CENTRAL VALLEY POSTHARVEST NEWSLETTER

COOPERATIVE EXTENSION **UNIVERSITY OF CALIFORNIA**
Kearney Agricultural Center, 9240 South Riverbend Avenue, Parlier, CA 93648

October 1999 Carlos H. Crisosto
Vol. 8, No. 3 Editor

Contents

KIWIFRUIT 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% with low acidity 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 2.0% leaf N.

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^oC, approximately one-third to one-half of the remaining flesh firmness may be lost per month.

Kiwifruit should be stored as near to 0^oC 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^oC. 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^oC, 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^oC, 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^oC 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 force) 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°C (68°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°C (32°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°C (32°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°C (32°F).

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°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°C (32-36°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.

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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/

ABSTRACTS FROM THE 4TH INTERNATIONAL SYMPOSIUM ON KIWIFRUIT

Santiago, Chile, January 11-14, 1999

POSTHARVEST PHYSIOLOGY OF KIWIFRUIT; CHALLENGES AHEAD

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Being a relatively new crop, introduced to international trade only during the past 30 years, the kiwifruit has been the subject of an increasing amount of physiological research. Kiwifruit has been a success largely because it can be stored for a long period of time at 0^{o}C. However, there are limitations to quality after long term storage, and the challenge to postharvest scientists is to understand and manipulate those factors that influence deterioration rate and quality after storage. This review will attempt to identify key research contributions that have been made in the following topics: preharvest factors that influence postharvest quality; harvest maturity; softening in kiwifruit; taste, aroma and flavour; and the role of ethylene in ripening. In addition it will attempt to issue challenges to postharvest scientists who will need to solve additional problems if this industry is to continue to expand internationally and continue to be profitable for growers.

KIWIFRUIT POSTHARVEST HANDLING STRATEGIES: NEW DEVELOPMENTS

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To maximize kiwifruit returns, five main new approaches are being used: reduction of production costs, delayed cooling ("curing"), supplying tasty fruit to consumers ("ready to eat"), extending supply availability (early harvest) and quality segregation. The use of bin storage under air or controlled atmosphere (CA or MAP) before packaging is a successful approach to reduce packaging and other costs, although kiwifruit water loss and softening should be carefully monitored during storage. Controlled environmental conditions during delayed cooling are essential for a successful "curing" treatment to reduce Botrytis. Ripening protocols for shippers, buyers, warehouse managers, store managers and consumers have been developed for marketing conditions in different countries (California and New Zealand). As it has been proved that delivery of kiwifruit "ready to eat" increases fruit sales; a pre-ripening treatment is becoming a requirement for early season sales in California. The pressure for early harvested fruit, as a way to extend the marketing period and increase returns, is challenging the current minimum maturity standards. Detailed sensory evaluation work on developing a "minimum quality index" based on consumer acceptability is being investigated for California kiwifruit. The potential commercial use of quality segregation according to the fruit total solids (TS) in the packingline by using non-destructive optical technology (NIR) and fruit individual labeling are also putting pressure on to develop a "minimum quality index".

DEVELOPING A SAFE AND SUCCESSFUL "CURING" TREATMENT FOR CALIFORNIA KIWIFRUIT

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Different environmental parameters affecting kiwifruit "curing" performance were studied during three seasons. Our work indicated that environmental conditions such as absence of ethylene, relative humidity, fruit temperature, length of curing period and air velocity during delayed cooling were important for the control of Botrytis gray mold of kiwifruit grown in California. The 48-hour delayed cooling treatment at 59^{o}F (150^{o}C) combined with high relative humidity (95%) and medium air velocity (2 m/sec) under ethylene free (less than 10 ppb) conditions was the most effective in inhibiting Botrytis gray mold development on stem-end inoculated kiwifruit. After a 4-month cold storage, fruit quality attributes such as fruit firmness, soluble solids concentration, and fruit shriveling were not significantly different between treatments. Cumulative water loss was significantly related to the length of the cooling delay period. The differences in percent water loss among the treatments were still present without any obvious fruit shriveling after four months cold storage. This work confirmed information from New Zealand on the importance of environmental conditions that are necessary to develop decay resistance to Botrytis gray mold during the delayed cooling period.

ADAPTING PERFORATED BOX LINERS TO THE CALIFORNIA KIWIFRUIT INDUSTRY

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The performance of California kiwifruit packed using solid liners, perforated liners, and micro-perforated liners on the rate of initial cooling time and quality attributes after shipping was evaluated under controlled laboratory and commercial conditions. Controlled cooling test using a portable cooling tunnel indicated an important cooling time reduction (reaching 7/8 cooling time) without affecting quality when perforated liners were used instead of solid ones. These vented box liners will result in direct energy savings to packinghouses proportional to the reduction in cooling times. Also, shorter cooling times will allow scheduling operations for the off-peak utility periods. Perforated liners allowed for some vapor exchange, and thus reduced problems associated with condensation in the package. Fruit quality attributes such as firmness, soluble solids, and titratable acidity were not affected by any of the box liner treatments. Kiwifruit weight loss depended on the box liner vented area. At the end of the 18 weeks storage period, kiwifruit packed in the solid, perforated and micro-perforated box liners had water losses of 0.7, 2.4 and 5.2 %, respectively. Fruit shrivel was only observed on fruit packaged in the micro-perforated liners when water loss exceeded 4.0 % in relation to the harvest fresh weight In one of the three seasons, high pitting incidence was measured on fruit from the micro-perforated box liner treatment.

MODIFIED PALLET ATMOSPHERE INCREASES SHELF LIFE OF KIWIFRUIT

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Modified atmosphere of kiwifruit pallet units (64 boxes of 10 Kg each) was obtained with a sealed polyethylene bag. The initial atmosphere was attained with an air vacuum at time of sealing. The pallets were stored for a period of 35 days at $0^{o}C$ followed by another 30 days storage at $0^{o}C$ at normal atmosphere. After every period of storage fruit quality was evaluated with emphasis in flesh firmness. Shelf life was calculated as days necessary to ripen fifty percent of fruit from a total of 4 groups of 40 fruits maintained during 10 days at $20^{o}C$. The modified pallet atmosphere resulted in increased firmness and shelf life of kiwifruit compared with control fruit. Firmness was 13.2 compared with 7.9 pounds after 35 days of treatment storage and 8.3 instead of 5.3 pounds after 30 additional days at normal atmosphere. Shelf life was 8 days compared to 5 days for control fruit. The atmosphere inside the pallet was modified to 31.7% of carbon dioxide and 3.5% of oxygen after 21 days storage. No phytotoxic effect was detected in this atmosphere but the amount of rotten fruit increased from 0.7 to 2.9%.

INFLUENCE OF NEW CURING AND CA STORAGE TECHNOLOGY ON BOTRYTIS ROTS AND FLESH FIRMNESS IN KIWIFRUIT

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Many producers in Italy cure kiwifruit at ambient temperature for 48-72 hours so as to reduce the incidence of *Botrytis cinerea* rots, and utilize CA storage as a means to maintaining flesh firmness above 2 kg for over 120-140 days postharvest.

In central and northern Italy, where harvesting is completed in just a few days, curing at ambient temperature gives rise to considerable logistics and warehousing difficulties, whilst CA storage is known to favour the spread of Botrytis rots, hence its relatively limited use.

Tests were carried out by our team during the 1996/97 and 97/98 season in order:

a) to find curing systems that could be implemented directly in refrigerated rooms,
b) to identify CA storage methods that would not cause rots to increasing.

Concerning point a) it was found that curing could indeed be carried out directly in refrigerated rooms, gradually reducing the temperature from 10 to 0^{o}C over a period of around 10 days. As to point b) we were able to confirm the findings of our previous tests, which was showed that by postponing the start of the gas treatment (O_2 pull down and CO_2 increasing) by 30-40 days postharvest (CA delay), the negative impact of CA storage (increasing of Botrytis rots) could be avoided without any adverse effects in terms of decrease in pulp firmness.

APPLICATIONS OF AVG, AN ETHYLENE BIOSYNTHESIS INHIBITOR, AND ITS EFFECTS, ON RIPENING AND SOFTENING IN KIWIFRUIT

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Two trials were performed with the objective of evaluating AVG, an inhibitor of ethylene biosynthesis, on kiwifruit maturation and ripening. In the first trial, spray applications of Retain (a.i. 15% AVG) of 20, 100 or 500 mg a.i./L were performed in kiwifruit plants cv. Hayward. The second trial, consisted of immersing the fruit in either 20, 100 or 500 mg a.i./L AVG solutions right after harvest. Fruit of both trials was cold stored for 120 days. Spray applications resulted in higher firmness for fruit treated with AVG 4 weeks prior to the first harvest, even with low dosages, as compared with control fruit. This difference was shown for the fruit of the two earlier harvests, and ceased to be significant after shelf life. Fruit from the third harvest did not show differences in firmness between treatments, perhaps as a result of advanced maturity and/or too early applications as referred to harvest time. Spray applications of AVG 2 weeks prior to first harvest did not result in clear differences in fruit firmness. Fruit applied with AVG by immersion also showed retention of firmness during cold storage. Prior to harvest, reductions in ethylene production rate and internal content were present for fruit treated with various dosages of AVG 4 weeks before the first harvest. These differences were no longer detected along cold storage and shelf life. Soluble solids evolution and physiological disorders did not show differences, both during cold storage and shelf life, between fruit treated with AVG and non-applied control fruit in both trials.

CPPU RESPONSE ON KIWIFRUIT GROWTH IS INFLUENCED BY THE TIME OF ANTHESIS

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Pre-anthesis factors and early fruit growth are important in determining final fruit size. 'Hayward' kiwifruit from early flowers may be larger at maturity than those from later blooms. The application of the synthetic cytokinin CPPU at fruit cell division is effective in increasing kiwifruit size. The effect of flowering date and CPPU application on the final 'Hayward' kiwifruit size was studied. Ovaries from early opening flowers had significantly greater ($P \leq 0.05$) fresh weight than late ovaries. Cell number and cell size in the inner and outer pericarp of the ovary at anthesis were similar for early and late opening flowers but core cell number was significantly higher ($P \leq 0.05$) in the early flowers. When fruitlets from both type of flowers were treated with CPPU at 15 ppm, the early flowers achieved a larger commercial fruit size (152.6 g) than fruit from later flowers (126.0 g). CPPU treated fruit in the two bloom dates achieved higher cell number in the outer pericarp at harvest. In contrast, the cell size in the inner pericarp of early and late untreated fruits was higher than CPPU-treated fruit.

EFFECTIVENESS OF SEVERAL GROWTH REGULATORS IN KIWIFRUIT GROWING

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CPPU (forchlorfenuron) alone and in combination with other growth regulators, were applied to 7 year old kiwifruits plants cv.Hayward growing at Nogales, in the 5th Region of Chile. Fruits were treated 30 days after anthesis to evaluate effects in weight, length, diameter and maturity of fruits at harvest time. Treatments: a) CPPU 3 ppm + n-m-tolilphtalamic acid 400 ppm sprays, b) CPPU 3 pprn immersion for 1 second (1"), c) CPPU 3 pprn immersion for 1" + CPPU 3 ppm spray, improved the weight of kiwifruits; in 54.4%, 47.3% and 40.3% respectively, compared to the control. In fruit length better results were: a) CPPU 3 ppm spray, b) CPPU 3 ppm + n-m-tolilphtalamic acid 400 ppm sprays, c) CPPU 3 pprn immersion for 1" + CPPU 3 ppm spray and d) CPPU 3 pprn immersion for 1". Compared to control, increases were 12%, 11.4%, 10.9% and 10.4% respectively. In equatorial diameter (widest section) best treatment was CPPU 3 ppm immersion for 1" + CPPU 3 ppm spray, with 21.6% increasing over control. No treatment exceeded 1.3 ratio of equatorial diameter highest/lower rate, meaning no flat fruits were present. Regarding maturity only CPPU 3 ppm x 2 sprays delayed 0.5^{o}Brix with respect to control, being remaining treatments same to the latter.

RELATIONSHIP BETWEEN NITROGEN AND FRUIT QUALITY IN KIWIFRUIT

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The effect of different nitrogen fertilization levels (0, 150, 300 and 450 kg N ha^{-1}) on kiwifruit production and quality was assessed in a long-term field trial (1992-1997). On the basis of the results until obtained now the following considerations could be made: after six years of evaluation, control vines did not show visible symptoms of deficiency; while in the first three years the highest rates of nitrogen appeared to increase fruit production, in the following period no differences were observed among treatments. Brix and flesh firmness values, chosen as the most used indexes in the practice, were monitored at harvest time and during storage to evaluate the fruit characteristics and storability. Both parameters maintained higher values in the control fruit than in the treated ones. However, in order for better prediction of fruit quality and storability, other fruit traits were determined, i.e. reducing sugars, sucrose, starch, organic acids (ascorbic, malic and citric), pH and protein at harvest and throughout the storage period (180 days). Changes in these parameters, Brix and flesh firmness as related to nitrogen fertilization levels are presented in this paper.

MINERAL ANALYSIS OF KIWIFRUIT: A POTENTIAL APPROACH TO SEGREGATE KIWIFRUIT FIRMNESS CAPACITY

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Fruit mineral analysis was used to characterise soft and firm fruit obtained from five groups of fruits from four orchards after 3 months of controlled atmosphere storage plus an additional 38 days in regular storage. In a separated experiment, four plants of five orchards were harvested and fruit mineral analysis was assessed and correlated with the fruit firmness after four months at 0°C. Soft fruit in all the orchards had higher concentration of nitrogen and potassium than firm fruits. Firmness at harvest of total of 20 data points allowed to identify critical values of mineral compounds of kiwifruits that segregated soft and firm fruit. The N+K/Ca+Mg > 21 was related with 100% of soft fruit instead of value of <16 where all the fruit was firm, in the range of 16 and 21 was not possible to segregate in term of soft and firm fruit. Critical values of nitrogen, calcium and N/Ca ratio are discussed.

Project financed by Fondecyt N° 1960237

KIWIFRUIT SIZE INFLUENCES SOFTENING RATE DURING STORAGE

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Large (~101 grams), medium (~93 grams) and small (~81 grams) 'Hayward' kiwifruits were stored in either ethylene-free air or in a controlled atmosphere (CA) of 5% carbon dioxide (CO_2) and 2% oxygen (O_2) at 32°F 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 lbf (the minimum pounds firmness required for packaging with minimal bruising) by 12, 10 and 8 weeks, respectively, while those stored under CA conditions softened to 5.0 lbf by 49, 30 and 20 weeks. Understanding the relationship between fruit size and the rate of softening under air and CA conditions will help cold storage managers safety monitor kiwifruit softening during bin storage.

KIWIFRUIT PRECONDITIONING PROTOCOL

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Kiwifruit (*Actinidia deliciosa* var. Hayward) flesh softening, the conversion of starch to sugars, and soluble solids content accumulation in response to temperature and exogenous ethylene applications have been studied for the last three seasons. The result of this research is a ripening protocol which deals with pre-conditioning kiwifruit prior to shipment (packers/shippers) by using ethylene and temperature combination treatments. The preconditioning treatment triggers the ripening process which continues during storage/transit. This protocol allows the California kiwifruit industry to deliver "ready to eat" kiwifruit early in the California season (September-December).