Kiwifruit

James W. Rushing
Clemson University, Coastal Research and Education Center
Charleston, SC

Scientific Name and Introduction: The most common of the edible kiwifruit in the Western world is *Actinidia deliciosa*, a perennial of the Actinidiaceae. The fruit, produced on climbing or straggling plants, is a berry containing hundreds of small, dark seeds embedded in green flesh. Its skin is hairy and light brown. Different species exhibit variability in numerous attributes, eg., skin color (green to brown), flesh color (yellow to green), degree of hairiness, taste, etc. (Ferguson, 1990a; 1990b). The guidelines presented herein are based on information published for the 'Hayward' cultivar and similar types of *A. deliciosa.* A yellow-fleshed fruit of *A. chinensis* is rapidly gaining favor in the market, but little information is available.

It is important to note that most of the following information, especially that related to grades, sizes, and packaging, is derived from U.S. and California literature. In order of importance in the world market, Italy is the leading producer followed by New Zealand, Chile, and California. Therefore, the guidelines utilized by the European Union should be considered as well.

Quality Characteristics and Criteria: High quality kiwifruit should not be shriveled and should be free from sunscald, scars, growth cracks, insect injury, bruises, internal breakdown, and decay. At table ripeness, fruit should have at least 14% SSC with flesh firmness of 2 to 3 lb (0.9 to 1.35 kg) force, which is the penetration force measured with a 5/16 in (8 mm) tip (Crisosto et al., 1999).

Horticultural Maturity Indices: Harvest maturity for kiwifruit produced in California is defined as a minimum of 6.5% SSC and flesh firmness of 14 lb (6.3 kg) force (Crisosto et al., 1999). In New Zealand, the index used for fruit destined for export is a minimum average SSC of 6.2% measured in 10 fruit. A general practice is that if two of the 10 fruit measured have < 5.8% SSC, the orchard is not considered acceptable for export picking. Fruit that are to be marketed locally with a minimum of handling may be held on the vine until the SSC reaches 10 to 12% (Beevers and Hopkirk, 1990).

Grades, Sizes and Packaging: Grades include U.S. Fancy, U.S. No. 1 and U.S. No. 2. Criteria that define Grades are subjective and are based primarily on the quality characteristics described above (USDA, 1986).

Because of the irregular shape of kiwifruit, it is difficult to define fruit size in terms of length or diameter. Since California is the most significant producer of kiwifruit in the U.S., the size criteria defined by the Kiwifruit Administrative Committee (KAC) are generally adhered to throughout the U.S. Size designations are based on number of fruit that can be placed on a single tray. Actual fruit size is based on weight and is defined as the number of uniformly sized fruit required to constitute an 8-lb sample. Current designations from the KAC (1999) are summarized in Table 1. Handlers should note this information is subject to change and the most recent information should be reviewed by anyone packing kiwifruit.

Table 1. 1999/2000 Kiwifruit Size Designation Chart

Tray equivalency size designation	Maximum No. of fruit in 8-lb sample[1]	Fairly uniform size variation (in)[2]
21	22	1/2
25	27	1/2
27/28	30	1/2
30	33	1/2
33	36	3/8

36	42	3/8
39	48	3/8
42	53	3/8
45	55	1/4

[1]Tolerance - Average weight of all sample units must be at least 8 lb and no sample unit may be > 4 oz less than 8 lb.
[2]Tolerance - Not more than 10% of the containers in any lot and not more than 5%, by count, of the fruit in any container may fail to meet the diameter range, except for sizes 42 and 45 in which the tolerance, by fruit count, may not be more than 25%.

A variety of packages are used for kiwifruit. Tray-packed fruit may be placed in cartons of wood or fiberboard that contain one, two, or three trays. Appropriate padding should be placed between trays. Alternatively, volume-filled (typically 23 lb; 10.4 kg) or count-filled cartons are available. Bagged fruit are generally placed in master cartons, a common arrangement being a master container containing twenty 1-lb (0.45 kg) bags. At the retail level, fruit are sometimes sold in lots of 6 to 10 fruit per bag with no size specifications. Mini wooden bins containing about 125 lb (56 kg) of fruit are used for some markets (KAC, 1999). Any size carton or configuration may be used in the U.S. as long as they are appropriately labeled.

Pre-cooling Conditions: Early literature recommends that kiwifruit should be cooled to near 0 °C as soon as possible after harvest for maximum storage potential. Forced-air cooling is preferred. Hydro-cooling has been utilized successfully but is not generally recommended because the hairs on the fruit surface tend to retain an excessive amount of water which can promote the growth of decay-causing microorganisms (McDonald, 1990). The decision to pre-cool remains a matter of choice for the packer and the process of curing (see below) is gaining acceptance. Lallu (1997) reports that rapid pre-cooling may exacerbate internal breakdown associated with chilling injury.

Curing: Curing occurs during the delay between harvest and cooling and is characterized by some water loss from fruit and a drying of the stem scar. In New Zealand, curing for at least 48 h has been reported to reduce the incidence of *Botrytis* decay (Lallu et al., 1997) and development of internal breakdown (Lallu, 1997) during subsequent cold storage. In Chile, Retamales et al. (1997) reported that curing up to 72 h did not increase softening during cold storage.

Optimum Storage Conditions: The recommended conditions for commercial storage of kiwifruit are 0 °C with 90 to 95% RH. Fruit that are properly handled before storage fruit may be held in good condition for 4 to 5 mo. Also, see "Ethylene Sensitivity."

Controlled Atmosphere (CA) Conditions: Kiwifruit respond favorably to CA. The potential for benefit is excellent, with extension of storage-life up to about 6 mo. The recommended conditions are 1 to 2% O_2 + 3 to 5% CO_2 at 0 °C. Less than 1% O_2 may induce off-flavors and > 7% CO_2 can cause internal breakdown of the flesh. However the risk of such injuries is moderate as long as management of the atmosphere is given reasonable attention. See "Physiological Disorders" below. There is increasing commercial use of CA during both storage and transport. Refer to Kader (1997) for selected references on kiwifruit CA research.

Retail Outlet Display Considerations: Kiwifruit may be displayed on unrefrigerated counters since it is desirable to have the fruit near eating ripeness at the time of sale.

Chilling Sensitivity: Lallu (1997) reports that the fruit of *A. deliciosa* cv. 'Hayward' are chilling sensitive at temperatures near 0 °C with symptoms appearing as a ring or zone of granular, water-soaked tissue in the outer pericarp at the stylar end of the fruit. Other symptoms may include the development of diffuse pitting and a dark, scald-like appearance on the skin. Curing (see above) alleviated symptoms of chilling injury. The terms low temperature breakdown (LTB), senescent breakdown (SB), and physiological pitting (PP) all appear in the literature, but the differences among these disorders are difficult to define in fruit stored for an extended period.

Ethylene Production and Sensitivity: At harvest maturity, kiwifruit are low ethylene producers with production rates of approximately 0.1 µL kg^{-1} h^{-1} at 0 °C and about 0.1 to 0.5 µL kg^{-1} h^{-1} at 20 °C. Fruit that are ripe at < 4 lb (1.8 kg) force produce 50 to 100 µL kg^{-1} h^{-1}. Kiwifruit in storage are extremely sensitive to the presence of ethylene and should not be stored with commodities that produce significant amounts. As little as 5 to 10 ppb (0.005 to 0.010 µL L^{-1}) ethylene in the storage atmosphere can accelerate softening without impacting other ripening processes, resulting in unripe fruit that are excessively soft (Crisosto et al., 1999; McDonald, 1990).

Respiration Rates:

Temperature	mg CO_2 kg^{-1} h^{-1}
0 ºC	3
4 to 5 ºC	5 to 7
10 ºC	12
20 to 21 ºC	16 to 22

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. Data are from Hardenburg et al. (1986).

Physiological Disorders: In storage or transit, the flesh of immature fruit may soften rapidly and have a watersoaked appearance while the core remains hard and tough (Beevers and Hopkirk, 1990). A similar type of hard-core disorder also has been attributed to exposure of the fruit to damaging levels of ethylene in combination with CO_2 of 8% or higher (Crisosto et al., 1999).

Inadvertent freezing results in flesh translucency (Beevers and Hopkirk, 1990). If freezing injury occurs, it usually appears first at the stem end and progresses to the stylar end. The flesh of damaged fruit may become somewhat yellow with prolonged storage (Crisosto et al., 1999).

Pericarp granulation and pericarp translucency may occur independently, but both are associated with long term storage. The presence of ethylene in storage may exacerbate symptoms. These disorders may simply be a consequence of senescence as other causes are not well defined (Crisosto et al, 1999).

The presence of ethylene in CA storage can cause the occurrence of white-core inclusions, which are distinct white patches of core tissue that are obvious in ripe fruit. Symptoms may develop as early as 3 weeks in storage when atmospheric composition is favorable for development of the disorder (Crisosto et al, 1999).

Postharvest Pathology: Kiwifruit from all growing areas may deteriorate due to infection by *Botrytis cinerea*, which causes Gray Mold decay. This fungus may infect the fruit through senescent flower parts, penetrate the fruit directly, or enter through wounds (see section on "Curing"). Other types of decay of lesser commercial significance are Blue Mold caused by *Penicillium expansum* and Phomopsis caused by *Phomopsis actinidiae*. An appropriate fungicide application program in the orchard coupled with harvest management practices to reduce wounding are the primary means of reducing incidence of decay (Snowdon, 1990). As fruit soften, they become more susceptible to all types of decay, so harvesting at the appropriate maturity and good temperature management in the storeroom, plus the use of CA, all are important in controlling decay (Crisosto et al., 1999).

Various types of pitting also are attributed to fungal infection (Manning and Beever, 1992; Testoni et al, 1997). Symptoms typically do not occur until fruit have been stored for several mo, and direct isolation of the fungi usually is required in order to distinguish between fungal pitting and physiological pitting.

Quarantine Issues: None in the U.S. However, importers and exporters should contact APHIS or other regulatory bodies in receiving countries to ensure quarantine requirements are met.

Suitability as Fresh-cut Product: The potential does not seem good for national or regional distribution of fresh-cut kiwfruit. However some restaurants do serve fresh-cut kiwifruit on salad bars and in fruit medlies so there is a degree of consumer demand for the product. Agar et al. (1999) reported that fresh-cut slices of kiwifruit could be stored from 9 to 12 days if calcium treatments and modified atmospheres were used. Emerging technologies in fresh-cut processing may facilitate greater availability in retail markets.

Special Considerations: One of the most troublesome concerns for storage of kiwifruit is management of ethylene in the atmosphere. Enormous losses are incurred when fruit soften prematurely in storage without ripening. The effectiveness of various ethylene removal techniques, eg., catalytic converters, potassium permanganate filters, ozone generators, simple ventilation systems, etc., must be evaluated carefully for specific situation. For example, the frequency of opening the storeroom doors, proximity of the storeroom to sources of ethylene, such as the packinghouse itself or nearby roadways, presence of decaying fruit in the storeroom, etc., all influence the efficacy of ethylene removal. Innovative managers should have a means of measuring ethylene in the storeroom and in the surrounding area.

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: 433-440.

Beever, D.J. and G. Hopkirk. 1990. Fruit development and physiology. In: I.J. Warrington and G.C. Weston (eds) Kiwifruit: Science and Management. Ray Richards Pub., Auckland, New Zealand.

Crisosto, Carlos H., Elizabeth J. Mitcham and Adel A. Kader. 1999. Kiwifruit. In: Fresh Produce Facts, Univ. of Calif., http://postharvest.ucdavis.edu/Produce/producefacts/fruit/kiwi/html.

Ferguson, A.R. 1990a. The genus *Actinidia.* In: I.J. Warrington and G.C. Weston (eds) Kiwifruit: Science and Management. Ray Richards Pub., Auckland, New Zealand.

Ferguson, A.R. 1990b. Botanical nomenclature: *Actinidia chinensis, Actinidia deliciosa,* and *Actinidia setosa.* In: I.J. Warrington and G.C. Weston (eds) Kiwifruit: Science and Management, Ray Richards Pub., Auckland, New Zealand.

Hardenburg, R.E., A.E. Watada and C.Y. Wang. 1986. The Commercial Storage of Fruits, Vegetables, and Florist and Nursery Stocks. USDA Handbook No. 66, pp. 11.

Kader, A.A. 1997. A summary of CA requirements and recommendations for fruits other than apples and pears. Proc. 7th Intl. Cont. Atmos. Res. Conf., Univ. Calif, Davis CA, 3:16.

Kiwifruit Administrative Committee. 1999. 1999/2000 Season California Kiwifruit Packing Regulations Bulletin, Sacramento, Calif. http.//www.kiwifruit.org/industry/grades

Lallu, N. 1997. Low temperature breakdown in kiwifruit. Acta Hort. 444:579-585.

Lallu, N., M. Manning and H. Pak. 1997. Best curing practices for the orchard and packhouse. New Zealand Kiwifruit Journal (March/April), pp. 35-37.

Manning, M. and D. Beever. 1992. An update on storage pitting research. NZ Kiwifruit (Feb), pp. 5-7.

McDonald, B. 1990. Pre-cooling, storage, and transport of kiwifruit. In: I.J. Warrington and G.C. Weston (eds) Kiwifruit: Science and Management. Ray Richards Pub., Auckland, New Zealand.

Retamales, J., T. Cooper and J. Montealegre. 1997. Effects of cooling and curing regime on ethylene production and storage behavior of kiwifruit. Acta Hort. 444: 567-571.

Snowdon, A.L. 1990. Soft fruits and berry fruits. Chapt. 6, In: A Color Atlas of Postharvest Diseases and Disorders of Fruits and Vegetables, Vol. 1. CRC Press, Boca Raton, FL.

Testoni, A., B. Grassi, S. Quaroni, M. Saracchi and P. Sardi. 1997. Pitting on kiwifruit in storage caused by

Phialophora sp. Acta Hort. 444:751-756.
USDA. 1986. United States Standards for Grades of Kiwifruit. October 15, 1986.