15 a 17 dias, respectivamente.

Palavras-chave: *Lycopersicon esculentum*, acidez, coloração, carotenóides, etileno, firmeza, pós-colheita.

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Ethylene plays a key role in the ripening of climacteric fruits such as tomatoes by triggering several ripening-related physiological changes (Lelièvre *et al.*, 1997). Many compounds have shown the ability to block the ethylene binding site, causing either the suppression or the inhibition of ethylene effects (Sisler *et al.*, 1990; Sisler, 1991). Diazocyclopentadiene and 2,5 norbornadiene have shown the ability to control both ripening and softening of apples (Blankenship & Sisler, 1993). However, none of these compounds

is commercially acceptable due to toxicity and manufacturing concerns (Fan *et al.*, 1999).

Other compounds with potential use are aminoxyacetic acid (AOA), aminoethoxyvinylglycine (AVG), and silver thiosulfate (STS). The effectiveness of AOA and AVG are reduced if external sources of ethylene are available, such as climacteric fruits, fungi, propane, and cigarette smokes (Abeles *et al.*, 1992). Amongst the inhibitors mentioned above, only STS

has commercial applications in many countries. However, its continued use is being questioned as silver is a potent pollutant, and many countries have proposed to prohibit its use (Abdi *et al.*, 1998).

Recently, a novel gaseous compound, 1-methylcyclopropene (1-MCP), has been reported to have inhibitory effects on ethylene action in various cut flowers and potted plants (Serek *et al.*, 1994; 1995), plums (Abdi *et al.*, 1998), apples (Fan *et al.*, 1999),

bananas (Golding *et al.*, 1998; Jiang *et al.*, 1999), citrus (Porat *et al.*, 1999), strawberries (Ku *et al.*, 1999), broccoli (Ku and Wills, 1999), and lettuce (Fan and Mattheis, 2000).

Tomato fruit handling, transportation, ripening and marketing involves sophisticated technology and facilities. A non-sophisticated technology to extend tomatoes shelf life at ambient conditions and with minimal impacts to the environment is needed to increase the competitiveness of this commodity in different countries.

The objective of the present work was to investigate the ability of 1-MCP to retard tomato fruit ripening.

MATERIAL AND METHODS

Plant material

Tomato (*Lycopersicon esculentum* Mill.) fruits 'Santa Clara', were harvested at the breaker stage (USDA, 1985) from commercial fields in Brazlândia, Brazil. After harvest, fruits with external blemishes were removed and the remaining fruits were graded for size (diameter = 80±5 mm) and mass (130 ±10 g) and placed inside hermetically sealed boxes (volume = 80 L) for 1-MCP treatment. Each box contained 55 ±0.3 kg of tomatoes. Mini-

fans were placed inside the boxes, attached to the lids, in order to make sure that 1-MCP dispersion would be as efficient as possible.

1-MCP preparation

Ethylbloc® (0.14% active ingredient) was used to release 1-MCP. It is formulated into a powder that releases 1-MCP when mixed in a diluted base or water. Mixing was carried out inside sealed glass jars placed in the center of the application boxes, where the required concentrations of 1-MCP were obtained by adding heated (40-60°C) sodium lauril sulphate solution (1000 mg.kg⁻¹) to appropriate amounts of the 1-MCP powder. Glass jars were opened, and 1-MCP was released in the vapor phase at the following concentrations: 0, 250, 500 and 1000 mL.L⁻¹.

Fruit treatment

Fruits were treated with 1-MCP in the concentrations mentioned above for 12 hours at 22±1°C and 80 to 85% RH. After treatment, fruits were left at ambient conditions (23±1°C; RH 80-85%) for 2 days to simulate handling conditions encountered in commercial marketing in Brazil. After this 2-day period, fruits were stored at 20±1°C and 85-95% RH for 15 days to simulate the best ripening conditions, and every 3 days were analyzed for firmness, total

soluble solids, titratable acidity, color, and total carotenoids.

Firmness

Firmness was assayed using a hand penetrometer (8 mm probe). Three fruits, in each replication, were penetrated at opposite sides of their equatorial axes.

Titratable acidity and soluble solids

For the determination of titratable acidity and soluble solids content, 40 g of fresh tissue were homogenized in a commercial blender at high speed and centrifuged for 15 min at 18,000 g. Aliquots of the supernatant were diluted with 50 mL of deionized water and titrated with 0.1 N NaOH to an end point of pH 8.2 using an automatic titrimeter. The amount of NaOH was converted to miliequivalents of citric acid per kg of fresh weight (mL NaOH x 0.1 N x 0.064). Soluble solids content was determined using a benchtop digital refractometer.

Color

For color assessment, fruits were marked along their equatorial axes and three readings were taken using a Minolta Chromo Meter, model CR 200b. Color was expressed as the ratio between a* and b* parameters. Ratios a*/b* > 0 indicate that the predominant color of the fruit surface is that of a mature fruit (red, in the case of tomatoes). On the other hand, a ratio a*/b* < 0 indicates color of immature fruit (green, for tomatoes).

Total carotenoids

Total carotenoids were analyzed according to Lime *et al.* (1957) and Umiel & Gabelman (1971), modified by Moretti *et al.* (1998). Pigment was extracted by homogenizing 15 g of fresh tissue with 30 mL of acetone in a Polytron (PT 1200, Brinkmann Instruments, Westbury, NY) for 1 min at a speed setting of 5. The acetone-pigment extract and 45 mL of hexane were mixed in a separatory funnel and, after phase separation, the lower phase was discarded and the pigment-hexane extract was washed three times with 100 mL of deionized water. After the final wash, the extract was transferred to a 100-mL volumetric flask and the volume was brought up with hexane.

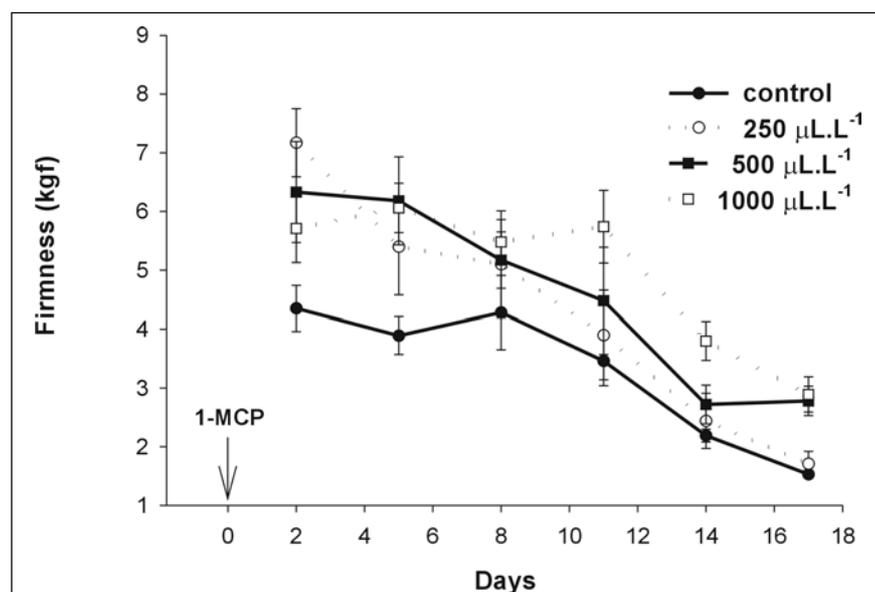


Figure 1. Firmness (kgf) of tomato fruits treated with 1-MCP, stored for 2 days at ambient conditions (23±1°C; RH 80-85%) with subsequent storage for 15 days at 20±1°C and 85-95% RH. Vertical bars indicate ± SD.

Absorbance was read in a spectrophotometer (Hitachi Model 550, Japan) at 451 nm and 503 nm. Total carotenoids were expressed as mg per kg of fresh tissue.

Statistical analysis

Analyses were performed using a completely randomized design, with 24 treatments arranged in a factorial scheme (four 1-MCP concentrations and six sampling times), and 4 replicates ($n=8$). Data were subjected to analysis of variance and the least significant difference procedure was carried out. Differences between any two treatments larger than the sum of two standard deviations were always significant ($P=0.05$).

RESULTS AND DISCUSSION

Firmness

Fruits treated with higher concentrations of 1-MCP were firmer than control fruits during the entire experiment. Two days after application, fruits treated with 1000 mL.L⁻¹ of 1-MCP were around 50% firmer than control fruit. As fruits ripened, firmness of treated and control fruits decreased gradually (Figure 1). Firmness of control fruits and fruits treated with 250 mL.L⁻¹ of 1-MCP were similar at the end of the storage period, whereas fruits treated with 1000 mL.L⁻¹ were significantly firmer than control fruits (Figure 1).

Our results are supported by the findings of Jiang *et al.* (1999) and Fan *et al.* (1999), who observed that 1-MCP application retarded softening of banana fruits and “Ginger Gold” apples, respectively. On the other hand, Porat *et al.* (1999) observed that 1-MCP had no effect on citrus fruits firmness.

Total soluble solids

Control and 1-MCP treated fruits had similar total soluble solids content during the entire experiment. Between 8 and 11 days after 1-MCP application, control fruits had a significant increase in total soluble solids content ($>$ than 4.0° Brix), whereas fruits treated with 1-MCP had an average total soluble solids content of 3.80 (Figure 2). By the end of the storage period, there were no significant differences in soluble solids for all treatments (Figure 2).

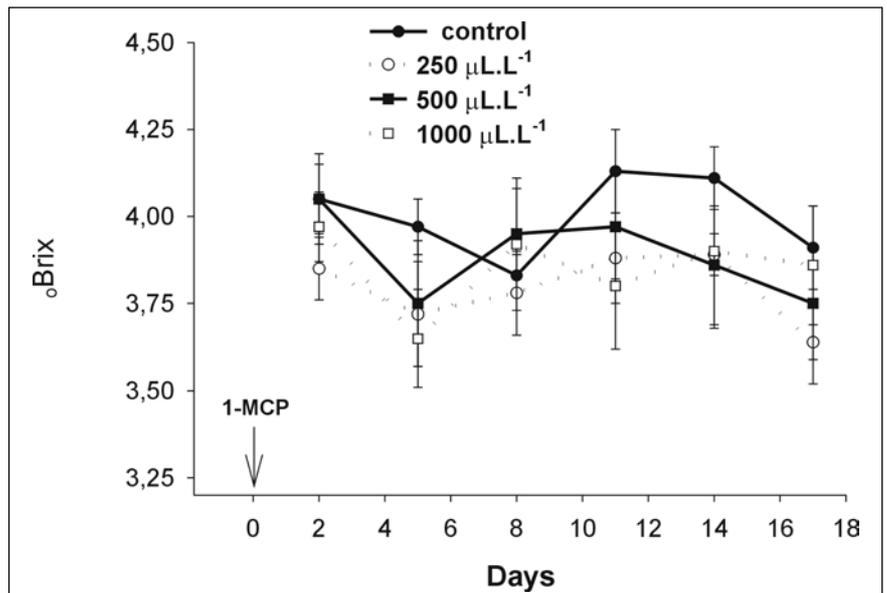


Figure 2. Total soluble solids (°brix) of tomato fruits treated with 1-MCP, stored for 2 days at ambient conditions ($23\pm 1^{\circ}\text{C}$; RH 80-85%), with subsequent storage for 15 days at $20\pm 1^{\circ}\text{C}$ and 85-95% RH. Vertical bars indicate \pm SD.

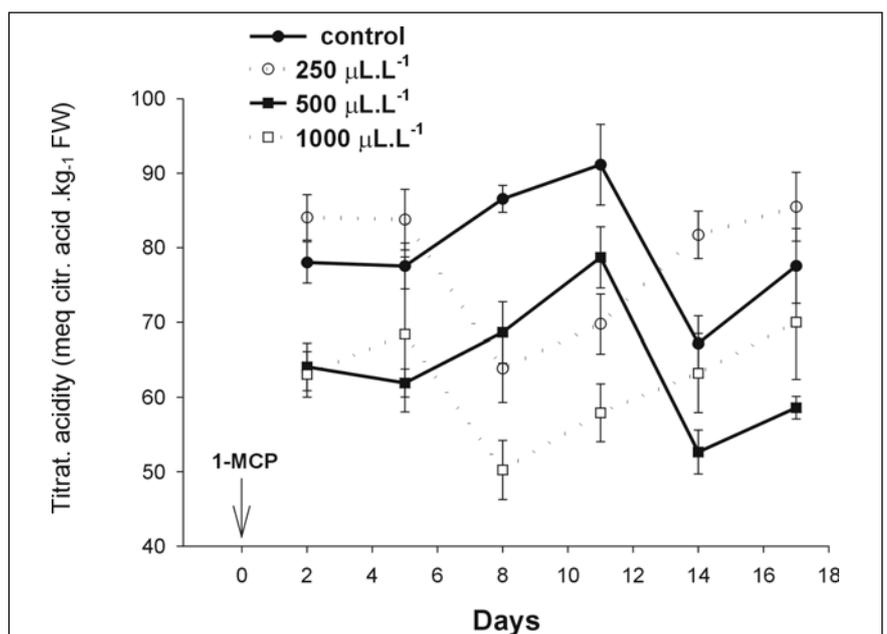


Figure 3. Titratable acidity (meq citric acid .kg⁻¹ fresh weight) of tomato fruits treated with 1-MCP, stored for 2 days at ambient conditions ($23\pm 1^{\circ}\text{C}$; RH 80-85%), with subsequent storage for 15 days at $20\pm 1^{\circ}\text{C}$ and 85-95% RH. Vertical bars indicate \pm SD.

The effects of 1-MCP on soluble solids content have been studied by different authors in different fruit crops. Fan *et al.* (1999) showed that soluble solids content were higher in 1-MCP treated “Delicious” and “Fuji” apples, but was not affected in “Ginger Gold”, “Gala” and “Jonagold”. Similarly, Porat *et al.* (1999) and Fan and Mattheis (2000) observed that citrus fruits and

lettuce treated with 1-MCP had no significant changes in soluble solids content.

Titrratable acidity

Titrratable acidity was not affected by 1-MCP treatment. At the end of the storage period there were no significant differences among control and 1-MCP treated fruits (Figure 3). The results are

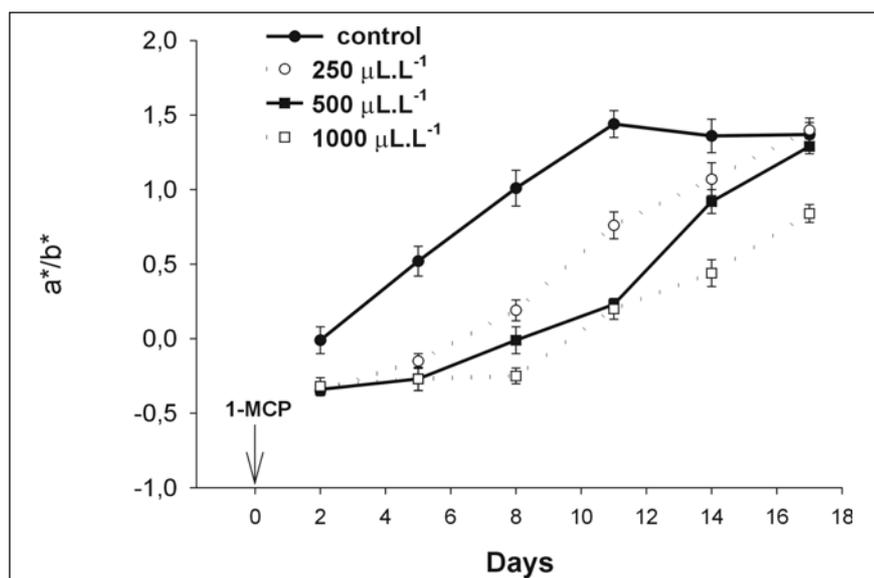


Figure 4. Color (a^*/b^* ratio) of tomato fruits treated with 1-MCP, stored for 2 days at ambient conditions ($23\pm 1^\circ\text{C}$; RH 80-85%), with subsequent storage for 15 days at $20\pm 1^\circ\text{C}$ and 85-95% RH. Vertical bars indicate \pm SD.

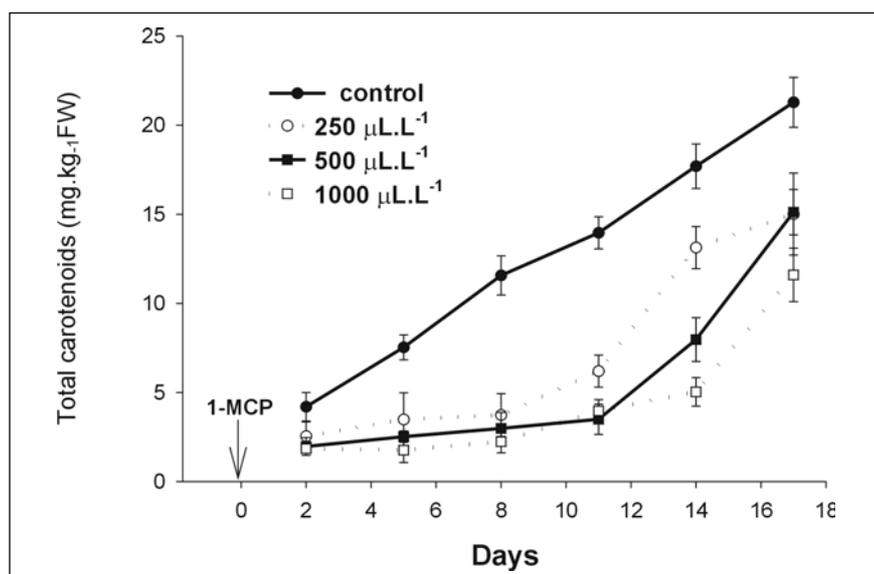


Figure 5. Total carotenoids (mg.kg^{-1} fresh weight) of tomato fruits treated with 1-MCP, stored for 2 days at ambient conditions ($23\pm 1^\circ\text{C}$; RH 80-85%), with subsequent storage for 15 days at $20\pm 1^\circ\text{C}$ and 85-95% RH. Vertical bars indicate \pm SD.

supported by Porat *et al.* (1999), who observed that citrus fruit treated with 1-MCP showed no significant changes in organic acid content. On the other hand, Fan and Mattheis (2000) and Fan *et al.* (1999) showed that titratable acidity was significantly affected by 1-MCP treatments in lettuce and apples.

Fruit color

As 1-MCP concentrations increased, fruit color development was further delayed. After five days in storage, there

was a significant difference in color development between control fruits and 1-MCP treated fruits (Figure 4). Tomato fruits treated with 250, 500 and 1000 mL.L^{-1} of 1-MCP showed degradation of chlorophyll and expression of carotenoids after 6 to 7, 8 to 9, and 10 to 11 days, respectively, of 1-MCP application.

External color development and firmness are among the most important quality characteristics of tomato fruits

perceived by consumers as indicators of maturity. The application of 1-MCP retarded color development, thus extending the shelf life of tomato fruits. These results are similar to those of Jiang *et al.* (1999), who reported that banana color change was delayed when treated with 1-MCP. Similarly, Porat *et al.* (1999) observed that 1-MCP application delayed degreening of citrus fruits.

Total carotenoids

Trends observed for total carotenoids were similar to those for color (ratio a^*/b^*). As 1-MCP dose increased, pigment synthesis and expression was further delayed. At the end of the storage period, control fruits contained around 190% more total carotenoids than fruits treated with 1000 mL.L^{-1} of 1-MCP (Figure 5).

Uneven degreening in individual fruits treated with 1-MCP was observed at the early stages of ripening. In some cases, color development started first at the stem end and then gradually shifted to the blossom end. Jiang *et al.* (1999) observed that bananas treated with 1-MCP showed uneven skin degreening. They attributed this to positional differences in the rate of new synthesis of ethylene binding sites.

In conclusion, postharvest application of 1-MCP was an efficient method of delaying tomato fruit ripening. Fruits treated with 1-MCP had dramatically reduced the rate of fruits softening and color development in comparison with nontreated tomatoes. Titratable acidity and soluble solids were not significantly affected. As 1-MCP concentrations increased, ripening was further delayed. Fruits treated with 250, 500, and 1000 mL.L^{-1} of 1-MCP had ripening delays of 8 to 11, 11 to 13 and 15 to 17 days, respectively. Thus, with the concentrations tested, 1-MCP allows growers to schedule tomato fruit ripening.

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