Ethylene in Cherimoya Fruit (*Annona cherimola* Mill.) under Different Storage Conditions

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Cherimoya fruits grown in the subtropical valleys of the southern Spanish coast were stored at 20 or 10 °C. Ethylene concentrations within the internal atmosphere of the fruits, determined by gas chromatography, show a peak coincident with the beginning of senescence at both temperatures. Production of ethylene was dependent on the storage temperature of the fruits, having maximum values of 46.2 ± 2.7 μL of ethylene kg^{-1} h^{-1} in cherimoya stored at 20 °C and of 1.91 ± 0.03 μL of ethylene kg^{-1} h^{-1} when they were stored at 10 °C. Implications of ethylene on the ripening of cherimoya are discussed.

INTRODUCTION

Cherimoya (*Annona cherimola* Mill.) is an important subtropical fruit crop extensively cultured in some areas in the south of the Spanish Mediterranean coast and in other areas of South America and California. It is a fruit with a typical climacteric maturation characterized by a rise in respiration followed by an ethylene peak production leading to senescence (Moreno and De la Plaza, 1983; Brown et al., 1988).

The shelf life of the fruit is very short, being inedible after 1 week of storage at 20–23 °C, the normal temperature of the areas of production (Brown et al., 1988). Several works have been carried out to delay senescence, increasing the marketing possibilities, including storage in controlled atmospheres (De la Plaza, 1979) and storage under refrigeration (Lahoz et al., 1990). Since it is a subtropical fruit, cherimoya is highly susceptible to chilling injury (Gutiérrez et al., 1992, 1993). *Annona squamosa* (sugar apple) develops chilling injury within 5 days at 4 °C (Broughton and Guat, 1979), while other *Annona* species such as *A. cherimola* var. Concha lisa seem to be more resistant. Varieties growing in Spain are Fino de Jete or Blanca (*A. cherimola* Mill. var. impressa) and Campa (*A. cherimola* Mill. var. mammilaris). Depending on the area of production and the month of recollection, 10 °C is the minimum storage temperature for local varieties allowing ripening of cherimoya without impairing the normal organoleptic characteristics of the ripened fruit, and without the development of chilling injury related symptoms (Lahoz, 1990; Gutiérrez et al., 1992).

Ripening of many fruits involves ethylene biosynthesis, being of greatest interest the possible linkage between ethylene, low temperature, and senescence phenomena (Field, 1990). In tomatoes, high ethylene production, chilling damage, and the progress of ripening are apparently related, but no causal relationships have been established (Autio and Bramlage, 1986).

In this work, the evolution in ethylene production and concentration in cherimoya stored at 20 and 10 °C are reported, showing that storage at 10 °C delays ethylene production, which may be responsible for the 2-fold increase in the ripening period of cherimoya stored at this nonchilling temperature.

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MATERIALS AND METHODS

Cherimoya fruits were harvested at the mature-green stage. They were immediately washed by dipping in 0.05% imazalil/0.2% deccosol to prevent fungal infections and, after drying at room temperature, stored at 20 or 10 °C.

To measure ethylene concentration in the fruits, the fruits were individually submerged in a saturated solution of $(NH_4)_2SO_4$ and covered with an inverted funnel ending in a sealed rubber top. Vacuum was applied until 100 mmHg was reached, and the fruits were maintained in this bath for 2 min (Beyer and Morgan, 1970). Three samples of the released gas were taken for each fruit through the rubber septum in the funnel. Ethylene production was determined by introducing the fruits in hermetically closed flasks of known volume with a silicone septum. After 2 min, samples of the atmosphere inside the flasks were taken.

Ethylene concentration in the samples was analyzed by gas chromatography using a Perkin-Elmer Sigma 300 with a flame ionization detector calibrated with different concentrations of pure ethylene. A Porapak-Q column was used. Ethylene retention time was 1 min.

Ripening of cherimoya was monitored by following softening of the fruits using a texturometer (Fuster and Prestamo, 1980), increase in soluble solids content (Gutiérrez et al., 1993), and evolution in the starch content as the glucose released from starch by digestion with amyloglucosidase (Haissig and Dickson, 1979; Bergmeyer and Bernt, 1974).

RESULTS AND DISCUSSION

When cherimoya fruits were stored at 20 °C, a fast maturation occurred, externally characterized by a softening of the fruit (Fuster and Prestamo, 1980). We have also measured the texture of cherimoya during storage as a control of the ripening process (Figure 1). Four days after harvesting, the textures of the fruits were reduced to a value of 23 ± 3% in relation to the texture of cherimoya freshly harvested. The softening was more evident on the fifth day, when a value of 3.1 ± 0.4% was reached. During this time the cell walls were degraded and most of the starch within the mesocarp was metabolized as detected by ultramicroscopy (Gutiérrez et al., 1992) and in this paper (Figure 1). As a consequence of starch degradation, increases in soluble solids content were monitored. Accumulation of sugars can be easily monitored by measuring the refraction index of an extract from mesocarp (Figure

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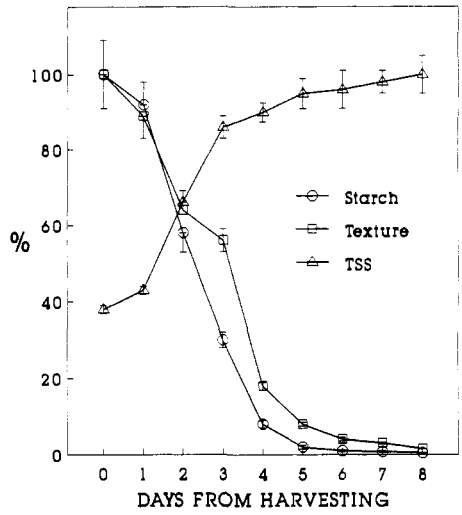

Figure 1. Evolution of texture, total soluble solids, and starch content in cherimoya stored at 10 or 20 °C. Results are mean ± SEM of six individual fruits. Determinations were made in triplicate.

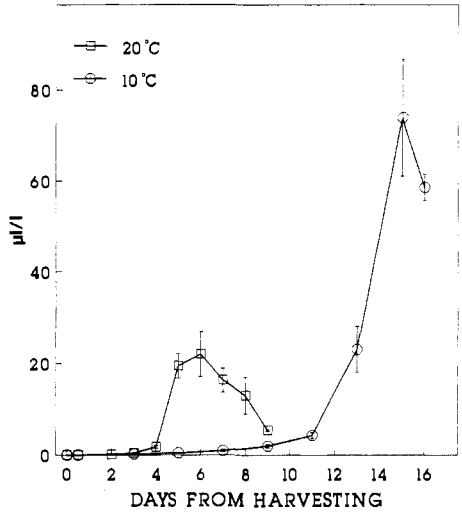

Figure 2. Ethylene concentration in cherimoya fruits stored at 10 or 20 °C. Results are mean ± SEM of six individual fruits. Determinations were made in triplicate.

1). A decrease in pH is also evident as a consequence of the production of organic acids (Gutiérrez et al., 1993). None of the above-described effects seems to be related to ethylene accumulation within the fruit as they occurred before the rise in ethylene concentration.

Ethylene concentration was barely detectable until the fourth day after harvesting, its concentration abruptly increasing by the fifth day (Figure 2) with a maximum on the sixth day. Later than that, the fruit was no longer edible due to fermentation reactions producing undesirable flavors, and a slow decrease in ethylene concentration was measured. When ripening occurred in cherimoya stored at 10 °C, the same pattern was observed but all of the described phenomena were delayed between 5 and 7 days (Lahoz et al., 1990; Gutiérrez et al., 1992, 1993). Ethylene peak was reached on day 15 (Figure 2), when the fruit had already suffered most of the typical ripening reactions and was close to senescence.

It was surprising that ethylene concentration in cherimoya stored at 10 °C was much higher than in fruits stored at 20 °C (Figure 2). This fact can be explained only by two different mechanisms: ethylene production must be higher or the hormone accumulates better in cherimoya tissues at the lower temperature. To ascertain the

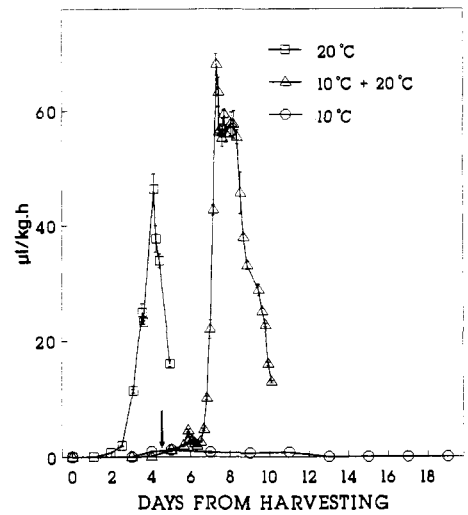

Figure 3. Ethylene production by cherimoya stored at 10 or 20 °C. Cherimoya stored at 10 °C were divided in two lots. One of them was rewarmed to 20 °C (arrow) and maintained at this temperature for the length of the experiment. Results are mean ± SEM of three individual fruits. Determinations were made in triplicate.

mechanism involved in the increased concentration of ethylene in cherimoya stored at 10 °C, an experiment to measure ethylene production was performed (Figure 3). Cherimoya stored at 20 °C produced a maximum of 46.2 ± 2.7 µL of ethylene kg^{-1} h^{-1} 4 days after harvesting; it should be noted that 2 days after harvesting they produced 1.91 ± 0.03 µL of ethylene kg^{-1} h^{-1}. When fruits were stored at 10 °C, a maximal production of 1.92 ± 0.11 µL of ethylene kg^{-1} h^{-1} 6 days after harvesting was reached. The rate of ethylene production decreased progressively until 19 days after harvesting. This very small rate of production was sufficient to produce a much higher concentration of the hormone inside the fruit, a fact that can be explained because gas dissolves better at low temperatures due to a smaller diffusion rate.

Cherimoya fruits stored at 10 °C for 5 days were rewarmed to 20 °C, and ethylene production was monitored every 3 or 4 h. In this situation, the high rate of hormone synthesis was recovered, reaching values similar to or even higher than those in fruits ripened at 20 °C (Figure 3). This result shows that ethylene production was highly dependent on the temperature.

The question to solve is, how important is ethylene for the control of ripening in cherimoya? We can argue that fruit stored at 10 °C presented delayed but completely normal ripening parameters even with a very low synthesis rate of the hormone. At both storage temperatures, a small production rate close to 2 µL kg^{-1} h^{-1} was measured simultaneously to the biggest increase in starch degradation and softening of cherimoya, making it plausible that this very small production rate was enough to unchain the ripening process. This result may explain the lack of success in delaying senescence when fruits were stored at low temperatures in the presence of several standard ethylene traps, as it was not possible to completely eliminate ethylene dissolved in the mesocarp of the cherimoya (Vargas, unpublished results). Higher ethylene production obtained at the normal temperature of 20 °C may be necessary to obtain the internal ethylene concentration probably needed to induce adequately the genes for complete ripening of cherimoya.

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