Kiwifruit
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Postharvest Quality Maintenance Guidelines

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Scientific Name and Introduction

Commercial cultivars of kiwifruit are large-fruited selections of *Actinidia deliciosa* (A. Chevalier, C.F. Liang et al., A.R. Ferguson). The genus *Actinidia* is solely of Asian origin; plants are found ranging from northeast India through China to tropical Java and into the cold climates of Manchuria, Japan, and eastern Siberia. In addition to *A. deliciosa*, there are other species of interest because of their edible fruits: *A. chinensis, A. arguta, A. kolomikta, A. polygama,* and *A. eriantha*. Perhaps the best known is *A. arguta*, plants of which are often sold in the U.S. as hardy kiwifruit, since the vines are winter hardy (tolerate temperatures below -5^{o}C). The fruits of the small-fruited species are usually consumed at a more advanced stage of ripeness. The berries have a pleasant and sweet flavor.

Botanically, the kiwifruit is a berry with numerous locules filled with many small, soft, black seeds. The green-colored flesh (edible portion) has three regions: the outer pericarp, the inner pericarp, and the columella (core), which is lighter green than the pericarp tissues. The relatively thin brown skin includes a periderm (rather than an epidermis) and hypodermal cells. Cork cells can sometimes be seen covering small wounds. No stomata are observed on the kiwifruit surface, but other openings where trichomes are removed provide adequate gas exchange.

Kiwifruit have large and small hairs (trichomes) on their surface; small

hairs may be an arrested early stage of development of large hairs, which are multicelled and sometimes branched. Most of the small unicellular hairs on the surface of mature kiwifruit are collapsed as a result of handling during harvesting and postharvest operations.

Quality Characteristics and Criteria

Quality defects include doubles, growth cracks, insect damage, bruises, scars, sunscald, and internal breakdown.

Consumer satisfaction is achieved when ripe fruit reaches at least 12.5% SSC (at consumption). Fruit at 2-3 pounds-force flesh firmness is considered ripe. Prediction of ripe kiwifruit quality can be done by measuring total solids at harvest destructively and non-destructively (near infrared).

Kiwifruit has high levels of vitamin C and citric acid. Vitamin C content is at least twice that of the orange. Starch is high at harvest, but it is converted to soluble sugars during storage and ripening.

Kiwifruit from vines with 2.0% or less leaf nitrogen retain their firmness better in long storage than those from vines with more than 2% leaf N_2.

Horticultural Maturity Indices

Kiwifruit should be harvested when it reaches 6.5 percent soluble solids concentration (SSC) measured by refractometer in the vineyard. Maximum maturity is reached when flesh firmness is equal to or higher than 14 pounds-force measured with the penetrometer (8-mm tip). Late harvested kiwifruit will retain their flesh firmness during storage better than early harvested fruit. After storage, transporting fruit to market at five pounds-force firmness or higher can reduce vibration injury. Late harvested kiwifruit will usually have high SSC at harvest and at consumption.

Grades, Sizes and Packaging

Once minimum maturity has been achieved, all kiwifruit from a vineyard can be harvested in a single pick because there are no visible distinguishing characteristics to help pickers separate immature from mature fruit. Fruit are harvested by hand, usually into picking bags. Bottom-dump design picking bags are typically used, and pickers transfer the fruit into wooden or plastic field bins.

Kiwifruit are packed into single-layer flats holding approximately 7 pounds (3 kg). Some sized fruit are bagged into small consumer bags holding 1 to 2 pounds (or ½ to 1 kg), with the bags in turn placed into boxes holding about 10 kg (22 pounds). There is increasing use of three-layer tray packs and volume-fill packs holding about 9 to 11 kg (20 to 23 pounds).

Optimum Storage Conditions:

Minimizing flesh softening after harvest is the key to successful kiwifruit postharvest handling. Flesh softening occurs rapidly during the first few weeks of air storage. The drop in flesh firmness roughly corresponds to the conversion of starch to soluble sugars. Even when fruit are held at 0^{o}C, approximately one-third to one-half of the remaining flesh firmness may be lost per month.

Kiwifruit should be stored as near to 0^{o}C as possible and under 90 to 95 percent relative humidity. Care should be taken to assure than the storage temperature is not lower than 0^{o}C. The freezing point of kiwifruit is difficult to predict. A freshly harvested fruit at 6.5 percent SSC may have a freezing point near 0.5^{o}C, especially in the stem end of the fruit where the lowest SSC is found. Freeze damage is characterized by a water-soaked appearance on both the fruit flesh and core. During storage, when starch is hydrolyzed and SSC levels reach at least 13 percent, the freezing point declines to about -1.5^{o}C, although even at this point a lower storage temperature is not recommended. All potential sources of ethylene contamination should be eliminated in the storage and handling area (ideally less than 10 ppb). For long-term storage, use

of controlled atmospheres (CA) has been shown to be effective provided that both 0°C and ethylene less than 50 ppb are maintained.

Controlled Atmosphere (CA) Considerations

The major benefits of CA are to retain firmness and reduce Botrytis incidence as compared to air storage. CA storage is successfully used commercially in the kiwifruit industry. Oxygen levels of 2% with 5% CO_2 are recommended (ethylene free), but establishment of CA conditions should be no later than 1 week after harvest.

Large (~101 g), medium (~93 g), and small (~81 g) 'Hayward' kiwifruits were stored in either ethylene-free air or in a controlled atmosphere (CA) of 5% CO_2 + 2% O_2 at 0°C for 16 weeks. Under both storage conditions, large fruit had a slower rate of softening than smaller fruit. Air-stored kiwifruit softened approximately 2.6 times faster than CA-stored fruit. Under air conditions, large, medium and small kiwifruit reached 5.0 pounds-force (minimum firmness required for packaging with minimal bruising) by 12, 10, and 8 weeks, respectively. Large, medium, and small kiwifruit stored under CA conditions softened to 5.0 pounds-force by 49, 30, and 20 weeks, respectively.

Retail Outlet Display Considerations

Use of cold tables is recommended when displaying ripe fruit. Warm tables during display is recommended on mature, but unripe, fruit.

Chilling Sensitivity

Not sensitive. However, recent preliminary studies reported chilling injury after fast cooling on kiwifruit grown in New Zealand and Chile.

Rates of Ethylene Production and Sensitivity:

Less than 0.1 µl/kg.hr at 0°C and 0.1-0.5 µl CO_2/kg.hr at 20°C by mature

but unripe kiwifruit. Very low ethylene levels (5-10 ppb) will induce fruit softening. Avoid ethylene exposure during harvest, transport and storage. Cooling delays should not exceed 6 hours. Continuous ventilation during air storage helps to assure low ethylene levels. Thus, ethylene removal and/or exclusion from transport and storage facilities is highly recommended for long-term storage of kiwifruit. The presence of ethylene during CA storage has been related to physiological problem. Ripe kiwifruit (less than 4 pounds fprce) produce 50-100 µl C_2H_4/kg.hr at 20°C (68°C)

Respiration Rates: Rates of Respiration

1.5-2.0 ml	CO_2/kg.hr at 0°C (32°F)
2.6-3.6 ml	CO_2/kg.hr at 5°C (41°F)
4.7-6.3 ml	CO_2/kg.hr at 10°C (50°F)
8.6-11.8 ml	CO_2/kg.hr at 15°C (59°F)
14.7-19.6 ml	CO_2/kg.hr at 20°C (68°F)
26.0-33.1 ml	CO_2/kg.hr at 25°C (77°F)

To calculate heat production multiply ml CO_2/kg.hr by 440 to get Btu/ton/day or by 122 to get kcal/metric ton/day

Physiological Disorders

Freezing Damage: Flesh translucency starting at the stem end of the fruit and progressing toward the blossom end as the symptom's severity increases. Susceptible fruit became somewhat yellow fleshed with prolonged storage. Freezing damage can occur on early picked kiwifruit when stored at -1.1°C, -0.6°C and 0°C or when they are subjected to an early frost in the vineyard. Fruit frosted late in the season are usually affected on the shoulder where the cells collapse to cause a pinching of the fruit at the stem end.

Hard-core. This disorder is induced by exposure to ethylene of kiwifruit stored with carbon dioxide levels above 8 percent. The fruit core

fails to ripen while the remainder of the fruit is soft and ripe.

Internal Breakdown: These symptoms start as a slight discoloration (water soaking) at the blossom end of the fruit. With time this progresses around the blossom end and ultimately encompasses a large part of the fruit. As symptoms progress a "graininess" is noted below the fruit surface beginning in the area around the blossom end of the fruit.

Pericarp granulation. The occurrence of granulation is predominantly at the stylar end of the fruit, but as in the case of translucency may extend up the sides of the fruit. This disorder also is more severe with prolonged storage and after ripening at 20^{o}C (68^{o}F). There is no obvious correlation between pericarp translucency and granulation since symptoms can occur independently.

Pericarp translucency. This disorder has been noted in both air- and CA-stored kiwifruit at 0^{o}C (32^{o}F). It appears as translucent patches in the outer pericarp tissue at the stylar end which may extend up the sides of the fruit. Pericarp translucency is more severe after prolonged storage, but it can be observed after 12 weeks of storage at 0^{o}C (32^{o}F). The presence of ethylene in the storage atmosphere exacerbates symptom development.

White-core inclusions: Distinct white patches of core tissue may result from exposure to elevated CO_2 and ethylene for longer than 3 weeks at 0^{o}C.

Postharvest Pathology

Botrytis: This disease occurs in kiwifruit from all growing areas, including New Zealand, USA, Chile, Greece, and Italy. The most common symptom is a soft rot starting at the stem-end or at wound sites. Affected tissue becomes dark and water-soaked. Even in the absence of decay, there may be superficial white mold growth or grey-brown spores on the remains of the calyx. Initial infection can occur via senescent flower parts, at any time from the end of blossoming until

harvest. Moist conditions are necessary for infection, after which the fungus may remain quiescent for several months, appearing only after a period of storage. Alternatively, or in addition, infection can occur via the cut stem at harvest time and through wounds in the skin. Grey mold is capable of slow growth even at $0^{o}C$ and, during long-term storage, can spread into healthy fruit, causing 'nesting'. Recommendations include pre-harvest fungicide sprays (starting at blossom time) and, if legislation permits, a fungicide treatment after harvest.

Minor storage diseases such as Alternaria rot, Blue mold, Dorthiorella rot, Phoma rot, Phomopsis rot, Sclerotinia rot, mucor rot and Buckshot rot are seldom a problem in kiwifruit.

Suitability as Fresh-cut Product

Fresh cut kiwifruit slices have a shelf life of approximately 9-12 days when handled under optimum conditions. The fresh cut slice quality maintenance procedures include handling at 0-$2^{o}C$ (32-$36^{o}F$), 90-95% relative humidity and oxygen level from 2-4%, and carbon dioxide levels from 5-10%. Off-flavor can be produced if kiwifruit slices are exposed to O_2 and CO_2 levels outside these optimum ranges. Ethylene presence (2-20 ppm) will increase the rate of slice softening.

Special Considerations

The need to avoid ethylene exposure continues throughout transportation and distribution. The possible role of fruit injuries and decay in accelerating ethylene production has been discussed. Other sources of ethylene contamination must be avoided. Just as kiwifruit cannot be stored with or near other ethylene-producing products, they also cannot be transported with them. Ethylene-producing equipment (such as propane forklifts) must not be used in storage facilities and kiwifruit loading and unloading areas must be free of ethylene-contaminated truck exhaust fumes.

References

Agar, I.T., R. Massantini, B. Hess-Pierce and A.A. Kader. 1999. Postharvest CO_2 and ethylene production and quality maintenance of fresh-cut kiwifruit slices. J. Food Sci. 64:432-440.

Arpaia, M.L., F.G. Mitchell, A.A. Kader, and G. Mayer. 1985. Effects of 2% O_2 and varying concentrations of CO_2 with or without C_2H_4 on storage performance of kiwifruit. J. Amer. Soc. Hort. Sci. 110:220-203.

Arpaia, M.L., F.G. Mitchell, G. Mayer, and A.A. Kader. 1984. Effects of delays in establishing controlled atmospheres on kiwifruit softening. J. Amer. Soc. Hort. Sci. 109:768-770.

Beever, D.J. and G. Hopkirk. 1990. Fruit development and fruit physiology. p. 97-126, in: I.J. Warrington and G.C. Weston (eds.). Kiwifruit: science and management. Ray Richards Publisher, Auckland, New Zealand.

Cheah, L.H. and D.E. Irving. 1997. Kiwifruit. p. 209-227, in: S. Mitra (ed.). Postharvest physiology and storage of tropical and subtropical fruits. CAB International, Wallingford, UK.

Crisosto, Carlos H., David Garner, and Gayle M. Crisosto. 1997. Kiwifruit preconditioning protocol. Acta Horticulturae 444(2):555-559.

Crisosto, Carlos H., David Garner, and Katia Saez. 1999. Kiwifruit size influences softening rate during storage. California Agriculture 53(4):29-31.

Ferguson, A.R. 1984. Kiwifruit: a botanical review. Hort. Rev. 6:1-64.

Harman, J.E. and B. McDonald. 1989. Controlled atmosphere storage of kiwifruit: effects on fruit quality and composition. Scientia Hort. 37:303-315.

McDonald, B. 1990. Precooling, storage and transport of kiwifruit. p. 429-459, in: I.J. Warrington and G.C. Weston (eds). Kiwifruit: science and management. Ray Richards Publisher, Auckland, New Zealand.

Mitchell, F.G. 1990. Postharvest physiology and technology of kiwifruit. Acta Horticulturae 282:291-307.

Mitchell, F.G. et al. 1994. Chapters on postharvest physiology and handling of kiwifruit. In: J.K.Hasey et al. (eds.). Kiwifruit growing and handling. Publ. No. 3344. Univ. Calif. DANR Publ., Oakland, CA.

Ritenour, Mark A., Carlos H. Crisosto, Davis T. Garner, Guiwen W. Cheng, Juan Pablo Zoffoli. 1999. Temperature, length of cold storage and maturity influence the ripening rate of ethylene-preconditioned kiwifruit. Postharvest Biology and Technology 15:107-115.

Snowdon, A.L. 1990. A color atlas of post-harvest diseases & disorders of fruits and vegetables, Volume 1: General introduction & fruits. CRC Press, Inc. Boca Raton, Florida.

Sommer, N.F., J.E. Suadi, and R.J. Fortlage. 1994. Postharvest storage diseases. p. 116-122, in: J.K. Hasey et al. (eds.). Kiwifruit Growing and handling. Publ. No. 3344. Univ. Calif. DANR Publ., Oakland, CA.

Acknowledgments

Some of the information included is from the University of California - Davis website on “Fresh Produce Facts” at http://postharvest.ucdavis.edu/produce/producefacts/