Best Management Practices, Food Safety & Post Harvest

Avocado Postharvest Quality

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This project is a collaborative effort between UC Riverside (Arpaia, Sievert, and Fjeld), UC Davis (Thompson and Slaughter) and HortResearch (Woolf, White and Feng).

As instructed in the January 2007 memo from CAC, the UC portion of the research team suspended all activities on the project until being notified of funding status (April 2007). This hiatus resulted in a delay in carrying out the planned work and summarizing the results.

We had several goals planned for the funding year. These included initiating work to examine the optimum ripening conditions for 'Hass' avocados in relationship to packaging (how the package influences ripening) and relative humidity during the ripening process. We also continued work at evaluating non-destructive methods in determining fruit ripeness using existing technologies. Finally, work continued on the development of the AvoCare Quality Assessment Manual and Identification Handbook.

<u>The influence of packaging on 'Hass' fruit ripening and quality.</u>

This work was carried out by the HortResearch team. Five trays of count 25 'Hass' avocado fruit were harvested on 9 October 2006 from a commercial orchard in Whangarei, New Zealand and sent to HortResearch Mt Albert Research Centre in Auckland (arrived on 11 October). Dry matter content of a 12 fruit sample was measured (average dry matter = 25.7%). After storage at 42°F (5.5°C) for 1 week fruit were ethylene treated for 24 hours (100 ppm ethylene at 68°F (20°C)). Prior to fruit being placed into the various packages, firmness was measured on a sub sample of fruit using a non-destructive device, the Sinclair iQ^{TM} (average iQ value = 66.0 ± 9.1). The Sinclair measures the electrical response from a sensor that taps the fruit and provides an iQ value. The iQ value is high in firm fruit and low in soft fruit.

Fruit were packed into 5 different types of packaging (Figure 1) approximately 1 hour after removal from ethylene treatment and left to ripen at 68°F (20°C).

1. Control: 15 loose fruit in an avocado tray
2. Five clamshells: A two-piece shell made of polyethylene terephthalate (PET) plastic (2 fruit per pack)
3. Five wrapped trays: A polystyrene tray covered with 2 layers of plastic wrap (Glad Wrap, 2 fruit per pack)
4. Five wrapped trays: A polystyrene tray covered with 1 layer of plastic wrap (Glad Wrap, 2 fruit per pack)

5. One hammock: A prototype clamshell that supports fruit in a polyethylene (PE) “hammock” (6 fruit per pack). (We reported results from this package type in previous years in terms of minimizing transit injury to ripe fruit.)

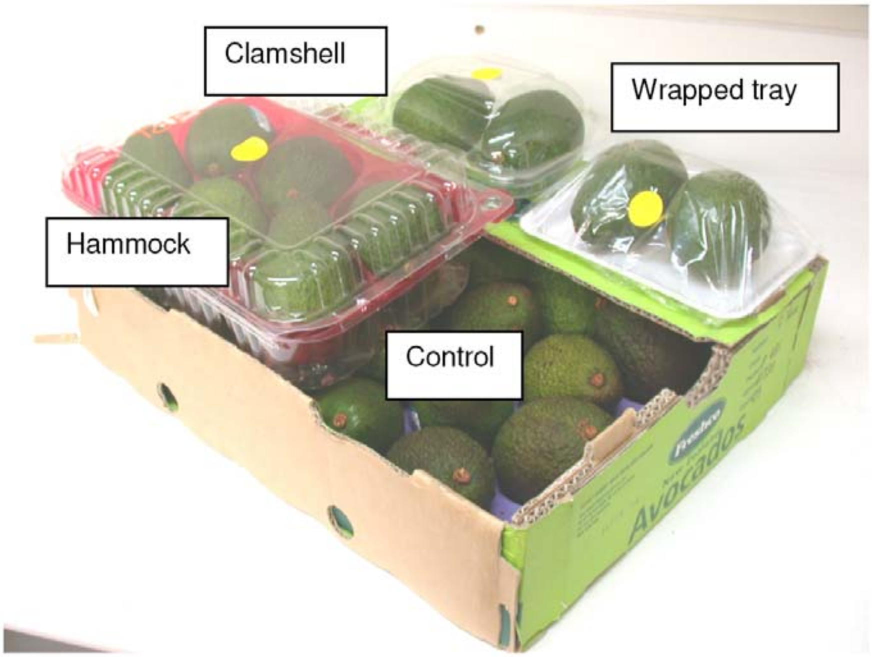


Figure 1. Example of packages used to ripen ‘Hass’ avocado.

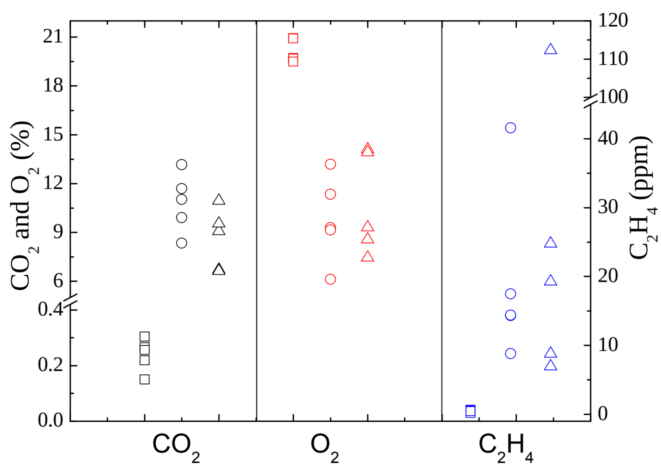


Figure 2. Variation in carbon dioxide (CO_2), oxygen (O_2) and ethylene (C_2H_4) concentrations measured 6 days after fruit were packed into clamshells (□), wrapped trays with 2 layers of plastic wrap (O), or wrapped trays with 1 layer of plastic wrap (Δ).

The key findings were that packaging had a significant effect on gas atmosphere inside the package (Figure 2), fruit softening (Figure 3) and internal disorders (Table 1) after 6 days at 68°F (20°C). Wrapped trays with 1 or 2 layers of plastic food wrap had high carbon dioxide (CO_2, above 10%), low oxygen (O_2, less than 12%), high ethylene (C_2H_4, above 6 ppm) and high relative humidity (RH, saturated). The clamshell and hammock packages had slightly modified atmospheres with 0.2-0.3%

CO_2, above 19% O_2, less than 1 ppm ethylene and moderate RH. Fruit ripened in wrapped trays were all at ready-to-eat firmness, while fruit ripened in open trays, clamshells or the hammock packaging included fruit that were either too firm to eat or over-ripe. Internal disorders were observed in 20% of fruit ripened in trays. In comparison, the percentage of disordered fruit was 1.5 and 3 times higher for fruit in clamshell or hammock packages and wrapped trays, respectively. A sound understanding of the interaction between temperature, gas atmosphere and RH is needed to define the optimum packaging specifications for avocado fruit ripening. Future experiments will utilize flow through controlled atmosphere systems to determine the interaction during ripening between temperature, CO_2, O_2, C_2H_4 and RH on fruit softening and the incidence of disorders.

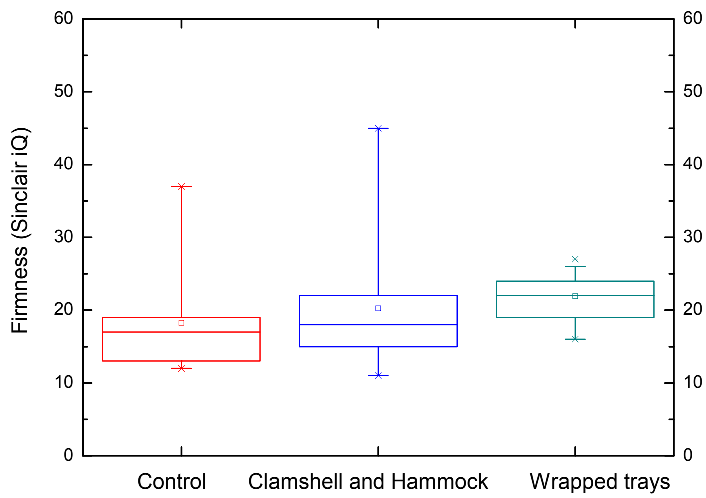


Figure 3. Firmness variation for fruit in different packages measured 6 days after packing. Data is presented as box plots where the box encloses 50% of the data. The line inside the box shows the median firmness value and the symbol inside the box shows the mean firmness value. The lines extending above and below the box show data which is not considered to be outliers.

Table 1. Effect of package on internal fruit quality assessed 6 days after packing.

Package	Fruit number	Percentage of fruit with a disorder	Percentage of unacceptable fruit*
Control	15	20	7
Clamshells and hammock	16	31	6
Wrapped trays	20	60	10

*Unacceptable fruit are fruit with any disorder rated above 1 (>10% of the fruit affected).

<u>The influence of relative humidity on ‘Hass’ fruit ripening and quality.</u>

This work was carried out by the UC Riverside team. Size 48 fruit were obtained from two commercial orchards in Ventura County twice during the season (May 14 and June 25). The fruit were taken to the UC Kearney Ag Center in Parlier, CA. After holding overnight at 55°F (12.5°C) the fruit from each grower lot were divided into 2 storage lots (ripened immediately or held for 21 days at 41°F (5°C)). When removed from the storage treatment all fruit were treated with approximately 50 ppm ethylene for 24 hours at 68°F (20°C). Following this treatment, the fruit from each grower lot were divided into 6 subsamples. Three subsamples were subsequently ripened at “low” relative humidity at 68°F (20°C) and the remaining 3 subsamples were ripened at “high” relative humidity also at 68°F (20°C). In the first test, we had difficulty maintaining the “low” humidity treatment below 50% RH and as the fruit ripened (increasing respiration and transpiration) the humidity in the treatment chambers rose substantially. Modifications to the ripening chambers were made in the second test so that this would not occur. The "low" relative humidity treatment averaged 53.1% in the second test as compared to 85.7% RH in the "high" relative humidity treatment.

Fruit were monitored daily and evaluated when an individual fruit ripeness was deemed "eating ripe" (penetrometer reading less than or equal to 1.5 lbf). When ripe each fruit was evaluated for both external and internal quality, weight loss, and decay. Additionally, the "days to ripe" for each fruit was determined. Fruit firmness was determined using both a penetrometer and the Aweta AFS™ unit (similar to the Sinclair IQ used by HortResearch). Varying relative humidity during fruit ripening resulted in few effects on fruit quality. For both harvests, the only factor negatively impacted was weight loss during ripening. The fruit ripened at "low" RH lost on average 3.76% of its initial weight as compared to 2.94% in the "high" humidity treatment across the two harvest dates. Not surprisingly, harvest date and storage duration had a greater influence on ripe fruit quality.

Table 2. Mean values for weight loss and days to "eating ripe" as influenced by harvest date, storage duration and relative humidity during ripening after ethylene treatment.

	Weight Loss (%)	Days to "eating ripe"
Harvest Date		
May 14	3.17	3.79
June 25	3.53	4.83
P Value	0.0160	0.0001
Storage Duration @ 41°F		
0 days	2.67	5.62
21 days	4.04	2.99
P Value	0.0104	0.0028
Relative Humidity during ripening		
Low	3.76	4.22
High	2.94	4.39
P Value	0.0408	n.s.

"Eating ripe" determined when average penetrometer reading for a fruit was $\leq$ 1.5 lbf.
n.s. = not significant

Due to these results, we converted the planned third harvest (August 2007) to a weight loss/ripening study. The results of this study aimed at looking at weight loss as a function of "ripeness" and stage of the climacteric (the increase in respiration (heat production)). This test is now possible to conduct since the Aweta AFS™ unit can determine flesh firmness non-destructively. Data collection was completed in September and we are in the process of summarizing this dataset which should be available shortly.

<u>Examination of non-destructive firmness detection in 'Hass' avocado.</u>

This work was carried jointly by the UC Riverside and UC Davis team. The goal of this research was to compare various instruments in their capability to detect softening changes in 'Hass' avocado using a penetrometer as the standard. This is a continuation of the work we initiated in 2006 (Arpaia et al., 2006). During this season we conducted 3 separate tests (May, June and August) that focused on slightly different objectives which are outlined below. Size 48 'Hass' fruit were used for all studies that were harvested from two commercial groves in Ventura County.

We examined different instruments for their effectiveness to gauge the stage of ripeness. The control treatment was a penetrometer (Imada) in all cases. We compared the penetrometer to the Sinclair

IQ™, the Aweta AFS™, a durometer (which measures compression force) and a hand-held impact firmness detection unit (HHIF) designed at UC Davis. The durometer was included only in the June and August tests. Data has been summarized for the first two studies. Data analysis and summation is still underway for the August 2007 study. A final report on this portion of the project will be submitted following final analysis of the data.

A. May 2007 Study.

The primary purpose of this test was to look at the HHIF in comparison to the Aweta AFS™. We also examined the influence of orientation (the direction we held to HHIF) on reproducibility on 'Hass' fruit of varying stages of ripeness. In this study we found that the HHIF firmness measurements are better correlated with the Aweta impact firmness than the Aweta acoustic firmness (The Aweta AFS™ unit measure firmness in two ways). We also observed that there does not appear to be an optimum orientation of the HHIF instrument. None of the orientations, 90° (pointed horizontally, 0° (pointed down) or 45° were significantly different from each other (Table 3). This is good news since it will enable the user to utilize the instrument under varying conditions.

Table 3. The influence of HHIF orientation on firmness reading of firm 'Hass' avocado.

Instrument Orientation	Hand-held impact firmness
Horizontal (90°)	82.5 a
Vertical (0°)	83.1 a
Angled (45°)	82.6 a

B. June 2007 Study.

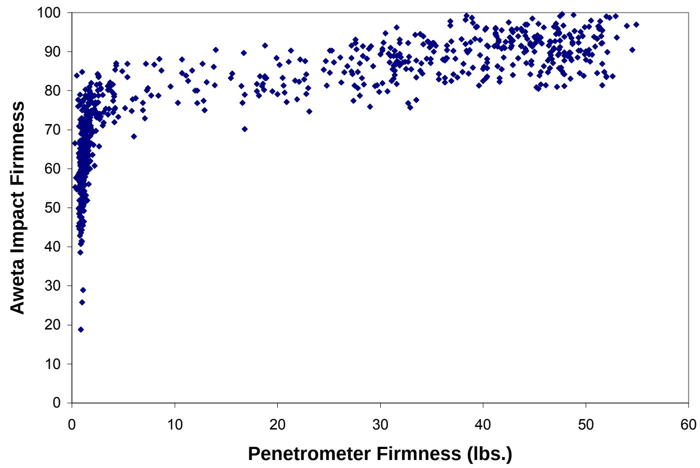
We followed the May study with a more detailed study in which we examined repeatability at a single point at varying stages of fruit firmness using the Aweta AFS™ system. We also conducted daily ripening curves using the varying instruments and finally we evaluated the potential for flesh damage following fruit ripening. We observed that there is varying levels of fruit damage that results with the use of these instruments. In general, the damage is slight and only occurs after the fruit is nearly "eating ripe" (Table 4). Note that the durometer caused the most damage to the fruit.

Table 4. Summary of flesh damage caused by non-destructive firmness measurements.

	Fruit damaged by Non-destructive Firmness Instrument (%)			
Penetrometer Firmness Level (lbf)	Aweta AFS™	Durometer	Hand-held Impact Firmness	Sinclair iQ™
1	3%	84%	55%	53%
2 - 3	5%	55%	20%	5%
4 or above	0%	0%	0%	0%

The penetrometer plots versus the various non-destructive firmness instruments show that there is a significant change in the tissue strength properties of avocado between 3 and 4 pounds penetrometer firmness (See Figure 4 for an example). All of the non-destructive measurement techniques show the same two basic relationships between penetrometer (destructive or tissue failure properties) and the non-destructive (or elastic) properties of the fruit. These two relationships are probably related to the change in tissue properties at 3 to 4 lbs. penetrometer firmness. This relationship needs to be further investigated.

We made several plots comparing the various non-destructive measurements. Perhaps, the most interesting is the one comparing the Aweta AFS™ acoustic and impact firmness values. Figure 5 A-B indicates that acoustic readings are more sensitive to changes in very hard fruit while the impact readings are more sensitive to changes in softer fruit.



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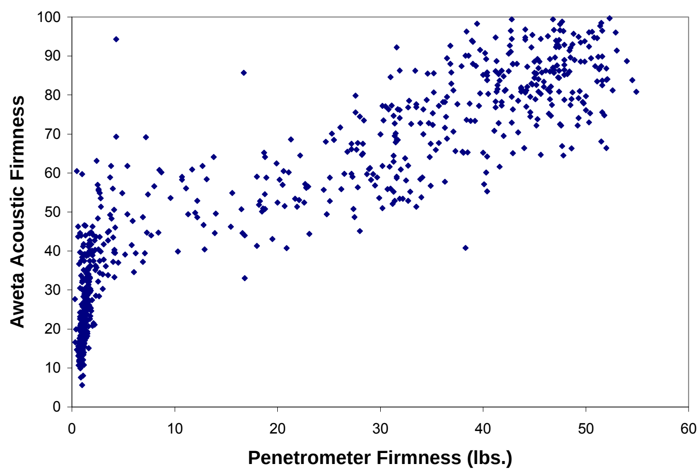

B.

Figure 5. A. The relationship between the Aweta AFS™ impact measurement and penetrometer firmness for 'Hass' avocado. B. The relationship between the Aweta AFS™ acoustic firmness and penetrometer firmness for 'Hass' avocado.

<u>AvoCare Quality Assessment Manual and Identification Handbook for California</u>

This work was carried jointly by the HortResearch and UC Riverside team The overall aim of this objective is to develop two booklets to accurately describe the large number of disorders that have been reported in avocados. Both the International Avocado Quality (IAQ) Manual and the smaller IAQ Pocketbook (intended for retail trade), employ high quality photographs and include clear descriptions of the disorders (Figure 6). Possible causes and damage scenarios are included in the Manual. It has generally been agreed that these assessment booklets should provide a step along a path to an international standard. This will provide an accurate, unambiguous means of communication between industry, extension and scientific personnel.

This year a final revision of the IAQ Manual has been initiated to improve some photos and include some new and important sections such as the new methods to assess fruit firmness, which are receiving increasing attention. Previous work has led to significant modifications to the Manual including review by Postharvest scientists and industry representatives.

The final revision of the IAQ Pocketbook has been completed and it has recently been translated into Spanish.

Both the IAQ Manual and Pocketbook will be promoted at the World Avocado Congress being held in Chile in November 2007. Negotiations are underway with the Postharvest Centre at University of California, Davis for the sale and distribution of the IAQ Manual and Pocketbook. This will then constitute a "complete package" of a detailed Avocado Assessment Manual, and a smaller Pocketbook. We envisage that the Pocketbook is more likely to be used at retail level.

The IAQ Manual

The IAQ Pocketbook

Figure 6. Cover and example pages from the International Avocado Quality (IAQ) Manual and IAQ Pocketbook.