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Avocado Postharvest Quality

Continuing Project: Year 7

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Benefit to the Industry

This project will help to maintain and enhance the California avocado industry by continuing our research efforts to examine the impact of temperature and ethylene on the ripening quality of 'Hass' avocado and the susceptibility of avocados to mechanical injury following harvest. The final objective is to continue our adaptation of 2 postharvest manuals developed in New Zealand for the California industry for use in standardization of terminology and measurement of fruit quality at the packinghouse, wholesale and retail levels.

Each of these project objectives will assist the California avocado industry in shipping fruit of high quality to the consumer. This in turn will assist the grower to maximize their profit potential and further build a market identity for California avocados as fruit of the highest quality. This is critical as the California industry faces increased competition in the domestic market and elsewhere. The research expertise of the project team includes individuals trained in postharvest physiology (Arpaia, Woolf, and White), sensory evaluation (Collin), postharvest pathology (Sievert) and postharvest engineering and transit research (Thompson and Slaughter) as well as commercial handling (Tokar).

Objectives

A) Continue a collaborative study with HortResearch to examine avocado oil in Hass and new selections from the breeding program.
B) Continue adapting AvoCare Quality Assessment Manual and Identification Handbook for California conditions in collaboration with A. White, A. Woolf, the CAC Merchandising Staff and interested packers.

C) Continue work examining the interaction of ethylene (timing after harvest and duration) and temperature on the postharvest quality of 'Hass' avocado.
D) Evaluation of susceptibility of 'Hass' avocado to mechanical injury during ripening and handling.

Summary

Continue a collaborative study with HortResearch to examine avocado oil in Hass and new selections from the breeding program.

Report on samples collected in 2003 – 2004

Overview. The present study on dry matter and oil composition is part of an ongoing postharvest project on the quality of existing avocado cultivars (e.g. 'Hass' and 'Lamb Hass') and new selections arising from the University of California breeding program.

During the 2004 season, samples from 'Gem', Harvest', 'Hass' and 'Lamb Hass', were collected from two varietal trials in California. The two sites were located in Ventura County, one near Pt. Mugu (a coastal environment) and the other just east of Santa Paula (an inland site). The first part of this study is focused on the cultivars 'Harvest', 'Lamb Hass', and 'Gem' in comparison to the main commercial cultivar 'Hass'. At the University of California Kearney Agricultural Center, fruit tissue samples were taken to determine dry matter content (maturity) during the season. A second sample of tissue was prepared for shipment to HortResearch in New Zealand for further composition analysis of the oil. Oil from avocados is known to have health attributes comparable to those in olive oil. The compositional information on the oil will provide further knowledge on these new cultivars that could be coupled with the postharvest and sensory qualities of the fruit to indicate best industry uses.

The main findings of this research objective are:

- Dry matter and oil accumulation were favoured in the Santa Paula block for the 'Harvest' cultivar while these attributes were favoured in the Pt. Mugu block for 'Hass'.

- Oil extracted from 'Gem and 'Hass' fruit from the Pt. Mugu block exhibited similar fatty acid make up in May; approximately 74% monounsaturated, 11% polyunsaturated and 13% saturated fatty acids. 'Lamb Hass' had the highest level of polyunsaturated fatty acids. While a high level of polyunsaturated fatty acids is desirable, it also makes the oil more unstable and prone to rancidity. In the Santa Paula block, each cultivar had comparable fatty acid composition as in the Pt. Mugu block in August where 'Harvest' had the highest level of saturated fatty acids.

- Growing conditions in the Santa Paula block resulted in the highest α- tocopherol content in 'Hass' (14 mg/ 100g). Overall the oil from 'Harvest' exhibited the highest level of α-tocopherol in the Pt. Mugu block (10 mg/100g) while 'Gem' exhibited the lowest levels of α-tocopherol of all the cultivars in both breeding blocks (4.5 mg/100g).

- Concentrations of β- sitosterol in the oil from 'Harvest' increased with fruit maturity in the Pt. Mugu location exhibiting the highest level at 6 mg/g. In the Santa Paula block, all four cultivars showed the same amount of β- sitosterol in the oil at approximately 5 mg/g.

- In both locations, the oil from ‘Lamb Hass’ contained the highest level of lutein (between 15- 17 µg/g), whereas the oil from ‘Gem’ contained the lowest levels (between 3- 5 µg/g). ‘Harvest’ showed an important increase in lutein content with increased maturity.
- In May in the Pt. Mugu block, no large differences in the amount of total chlorophyll in oil were found between cultivars. However, concentrations of total chlorophyll in the later harvest decreased in the cultivars except for ‘Harvest’. In the Santa Paula block, total chlorophyll concentrations were highest in ‘Lamb Hass’ oil while the lowest level was found in the oil from ‘Gem’.
- ‘Minor carotenoids’ content between harvests almost double in ‘Gem’ oil in the Pt. Mugu block. In the Santa Paula block, the highest value of ‘minor carotenoids’ was measured in the oil from ‘Lamb Hass’ and this value was higher than the one found in the Pt. Mugu block.

In summary, dry matter, oil content and composition differed among cultivars, at different harvests and between orchard locations.

Detailed results from 2003-2004. Dry matter increased in all cultivars from the Pt. Mugu block between the first harvest in May and the later harvest in August (Figure 1a). At both sampling times, ‘Gem’ and ‘Hass’ had higher levels of dry matter than the other two cultivars. This is not surprising as ‘Gem’ and ‘Hass’ are earlier maturing cultivars, and harvests usually commence around March while ‘Harvest’ and ‘Lamb Hass’ commence later in July. Dry matter in ‘Lamb Hass’ increased from 24% in May to approximately 30% in early August. Cultivars in the Santa Paula block showed a similar pattern to those in the Pt. Mugu block with dry matter values in August being highest for ‘Gem’ and ‘Hass’ at approximately 33% and 31% respectively, while ‘Harvest’ and ‘Lamb Hass’ had 29% and 26% respectively (Figure 2a).

Oil content has been reported to be highly correlated with dry matter content. In the Pt. Mugu block, changes in oil content between May and August reflected the changes in dry matter content for each cultivar. The highest oil content was found in ‘Gem’ (23%) and the lowest in ‘Harvest’ (15%) (Figure 1b). In the Santa Paula block, the highest oil content was found again in the cultivar 'Gem’ (22%) and the lowest in ‘Lamb Hass’ (15%) while ‘Hass’ and ‘Harvest’ showed similar oil content at approximately 19% (Figure 2b).

Of importance from the human health point of view is the fatty acid make up of the oil. Avocado oil contains high amounts of oleic acid (18:1), medium amounts of palmitic acid (16:0), palmitoleic acid (16:1) and linoleic acid (18:2) and smaller amounts of linolenic acid (l8:3) and stearic acid (18:0). According to their chemical properties, these fatty acids can be grouped into saturated fatty acids (16:0 and 18:0), monounsaturated fatty acids (16:1 and 18:1) and polyunsaturated fatty acids (18:2 and 18:3). Experts recommend including in the diet oils that contain more of the monounsaturated and polyunsaturated and less of the saturated fatty acids to maintain a healthy heart. Oil extracted from ‘Gem and ‘Hass’ fruit from the Pt. Mugu block exhibited similar fatty acid make up in May; approximately 74% monounsaturates, 11% polyunsaturates and 13% saturates (Figure 1c). ‘Harvest’ and ‘Lamb Hass’ differed in their monounsaturates, polyunsaturates and saturates fatty acid content where the former had higher monounsaturates and saturates but lower polyunsaturates. A high level of polyunsaturated fatty acids, as seen in ‘Lamb Hass’, is desirable however, it also makes the oil unstable and prone to rancidity. In August, the fatty acid composition changed slightly for ‘Gem’ and ‘Lamb Hass’ while in ‘Hass’ the level of monounsaturated fatty acids decreased from 73 to 69% while the polyunsaturated fatty acids increased from 12 to 16% (Figure 1d). The monounsaturated fatty acids in the oil of ‘Harvest’ decreased from 73 to 64%, with a concurrent increase in the polyunsaturated and saturated fatty acids (from 10 to 13% and from 15 to 20% respectively). In the Santa Paula block, each cultivar had a similar composition as the cultivars grown in the Pt. Mugu block. ‘Gem’ showed the highest level of monounsaturated fatty acids while ‘Lamb Hass’ exhibited the highest level of polyunsaturated fatty acids and ‘Harvest’ the highest level of saturated fatty acids (Fig 2c).

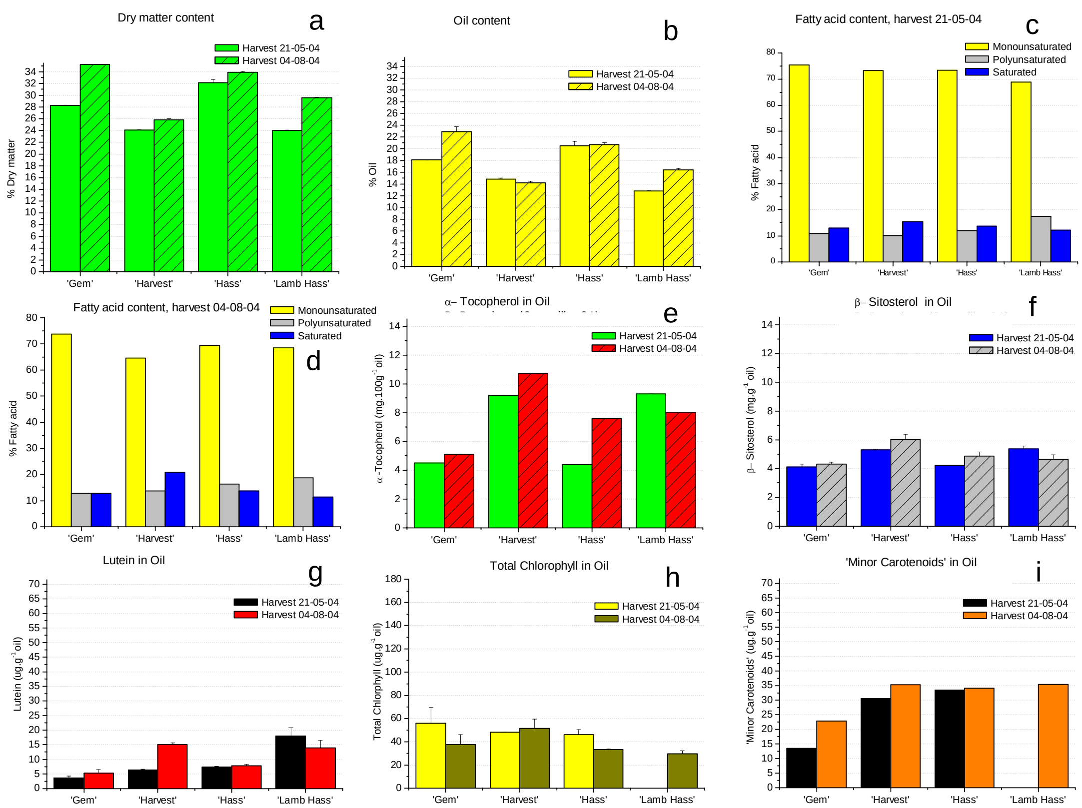


Figure 1. Dry matter and oil content and composition of ‘Gem’, ‘Hass’, ‘Harvest’ and ‘Lamb Hass’ avocados from two harvests (in May and in August) during the 2004 production season from the Pt. Mugu research site.

α- tocopherol is one of the most potent antioxidants that occur in nature, neutralizing the free radicals produced during the normal metabolism of lipid compounds. In May in the Pt. Mugu block, ‘Harvest’ and ‘Lamb Hass’ showed similar levels of α- tocopherol (between 9 and 10 mg/100 g) whereas the levels of this compound in oil from ‘Gem’ and ‘Hass’ were lower at approximately 4.5 mg/100 g. α- tocopherol in oil from ‘Gem’, ‘Harvest’ and ‘Hass’ cultivars increased with increased fruit maturity. However, ‘Gem’ exhibited the lowest levels of α- tocopherol of all the cultivars (Figure 1e). In the Santa Paula block, α- tocopherol concentrations in the oil were higher than in oil from fruit harvested from the Pt. Mugu block at the same time; α- tocopherol content in the oil from ‘Hass’ was the highest (approximately 14 mg/ 100 g) followed by ‘Lamb Hass’ (12 mg/ 100 g) and ‘Harvest’ (9.5 mg/ 100 g) while levels in ‘Gem’ cultivar were 4.5 mg/100 g (Figure 2d).

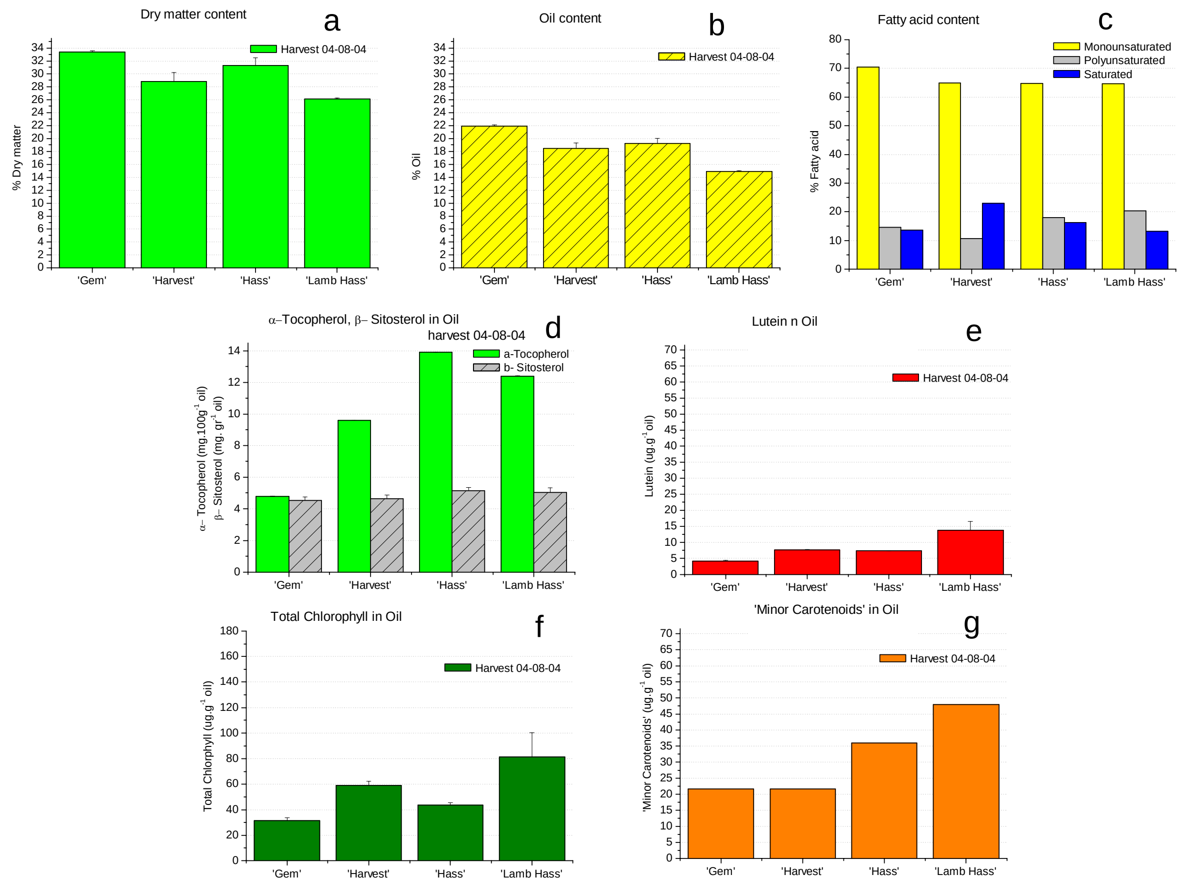


Figure 2. Dry matter and oil content and composition of 'Gem, 'Harvest', 'Hass', and 'Lamb Hass' avocados from one harvest (August) during the 2004 production season from the Santa Paula research site.

β- sitosterol is the most abundant plant sterol in avocado oil and is desirable for its ability to interfere with cholesterol absorption in the intestine, lowering total plasma cholesterol. In the Pt. Mugu block, the highest level of β- sitosterol was found in the oil from 'Harvest' and 'Lamb Hass' (approximately 5 mg/g) during May (Figure 1f). β- sitosterol increased in some cultivars with increased fruit maturity. Thus in August, 'Hass' and 'Lamb Hass' contained the same level of β-sitosterol (5 mg/g), 'Gem' (4 mg/g) while this compound level in the oil from 'Harvest' was the highest (6 mg/g). In the Santa Paula block, all four cultivars showed the comparable amounts of β-sitosterol in the oil at approximately 5 mg/g (Figure 2d).

The distinctive emerald green color of avocado oil gives us an indication that there are a wide range of oil soluble pigments (carotenoids) in avocado oil such as carotenes, xanthophylls and significant amounts of chlorophyll. These pigments are thought to protect the fruit and the human body by absorbing the UV light and quenching the free radicals. Especially relevant from a health perspective is the presence of the pigment lutein in avocado oil. Lutein has been implicated in reducing the risk of age related macular eye disorders and the risk of cataracts. In May, the oil from 'Lamb Hass' contained the highest level (17 μg/g) of lutein, whereas the oil from 'Gem' contained the lowest level (3 μg/g) (Figure 1g). In August, in the Pt. Mugu block, lutein concentrations in the oil from ‘Lamb Hass’ and ‘Harvest’ were similar at approximately 15 μg/g while in the Santa Paula block they were 15 and 7.5 μg/g respectively. Lutein amounts in the oil from ‘Gem’ and ‘Hass’ in August was similar in both blocks (5 and 7.5 μg/g respectively) (Figure 1g and 2e). In May, the amount of total chlorophyll in the oil for all cultivars was similar, ranging from 46 to 56 μg/g (Figure 1h). In the Pt. Mugu block in August, total chlorophyll content remained in this range for ‘Harvest’ while it dropped for ‘Hass’ and ‘Gem’ to 33 and 35 μg/g respectively. In the Santa Paula block, oil from ‘Lamb Hass’ showed the highest level of chlorophyll (80 μg/g) and the lowest level was found in the oil from ‘Gem’ (30 μg/g) (Figure 2f). Concentrations of other carotenoids commonly found in avocado oil such as neoxanthin, violaxanthin, antherxanthin, zeaxanthin are very small. In order to evaluate the changes of these concentrations in the extracted oil these carotenoids have been added and grouped under a ‘minor carotenoids’ category. In the Pt. Mugu block, ‘minor carotenoids’ content between harvests did not change significantly in the oil from ‘Hass’ and ‘Harvest’ ranging between 30 to 35 μg/g while amounts almost double in ‘Gem’ oil (from 12 to 22 μg/g) (Figure 1i). In the Santa Paula block, the highest value of ‘minor carotenoids’ was measured in the oil from ‘Lamb Hass’ and this value was higher than the one found in the Pt. Mugu block (47 vs. 35 μg/g) (Figure 2g and 1i).

Conclusions. The information gathered in this preliminary study is based only on results for fruit from two orchards locations during one season. In general, the oils from the four cultivars evaluated in this study had good levels of healthy components. Dry matter, oil content and composition differed among cultivars, at different harvests and between orchard locations. For a given cultivar, the harvest date, and therefore maturity had the greatest impact on dry matter and oil content but also impacted on some of the key compounds particularly α- tocopherol. Orchard location also had a large impact on the oil composition. For instance α- tocopherol content in ‘Hass’ oil doubled in the Santa Paula block than in the Pt. Mugu block for a similar dry matter percentage. Other factors such as tree age and health and, soil nutrition may also have a role in influencing the composition of the oil from avocados. These factors need to be studied further.

Progress during 2005-2006

Following our planned research outline, we sampled 3 ‘Hass’ groves in 3 areas of California (San Diego County – Bonsall, Rainbow, De Luz; Ventura County – Moorpark, Saticoy, Fillmore; and San Luis Obispo County – 2 sites in Arroyo Grande and Cambria). Each site was sampled 3 times during the relative maturity season of the site. We provided the HortResearch team with the 2004-05 samples as well as part of this year’s samples in July 2006. The remaining fruit samples from this season will be sent to New Zealand by the end of November.

Adapt AvoCare Quality Assessment Manual and Identification Handbook for California conditions in collaboration with A. White, A. Woolf, the CAC Merchandising Staff and interested packers.

The overall aim of this project is to develop manuals that accurately describe disorders of avocados for use in California. These manuals will provide a means to accurately communicate any problems that are observed with fruit quality, rather than using terms such as “cut black” which might describe many disorders. ‘The International Avocado Quality Manual’ has now been printed and is available for purchase. The IAQ Manual employs high quality photographs and includes clear descriptions of disorders with possible causes. A simpler and smaller version of this manual for use by the wholesale and retail segments of the industry has now been developed; ‘The International

Avocado Quality Pocketbook'. The Pocketbook is primarily for the identification of disorders rather than determining the severity of disorders and does not include possible causes of disorders.

A meeting to determine the content and format of the IAQ Pocketbook was held in September 2005 in Auckland, New Zealand, with the following participants: Anne White and Allan Woolf (HortResearch), Mary Lu Arpaia (University of California), Guy Witney (CAC), Reuben Hofshi (Hofshi Foundation) Peter Hofman (QDPI Australia) and John Bower (South Africa). A draft version of the Pocketbook was sent to CAC in December 2005 for limited comment and "road testing". Revisions to the Pocketbook are currently being undertaken and a completed version of the Pocketbook will be available for purchase in November 2006.

Continue work examining the interaction of ethylene (timing after harvest and duration) and temperature on the postharvest quality of 'Hass' avocado.

Overview. We continued the work initiated in 2004-2005 which is focused on two aspects of ethylene treatment of 'Hass' avocado in the postharvest environment. In the previous year, using fruit from a single location, we examined a matrix of postharvest ethylene treatments either prior to or after low-temperature storage. In this funding cycle, we selected specific treatments from the previous year for additional study. In 2005-2006 we obtained fruit from 3 growers in Ventura County: Moorpark, Saticoy and Fillmore. We divided our tests into two sections: one examining the impact of preharvest ethylene treatment on subsequent storage potential and the other examining the response of the fruit to ethylene following storage. Table 1 presents the dry matter and harvest dates of the fruit used in these tests. Fruit harvested on January 23, April 24 and July 17 were used in the pre-storage ethylene tests and fruit harvested on March 20, June 5 and August 24 were used in the post-storage ethylene test. The fruit for all tests were harvested in the morning and then transported to the F. G. Mitchell Postharvest laboratory at the UC Kearney Ag Center in Parlier. The fruit were held overnight at 54 F, then sorted and assigned to the various treatments the following day.

Table 1. The average dry matter content (%) of avocado fruit harvested from the 3 orchard sites from January through August 2006. Fifteen fruit (size 48) were used per grower lot at each sampling date.

	Harvest Date					
	January 23	March 20	April 24	June 5	July 17	August 24
Fillmore	22.28	23.07	24.64	26.48	28.46	27.37
Moorpark	22.59	23.67	26.17	27.23	33.07	-[z]
Saticoy	22.38	21.60	26.09	24.75	32.48	27.37

[z] Orchard picked prior to harvest date.

Pre-storage ethylene treatments. The idea behind this part of the project was to examine the impact of ripening fruit to different stages of ripeness, followed by cooling and storage. This is a common practice in the California industry since many packinghouses currently pre-ripen fruit prior to shipment. We examined the following variables: stage of ripeness, storage duration and storage temperature. We used three stages of fruit ripeness: harvest firmness (approximately 45 lbf), 15-20 lbf (approximately the time of "button popping"; actual average – 17.9 lbf) and near to eating ripeness (1-5 lbf; actual average – 4.31 lbf). In the latter two firmness categories, the amount of time it took for the fruit to reach this stage varied with harvest, with the longer duration of treatment occurring in the earlier harvests. We held fruit in storage following treatment for 0, 4 or 14 days at either 54 F or 41 F (95% RH). Following storage the fruit were held at 68 F (90-95 % RH) until the average flesh firmness was < 1.5 lbf. The fruit were then evaluated for the presence/absence and severity of postharvest decay and various physiological disorders.

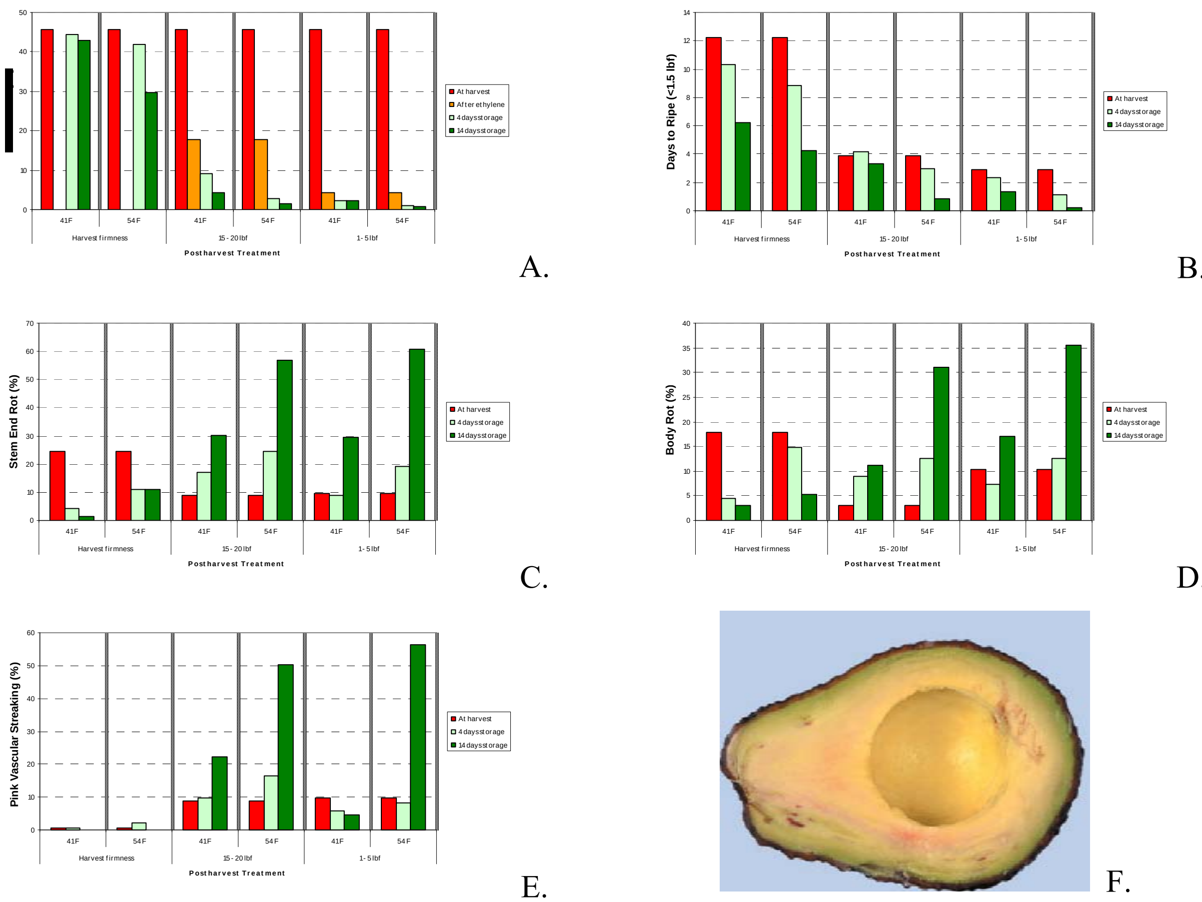


Figure 3. Means presented are the averages across the 3 grower lots and 3 harvests. A) The average flesh firmness (lbf, measured with an 8 mm tip) following ethylene treatment to varying flesh firmness and storage at either 41 or 54 F. B) The average days to flesh firmness of < 1.5 lbf following ethylene pretreatment and storage. C) The overall incidence of stem end rot following ripening at 68 F after various ethylene treatments and storage. D) The overall incidence of body rots following ripening at 68 F after various ethylene treatment and storage. E) The overall incidence of pink vascular staining following ripening at 68 F after various ethylene treatments and storage. F) An example of pink vascular and flesh staining (Photo from the IAQ Manual).

Figure 3A illustrates the fact that once fruit softening is triggered with ethylene softening will continue in subsequent storage. The data also demonstrates the impact of storage temperature on flesh softening. This effect is most dramatic in the "harvest firmness" fruit following 14 days storage at 54 F. The impact of storage duration on the rate of ripening is shown in Figure 3B. In this figure, again the impact of ethylene treatment prior to storage on average ripening time is evident, with temperature playing a large role in ripening time. The impact of storage duration is most evident on the rate of ripening in the "harvest firmness" fruit. Note that the average days to ripe drops from 12.25 days at harvest to 6.21 days at 41 F or 4.27 days at 54 F after 14 days storage.

The overall incidence of stem end rot and body rot is presented in Figures 3 C, D. The incidence of stem end rot dramatically increased to over 50% following 14 days storage at both 41 F and 54 F for both the "15 – 20 lbf" and "1 – 5 lbf" treatments. The trend of decreasing decay incidence with storage duration in the "harvest firmness" fruit is typical of what we have previously observed when unripe fruit are stored and corroborates data previously presented by J. Smilanick and D. Margosan (CAC Annual Reports). The incidence of moderate/severe stem end rot was substantially lower but mirrored the overall incidence trends (data not presented). The same general trends were observed in relation to the overall incidence of body rots with the highest incidence occurring following storage of the ethylene treated fruit at 54 F. Most of the body rots that we observed were graded as "slight", since the incidence of moderate/severe body rots were less than 3%. Figure 3E reports the incidence of pink vascular streaking in the ripe fruit. Our observations during this research study are similar to our experience in 2004-2005. This relative rare disorder (Figure 3F) was most prevalent in ethylene treated fruit that were held at 54 F for 14 days.

Post-storage ethylene treatments. The second component of our research was to examine the interrelationship between storage duration and receptivity to ethylene following storage. It is also an increasingly common practice to ship unripe fruit to a central distribution point and then ethylene treat fruit prior to marketing. Depending on market conditions as well as the source of the fruit, the fruit can vary in age from just a few days to several weeks old. In this year's project we stored fruit for 0, 7, 14 or 28 days at 41 F. Following storage the fruit were warmed to 68 F and treated with approximately 50 ppm ethylene for 0, 24 or 48 hours. Following treatment the fruit were held at 68 F until ripe (< 1.5 lbf) and then evaluated as described above. We present below the data from the first two harvests (data collection on the third harvest has just been completed).

Figure 4A presents the average flesh firmness of the fruit following storage and upon removal from the ethylene treatment for the first 2 harvests. Note that in the "0 days" 24-hour treatment virtually no softening occurs. However, approximately one-third of the firmness is lost following a 48 hours ethylene treatment. As storage progresses, the amount of fruit softening following the ethylene treatment increases, indicating that the fruit becomes "more receptive" to the ethylene treatment during storage. A similar phenomenon has been reported for 'Bartlett' pears. The other noteworthy item is the softening of the fruit during storage (compare the first bar in each group across the storage days). Even though we had non-detectable amounts of ethylene in our storage rooms, flesh softening occurred in the fruit, particularly between 14 and 28 days storage. The other notable impact of storage time on fruit ripening is evident when comparing the results of the fruit not receiving any ethylene (the middle bar in each grouping) to the ethylene treated fruit. Note that by 28 days, within 48 hours of removal from storage both sets of fruit are nearly equal in flesh firmness.

Figure 4B presents the average days to eating ripeness (<1.5 lbf). When comparing the first bar of each group (the fruit which did not receive and ethylene treatment) note the dramatic reduction in the days to ripe which occurs solely due to storage duration. Fruit ripening times for these fruit declined from 13.98 days (0 days storage) to 10.12 days (7 days storage) to 7.98 days (14 days storage) to 6.13 days (28 days storage). The other item to notice in this figure is that the benefit of the ethylene treatment decreases with increasing storage time. Not presented here, but discussed in previous reports, is the standard deviation of these averages. Although the average time to ripe in the non-treated fruit declines to near that of the ethylene treated fruit, the standard deviation of these means is still greater than the ethylene treated fruit. This means that ripening uniformity is still greater in the ethylene treated fruit, thus the continued potential benefit of ethylene treatment.

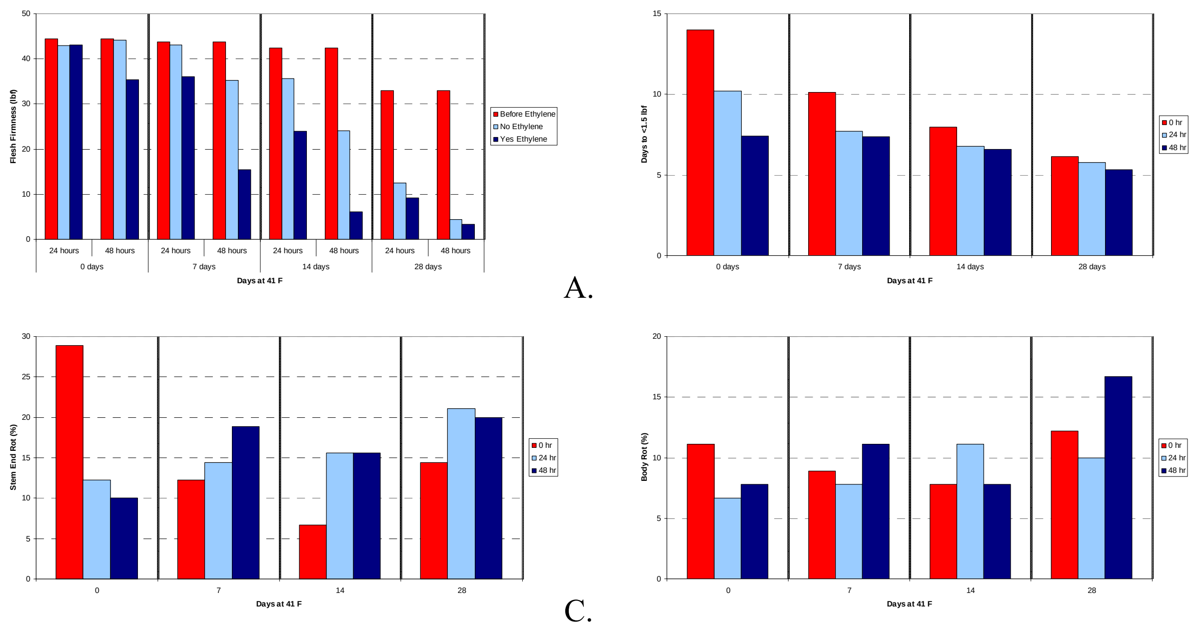


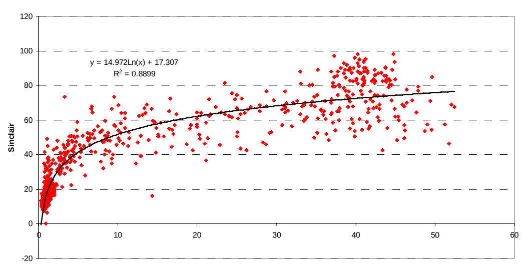
Figure 4. Means presented are the averages across the 3 grower lots and 2 harvests. A) The average flesh firmness (lbf, measured with an 8 mm tip) following 41 F storage and either a 0, 24 or 48 hour 50-ppm ethylene treatment. B) The average days to flesh firmness of < 1.5 lbf following ripening at 68 F after storage and ethylene treatment. C) The overall incidence of stem end rot following ripening at 68 F after storage and ethylene treatment. D) The overall incidence of body rots following ripening at 68 F after storage and ethylene treatment.

Figures 4C and 4D present the data pertaining to the overall incidence of stem end rot and body rots, respectively. If you compare the first bar in each grouping across the storage days you will note that the overall incidence of stem end rots and body rots decline with storage up to 14 days. Note that there is an increase in incidence between 14 days and 28 days. As mentioned above, this is the same general trend that we have observed many times in our research studies on storage of ‘Hass’ avocado. With the exception of the 0 days storage, the incidence of both categories of fruit decay tends to increase following ethylene treatment. Although we do not understand why this occurs, this is in line with our observations from previous work. We believe that the higher incidence of decay following ripening of the non-ethylene-treated fruit at 0 days is due to the protracted time for the fruit to ripen. The severity of decay during this project was very slight, so even though the incidence of decay was relatively high in some treatments, the lesions were relatively small (as discussed in the IAQ Manual). We did not observe any marked amounts of pink vascular streaking in these studies. This suggests that the occurrence of this disorder is directly linked to the prior treatment of ethylene in combination with storage, particularly at intermediate temperatures.

Evaluation of susceptibility of 'Hass' avocado to mechanical injury during ripening and handling.

Work on this segment of the project was conducted in collaboration with J. Thompson and D. Slaughter (Agricultural Engineering, UC Davis) as well as V. Tokar (consultant). We focused our attention upon two activities.

Non-destructive firmness detectors have been introduced recently to the avocado industry as a tool in the management of fruit ripening. There are currently two units which are commercially available that use similar technology. Previous to this year, we had a desktop unit of Sinclair SIQ unit and we have collected considerable data using this unit as compared to the penetrometer (with an 8-mm tip). In April of 2006, we acquired a desk top unit of the Aweta AFS system. After running a series of tests to determine the proper settings for the unit, we have incorporated this unit as well into our daily data collection. At the same time we also purchased a digital penetrometer that has a higher range in order for us to more accurately measure "hard" avocado fruit. Figures 5A-C illustrates the relationship of the Sinclair SIQ unit to the penetrometer, the Aweta AFS unit to the penetrometer and the relationship between the Sinclair SIQ unit and the Aweta AFS unit, respectively. The data in these graphs are from our ethylene studies described above (the last 2 harvests). We do not know if the relationship between the instruments will change if we have less mature fruit (which have different internal texture when ripe), fruit of varying peel thickness, peel texture or seed size. This will be a focus of our research for the upcoming year.



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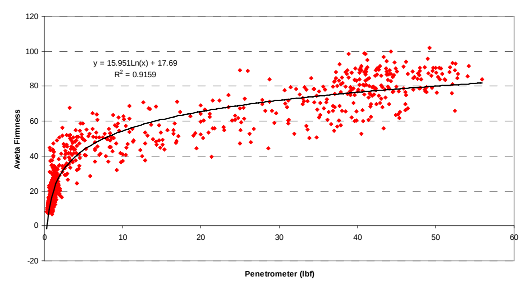

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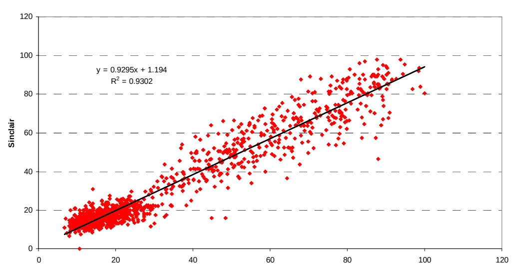

C.

Figure 5. A) The relationship between the Sinclair SIQ unit and penetrometer. B) The relationship between the Aweta AFS unit and penetrometer. C) The relationship between the Sinclair SIQ unit and the Aweta AFS unit.

We also continued our work on alternative packaging for partially ripe 'Hass' avocados. We know from previous work (Arpaia et al., 1987) that avocados increase in susceptibility to mechanical injury as they ripen. We also know that fruit bruising is a major cause of fruit defects at the consumer level (Arpaia, various reports to the California Avocado Commission). In 2004-2005 we conducted a simulated transit test of partially ripened avocados. The question we posed in that study, therefore, was whether an alternative packaging method designed for fresh, ripe Bartlett pears would also protect differentially ripened 'Hass' avocados from mechanical damage during simulated transit conditions. The answer to this question was, yes, it is possible to protect partially ripened fruit from transit damage. We reported the preliminary results of this study in last year's annual report and have subsequently presented these results at the 2006 ASABE meeting in Portland Oregon.

In September of this year, we conducted an additional study in which we shipped completely ripe 'Hass' avocado (average firmness at the initiation of the study was 1.79 lbf) in varying packages from a central distribution center in Los Angeles to a restaurant in Chicago. The fruit were obtained from a commercial packinghouse in Fallbrook following a standard commercial ripening treatment. The fruit were randomly assigned to one of 4 packaging types: standard tray pack, volume fill, RPC with tray and the UC hammock pack. The fruit then were driven to a central distribution center in Los Angeles where they were loaded on a truck with other avocados and shipped to Chicago. The fruit were held in the restaurant warehouse for 2 days then delivered to a pre-determined restaurant location in the greater Chicago area. The fruit were retrieved at the restaurant upon delivery and evaluated within 6 hours for the presence and severity of transit related damage. We used similar evaluation criteria as described in our previous reports.

Table 2. Fruit damage scores (surface dents, internal bruises and flesh adhesion to peel), weight loss (%) and firmness loss (%) from beginning to end of study. Data analyzed as a 1W Complete Randomized Design where individual fruit are the replicates.

	Fruit Damage				
Carton Type	Surface Dents (0-5)	Internal Bruising (0-5)	Flesh Adhesion to Peel (0-5)	Weight Loss (%)	Firmness Loss (%)
Volume Fill	0.47 a	0.26 ab	1.03 a	1.33 a	38.25 a
Tray Pack	0.29 a	0.35 a	0.98 a	1.04 b	38.22 a
RPC	0.03 b	0.08 bc	0.38 b	0.83 b	34.97 a
UC Hammock	0.00 b	0.02 c	0.46 b	0.94 b	28.00 b
Significance	0.01	0.01	0.01	0.01	0.01

Significant differences between means calculated using Tukey-Kramer Test.

Table 2 presents the overall results of our evaluations. First, note that the severity of damage to the fruit is slight overall. Not withstanding this, we were able to detect significant differences in damage to the fruit related to packaging type. The two packaging types which have trays which hold the fruit tightly in the tray (RPC and UC Hammock) resulted in significantly less damage. At the beginning of this test, we were able to measure the Aweta AFS firmness and weight of each fruit. These measurements were repeated at the time of final evaluation. An interesting result of this study, which warrants further investigation, is the differences in overall fruit weight loss and firmness loss between the Fallbrook packinghouse and Chicago. We also placed a temperature datalogger in each carton type and noted, at least in the pallet configuration used, that there were differences in the temperature profiles during the transit period (Figure 6). Note that the tray pack and volume fill package types had higher temperature during transit. Whether these differences or the slight differences in fruit damage are responsible for the differences in the weight and firmness loss is unknown but strongly suggests that further work is needed.

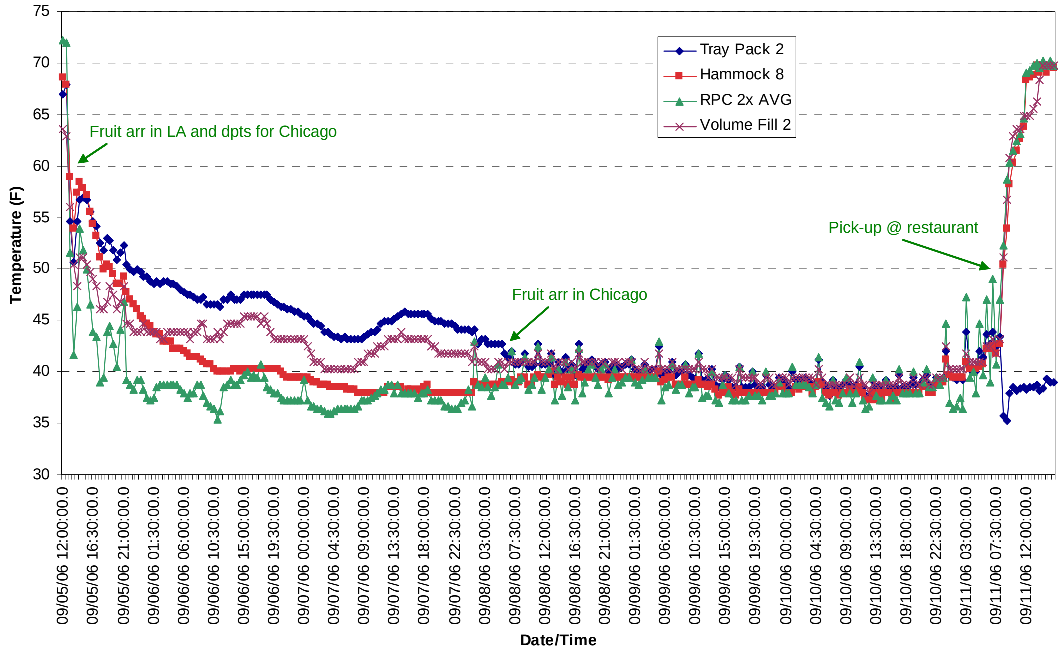

Figure 6. Temperature profile during transit to Chicago and holding until final evaluation.