

Papaya

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Scientific Name and Introduction

Papaya, papaw, or paw paw (*Carica papaya* L.) is cultivated throughout the tropics for its fruit (Nakasone 1986). Fruit are eaten green or ripe, in salads or fresh. The related Ecuadorian babaco (*C. pentagonia*) is also eaten fresh.

Fruit are pyriform (pear-shaped), spherical, or cylindrical. The pyriform, hermaphroditic fruit is the most common in commerce. These belong to the 'Solo' group and includes the cultivars 'Kapoho,' 'Rainbow,' 'Sunup,' 'Sunrise,' and 'Sunset'; these varieties weigh 300 to 700 g (10 to 25 oz). Other varieties range from 200 g to 10 kg (0.4 to 22 lbs), with flesh 1.5 to 4 mm (0.06 to 0.16 in) thick. Flesh is greenish-white in immature fruit to pale orange-yellow, salmon pink, or red, depending on cultivar, when ripe.

Quality Characteristics and Criteria

Size, shape, a smooth skin, and absence of blemishes are major quality characteristics. Consumers in Western countries also prefer fruit without a heavy musky, sweaty odor found in some Southeast Asian cultivars. Small, dry, brown-black "freckles" on the skin are nonpathogenic and do not detract from ripening or flavor (Reyes and Paull 1994).

Horticultural Maturity Indices

In Hawaii, minimum grade standard requires 11.5% SSC (Hawaii Department of Agriculture 1990), so fruit should have started ripening before harvest, indicated by some skin yellowing (Akamine and Goo 1971). Less mature fruit are lower in sugar and ripen poorly.

Grades, Sizes, and Packaging

The most common package size is a 4.5-kg (10-lb) carton; larger 10-kg (22-lb) cartons are also used. Cartons from areas requiring insect disinfestation are fully sealed to meet regulatory requirements, while fruit from other areas can be in open-topped cartons. Count size ranges from 6 to 18, depending on fruit and carton size. Fruit are marketed as color break, quarter, half, or three-quarters ripe and are normally ready to eat when there is 75% or more skin color. Foam mesh sleeves, foam padding on the bottom of cartons, or paper wrapping prevents abrasion injury, a major problem in fruit still having green areas of skin (Quintana and Paull 1993).

Precooling Conditions

Room-cooling and forced-air cooling are commonly used. Hydrocooling is possible. However, rapid cooling after insect disinfestation treatments can lead to skin scalding.

Optimum Storage Conditions

Store at 7 to 13 °C (45 to 55 °F) with 90 to 95% RH. At 7 to 10 °C (45 to 50 °F), storage life is limited by chilling injury, while at 10 to 13 °C (50 to 55 °F) fruit ripens slowly (Chen and Paull 1986). Papaya fruit at color-turning (break) stage can be stored at 7 °C (45 °F) for 14 days and will ripen normally when transferred to room temperature (Thompson and Lee 1971, Chen and Paull 1986). Ripe, full-color fruit can be held for >1 week at 1 to 3 °C (34 to 37 °F).

Controlled Atmosphere (CA) Considerations

Shelf-life was extended 1 to 1.5 days when papaya were stored at 12 °C (54 °F) in 1 to 1.5% O₂ for 6 days (Akamine and Goo 1969). Low O₂ (1 to 5%), with or without high CO₂ (2 to 10%), reduces decay (Hatton and Reeder 1969) and delays ripening (Akamine 1959, Chen and Paull 1986). High CO₂ (30%) adversely affects internal color, aroma, and flavor, while there is no residual effect of 10% CO₂ on decay control, though skin degreening is delayed.

At 10 °C (50 °F), fruit can be stored for 36 days in 8% CO₂ and 3% O₂ and still have 5 days at 25 °C (77 °F) for retail (Cenci et al. 1997). Ethylene removal prior to storage has shown variable results (Nazeeb and Broughton 1978). CA recommendations are 2 to 5% O₂ plus 5 to 8% CO₂. However, no commercial use has so far been reported (Yahia 1998). Fruit stored at 10 °C (50 °F), 98% RH, and low pressure of 20 mm Hg ripened more slowly than fruit at normal atmospheric pressure. Low-pressure storage appears to suppress disease development (Alvarez 1980, Chau and Alvarez 1983).

Retail Outlet Display Considerations

The optimum temperature for fruit ripening is 23 to 28 °C (73 to 82 °F), with fruit taking 10 to 16 days to reach full skin yellowing from the color-break stage (An and Paull 1990). Severe weight loss and external abnormalities become significant at temperatures higher than 28 °C (82 °F). Display temperatures should not be less than 10 °C (50 °F) if fruit are not fully ripe. Fully ripe fruit at the edible stage can be held at 1 to 3 °C (34 to 37 °F). Fruit should not be stacked more than two or three deep in racks, and wicker baskets with uneven bottoms and sides should be avoided; or at least a layer of protection should be placed between racks and fruit (Paull et al. 1997). Loss of about 8% of weight from color break produces rubbery, low-gloss, unmarketable fruit (Paull and Chen 1989). Diseased and bruised fruit should be removed from display and used immediately, if possible, in salads or mixed fruit cocktails. Papaya should not be misted.

Chilling Sensitivity

Chilling injury symptoms include skin scald, hard lumps in the pulp around vascular bundles, and water-soaking of flesh (Thompson and Lee 1971, El-Tomi et al. 1974, Chen and Paull 1986). Fruit become progressively less susceptible to chilling stress as they ripen (Chen and Paull 1986). Symptoms of chilling injury occur after 14 days at 5 °C (41°F) in mature green fruit and 21 days in 60% yellow fruit. Skin scald can be induced in color-break fruit after chilling at 1 °C (34 °F) for 24 h. At a storage temperature of 7 °C (45 °F) for 14 days, storage decay is less than when fruit are held at 12 to 13 °C (54 to 55 °F) (Arisumi 1956, El-Tomi et al. 1974).

Ethylene Production and Sensitivity

Ethylene rates in ripening fruit are 6 to 10 $\mu\text{L kg}^{-1} \text{h}^{-1}$ (Paull and Chen 1983, Paull 1993). Ethylene-treated papaya ripen faster and more uniformly in terms of skin degreening, softening, and flesh color (An and Paull 1990). Since papaya ripen from the inside outwards, the effect of ethylene treatment is to accelerate the rate of ripening of the mesocarp tissue nearer the skin that has not started to soften. Ethylene is not recommended commercially, as rapid softening severely limits available marketing time (An and Paull 1990).

Respiration Rates

Papaya are climacteric and begin to yellow from the blossom end (Akamine 1966).

Temperature	$\text{mg CO}_2 \text{ kg}^{-1} \text{ h}^{-1}$
5 °C	4 to 6
15 °C	15 to 22
20 °C - color break	9 to 18
20 °C - ripe	70 to 90

To get $\text{mL CO}_2 \text{ kg}^{-1} \text{ h}^{-1}$, divide the $\text{mg kg}^{-1} \text{ h}^{-1}$ rate by 2.0 at 0 °C (32 °F), 1.9 at 10 °C (50 °F), and 1.8 at 20 °C (68 °F). To calculate heat production, multiply $\text{mg kg}^{-1} \text{ h}^{-1}$ by 220 to get $\text{BTU ton}^{-1} \text{ day}^{-1}$ or by 61 to get $\text{kcal tonne}^{-1} \text{ day}^{-1}$.

Physiological Disorders

A number of nonpathological disorders are seen in marketed fruit (Paull et al. 1997). Green, slightly sunken areas on ripe yellow fruit are caused by abrasion injury when fruit were still green (Quintana and Paull 1993). Unsightly skin freckles (small, brown, slightly raised areas) that are more common on the side of the fruit exposed to the sun is seasonal, developing when rainfall and low temperatures occur 2 mo before harvest (Reyes and Paull 1994). This disorder is nonpathogenic and does not influence ripening or flavor. Sunscald, a dark-olive-brown discoloration, occurs on fruit developing on trees with very sparse foliage, on trees that are leaning over with fruit directly exposed to the sun, and where harvested fruit are left exposed to the sun.

Blossom end defect can be severe at some times of the year (Zee et al. 1989). It leaves an open channel at the blossom end to the fruit seed cavity. Fruit with this disorder are prone to bacterial diseases in the fruit seed cavity before harvest.

Hard lumps in the flesh occur infrequently in otherwise ripe, non-heat-treated fruit (Magalona 1963, Cavaletto 1989). The lumps are thought to be associated with insect injury, disease, or other foreign material in the flesh. The condition can also occur in heat-treated fruit. Premature ripening of fruit, referred to as “soft fruit,” is related to low calcium content. This condition is more common following periods of heavy rainfall 2 to 3 mo before harvest, at the start of the final phase of fruit growth (Qiu et al. 1995).

Intra-ovarian ovaries are common in some strains of papaya (Nakasone and Arkle 1971). These ovaries occur as a proliferation of tissue in the seed cavity and can be a threadlike appendage to round or elongated structures of various sizes and shapes. A few fill the entire seed cavity of the fruit and have their own seed cavity.

Sunken, dry, brownish-grey areas are caused by mites feeding on skin during early fruit growth. The red and black mite (*Brevipalpus phoenicis* [Geijskes]) generally causes this damage in Hawaii.

Postharvest Pathology

The major postharvest diseases are anthracnose and stem end rot. Postharvest diseases, especially anthracnose, become a problem when fruit have 25% or more skin yellowing (Wardlaw et al. 1939, Alvarez and Nishijima 1987). Papaya diseases greatly increase in severity and incidence following 4 weeks storage at 10 °C (50 °F). Mechanical injury and chilling injury can enhance development of postharvest diseases (Somner and Mitchell 1978, Alvarez and Nishijima 1987, Nishijima et al. 1990). *Rhizopus* requires breaks in the cuticle for the disease to develop (Nishijima et al. 1990). Cuticle disruption occurs as latex vessels break down, when the fruit is 40 to 60% yellow (Paull and Chen 1989). Fruit fly punctures can also increase *Rhizopus* rot (Hunter and Buddenhagen 1972), as can mechanical injuries and lesions caused by fungi such as anthracnose and *Cercospora* black spot (Nishijima et al. 1990). Postharvest diseases are effectively controlled by hot water at 49 °C (120 °F) for 20 min (Akamine and Arisumi 1953, Couey et al. 1984, Glazener et al. 1984) and fungicide treatment (Couey and Farias 1979).

Quarantine Issues

Fruit fly infestation becomes a problem with papaya after fruit have 25% skin yellowing (Seo et al. 1982). The damage caused by fruit flies include small surface blemishes, destruction of the edible flesh, and spoilage from decay. Heat treatments and irradiation are used for fruit fly disinfection (Couey 1989, Paull 1990, Armstrong 1994). Occasionally, heat treatment can cause internal injury and scald (Paull 1995), limit postharvest life, and reduce quality (Paull 1990). Papaya can tolerate insecticidal atmospheres (0.17 to 0.35% O₂, balance N₂) at 20 °C (68 °F) for up to 5 days (Yahia et al. 1989), though its disinfection potential has not been shown.

Suitability as Fresh-Cut Product

Fruit are prepared as deseeded, halved fruit, slices, and chunks. Fresh-cut products made from 60 to 80% yellow-skinned fruit, overwrapped with plastic film, can be held for up to 3 weeks at 0 to 4 °C (32 to 39 °F) (Paull and Chen 1997). Powrie et al. (1990) patented a procedure in which pieces dipped in citric acid held in multilayer bags with 15 to 20% O₂ and 3% helium had little loss in taste and texture after 16 weeks at 1 °C (34 °F).

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