California Avocado Research Symposium 2006

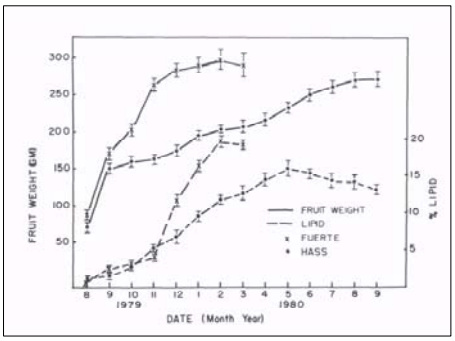
November 4, 2006
University of California, Riverside

California Avocado Commission
Production Research Committee

Our Mission: To provide California Avocado Growers a means to achieve optimum profitability, now and in the future, through focused research, global collaboration, and effective communication of results

Unusual things about the avocado fruit:

- ✓ Continued cell division during growth and development
- ✓ Contains many healthy phytochemicals and unusual sugars
- ✓ Accumulates large quantities of lipids in the fruit flesh



Eaks, 1990

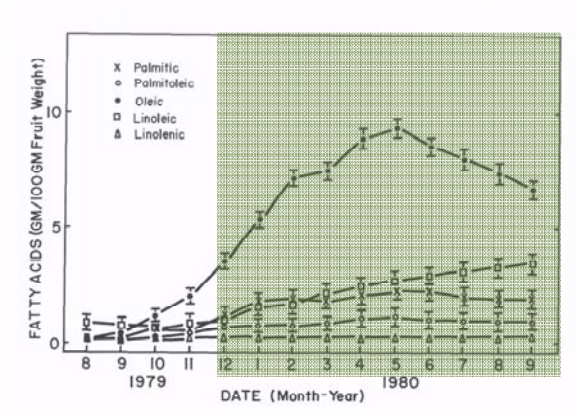
Avocado – Healthy Phytochemicals

- » **Fatty acids (triglycerides, or oils)**
  - » **High monounsaturated (18:1 Oleic; 16:1 Palmitoleic)**
  - » **Low saturated (16:0 Palmitic)**
  - » **Moderate polyunsaturated (18:2 Linoleic; 18:3 Linolenic)**

Work of Eaks, 1990

'Hass' avocado

Changes in fatty acids per 100 g fresh weight



Avocado – Healthy Phytochemicals

- **Vitamin E**
  - **alpha tocopherol and other tocopherols**
- **Sterols**
  - **beta sitosterol and other sterols**
- **Pigments**
  - **Carotenoids (e.g. lutein)**
  - **Chlorophylls**
- **Health: Strong antioxidants and linked to reduced cancer, and heart and eye health.**

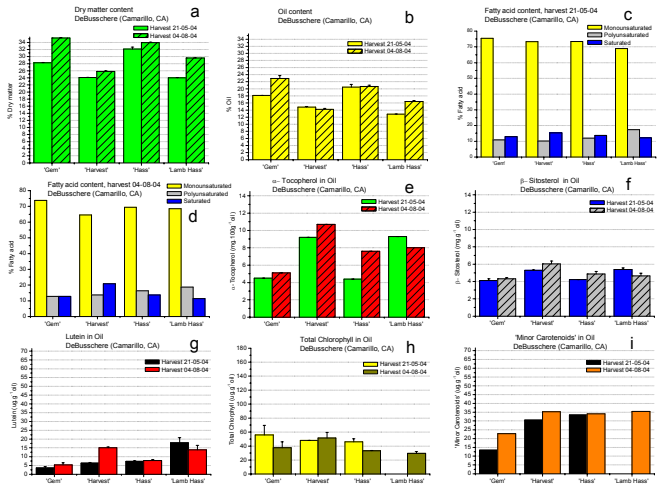
HortResearch

Factors Influencing "Health" Phytochemicals in avocado and avocado oil

- **Preharvest**
  - **Cultivar, maturity, country/region, season, orchard practices**
- **Postharvest**
  - **Storage, ripening, fruit quality**
- **Processing**
  - **Tissue types**
- **Post-Processing**
  - **Light, temperature and duration**

HortResearch

Preliminary results from joint work with HortResearch (NZ)



4 varieties

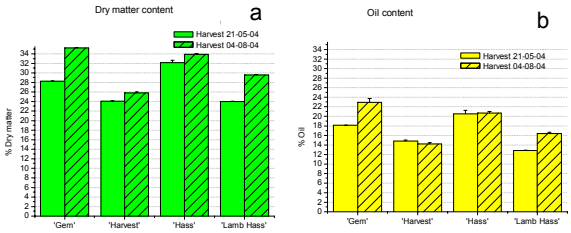
GEM, Harvest, Hass, Lamb Hass

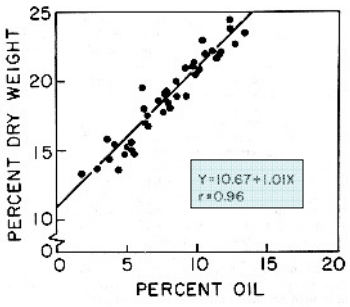
2 harvests

May, August

Dry weight at each harvest varied between varieties

Oil content (%) also varied but the lower dw varieties tended to have lower oil

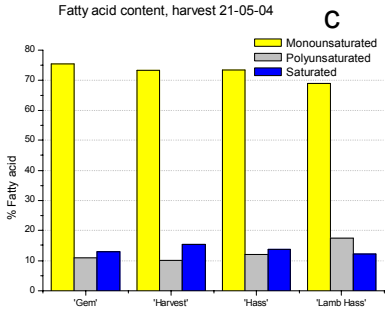


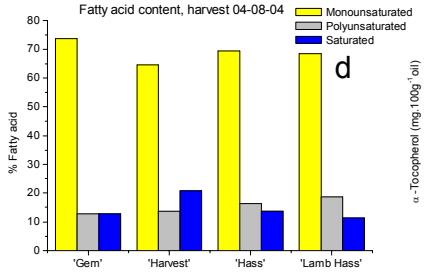


Relationship between percent dry weight and percent oil during development and maturation of 'Hass' fruit at Escondido (Lee et al, 1983)

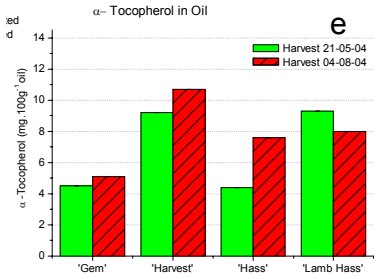
The relative proportion of fatty acids remained fairly constant from harvest to harvest within a variety

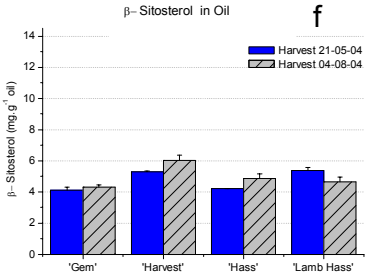
'Harvest' seems to have the highest saturated %



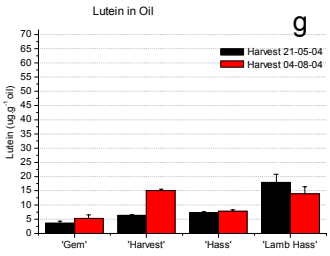


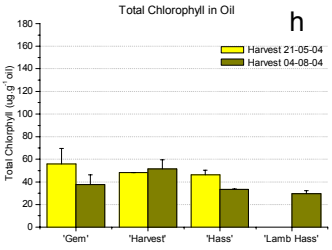
There appears to be large differences between cultivars in terms of alpha tocopherol and less of a difference in β-sitosterol





There appears to be large differences between cultivars in terms of lutein (derived from the carotenoids) as well as total chlorophyll





The Question

All this is great news for an avocado grower - The fruit is nutritious, healthy and good to eat

The QUESTION is how to we insure that the consumer receives the maximum benefit?

The Answer

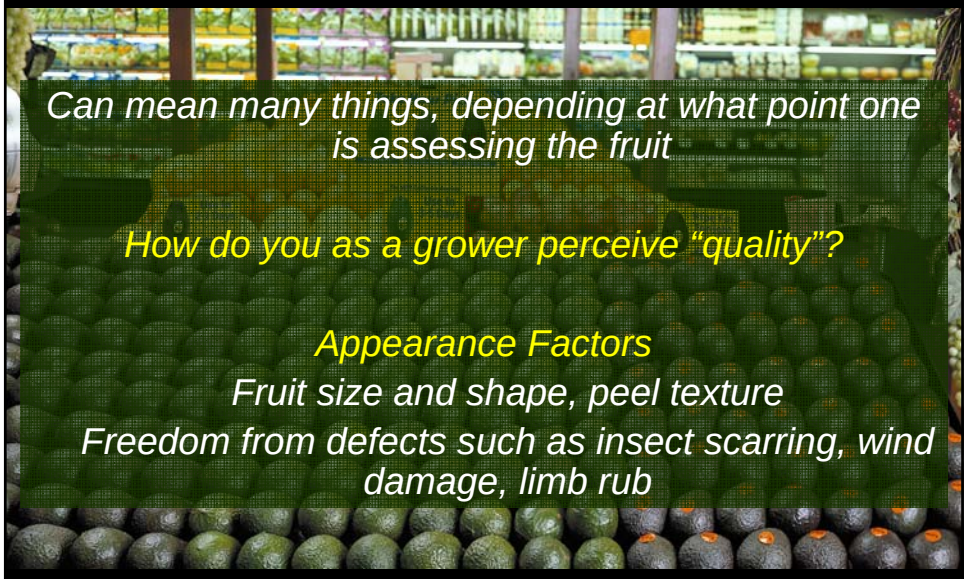
The most important thing to remember is that there is a **continuum** from the grower to the consumer

The steps in the continuum

Grower *– Packer – Distribution –* ***Consumer***

For this reason it is imperative that growers be involved at all levels of our industry

We all talk about quality but how do we define it????



Can mean many things, depending at what point one is assessing the fruit

How do you as a grower perceive "quality"?

Appearance Factors

Fruit size and shape, peel texture

Freedom from defects such as insect scarring, wind damage, limb rub

We all talk about quality but how do we define it????

Well, you know I have always maintained that, if we can't provide the consumer with something that they would be happy with and come back to buy more, then we have not succeeded. And one of the things ….that I've always wanted to emphasize flavor and nutritional quality more than appearance and texture quality.

I know as producers and shippers, appearance and firmness, shipping capability of the fruit are very important, but I, taking the consumer side, I think that flavor and nutritional quality are extremely important. And I'm very happy to report that a lot of my colleagues and a lot of the industry people are talking about flavor, are doing things to enhance flavor, and this is really- should be at the top of definition of quality.

So, a really good quality avocado is avocado that has a good flavor that the consumer will appreciate, and good nutritional quality for the consumer. You know, all of the other things are detail, in terms of freedom from defects, and the firmness, avocado that's not bruised, etc. All of these things are details, but the key issue, really, is good flavor quality, no off flavors, which would be devastating to anybody who starts to eat an avocado. So, that's my definition.

Adel Kader, Brainstorming 2003

Quality aspects for fresh produce

External characteristics

- Color
- Shape
- Blemishes
- Decay
- Affects initial decision to purchase
- Generally longer shelf life

Internal characteristics

- Flavor
- Texture
- Nutrition
- Affects decision for repeat purchase
- Generally shorter shelf life

Flavor Life versus Shelf Life

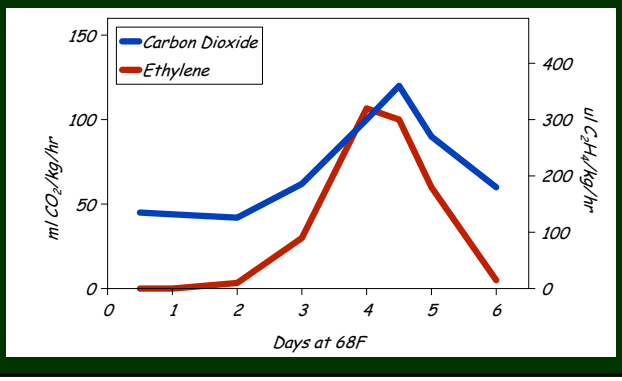
- Variety
- Harvest maturity
- Storage temperature
- Storage atmosphere
- Packaging – MAP
- Coatings
- Postharvest handling and treatments

- Reduce ethylene
- Suppress respiration
- Retard water loss
- Maintain appearance (extend visual shelf life)

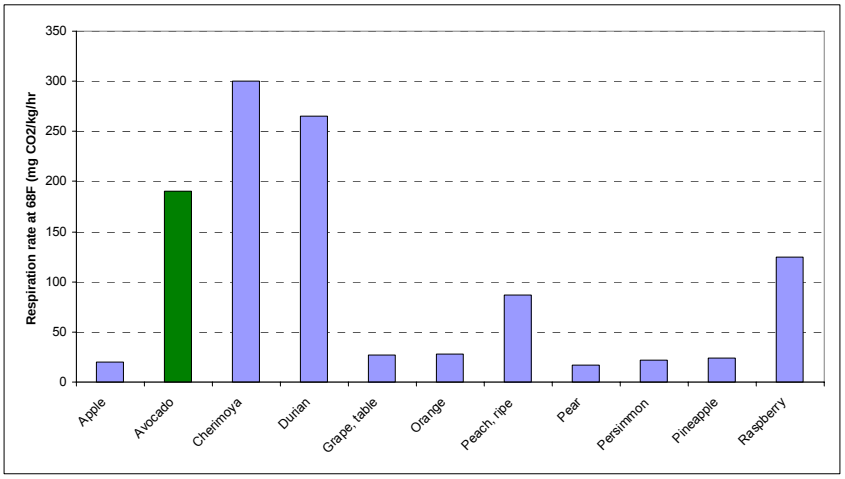
What we know about the avocado fruit

- A climacteric fruit showing an increase in respiration and ethylene production during ripening
- Influenced by maturity, time after harvest, temperature and atmosphere

Adapted from Eaks (1978) for 'Hass'



The avocado has a high rate of respiration as compared to other fruits; it is also considered a high ethylene producer



Susceptibility to low storage temperatures

External Chilling Injury

Internal Chilling Injury

Postharvest Diseases

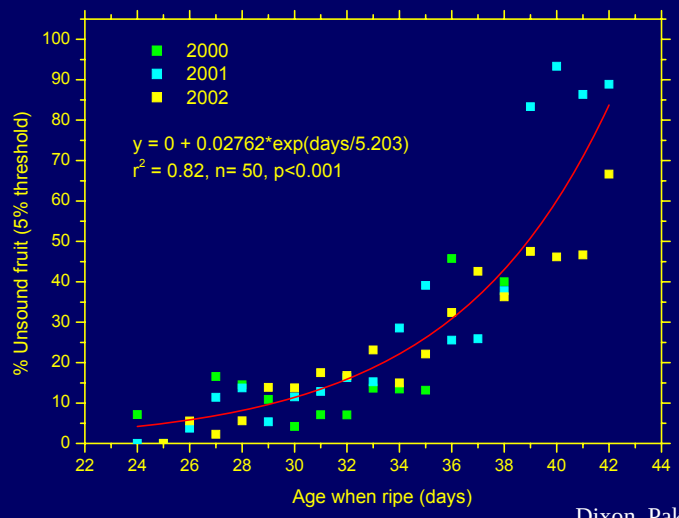
Stem End Rot

Anthracnose Body Rot

Alternaria Stem End Rot

Dothiorella Stem End Rot

Relationship between fruit age and unsound fruit



Dixon, Pak and Cutting

Problems at retail

Conducted in collaboration with CAC Merchandising Staff

Example of fruit shriveling

Example of an overripe fruit with stem end rot, body rot and internal bruising

Example of a stem end rot

Example of body rots

A. Fruit with no bruising under the peel.
B. Fruit which is very overripe and is exhibiting bruising under the peel.

A. Very ripe fruit compressed by other fruit on display.
B. Example of internal bruising.
C. Very ripe fruit showing severe internal damage.

There are problems with fruit arrivals

Who is at fault?

Remember the continuum

Grower Inputs

Need to work closely with your packhouse

Maturity – optimize shipping quality

Rainfall and decay

Temperature management at harvest

Speed at which fruit is moved to packinghouse

Quality vs. Maturity

- Immature
  - o Poor quality when ripe
  - o More shriveling and physical damage
- Mature
  - o Good quality when ripe
  - o Longest postharvest life
- Overmature
  - o Too soft, poor flavor
  - o More physiological disorders and decay

Fruit quality to consumers is limited by harvest maturity:

- Immature – watery, shriveling, inconsistent ripening, physiological disorders, susceptible to decay
- Overmature – can be dry, rancid, seed germinating and more susceptible to decay

Physiological disorders accentuated with low maturity fruit

External Chilling Injury

Flesh Discoloration

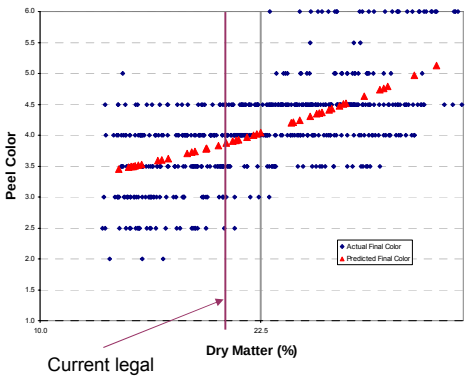
Poor RIPE Skin Colouration

Relationship between dry matter and final peel color

Final Peel Color = 3.06261- 0.00264DW +0.0020DW^2

where DW = Dry weight

R^2 = 0.621 ***



Skin Shriveling

Checkerboarding (Ripening Variability)

Difficult to predict time of ripeness

Great variation in the days to ripe within a package even with ethylene treatment

RESULT:
Lack of ripe uniformity means more loss at point of purchase

Current California Minimum Maturity Standards

DRY MATTER %	VARIETIES
17.7	Bacon
18.7	Zutano
18.7	Reed
19.0	Fuerte
20.8	Hass
21.6	Pinkerton
24.2	Gwen
22.8	Lamb Hass

Date/Size Maturity Releases

- Date/Size maturity releases allow avocados to move in a uniform manner.
- Avocados can still be harvested before the release dates, but they will be tested for minimum maturity standard.
- Regulated by CA Dept of Food and Ag.

'Hass' size and release dates

size 40 and larger	size 48	size 60	size 70 and smaller
Nov 28	Dec 12	Jan 2	Jan 16

Determination of fruit maturity

Using dry matter as the standard reference when talking about fruit maturity

A comparison of three avocado maturity studies

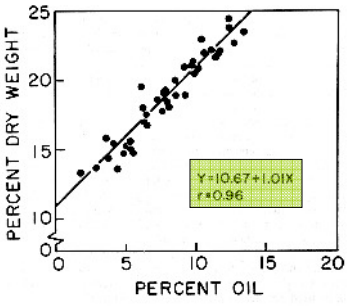
- ***Lee, Seung-Koo***. 1981. Maturity studies of avocado (*Persea americana* Mill.) fruit in California. PhD. Thesis. University of California, Riverside.
- ***Ranney, Cliff***. 1998. Avocado maturity study 1985-1993. Report of final conclusions from 1989-90, 1990-1991, 1991-1992, 1992-1993. Avocado Inspection Committee.
- ***Arpaia, Mary Lu***. 2002. Hass maturity project. Production Research Committee, Avocado Inspection Committee.

Major Findings

Lee	Demonstrated the relationship between oil content and dry matter over a wide range of varieties and growing locations; Concluded that growth measurement could predict horticultural maturity; Concluded that an assigned picking date within a geographical area (San Diego/Orange County, Ventura Coastal and Tulare Inland) was possible depending on fruit size; Developed the current microwave technique for determining dry matter; Demonstrated that minimum maturity standard of 8% oil content was not sufficient for acceptability.
Ranney	Collected several years of data and made recommendations to industry for current minimum maturity standards
Arpaia	Re-evaluated the current minimum maturity standard for 'Hass' avocado using taste panels. Similar to Lee used fruit acceptance as guide for determination of dry weight.

Correlation between oil and dry matter

- Lee et al, 1983, J. Amer. Soc. Hort Sci.
- Demonstrated relationship between oil and dry matter
- Basis of recommendation to CA industry to switch to dry matter
- Now internationally used for maturity standard

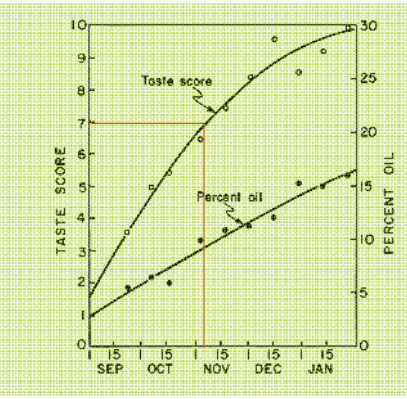


Relationship between percent dry weight and percent oil during development and maturation of 'Hass' fruit at Escondido.

Relationship between oil and acceptability

- Lee et al, 1983, J. Amer. Soc. Hort Sci.
- Minimum acceptable taste score = 7

- HASS variety
  - Oil content = 11.2%
  - Dry weight equivalent = 22.8%



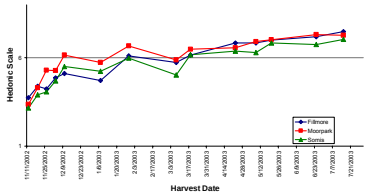
Taste and oil development during maturation of **'Fuerte'** fruit grown at Irvine.

Statistical Evaluation

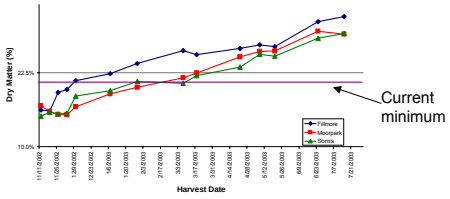
Lee	Regression analysis of Taste panel vs. Oil content (dry matter). Pooled averages per site/harvest date.
Ranney	Regression analysis of Maturity Value vs. dry matter. Pooled averages per site/harvest date.
Arpaia	Regression analysis of Taste panel vs. dry matter. Pooled averages per site/harvest date.

Recommended dry matter content for Hass

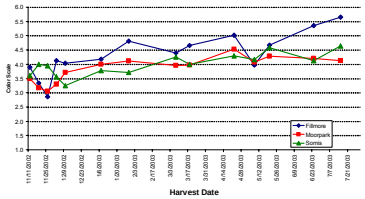
Lee	22.8%
Ranney	21.4%
Arpaia	22.5%



Harvest Date vs. Hedonic Score



Harvest Date vs. Dry Matter



Harvest Date vs. Ripe Peel Color

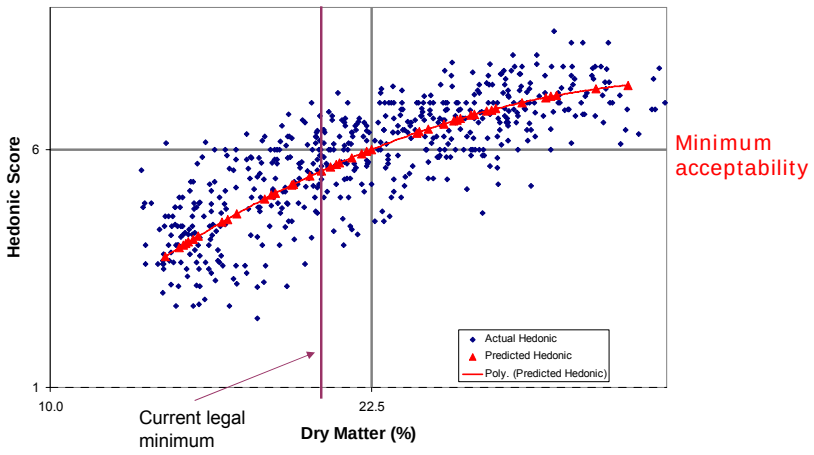
Hass Maturity Project – 2002

Results presented by grower location and harvest date

California 2002-03 results with Ventura Co. Hass fruit

Regression analysis

Hedonic Score = 2.92669 + 0.57765DW – 0.0008DW^2
where DW = Dry weight
R^2 = 0.867***



Equivalent dry weights based on hedonic evaluation

Hedonic Rating		Lamb Hass	Hass
Dislike Slightly	4.0		15.3
	4.5	18.3	16.8
Neither Like or Dislike	5.0	19.5	18.5
	5.5	20.9	20.4
Like Slightly	**6.0**	**22.8**	**22.5**
	6.5	26.7	25.1

Source: Associated Marketing Special report to CAC 11/01 – 7/02

- *Product satisfaction held at 81% of purchasing…..*
- *Early months of the crop year (N-J) may furnish the market with a highly disproportionate share of annual buyers… This surely suggests the special importance of marketing quality product during the early months of the season*
- *Avocados held high repeat rate – buyers highly concentrated (22% of households account for 46% of purchases*

Consumer Satisfaction

Overall satisfaction – 81%

HOWEVER, from November to January 2000-01, satisfaction claims were *below* the annual average and among the lowest of the year.

This strongly suggests the importance of *early season avocado quality* if high repeat performance may be expected to follow.

Too, it suggests the need for *increased product identification* designed to convey a consistent quality and upon which the consumer may learn to rely.

Things to consider:

- At retail level, fruit from all sources are mixed together – loss of identity
- Increasing importance of discount, club stores
- Importance of maintaining Food Service (currently 30% of CA fruit)
- Consumer satisfaction results
  - Repeat buyers
  - "Expectations" of the consumer

Considerations During Harvest

Before harvesting begins - remember!

If pesticides were used during production, double-check orchard treatment records before picking fruit to ensure that all preharvest intervals were followed.

Picking Method:

Fruit should be picked using hand clippers or picking poles. Clip the stalk to leave a button of 1/8 inch or less.

Ladders need to be Cal-OSHA approved – do not modify ladders.

Move ladders frequently to avoid stretching, fatigue and to see more fruit.

Empty picking bags at bottom of bins to prevent bruising.

Can you “snap” harvest ‘Hass’ avocados?

A *“snapped” fruit* is a fruit harvested from the tree by 'snapping' the stem and leaving the stem-end exposed.

Why consider “snap” harvesting?

•Increases efficiency - labor savings
•Worker safety issues – hands freed from clippers

Can you “snap” harvest ‘Hass’ avocados?

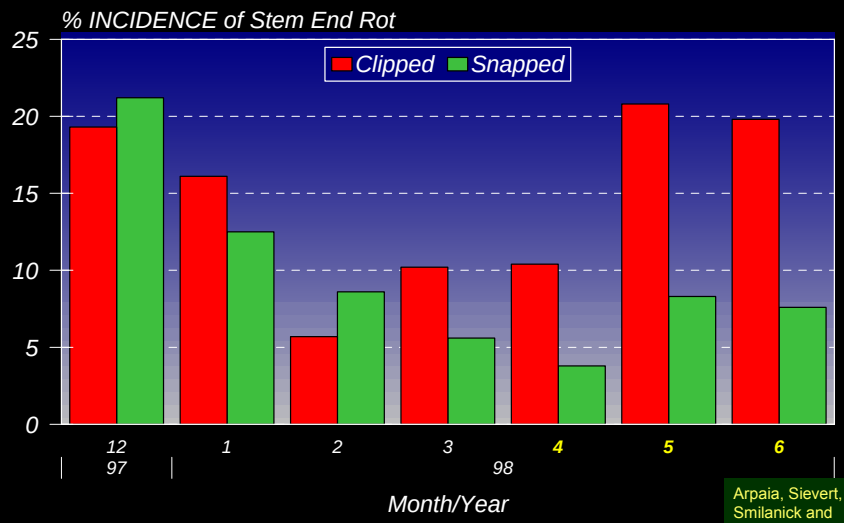
Snap vs. Clip 1997 - 98
'Hass' - 4 sites; 7 harvests

*Probability Levels: *** = P<0.001; ** = P<0.01; * = P<0.05*

	Days to Ripen	% Wt. Loss	% No Shrivel	% Body Rot	% Stem End Rot
Snap/Clip	ns	ns	***	ns	*

Arpaia, Sievert, Smilanick and Margosan (unpublished results).

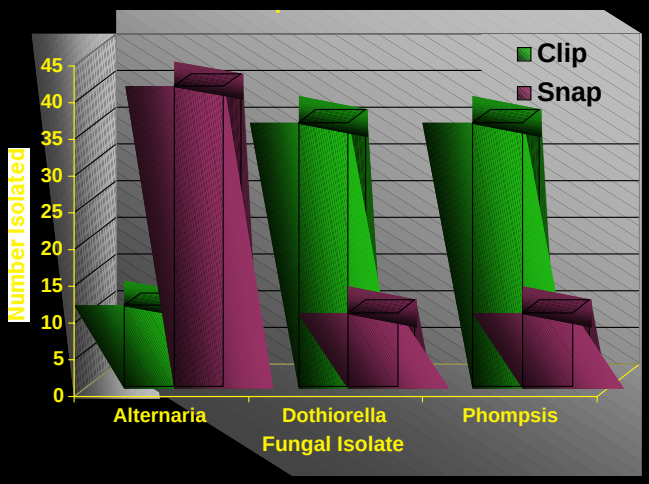
Can you “snap” harvest ‘Hass’ avocados?



Significant Differences detected at P<0.05

Arpaia, Sievert, Smilanick and Margosan (unpublished results).

Number of fungal isolates from stem end rot of “clip” or “snap” harvested avocados.



Arpaia, Sievert, Smilanick and Margosan (unpublished results).

Q: What should you put in the bin and when should you avoid picking?

Picking Bags and Equipment:

Keep clippers and bags clean and in good working order.

Minimize the distance that pickers have to walk with a full bag by placing field bins close to the pickers.

- Keep fruit in a cool place, out of the sun
- Work with packinghouse to minimize delays from time of harvest to cooling
- Avoid picking when temperatures are high especially with late season fruit
- Avoid picking during or shortly after a rain event

Transport:

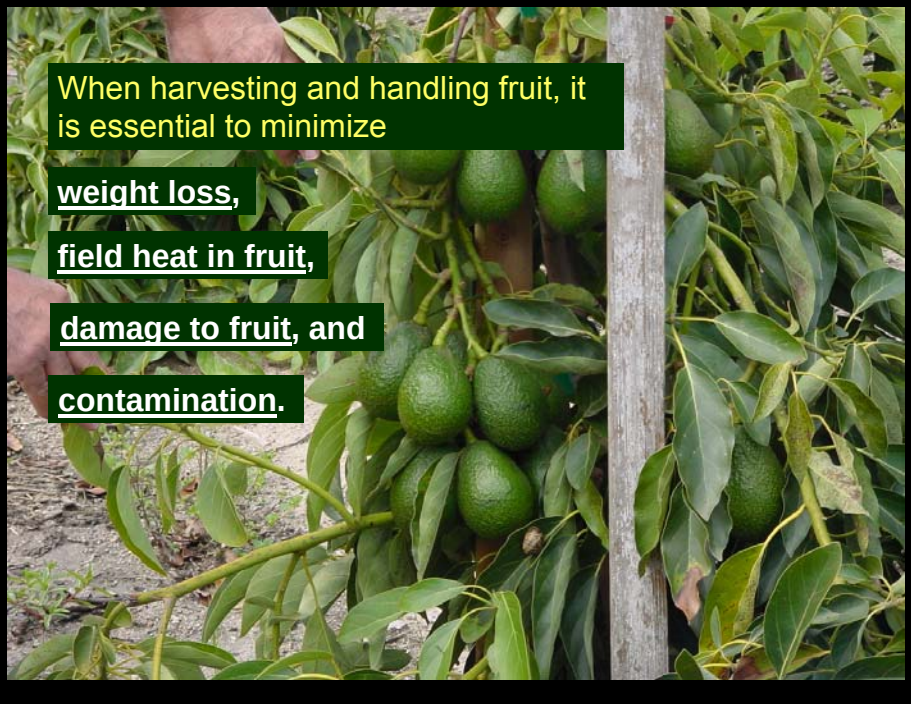
To avoid unacceptable levels of rot, do not hold fruit too long after harvest.

If feasible transport fruit to the packinghouse at least twice daily.

Do not leave bins in the orchard for more than 8 hours, and do not store full bins overnight.

Cover bins during transport to minimize water loss and exposure to direct sunlight.

Repair potholes and maintain access roads to minimize fruit damage during transport.



When harvesting and handling fruit, it is essential to minimize

weight loss,

field heat in fruit,

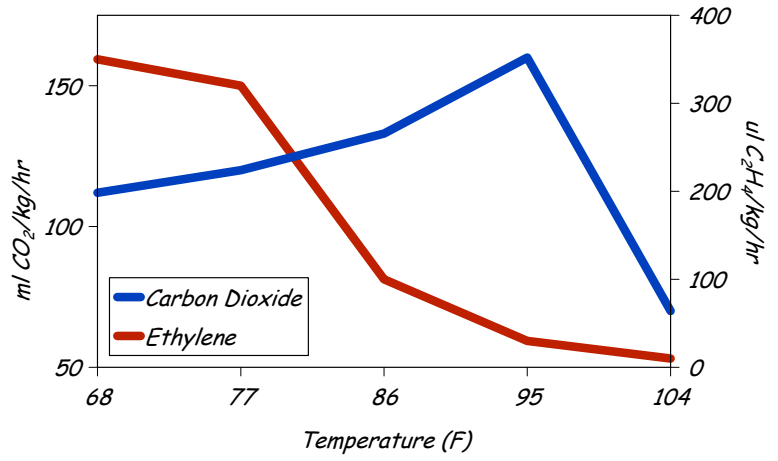
damage to fruit, and

contamination.

The importance of temperature management when harvesting

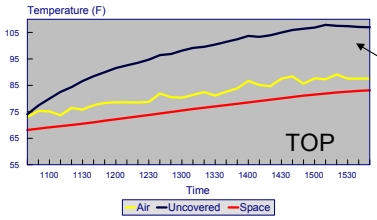
From the grove onward

High Temperature Effects on 'Hass' Fruit Respiration and Ethylene Production (Eaks, 1978)

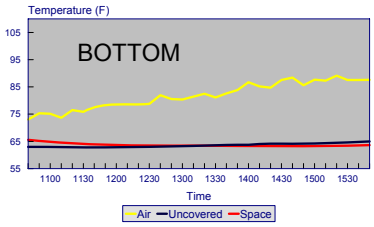


Peak respiratory rate and ethylene production. Fruit held continuously at temperature.

Protecting the fruit after harvest from high temperature has implications in the market place



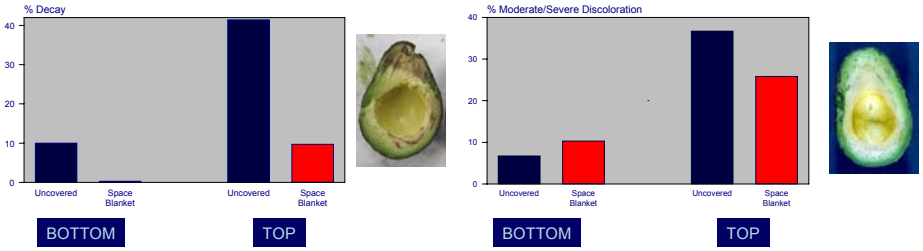
During the course of the day, fruit in the TOP 12" of the bin with no protection can reach temperatures in EXCESS of 35C whereas covered bins or those held in the shade can maintain temperatures close to ambient



Fruit at the BOTTOM of the bin stay cool during the day

Source: Arpaia, M. L., 1994; 'Hass' fruit harvested from Riverside county.

What is the outcome of high temperatures in the field after harvest?



Fruit from the BOTTOM of the bin (lower temperatures) had lower decay and less chilling injury after storage at 5C and ripening.

However, fruit from the TOP of the bin, which were warmer, had higher levels of both decay and chilling injury. This is especially true for the fruit which came from the uncovered bins.

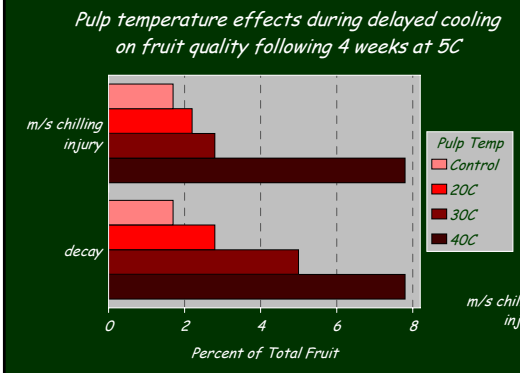
Source: Arpaia, M. L., 1994; storage was for 6 weeks at 5C.

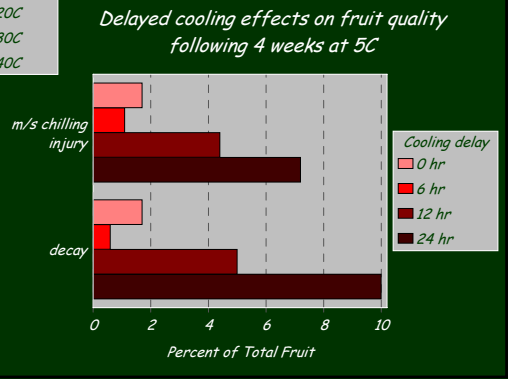
Short Duration High Temperature Effects on 'Hass' Fruit Storage and Quality (Arpaia, 1994)

- Fruit held at 68, 86 or 104F for 0, 6, 12 or 24 hr then stored at 5C for 0, 2, 4, 6 wks
- No ethylene treatments

- Fruit held at 104F for >6 hrs exhibited greater fruit decay and chilling injury following storage
- Fruit held at 86F for >12 hrs exhibited greater fruit decay and chilling injury following storage

Short Duration High Temperature Effects on 'Hass' Fruit Storage and Quality (Arpaia, 1994)





Summary of results

High temperatures (>68F) even for 24 hours results in more “ripe” fruit decay, longer times to ripen and non-uniform ripening. This affect is greatest with increasing temperature.

If fruit are stored at 41F following exposure to high temperature, there was a substantial increase in fruit decay following ripening.

Temperature: **Preferably** pick fruit when the air temperature is below 90 °F.

Hang a thermometer in a shaded area of the orchard and monitor the temperature during picking.

When > 90 °F, **consider** picking shaded fruit and be sure to use bin covers to reduce sunlight on fruit.

During very warm weather **consider** half-filling bins to help dissipate field heat, and transport to packing facility as quickly as possible.

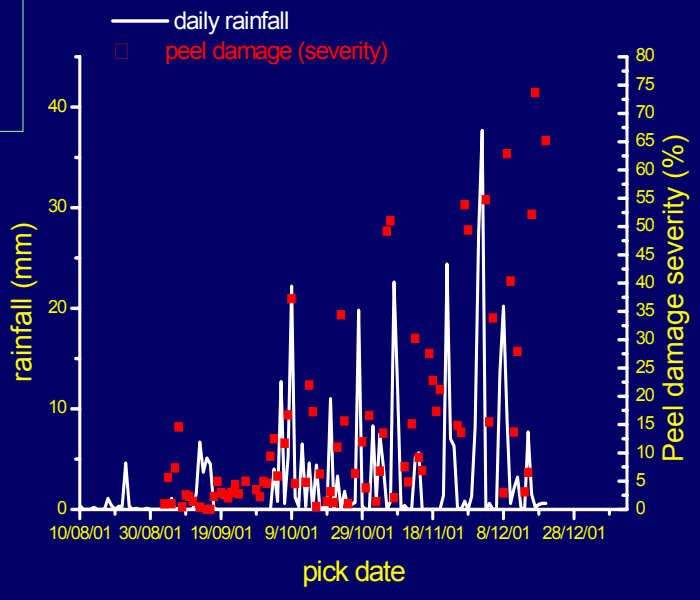
Physical damage and chilling

Lentical damage

External chilling

Source: Cutting, Dixon, Pak

Relationship between rainfall and peel damage

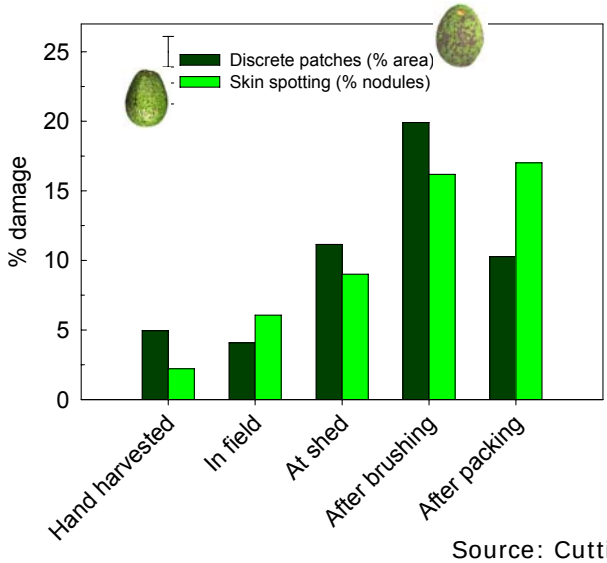


Dixon, Mandemaker, Pak and Cutting

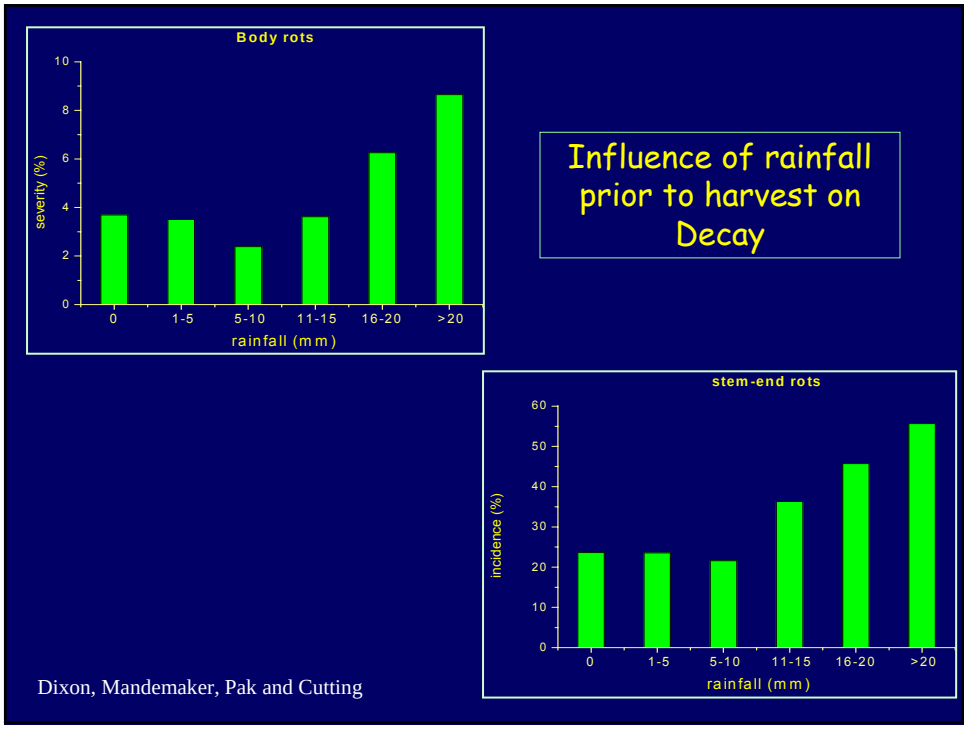
Physical damage and chilling

Source: Cutting, Dixon, Pak

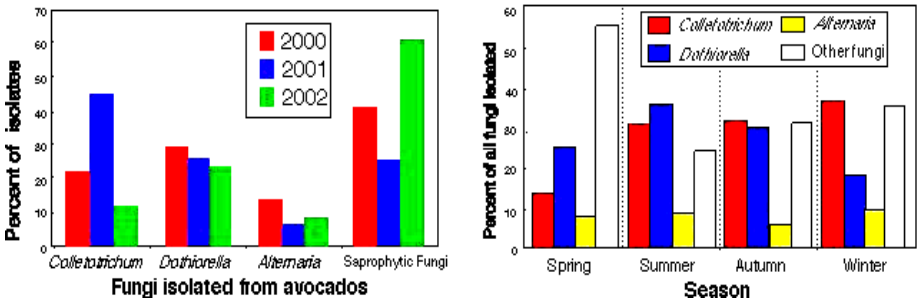
Physical damage and chilling



Source: Cutting, Dixon, Pak



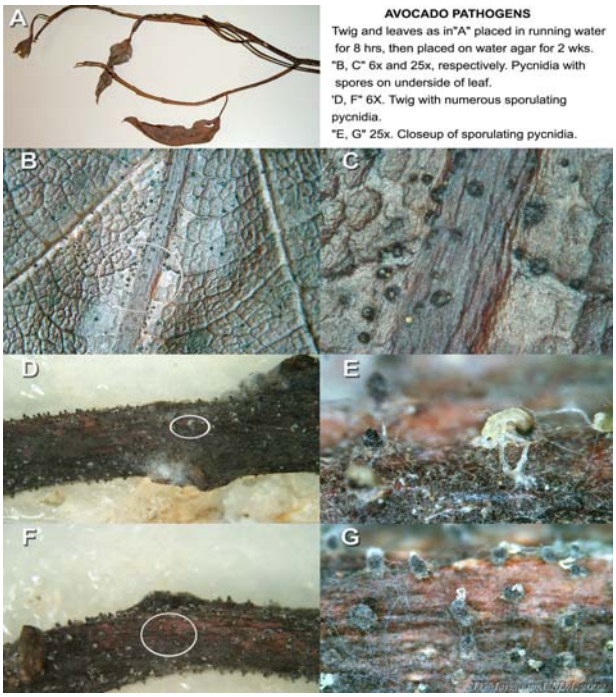
Fungi isolated from decayed California avocados



• The commonly isolated fungi were *Colletotrichum*, *Dothiorella*, and *Alternaria* species. *Colletotrichum* dominated on fruit harvested during rainy periods (winter season, year 2001).
• *Dothiorella* incidence was relatively constant. *Alternaria* incidence, entirely stem-end rot, varied little from year to year or with season.

- Holding the fruit at 5C before ripening greatly reduced decay
- Stem-end rot losses were higher among fruit from denser groves with lots of dead wood

Dothiorella on infected twigs and leaves



Ground Contact:

Fruit which has been in contact with the ground should, **preferably,** be handled separately. This includes windfalls and fruit on lower branches that have touched the ground.

Prevent fruit from direct contact with the ground.

Fruit that has had ground contact holds the greatest potential for contamination. This problem can be reduced or eliminated by laying fruit on tarps for stem clipping before transporting it to bins. These tarps should be cleaned or replaced frequently. Always place tarps the same way up!

Q: What should you put in the bin and when should you avoid picking?

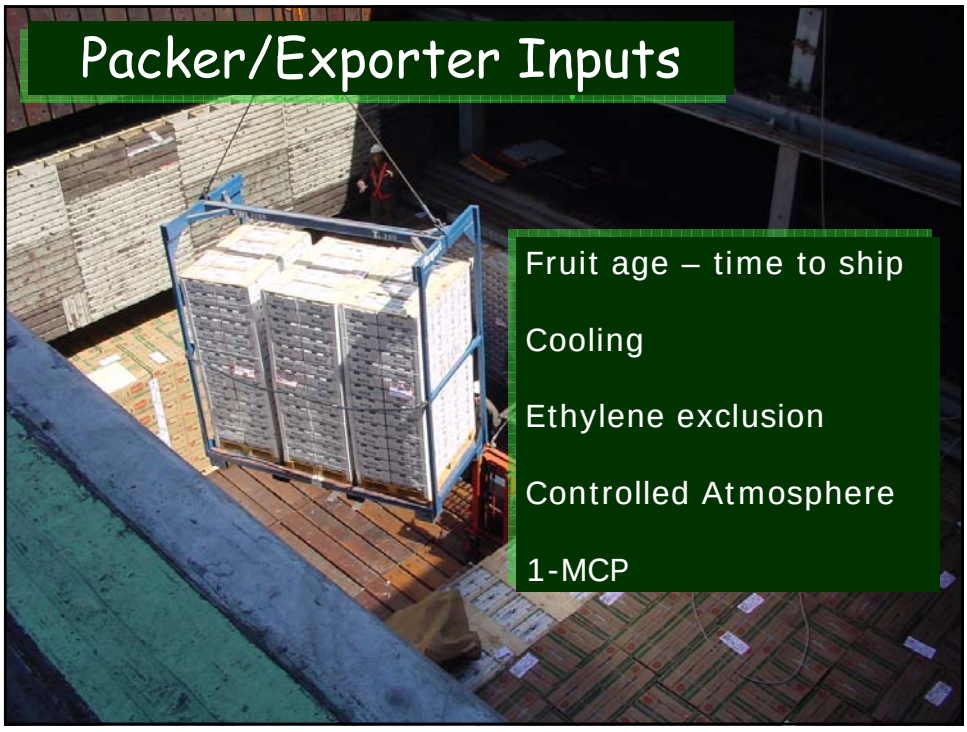
A: Avoid distressed fruit and don't harvest during periods of high temperature; after heavy rainfall

The link between the preharvest environment and fruit quality

BOTTOM LINE: Quality does NOT improve after harvest

- Nutritional management – N, Ca relationships
- Rootstocks/pollinizers – what influence do they have?
- Stress – Cold, Salinity, Irrigation management
- Canopy management – managing light

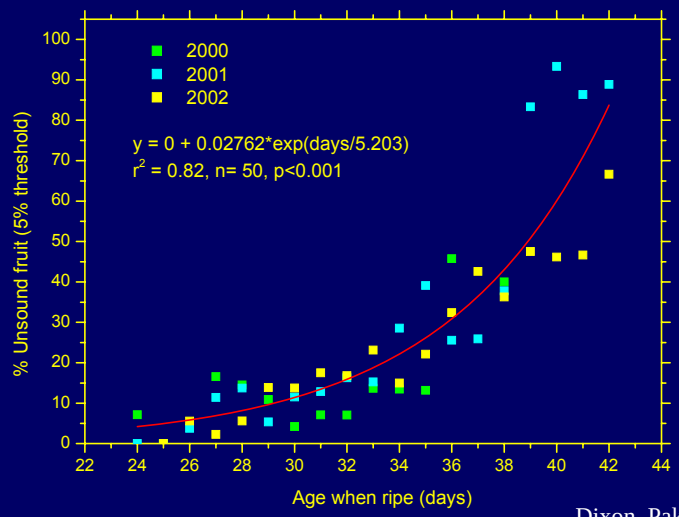
- *All contribute to fruit quality; interact with each other*
- *Important to understand interaction with fruit maturity as well*



Limitations to avocado postharvest handling

- Fruit maturity and quality at time of ripeness
- Time after harvest (fruit age)
- Stage of ripeness – more difficult to handle "ripe" fruit

Relationship between fruit age and unsound fruit



Dixon, Pak and Cutting

Avocado Storage and Transit

- California fruit marketed within 1 – 2 weeks of harvest; storage at 5C
- US imports arrivals vary in time after harvest:
  - <10 days (Mexico)
  - 12 – 21 days (Chile)
  - approximately 28 days (New Zealand)
- Fruit quality has been mixed on longer transit times…….
- 1-MCP ???????????

Ethylene - hastens deterioration

Ethylene contamination
- Softening
- Physiological disorders

Use of CA
- High CO_2 counteracts ethylene
- Slows softening

Use of 1-MCP
- Can slow softening
- Development of disorders
- Risks – overdose fruit; ripening

Destination Market Inputs

Delays in handling

Market movement

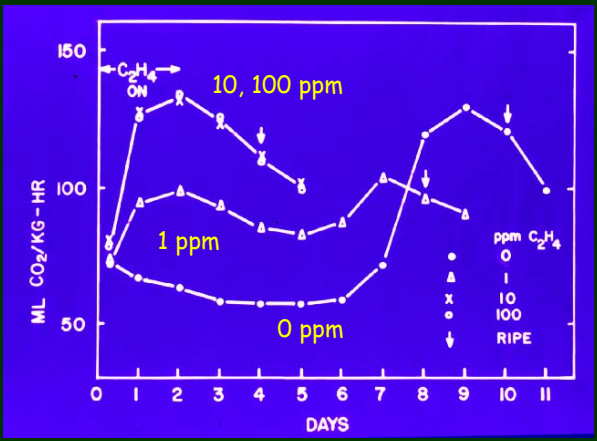
Ethylene ripening

Why Ripen Avocados?

Untreated, fruit ripening may range from a few days to even weeks within a carton

Increase Uniformity
Decrease Checkerboarding

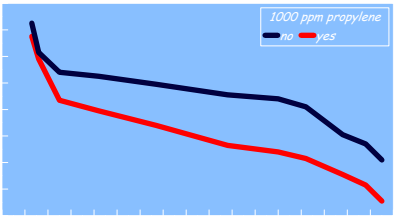
How much to apply?



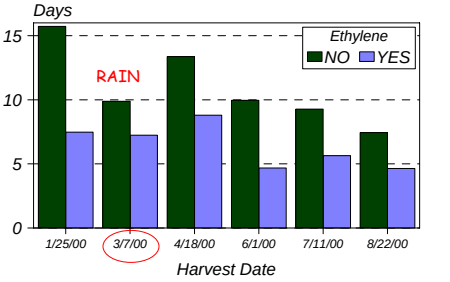
- Short exposures to ethylene can trigger ripening
- Threshold is believed to be around 10 ppm
- Commercial application of 20 - 100 ppm is recommended

Source: I. L. Eaks, UC, Riverside

Maturity and "days to ripe"

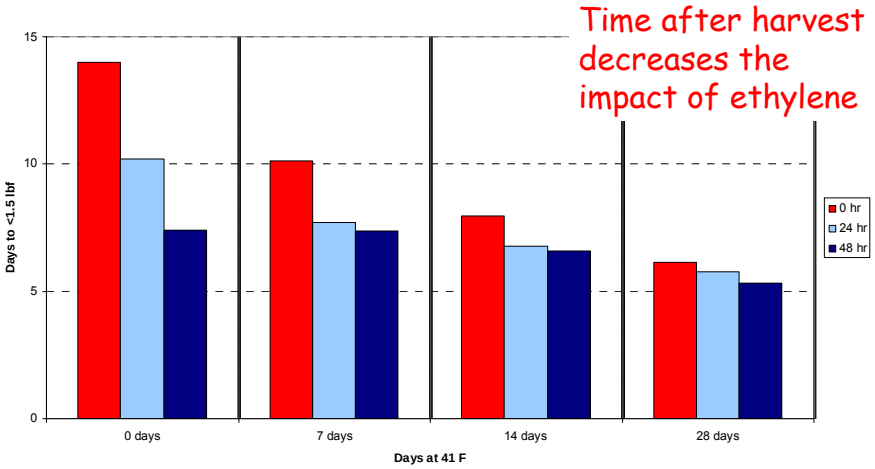


Average Days to Eating Ripeness (≤1.5 lbf) in response to 24 hour treatment of 40 ppm ethylene.



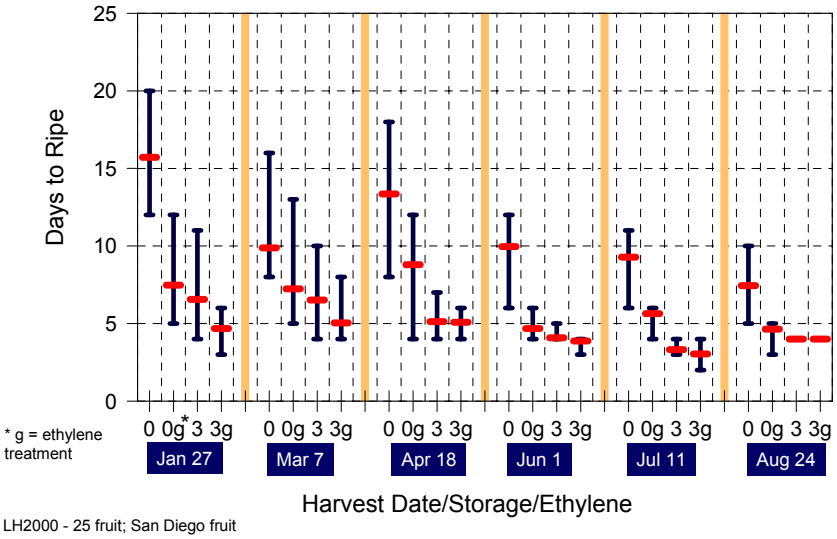
Ethylene hastens ripening regardless of stage of maturity

Time after harvest



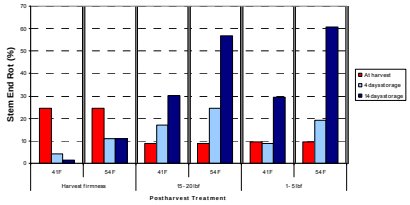
California Hass fruit

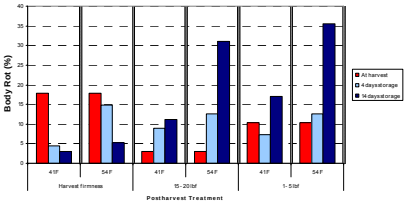
Note the affect of maturity, storage (3 wks @ 41F) and ethylene (50ppm) on the amount of days to ripe to <1.5 lbf at 68F as well as the variability of the data (checkerboarding)

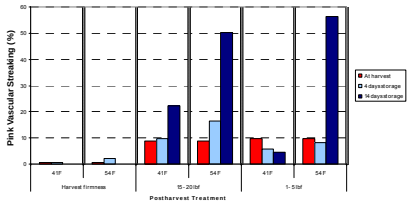


LH2000 - 25 fruit; San Diego fruit

Pretreatment followed by storage







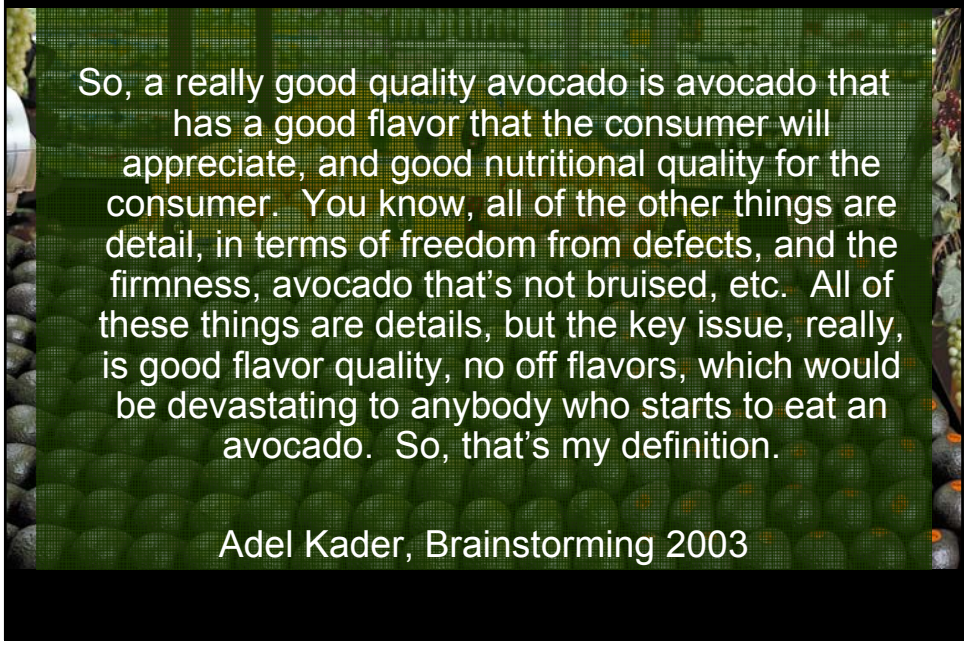
Ethylene dose considerations

- Ethylene concentration
  - >20 ppm; no more than 100 ppm
- Fruit Maturity
  - Less mature; longer treatment
- Time after Harvest
  - With increasing time after harvest; shorter durations needed

Looking to the future

- Greater international coordination
- New varieties with improved attributes
- Better orchard management
- New postharvest technologies to assist in maintaining fruit quality
- Emphasis on maintenance of “flavor” quality

We all talk about quality but how do we define it????



The Continuum

The most important thing to remember is that there is a **continuum** from the grower to the consumer

The steps in the continuum

Grower *– Packer – Distribution –* ***Consumer***

For this reason it is imperative that growers be involved at all levels of our industry

For more information

Review the CAC manual and video, "Growing for Quality"

These 2 publications provide an excellent overview on what growers can do to help to insure product arriving to the consumer in optimal quality