College of Tropical Agriculture and Human Resources
University of Hawai'i at Mānoa

Fruit, Nut, and Beverage Crops
May 2014
F_N-34

Papaya: Postharvest Quality-Maintenance Guidelines

Lili Zhou, Robert E. Paull, and Nancy Jung Chen
Department of Tropical Plant and Soil Sciences

Papaya, papaw, or paw paw 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 include the cultivars 'Kapoho', 'Rainbow', 'Sunup', 'Sunrise', and 'Sunset', which weigh from 300 to 700 g (10 to 25 oz). Sizes of other varieties range from 200 g to 10 kg (0.4 to 22 lbs), with flesh thickness from 1.5 to 4 mm (0.06 to 0.16 in). Flesh is greenish-white in immature fruit to pale orange-yellow, salmon pink, or red, depending on cultivar, when ripe (Paull and Duarte 2011).

Papaya, *Carica papaya* L.

Quality Characteristics and Criteria

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

Horticultural Maturity Indices

In Hawai'i, minimum grade standard requires 11.5% SSC (Anon 1990). Therefore, fruit should have started ripening before harvest, as 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, and 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 upon fruit and carton size. Fruit are marketed as "color break" and ¼, ½, and ¾ ripe, and it is 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 prevent abrasion injury, which is a major problem in fruit still having green areas of skin (Quintana and Paull 1993; Sivakumar and Wall 2013).

Pre-Cooling Conditions

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

Published by the College of Tropical Agriculture and Human Resources (CTAHR) and issued in furtherance of Cooperative Extension work, Acts of May 8 and June 30, 1914, in cooperation with the U.S. Department of Agriculture, under the Director/Dean, Cooperative Extension Service/CTAHR, University of Hawai'i at Mānoa, Honolulu, Hawai'i 96822.

Optimum Storage Conditions

Store from 7 to 13°C (45 to 55°F) with 90 to 95% relative humidity. 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) ripening occurs 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 more than 1 week at 1 to 3°C (33.8 to 37.4°F).

Controlled Atmospheres (CA) Consideration

Shelf-life extension of 1 to 1.5 days was obtained when papaya were stored at 12°C (54°F) in 1 to 1.5% O_2 for 6 days (Akamine and Goo 1969). Low O_2 (1 to 5%), with or without high CO_2 (2 to 10%), reduces decay (Hatton and Reeder 1969) and delays ripening (Akamine 1959, Chen and Paull 1986). High CO_2 (30%) adversely affects internal color, aroma, and flavor, while there is no residual effect of 10% CO_2 on decay control, though skin de-greening is delayed.

At 10°C (50°F), fruit can be stored for 36 days in 8% CO_2+3% O_2 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 in the range 2 to 5% O_2 plus 5 to 8% CO_2. However, no commercial use has so far been reported (Yahia 1998). Fruit stored at 10°C (50°F), 98% relative humidity 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, Alvarez and Chau 1983).

Retail Outlet Display Considerations

The optimum temperature for fruit ripening is 22.5 to 27.5°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 27.5°C (82°F). Display temperatures should not be less than 10°C (50°F) if fruit is 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 2 or 3 deep in racks, and wicker baskets with uneven bottoms and sides should be avoided, or at least contain a layer of protection 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. Do not mist.

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) for mature green fruit and 21 days for 60% yellow fruit. Skin scald can be induced in color-break fruit after chilling at 1°C (34°F) for 24 h. At a 7°C (45°F) storage temperature 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 $\mu L\ kg^{-1}\ h^{-1}$ (Paull and Chen 1983, Paull 1993). Ethylene-treated papayas 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

Chilling damage to ripe fruit (left) and unripe fruit (right).

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). See Table 1 for respiration rates at specific temperatures.

To get mL kg^{-1} h^{-1}, divide the mg kg^{-1} 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 mg kg^{-1} h^{-1} by 220 to get BTU per ton per day or by 61 to get kcal per metric ton per day.

Physiological Disorders

There are a number of non-pathological disorders seen in marketed fruit (Paull et al. 1997; Sivakumar and Wall 2013). The disorders include the following:

Green, slightly sunken areas on ripe yellow fruit are due to abrasion injury that occurs when fruit are 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 and are seasonal, occurring when rainfall and low temperatures occur 2 mo before harvest (Reyes and Paull 1994). This disorder is non-pathogenic and does not influence ripening or flavor.

Sun scald, 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). The disorder 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 ripe fruit, referred to as "soft fruit," is related to low fruit calcium. The 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 thread-like 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 caused by mites feeding on skin during early fruit growth. The red and black mite (*Brevipalpus phoenicis* [Geijskes]) generally causes this damage in Hawai'i.

Table 1. Respiration Rates for Papaya

Temperature	mg CO_2/$kg^{-1}h^{-1}$
5°C	4 to 6
15°C	15 to 22
20°C - color break	9 to 18
20°C - ripe	70 to 90

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 disease incidence (Somner and Mitchell 1978, Alvarez and Nishijima 1987, Nishijima et al. 1990).

Rhizopus requires breaks in the cuticle for the disease to occur (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, Glazener et al. 1984, Couey et al. 1984) and fungicide treatment (Couey and Farias 1979).

Top to bottom: Anthracnose disease, mechanical injury, and the effects of impact bruising.

Quarantine Issues

Fruit fly infestation becomes a problem with papayas after fruit have 25% skin yellowing (Seo et al. 1982). The damage caused by fruit flies includes small surface blemishes, destruction of the edible flesh, and spoilage from decay. Heat treatments and irradiation are used to achieve fruit fly disinfestation (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% O_2, balance N_2) at 20°C (6°F) for up to 5 days (Yahia et al. 1989), although its disinfestation potential has not been shown.

Suitability as Fresh-Cut Product

Fruit are prepared as de-seeded, halved fruit, slices, and chunks. Fresh-cut products made from 60 to 80% yellow-skinned fruit, over-wrapped 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 whereby pieces dipped in citric acid and held in multi-layer bags with 15 to 20% O_2 and 3% helium had little loss in taste and texture after 16 weeks at 1°C (34°F).

Special Considerations

None

Abrasion injury.

An earlier version of this article was originally published at the USDA's website: www.ba.ars.usda.gov/hb66/contents.html

References

Akamine, E.K. 1959. Effects of carbon dioxide on quality and shelf-life of papaya. *Hawaii Ag. Exp. Sta. Tech. Progr. Rpt.* No. 120.

Akamine, E.K. 1966. Respiration of fruits of papaya (*Carica papaya* L. var. Solo) with reference to effect of quarantine disinfestation treatments. *Proc. Amer. Soc. Hort. Sci.* 89:231–236.

Akamine, E.K. and T. Arisumi. 1953. Control of postharvest storage decay of papaya (*Carica papaya* L.) with special reference to the effect of hot water. *Proc. Amer. Soc. Hort. Sci.* 61:270–274.

Akamine, E.K. and T. Goo. 1969. Effects of controlled atmosphere storage of fresh papaya (*Carica papaya*, L. var. Solo) with special reference to shelf-life extension of fumigated fruit. *Hawaii Ag. Sta. Res. Bull.* No. 144.

Akamine, E.K. and T. Goo. 1971. Relationship between surface color development and total soluble solids in papaya. *HortScience* 6:567–568.

Alvarez, A.M. 1980. Improved marketability of fresh papaya by shipment in hypobaric containers. *HortScience* 15:517–518.

Alvarez, A.M. and W.T. Nishijima. 1987. Postharvest diseases of papaya. *Plant Dis.* 71:681-686.

An, J.F. and R.E. Paull. 1990. Storage temperature and ethylene influence on ripening of papaya fruit. *J. Amer. Soc. Hort. Sci.* 115:949–953.

Anon. 1990. *Standards for Hawaii-grown papaya*. Hawaii Dept. Ag., Marketing Div.

Arisumi, T. 1956. Test shipments of papaya with special reference to storage decay control. *Hawaii Ag. Exp. Sta. Tech. Bull.* No. 29.

Armstrong, J.W. 1994. Tropical and subtropical fruits. *In*: R.E. Paull and J.W. Armstrong (eds) *Insect pests and fresh horticultural products: Treatments and Responses*. CAB Intl., Wallingford, UK, pp. 275–290.

Cavaletto, C.G. 1989. Quality of high temperature forced air treated papaya. 25th Ann. Papaya Ind. Assoc. Conf., Sept. 1998, Hawaii Ag. Exp. Sta., Honolulu, Hawaii. pp. 10–15.

Cenci, S.A., A.G. Soares, J.M.S. Bibino and M.L.M. Soiya. 1997. Study of the storage of 'Sunrise' and 'Solo' papaya fruits under control atmospheres. *Proc. 7th Intl. Contr. Atmos. Res. Conf.* July 1997, Univ. of Calif., Davis CA, Abstract No. 112.

Chau, K.F. and A.M. Alvarez. 1983. Effects of low-pressure storage on *Colletotrichum gloeosporioides* and postharvest infection of papaya. *HortScience* 18:953–955.

Chen, N.M. and R.E. Paull. 1986. Development and prevention of chilling injury in papaya fruit. *J. Amer. Soc. Hort. Sci.* 111:639–643.

Couey, H.M. and G. Farias. 1979. Control of postharvest decay of papaya. *HortScience* 14:719–721.

Couey, H.M., A.M. Alvarez, and M.G. Nelson. 1984. Comparison of hot-water spray and immersion treatments for control of postharvest decay of papaya. *Plant Dis.* 68:436–437.

El-Tomi, A.L., A.B. Abon-Aziz, A.S. Abdel-Kader, and F.K. Abdel-Wahab. 1974. The effect of chilling and non-chilling temperatures on quality of papaya fruit. *Egypt J. Hort.* 1:179–185.

Glazener, J.A., H.M. Couey, and A. Alarez. 1984. Effect of postharvest treatments on Stemphyllium rot of papaya. *Plant Dis.* 68:986–988.

Hatton, T.T. and W.F. Reeder. 1969. Controlled atmosphere storage of papaya. *Proc. Trop. Reg. Amer. Soc. Hort. Sci.* 13:251–256.

Hunter, J.E. and Buddenhagen, I.W. 1972. Incidences, epidemiology and control of fruit disease of papaya in Hawaii. *Trop. Ag.* 49:61–71.

Magalona, N. 1964. Artificial induction of lumps in the fruit of papaya (*Carica papaya* L.) M.Sc. Thesis, University of Hawai'i, 48 pp.

Nakasone, H.Y. 1986. Papaya. *In*: S.P. Monselise (ed) CRC Handbook of Fruit Set and Development. CRC Press, Boca Raton FL, pp. 277–301.

Nakasone, H.Y. and T.D. Arkle. 1971. Development of intra-ovarian ovaries in *Carica papaya* L. *J. Amer. Soc. Hort. Sci.* 96:550–553.

Nazeeb, M. and W.J. Broughton. 1978. Storage conditions and ripening of papaya 'Bentong' and 'Taiping.' *Sci. Hort.* 9:265–277.

Nishijima, W.T., S. Ebersole, and J.A. Fernandez. 1990. Factors influencing development of postharvest incidence of *Rhizopus* soft rot of papaya. *Acta Hort.* 269:495–502.

Paull, R.E. 1990. Postharvest heat treatments and fruit ripening. *Postharv. News Info.* 1:355–363.

Paull, R.E. 1995. Pre-harvest factors and the heat sensitivity of field grown ripening papaya fruit. *Postharv. Biol. Technol.* 6:167–175.

Paull, R.E. 1993. Pineapple and Papaya. In: G. Seymour, J. Taylor and G. Tucker (eds) *Biochemistry of Fruit Ripening*. Chapman and Hall, London, U.K., pp. 291–323.

Paull, R.E. and N.J. Chen. 1983. Postharvest variation in wall degrading enzymes of papaya fruit during ripening. *Plant Physiology* 72:131–138.

Paull, R.E. and N.J. Chen. 1989. Waxing and plastic wraps influence water loss from papaya fruit during storage and ripening. *J. Amer. Soc. Hort. Sci.* 114:937–942.

Paull, R.E. and N.J. Chen. 1997. Minimal processing of papaya (*Carica papaya* L.) and the physiology of halved fruit. *Postharv. Biol. Technol.* 12:93–99.

Paull, R.E. and O. Duarte. 2011. Tropical Fruit - Volume I. Chapter 11, Papaya, p 291–326. CAB

Paull, R.E., W. Nishijima, M. Reyes, and C. Cavaletto. 1997. A review of postharvest handling and losses during marketing of papaya (*Carica papaya* L). *Postharv. Biol. Tech.* 11:165–179.

Powrie, W.D., R. Chiu, H. Wu, and B.J. Skura. 1990. Preservation of cut and segmented fresh fruit pieces. U.S. Patent No. 4,895,729.

Qiu, Y., M.S. Nishina, and R.E. Paull. 1995. Papaya fruit growth, calcium uptake and fruit ripening. *J. Amer. Soc. Hort. Sci.* 120:246–253.

Quintana, M.E.G. and R.E. Paull. 1993. Mechanical injury during postharvest handling of 'Solo' papaya fruit. *J. Amer. Soc. Hort. Sci.* 118:618–622.

Reyes M.E.Q. and R.E. Paull. 1994. Skin freckles on 'Solo' papaya fruit. *Sci. Hort.* 58:31–39.

Seo, S.T., G.B. Farias, and E.J. Harris. 1982. Oriental fruit fly: ripening of fruit and its effect on index of infestation of Hawaiian papayas. *J. Econ. Ent.* 75:173–178.

Sivakumar, D., and M.M. Wall. 2013. Papaya fruit quality management during the postharvest supply chain. *Food Reviews International* 29:24–48.

Somner, N.F. and F.G. Mitchell. 1978. Relation of chilling temperatures to postharvest *Alternia* rot of papaya fruit. *Proc. Trop. Reg. Amer. Soc. Hort. Sci.* 22:40–47.

Thompson, A.K. and G.R. Lee. 1971. Factors affecting the storage behaviour of papaya fruit. *J. Hort. Sci.* 46:511–516.

Wardlaw, C.W., R.E.D. Baker, and S.H. Crowdy. 1939. Latent infections in tropical fruits. *Trop. Ag.* 16:275–276.

Yahia, E. 1998. Modified and controlled atmospheres for tropical fruits. *Hort. Rev.* 22:123–183.

Yahia, E., F. Medina, and M. Rivera. 1989. Tolerance of mango and papaya to atmospheres containing very high levels of CO_2 and/or very low levels of O_2 as a possible insect control treatment. *Proc. 5th Intl. CA Res. Conf.*, June 1989, Wenatchee WA, 2:77–89.

Zee, F.T., M.S. Nishina, H.T. Chan, and K.A. Nishijima. 1989. Blossom end defects and fruit fly disinfestation in papayas following hot water quarantine treatment. *HortScience* 24:323–325.