



ELSEVIER

Postharvest Biology and Technology 7 (1996) 129–136

**Postharvest  
Biology and  
Technology**

## Postharvest studies on pepino dulce (*Solanum muricatum* Ait.): maturity at harvest and storage behavior

Miguel Ahumada, Marita Cantwell\*

Department of Vegetable Crops, Mann Laboratory, University of California, Davis, CA 95616, USA

Accepted 20 May 1995

---

### Abstract

Pepino fruits (cv. Toma) were harvested at three stages of ripeness (mature-green, turning, and ripe) and stored at various temperatures (0–20°C) for up to four weeks. Fruits of all ripeness classes showed low respiration rates ( $\sim 10 \text{ ml kg}^{-1} \text{ h}^{-1}$ ) and a nonclimacteric respiratory pattern at 20°C. Fruits of all ripeness classes had very low ethylene production rates ( $< 0.1 \mu\text{l kg}^{-1} \text{ h}^{-1}$ ) at 20°C. After storage at 5°C, ethylene production rates at 20°C never exceeded  $0.4 \mu\text{l kg}^{-1} \text{ h}^{-1}$ . Exposure of fruits to 10 ppm ethylene resulted in a 30% increase in respiration and an advance in stage of ripeness. Pepinos of all ripeness classes were stored successfully for four weeks at 7.5–10°C. Ripening fruits were stored at 5°C without causing chill-induced discoloration and decay. Less ripe fruits were severely damaged within two weeks by storage temperatures  $< 5^\circ\text{C}$ .

**Keywords:** Respiration; Ethylene production rates; Soluble solids; Titratable acidity; Firmness

---

### 1. Introduction

The pepino (*Solanum muricatum* Ait.), also called pepino dulce (Spanish for “sweet cucumber”), melon pear or melon shrub, is an evergreen frost-sensitive plant native to the Andean regions of South America. This perennial solanaceous shrub is grown as an annual in many areas and requires cool nights and mild days (12–25°C) for good fruit set (Bravo and Arias, 1983; Dennis et al., 1985). Pepino fruits are round to elongate in shape, can weigh from 100 to 500 g at maturity and contain 6–12% soluble solids. The thin skin is light green to cream-yellow with distinctive purple stripes. The pulp is light green to light yellow in color and is reminiscent of melon fruit with its mild, pleasant, but unique flavor. In recent years

---

\* Corresponding author. Fax: 916 752-4554.

the pepino has become a specialty fruit exported from Chile and New Zealand, and is produced commercially in California along the coast. There are several named varieties produced commercially including 'Toma', 'Miski Prolific', 'Colossal', and 'El Camino'.

Ripe pepino fruits of a local selection contained 9.50% soluble solids, 4.06 g 100 g<sup>-1</sup> total sugars, 0.06 g 100 g<sup>-1</sup> acidity, and 34.25 mg 100 g<sup>-1</sup> vitamin C according to de Arriola et al. (1976). Harman et al. (1986) reported that as the fruit matures, soluble solids, pH and titratable acidity did not vary significantly, but that total sugar content increased during maturation and ripening. They considered 'El Camino' and 'Suma' pepino fruits to be good flavored if they had 10% soluble solids. Redgwell and Turner (1986) reported the fresh-weight composition of ripe 'El Camino' fruits to be 0.1% protein, 4.9–6.4 g 100 g<sup>-1</sup> sugars, 48–68 mg 100 g<sup>-1</sup> vitamin C, 119–153 mg 100 g<sup>-1</sup> organic acids, and 52–70 mg 100 g<sup>-1</sup> amino acids. During fruit ripening, simple sugars increased dramatically. Citric acid was the predominant nonvolatile organic acid and also increased as the fruit ripened. The fruit core contained higher amounts of sugars and acids than did outer pulp tissue.

Lizana and Levano (1977) studied the quality and physiological behavior of typical Chilean pepinos which had 8.5% soluble solids when ripe. Based on the respiratory pattern, they concluded that the pepino was a climacteric fruit. Heyes et al. (1994) concluded that the fruit are nonclimacteric after demonstrating that pepino fruits do not produce ethylene autocatalytically in response to propylene treatment, and that respiration rates increased only slowly during storage in air at 20°C.

Lizana and Levano (1977) concluded that pepino fruits could be stored successfully at 10°C, that the fruit suffered from chilling injury if stored at 5°C or below and that less ripe fruits suffered more chill damage than ripe fruit. Dennis et al. (1985) and El-Zeftawi et al. (1988) reported a one to two week shelf-life for pepino fruits under ambient conditions. Shelf-life was extended to four weeks when fruits were stored at 10°C with 90–95% relative humidity (RH) (Dennis et al., 1985).

The objective of this study was to further characterize the postharvest physiology and quality of pepino fruits in relation to maturity at harvest and storage conditions, including time, temperature and ethylene application.

## 2. Materials and methods

Fruits of cv. Toma were harvested from a commercial planting along the central coast of California from October to December. Fruits were clipped from the plant, and were harvested at distinct stages of ripeness based on color and firmness. Table 1 briefly describes the quality characteristics of the ripeness classes used in this study. Fruits were transported in containers in an air-conditioned car to the laboratory at Davis, where fruit were selected, classified, and stored overnight at 10°C.

Fruits of the three ripeness classes were monitored for respiration and ethylene production rates by placing individual fruits in glass containers connected to a humidified air flow-through system. Flow rates were calculated to maintain the carbon dioxide levels between 0.25 and 0.5% at the outlet ports. Respiration and

Table 1

Quality of pepino dulce (cv. Toma) fruits harvested at four stages of ripeness

| Ripeness class | Description   | Firmness (N)            | Soluble solids (%) | Titrateable acidity (%) |
|----------------|---|-------------------------|--------------------|-------------------------|
| 1              | <i>Mature green</i> ; no yellowing at blossom end; ground color light green   | 54.9 ± 8.8 <sup>a</sup> | 6.4 ± 0.7          | 0.070 ± 0.009           |
| 2              | <i>Turning</i> ; 10–30% yellow color; cream color as predominant ground color | 29.5 ± 9.8              | 6.8 ± 0.5          | 0.071 ± 0.011           |
| 3              | <i>Ripe</i> ; 30–90% yellow ground color                                      | 18.0 ± 7.0              | 7.8 ± 0.2          | 0.074 ± 0.006           |
| 4              | <i>Overripe</i> ; >90% yellow ground color; yellow color intensified          | 6.9 ± 2.9               | 8.5 ± 0.4          | 0.065 ± 0.009           |

<sup>a</sup> Data from eight fruits per ripeness class.

ethylene production rates were determined by taking 1-ml gaseous samples from the outlet ports for analysis of carbon dioxide on an Infrared Analyzer and for ethylene on a gas chromatograph equipped with a flame ionization detector. Some fruits were treated with 10 ppm ethylene in a humidified flow-system.

Other fruits were placed on fiber trays, overwrapped loosely with low-density polyethylene film, and stored for different periods in the dark at 0, 2.5, 5, 7.5, 10 and 20°C. Quality evaluations included: decay incidence, surface discoloration, internal appearance (using scales of 1 to 5 where 1 = none; 2 = slight; 3 = moderate; 4 = moderately severe; and 5 = severe), weight loss, firmness (force of penetration by an 8-mm probe on a mounted 49-N firmness tester, measured at the equator on peeled fruit), soluble solids (temperature-compensated refractometer), pH and titrateable acidity (by titration with 0.05 N NaOH to an 8.1 pH endpoint and calculated as % citric acid). Fruit composition was determined on a homogenate of equal weight of fruit pulp and water which was filtered before use. Data are the means of at least four replications per treatment.

### 3. Results and discussion

The respiration rate of pepino fruits is low to moderate, with the ripe class 3 fruit having respiration rates 50% greater than those of the less ripe class 1 fruits (Fig. 1). Respiration rates of cv. Toma fruits were lower than those reported for cv. El Camino fruits and did not increase at 20°C (Heyes et al., 1994). Freshly harvested fruit held at 20°C under 10 ppm ethylene (Fig. 1C) showed a 25–30% increase in respiration rates over those stored in air (Fig. 1A). Less ripe fruit stored two weeks at 5°C and then transferred to 20°C in air (Fig. 1B) showed increased respiration rates over freshly harvested fruits (Fig. 1A). Ethylene treatment of these same fruits (Fig. 1D) resulted in increased respiration rates with the least mature fruit showing the greatest stimulation of respiration rate.

Fruits produced very low levels of ethylene (0.02–0.05  $\mu\text{l kg}^{-1} \text{h}^{-1}$  at 20°C), and no consistent differences in ethylene production were found among fruits of

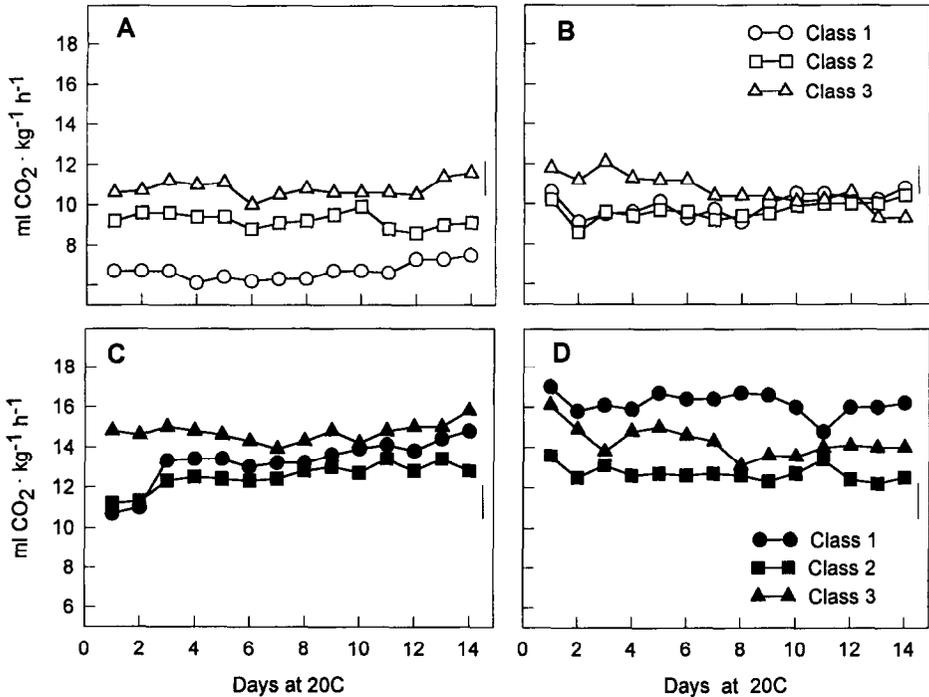


Fig. 1. Respiration rates of pepino fruits harvested at the mature-green (class 1), ripening (class 2) and ripe (class 3) stages of development. Fruits were stored at 20°C in air (open symbols) or 10 ppm ethylene (closed symbols) immediately after harvest (A and C) or after two weeks of storage at 5°C (B and D). Data are the averages of measurements of four individual fruits with vertical bars indicating standard deviations.

different ripeness classes. These low ethylene production rates are similar to those reported by Heyes et al. (1994) for 'El Camino' fruit of different ripeness stages. After storage at 5°C and transfer to 20°C, ethylene production rates increased to  $0.4 \mu\text{l kg}^{-1} \text{h}^{-1}$  in ripeness class 1 'Toma' fruits. Fruits of ripeness classes 2 and 3 had ethylene production rates of  $0.05\text{--}0.12 \mu\text{l kg}^{-1} \text{h}^{-1}$  after transfer to 20°C from 5°C storage. El-Zeftawi et al. (1988) reported low initial internal ethylene concentrations in pepinos but found that levels increased notably with ripening. In the present study, ethylene production rates  $>0.4 \mu\text{l kg}^{-1} \text{h}^{-1}$  were only associated with fruits with visible decay.

Increases in respiration and ethylene production rates after harvest are the criteria used to classify fruit ripening behavior as climacteric (Biale and Young, 1981; Saltveit, 1993; Tucker, 1993). The low respiration rates and lack of a climacteric respiratory pattern, the very low ethylene production rates, and the increased respiration rates in response to continuous ethylene treatment all indicate that the pepino has a nonclimacteric ripening physiology. The respiration rates of cv. Toma fruits were about 50% lower than those of the fruit studied by Lizana and

Levano (1977) and by Heyes et al. (1994), and did not show postharvest increases in respiration as reported by these authors. The differences in respiration rates among ripeness classes were consistent with the results of El-Zeftawi et al. (1988).

Different physiological behavior may be found in solanaceous fruits of the same species, as illustrated by the nonclimacteric behavior of bell peppers (Saltveit, 1977) but the climacteric ripening pattern of chile peppers (Gross et al., 1986). Variation in ripening physiology has also been extensively documented among different tomato cultivars (Hobson and Grierson, 1993). The fact that the fruit need to be harvested as ripe as possible to have good eating quality (Dennis et al., 1985; Harman et al., 1986; El-Zeftawi et al., 1988) is also consistent with the pepino being classified as a nonclimacteric fruit. There is an increase in soluble solids during the ripening of the fruit on the plant (Table 1) and relatively small changes during storage (Tables 2 and 3).

Fruits of three ripeness classes stored at 20°C for two weeks showed decreases in firmness, soluble solids and acidity (Table 2). When stored in air, little external color change was noted, whereas treatment with ethylene during two weeks advanced external color development. Soluble solids and acid contents were similar between the ethylene-treated and air-stored fruit, but the less mature ethylene-treated fruit were less firm than air-stored fruit. These results are similar to those reported by El-Zeftawi et al. (1988) with ethephon-treated 'Golden Spendour' fruits. Heyes et al. (1994) showed a 40% decrease in pepino firmness with propylene treatment as compared to that of air-stored fruit. When pepinos were stored for two weeks at 5°C and then held in air or ethylene at 20°C, ethylene treatment advanced fruit color development, but was also associated with a higher decay score (data not shown). The most common decay was a dark brown rot, often developing from the stem end but eventually enveloping all the fruit pulp. Lizana and Levano (1977) reported that *Alternaria solani* and *Botrytis cinerea* were the most common storage pathogens on pepino fruits, with the former presenting symptoms similar to those observed in the present study.

Table 2

Quality characteristics of pepino dulce (cv. Toma) fruits harvested at three stages of ripeness and stored two weeks at 20°C in air and ethylene

| Initial ripeness class <sup>a</sup>                | Final ripeness class | Pulp firmness (N) | Soluble solids (%) | Titrateable acidity (%) |
|--|----------------------|-------------------|--------------------|-------------------------|
| <i>Stored in air</i>                               |                      |                   |                    |                         |
| 1  | 1                    | 36.3 ± 17.6       | 6.5 ± 0.7          | 0.038 ± 0.005           |
| 2  | 2.2                  | 10.8 ± 4.9        | 6.1 ± 0.9          | 0.046 ± 0.008           |
| 3  | 3                    | 9.8 ± 7.4         | 6.7 ± 0.4          | 0.042 ± 0.003           |
| <i>Stored in 10 ppm C<sub>2</sub>H<sub>4</sub></i> |                      |                   |                    |                         |
| 1  | 2.3                  | 9.8 ± 2.9         | 6.3 ± 0.6          | 0.038 ± 0.014           |
| 2  | 2.5                  | 8.8 ± 2.9         | 6.1 ± 0.7          | 0.042 ± 0.011           |
| 3  | 3                    | 9.8 ± 3.9         | 6.8 ± 0.8          | 0.040 ± 0.009           |

<sup>a</sup> See Table 1 for description of ripeness classes. Data are means of four fruits.

Table 3

Firmness and composition of pepino fruits (*cv. Toma*) harvested at three stages of ripeness and stored in air at 0, 5 and 10°C for two and four weeks

| Storage condition | Initial ripeness class <sup>a</sup> | Decay <sup>b</sup> | Firmness (N) | Discoloration <sup>b</sup> | Soluble solids (%) |
|-------------------|-------------------------------------|--------------------|--------------|----------------------------|--------------------|
| <i>Two weeks</i>  |                                     |                    |              |                            |                    |
| 0°C <sup>b</sup>  | 1                                   | 1 ± 0 <sup>c</sup> | 64.7 ± 9.8   | 1 ± 0                      | 5.8 ± 0.6          |
|                   | 2                                   | 1 ± 0              | 35.3 ± 8.8   | 1.6 ± 0.5                  | 6.4 ± 0.9          |
|                   | 3                                   | 1 ± 0              | 17.6 ± 3.9   | 1.2 ± 0.4                  | 6.6 ± 0.4          |
| 5°C               | 1                                   | 1 ± 0              | 34.3 ± 11.8  | 1 ± 0                      | 5.9 ± 0.1          |
|                   | 2                                   | 1 ± 0              | 31.4 ± 9.8   | 1 ± 0                      | 7.2 ± 0.5          |
|                   | 3                                   | 1 ± 0              | 17.6 ± 4.9   | 1 ± 0                      | 7.7 ± 0.3          |
| 10°C              | 1                                   | 1 ± 0              | 17.6 ± 7.8   | 1 ± 0                      | 6.3 ± 0.5          |
|                   | 2                                   | 1 ± 0              | 11.8 ± 1.0   | 1 ± 0                      | 6.8 ± 0.8          |
|                   | 3                                   | 1 ± 0              | 10.8 ± 2.0   | 1 ± 0                      | 7.5 ± 0.5          |
| <i>Four weeks</i> |                                     |                    |              |                            |                    |
| 0°C               | 1                                   | 1 ± 0              | 49.0 ± 3.9   | 5 ± 0                      | 6.0 ± 1.0          |
|                   | 2                                   | 1 ± 0              | 23.5 ± 15.7  | 5 ± 0                      | 6.9 ± 1.3          |
|                   | 3                                   | 1 ± 0              | 12.7 ± 0     | 3.8 ± 1.0                  | 6.4 ± 0.4          |
| 5°C               | 1                                   | 1.7 ± 0.3          | 24.5 ± 12.7  | 1.8 ± 0.6                  | 6.0 ± 0            |
|                   | 2                                   | 2.5 ± 0.6          | 11.8 ± 7.8   | 1 ± 0                      | 6.7 ± 0.3          |
|                   | 3                                   | 1.5 ± 0.2          | 6.9 ± 5.9    | 1 ± 0                      | 7.0 ± 0            |
| 10°C              | 1                                   | 1.0 ± 0            | 7.8 ± 2.9    | 1 ± 0                      | 5.6 ± 0            |
|                   | 2                                   | 1.6 ± 0.4          | 9.8 ± 1.0    | 1 ± 0                      | 6.4 ± 0.4          |
|                   | 3                                   | 1.2 ± 0.3          | 4.9 ± 1.0    | 1 ± 0                      | 7.3 ± 0.3          |

<sup>a</sup> See Table 1 for description of ripeness classes.

<sup>b</sup> Rated on a 1 to 5 scale, where 1 = none; 2 = slight; 3 = moderate; 4 = moderately severe; and 5 = severe.

<sup>c</sup> Data from eight fruits per treatment.

Table 3 shows the visual quality, firmness and composition of fruits of three ripeness classes stored at 0, 5 and 10°C for two and four weeks. Fruits stored at 0°C showed slight external discoloration after two weeks and severe discoloration after four weeks. In numerous fruits stored at 0°C, internal discoloration was noted after four weeks. Fruits of low maturity (class 1) stored at 5°C showed some surface discoloration after four weeks, but if they were stored for six weeks (data not shown), they showed significant chilling injury symptoms. Water loss was greater at 10°C than at 5°C and shrivel was visible after about three weeks at 10°C. In another experiment, soft ripe (class 3) pepino fruits stored for four weeks at 0, 2.5, 5 and 7.5°C showed moderate external discoloration at 0 and 2.5°C, slight discoloration at 5°C, and no discoloration after storage at 7.5°C (Table 4). The symptoms described and their variable development depending on storage temperature and fruit maturity are consistent with those reported by Lizana and Levano (1977). It is clear that the development of chilling injury symptoms in the pepino fruit depends on stage of ripeness and requires a long-term exposure to very low temperatures.

Table 4

Quality characteristics of ripe (class 3) pepino dulce (cv. Toma) fruits stored four weeks at 0, 2.5, 5 and 7.5°C

| Storage condition | Discoloration <sup>a</sup> | Decay <sup>a</sup> | Firmness (N) | Soluble solids (%) |
|-------------------|----------------------------|--------------------|--------------|--------------------|
| Initial           | –                          | –                  | 8.8 ± 2.0    | 7.8 ± 1.1          |
| 0°C               | 2.9 ± 1.3 <sup>b</sup>     | 1.8 ± 1.0          | 6.9 ± 2.9    | 8.7 ± 1.3          |
| 2.5°C             | 3.5 ± 1.1                  | 2.3 ± 1.0          | 6.9 ± 2.9    | 7.9 ± 1.4          |
| 5°C               | 1.9 ± 0                    | 2.3 ± 1.0          | 6.9 ± 2.0    | 8.4 ± 1.3          |
| 7.5°C             | 1.0 ± 0                    | 1.6 ± 0.7          | 5.9 ± 2.9    | 8.6 ± 0.8          |

<sup>a</sup> Discoloration and decay rated on 1 to 5 scale, where 1 = none; 2 = slight; 3 = moderate; 4 = moderately severe; and 5 = severe.

<sup>b</sup> Data are means from eight fruits per treatment.

#### 4. Conclusions

It can be concluded that the pepino melon is a nonclimacteric fruit, that it has higher sugar content if harvested in the later stages of maturation and ripening, and that it can be stored successfully at 7.5–10°C for up to four weeks. Storage of ripening and ripe fruits at 5°C did not usually result in chill-induced discoloration. Storage of pepino fruits at temperatures below 5°C resulted in severe surface and internal discoloration.

#### Acknowledgements

Fruit for this study were kindly provided by John Swift, Swift Subtropicals, Los Osos, Calif. We appreciate the helpful review of this manuscript by Adel Kader.

#### References

- Biale, J.B. and Young, R.E., 1981. Respiration and ripening in fruits — retrospect and prospect. In: J. Friend and M.J.C. Rhodes (Editors), *Recent Advances in the Biochemistry of Fruits and Vegetables*. Academic Press, New York, NY, pp. 1–39.
- Bravo, M. and Arias, A.E., 1983. Cultivo del pepino dulce. *El Campesino* (journal of the Facultad de Agronomía, Universidad Católica de Chile), March, 114: 16–33.
- de Arriola, M.C., Menchú, J.F. and Rolz, C., 1976. Caracterización, manejo y almacenamiento de algunas frutas tropicales. Rep. ICAITI, Guatemala, pp. 50–52.
- Dennis, D.J., Burge, G.K. and Lill, R., 1985. *Pepinos: cultural techniques*. Information Services, Ministry of Agriculture, Wellington, N.Z., 2 pp.
- El-Zeftawi, B.M., Brohier, L., Dooley, L., Goubran, F.H., Holmes, R. and Scott, B., 1988. Some maturity indices for tamarillo and pepino fruits. *J. Hortic. Sci.*, 63(1): 163–169.
- Gross, K.C., Watada, A.E., Kang, M.S., Kim, S.D., Kim, K.S. and Lee, S.W., 1986. Biochemical changes associated with the ripening of hot pepper fruit. *Physiol. Plant.*, 66: 31–36.
- Harman, J.E., Hogg, M. and Horne, S.F., 1986. Maturity and quality indices for pepino fruit. *HortScience*, 21(3): 129 (abstract).
- Heyes, J.A., Blaikie, F.H., Downs, C.G. and Sealey, D.F., 1994. Textural and physiological changes during pepino (*Solanum muricatum* Ait.) ripening. *Sci. Hortic.*, 58: 1–15.
- Hobson, G. and Grierson, D., 1993. Tomato. In: G.B. Seymour, J.E. Taylor and G.A. Tucker (Editors), *Biochemistry of Fruit Ripening*. Chapman and Hall, New York, NY, pp. 405–442.

- Lizana, L.A. and Levano, B., 1977. Caracterización y comportamiento de post-cosecha del pepino dulce *Solanum muricatum*, Ait. Proc. Trop. Reg. Am. Soc. Hortic. Sci., 21: 11–15.
- Redgwell, R.J. and Turner, N.A., 1986. Pepino (*Solanum muricatum*): chemical composition of ripe fruit. J. Sci. Food Agric., 37: 1217–1222.
- Saltveit, M.E. Jr., 1977. Carbon dioxide, ethylene, and color development in ripening mature green bell peppers. J. Am. Soc. Hortic. Sci., 102: 523–525.
- Saltveit, M.E. Jr., 1993. Internal carbon dioxide and ethylene levels in ripening tomato fruit attached to or detached from the plant. Physiol. Plant., 89: 204–210.
- Tucker, G.A., 1993. Introduction. In: G.B. Seymour, J.E. Taylor and G.A. Tucker (Editors), *Biochemistry of Fruit Ripening*. Chapman and Hall, New York, NY, pp. 1–51.