Postharvest Quality of Passion Fruit as Influenced by Harvest Time and Ethylene Treatment

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Abstract. Greenhouse-grown purple passion fruit (*Passiflora edulis* Sims) were harvested mature-green 55 or 60 days after anthesis (DAA) and stored for 10 days at 10C. After storage, half the fruit were treated with 10 µl ethylene/liter for 35 hours and then stored at 21C for 48 hours. Juice of treated and nontreated fruit was analyzed for comparison with juice of vine-ripened fruit (harvested 70 to 80 DAA). Sucrose concentration decreased and fructose and glucose concentrations increased after storage, regardless of ethylene treatment. Fruit harvested 55 or 60 DAA, with or without ethylene, had the same sugar and soluble solids concentrations and pH as vine-ripened fruit. Ethylene treatment enhanced surface purple pigmentation of fruit harvested mature-green.

Passion fruit, a tropical fruit species produced in the United States, has become a popular addition to some diets (Campbell, 1986; Campbell and Knight, 1983; Knight and Sauls, 1983). Juice of the fruit is a good source of vitamins A and C, and its aroma and flavor make pleasant contributions to drinks and desserts (Campbell and Knight, 1983; Pruthi, 1963).

Commercially matured fruit are ground-harvested after natural drop. Fruit that abscise from the vine begin dehydrating immediately and are frequently contaminated with soil-borne pathogens. Passion fruit is climacteric, and the climacteric rise occurs while the fruit is still attached to the plant (Biale, 1975). Fruit picked from the vine have an unripened flavor (Campbell and Knight, 1983; Knight and Sauls, 1983). The storage life may be extended considerably if mature-green fruit could be harvested before the climacteric rise and induced to ripen in storage at low temperatures (Biale, 1975). Ethylene-

induced ripening of mature-green bananas and tomatoes after harvest is a widely accepted commercial practice (Jeffery et al, 1984; Liu, 1976).

The objective of this study was to examine the effect of harvest time and ethylene treatment on postharvest quality of mature-green passion fruit, aiming at determining the optimum physiological maturity for harvesting the fruit.

Purple passion fruit vines were grown at the Box Horticultural Greenhouse, Mississippi State Univ. Plants were produced from vegetative tip cuttings and grown in the greenhouse at 30 ± 2C. Plants were irrigated as needed and fertilized with 13N-5.7P-10.7K at 200 mg N/liter every 2 weeks. Flowers were tagged at anthesis (late May and early June 1989), and fruit was harvested at three developmental stages: 1) mature-green, harvested 55 days after anthesis (DAA); 2) mature-green, harvested 60 DAA; and 3) fully ripe, harvested immediately after abscission (70 to 80 DAA). Immediately after harvest, fruits were surface-disinfected by holding them for 5 min in a 10% sodium hypochlorite (chlorine bleach) solution. Some fruits were used for initial evaluations. For the fruit used for storage, the following four treatments were established: 1) mature-green, harvested 55 DAA, no ethylene; 2) mature-

green, harvested 60 DAA, no ethylene; 3) same as treatment 1, but with ethylene; and 4) same as treatment 2, but with ethylene. The experiment was conducted twice using a completely randomized design with three replications. Each replicate contained three fruits.

For initial evaluations, juice was extracted from the fruit immediately after harvest and analyzed for pH, soluble solids concentration (SSC), fructose, glucose, and sucrose. Sugars were determined by high-performance liquid chromatography (HPLC). Fruit were cut in half. The pulp was spooned out, and the juice and seeds were separated by squeezing the pulp in two-layers of cheesecloth. The juice was collected and then centrifuged at 1500× g for 1 h. The supernatant was collected and filtered through a sep-pack C18 cartridge previously activated with 2.0 ml methanol and rinsed with 10 ml distilled water. The sample was filtered with a 0.45-µm pore filter, collected, and injected into the HPLC system. Acetonitrile (80%) in water was used as a solvent. A 10-µl sample was manually injected for every determination. The pump (Waters Assoc., Milford, Mass.) was calibrated to deliver 2.0 ml·min⁻¹ at 10,545 kPa. A carbohydrate analysis column (Waters Assoc.) was used. Sugars were detected with a differential refractometer (Waters Assoc.). Chromatograms were plotted in a standard strip chart recorder. A series of 1.0%, 2.5%, 5.0%, and 10.0% solutions of each

Table 1. Effect of interval between anthesis and harvest (DAA) and ethylene treatment on color development of purple passion fruit.

Time of evaluation (DAA)	Ethylene ^a (µl·liter ⁻¹)	Surface purple (%) ^b
Initial		
Vine-ripened, 70 to 80	---	92 a
Green, 55	---	3 c
Green, 60	---	5 c
After storage		
Green, 55	10	88 a
Green, 60	10	92 a
Green, 55	0	34 b
Green, 60	0	42 b
LSD ^c		7

^aMeasured after the fruits were stored at 10C for 10 days, followed by exposure to ethylene for 35 h and holding in air at 21C for 48 h.

^bThe percentage of purple on the fruit surface was visually estimated. Values are the means for four fruit.

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Fig. 1. Sucrose, fructose, and glucose contents of passion fruit harvested 55, 60, or 70 to 80 days after anthesis (DAA). I, initial; -, no ethylene; +, ethylene (LSD test, $P \leq 0.05$). Measurements were made: 1) immediately after harvest for initial evaluations and 2) after the following sequence: storage at 10C for 10 days, exposure to 0 or 10 μl ethylene/liter for 35 h, holding in air at 21C for 48 h.

sugar was used to obtain a standard curve. Juice pH was measured with an Accumet pH meter 925 (Fisher Scientific, Pittsburgh). SSC was determined with a 5.5 Bausch and Lomb (Rochester, N.Y.) optical refractometer.

The remaining fruits harvested 55 or 60 DAA were arranged in a 2×2 factorial with fruit age (55 or 60 DAA) and ethylene treatment (0 and 10 $\mu\text{l}\cdot\text{liter}^{-1}$, as main effects. These fruit were stored in darkness at 10C and 80% relative humidity (RH) for 10 days. Following storage, half the fruit from each harvest were treated with 10 μl ethylene/liter for 35 h using a commercial ripening banana chamber maintained at 10C and 80% RH. Ethylene was applied with a catalytic generator (Catalytic Generators, Chesapeake, Vs.) preset to deliver the appropriate concentration. The remaining half of the fruit was maintained in a separate chamber, also at 10C and 80% RH, without ethylene. After the ethylene treatment, the fruit were taken from the storage chambers and placed at room temperature (21C) and 30% RH for 48 h for continued ripening. The percentage of fruit surface with purple pigmentation was determined visually. Analysis of variance was performed for all variables, and orthogonal contrasts, as well as LSD, were used to compare treatments ($P = 0.05$).

Juice pH (range 2.8-3.3) and SSC (range 10.8% to 12.5%) did not differ significantly among treatments.

Fruit harvested at 55 and 60 DAA and analyzed immediately had an entirely green surface. Since consumers prefer purple pigment on at least 90% of the fruit surface,

fruits harvested at 55 and 60 DAA with <10% purple (Table 1) were unacceptable for market. Fruit harvested at 55 and 60 DAA, stored for 10 days at 10C, and not treated with ethylene developed the typical purple pigmentation of the ripe stage on $\approx 30\%$ of the fruit surface, particularly at the peduncle and in the blossom-end areas. The remaining 70% of the surface turned a yellowish-green. These fruit also would have been unmarketable. Fruit harvested at 55 or 60 DAA, stored, and treated with ethylene developed the characteristic purple surface of vine-ripened fruit on more than 80% of the surface, indicating that ethylene enhanced pigment development (Table 1).

These results with ethylene are consistent with the literature, in which the role of ethylene in enhancement of fruit color has been well established (Moore, 1979).

The sucrose content of fruit harvested at 55 or 60 DAA and stored for 10 days decreased during storage (Fig. 1). Ethylene-treated fruit harvested 55 DAA had less sucrose than the same fruit without ethylene (Fig. 1). Sucrose is metabolized during storage and yields fructose and glucose (Jeffery et al., 1984), thereby accounting for the reduction in sucrose and the increase in fructose and glucose after storage. Vine-ripened fruit (70 to 80 DAA) and fruit harvested at 55 DAA and treated with ethylene after storage contained less sucrose than fruit analyzed at harvest or fruit harvested 55 DAA and not treated with ethylene. Sucrose content was similar for vine-ripened fruit and fruit treated with ethylene. Thus, sucrose

content remained the same whether fruit ripened on the vine or were induced to ripen with ethylene after harvest.

In general, fructose concentration increased as fruit ripened and as sucrose content decreased (Fig. 1). Fructose content of fruit harvested at 55 DAA and analyzed immediately was lower than that of most other samples harvested 55 DAA.

Glucose followed a similar pattern as fructose (Fig. 1). The glucose content in fruit harvested at 55 DAA and analyzed immediately was significantly lower than that of vine-ripened fruit or that harvested at 60 DAA and not treated with ethylene. As in the case of fructose, glucose content increased as ripening proceeded.

Results from this study indicate that, regardless of ethylene treatment, mature-green fruit harvested 55 or 60 DAA, stored at 10C for 10 days, and allowed to ripen for 48 h develop the same SSC and juice pH as those allowed to ripen on the vine. Mature-green fruit (harvested 55 to 60 DAA) lost sucrose and gained fructose and glucose during storage. Sugar concentrations were not influenced by ethylene. It appears that mature-green fruit may be harvested from the vine and allowed to ripen to obtain postharvest quality similar to vine-ripened fruit. However, an ethylene treatment is required to enhance pigment development of fruit harvested at the mature-green stage to render them marketable. No effort was made to relate flavor to maturity indices of passion fruit. Tests to determine the influence of storage conditions and ethylene treatment on fruit flavor warrant investigation.

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