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Growing and Presenting to the Consumer the Best Quality Hass Avocados

A number of factors explain why consumers choose California avocados over imported ones. These factors, real or perceived, can be summarized into what many people describe as quality. For California avocados to have a premium position and/or price their quality has to be better than their competitors.

The market research conducted for CAC has shown that California avocados generally sell for a premium compared to imports because they are believed to have better quality. With a quality advantage already present for California avocados, it would be easy for California to become complacent and take quality for granted. This would be a mistake since maintaining, or even improving, quality is an easy way for California to distinguish itself from the ever-increasing flow of avocado imports.

Avocado fruit quality is difficult to define precisely and consequently to measure since much of what defines quality can be subjective. The word quality has many definitions with the most appropriate for California avocados appearing to be: an inherent feature; how good or bad something is; a high level of value or excellence. (The online Merriam-Webster's Dictionary). Each of these definitions can be associated with different characteristics of the fruit. Hence, there are no easy measurements for what makes California avocado fruit quality better than avocados grown in other parts of the world.

Cultural management	Stage	Description
Grower has the most influence	Cultivar/Location	Defines the inherent nature of the fruit: thickness of skin, skin color change during ripening, seed size, etc.
	Fruit set	Defines the nature of the fruit in terms of potential fruit size, growth rate, location on the tree, crop load and tree vigor
	Fruit growth	Defines the composition of the fruit with respect to calcium and nitrogen content, accumulation of dry matter and exposure to latent infections of postharvest rots and time to reach maturity
	Maturity	Establishes the postharvest quality and characteristics of the fruit in ripening, flavor and storability
	Harvest	Sets up the physical nature of the fruit, in particular size and susceptibility to physical damage, defines dry matter and mineral content and the amount of temperature control needed
Supply chain	Steps	
Handler has the most influence	Packing	Fruit are cleaned, sorted by grade into number ones and twos, culls removed, and placed by size into packaging then if necessary stored at cold temperatures for transport
	Transport	Fruit may be taken to a ripening center close to the retail market under temperature controlled conditions
	Ripening	Fruit are ripened by an ethylene treatment according to established protocols
	Transport	Fruit are taken to a retail outlet under temperature controlled conditions
	Retail	Fruit are displayed for sale, typically not under temperature controlled conditions
	Consumption	The fruit is eaten and enjoyed by the consumer

Avocado quality has a different meaning to different people depending on which part of the supply chain they occupy. In general, for growers to get the best price the fruit need to be of a certain size, shape, color, and have skin free from defects. Additionally, the fruit should have enough oil to be palatable when ripe. This is usually expressed as exceeding a minimum percentage dry matter. For the handler and retailer the fruit should also ripen evenly, be free from internal defects (discoloration) and rot, and not develop chilling injury when stored at low temperatures. A consumer may look for fruit that is clean with no discoloration or marks when cut, have flesh that is soft and creamy, and have good flavor attributes (nutty or buttery with no aftertaste). The factors that affect quality as seen by the consumer are related to how the fruit are grown, harvested, and handled by the packer, handler and retailer.

Information on what makes an avocado fruit unique and its postharvest characteristics are covered in Dr. Arpaia's compan-

ion article. Outlined in the accompanying table are descripts of how the growing and handling environments influence the positive quality advantages California avocados enjoy, and the quality challenges in assuring California avocados retain their distinct identity from imports.

From the tree to the consumer, the quality of avocado fruit is affected by cultural management and the steps of the supply chain as described in the table on the previous page.

The highest quality avocado fruit at harvest are achieved when cultural management practices promote the best aspects of quality and minimize the negative aspects of quality. This then feeds into the postharvest chain since the postharvest characteristics of the fruit entering the supply chain are strongly influenced by the grower's cultural practices and the environmental conditions at harvest. This results in fruit that may be high risk for developing postharvest disorders or low risk fruit with high storage and shelf life potential. Looking at the bigger picture, California avocados are affected by the many factors that influence fruit quality.

Freshness Advantage

Avocados have a naturally short postharvest life, driven mainly by the fruit's sensitivity to chilling injury, which limits the time they can be kept in cold storage. At about 30 to 32 days from harvest, the postharvest disorders increase exponentially with additional time. Avocados shipped long distances must be handled very carefully handled to avoid rapid deterioration.

On the other hand, most California avocados are sold close to where the fruit are grown and harvested, along the U.S. West Coast, giving California avocados a unique advantage over their imported competitors. The usual time from harvest to the consumer is relatively short at 9 to 12 days. Even when fruit movement through the marketing channels is slow, avocados are still less than three weeks old when sold to consumers. This short time gives California avocados an unbeatable freshness compared to many of the imported avocados.

Most imported avocados, Mexican being an obvious exception, take three to four weeks from harvest to landing in the United States before distribution. Maintaining fruit age to around two weeks ensures that many of the negative postharvest issues that may affect imported fruit do not have time to develop.

The bottom line: keep the time in the supply chain short for the best quality.

Dry Climate

Avocados do not ripen when attached to the tree. Once removed, the fruit are set on an irreversible course of ripening during which they lose their natural resistance to fungal rots. It is the development of fungal rots in ripe avocados that limits their shelf life and makes them inedible. The rot is caused by fungi that live mostly in the trees and on dead plant material in the grove. Fungi are micro-organisms that like to grow in warm, humid and wet conditions and are very effectively suppressed in a dry climate. California avocado growers are fortunate to have a dry climate well-suited to producing high quality avocados with few rots when ripe. When avocados are grown in a high rainfall, humid climate the greatest challenge in handling the fruit becomes postharvest rot management during ripening. The rots come from the continual exposure of the fruit to fungal spores in the air as it grows. As these spores settle on the

fruit, they create latent infections on the skin that remain dormant until the fruit ripen. In a low humidity, dry climate like that of California there are fewer fungal spores to create infections. At times, the number of fungal spores is so low that the fruit are effectively rot free.

A dry climate also helps to minimize a second class of avocado postharvest rots, stem end rots. These rots are strongly correlated with harvesting practices and climate. When the fruit are harvested, the stalk is cut or plucked out creating a fresh wound. This wound is a great place for opportunistic fungal spores to land, germinate and start to grow. In high humidity growing environments there are a lot of fungal spores in the air that infect the fruit stems at the time of harvest. When stems are infected, the fungi have no dormant period and the rot grows into the top of the fruit. Once the rot appears the fruit quality becomes poor. In a dry climate, there is a very small amount of stem end rot and labor saving harvest methods like pluck picking become possible.

The downside to having a strong freshness advantage and a dry climate is that avocados are inherently more forgiving of rough handling than the fruit grown in a wet climate. There is a tendency to use handling practices that damage the skin creating small wounds that are susceptible to fungal infection. It is not uncommon to see fruit thrown to the ground, dropped into bins and scarred from the nodules on the skin being rubbed off. All this damage to the skin is an opening for opportunistic fungal rots to infect the fruit. As long as the fruit age can be kept low, the quality of the fruit is generally acceptable, but should the market slow and the fruit need to last three weeks or longer, the quality can become very poor due to rots. Maintaining a soft handling system even though the fruit are robust should be a best practice to ensure California avocados are always the best quality.

The bottom line: avocado fruit grown in a dry climate have fewer postharvest rots and better quality, but the freshness and dry climate can lead to complacency and the fruit may be roughly handled increasing the potential for ripe rots to develop and reduce quality.

Maturity

Avocado fruit are unusual in that they can be stored on the tree long after they have reached maturity and are capable of ripening. The maturity of avocado fruit is one of the most important characteristics defining quality. The maturity of the fruit has a large influence on how long the fruit take to ripen; immature fruit can take three weeks to ripen while over mature fruit can take only three to four days. It is important to identify the minimum maturity where the fruit will ripen to an acceptable eating quality with minimum disorders. The minimum maturity is defined by the average dry matter content, which is used as a proxy for oil content, with high oil content associated with good eating quality. Knowing when the fruit can be harvested and sold with good quality is important to take advantage of potential high prices early in the harvest season. Immature fruit have very poor quality as they do not ripen properly, and have shriveling, rubbery texture, bland watery taste, stringy flesh, incomplete softening and high incidence of rot.

While the fruit are on the tree they continue to grow in size and accumulate oil. This means the fruit are constantly changing over time, which is most noticeable in the ripening of the fruit and often referred to as an increase in maturity. Avocados past minimum maturity but not over mature have very good quality when ripe. These fruit express few ripe rots, ripen evenly to a smooth creamy texture with good flavor, and are more tolerant of handling conditions in the supply chain. Both commercially and for the consumer these are the best quality avocados.

Fruit held on the tree for too long become over mature and have poor quality as they ripen very quickly and store poorly, not allowing enough time to move through the supply chain. Over mature fruit can also develop off-flavors from too much oil and express high levels of ripe rots resulting in a much reduced time they can be presented for sale.

The bottom line: maturity is a key factor in determining the quality of ripe fruit. Early season and late season fruit have poorer quality than mid-season fruit.

Managing Maturity

Better management of avocado maturity, particularly in the early and late season, has the potential to improve quality at times in the harvest season when poor quality fruit can be found in the supply chain. There is the potential to define an ideal harvest window based on ideal maturity, such that high risk fruit, with respect to having poor quality after harvest, can be more easily identified. The high risk fruit could then be handled with care to minimize the expression of disorders. A significant problem with low maturity avocados is their large variability in ripening times. Slow ripening fruit are more susceptible to developing postharvest disorders, especially rots, while fast ripening fruit have fewer ripe rots. Ripening low maturity avocados with ethylene is an effective technology to even out ripening times leading to improved quality.

As previously mentioned, avocado fruit are stored on the tree and continually change over the season, but this change in fruit maturity can be influenced by cultural practices and the weather during the growing season. This results in maturity being variable from year to year, between growing regions, grove to grove

within the same growing region, and even from tree to tree. This high degree of variability makes a maturity standard very important, since for best quality the fruit should not be harvested by the calendar alone. Maturity needs to be measured accurately so the ripening and storage characteristics of the fruit are predictable in the supply chain.

There are two challenges with maturity, 1) setting a minimum maturity that consistently results in good quality ripe fruit and doesn't just define a minimum acceptable maturity, and, 2) determining a marker of over maturity that defines the harvest window for ideal fruit quality. To improve the quality of California avocados the maturity standards need to be set around a quality expectation designed to establish a premium position in the market rather than what is minimally acceptable.

The standard measure of maturity for California avocados is the average dry matter of a small number of fruit. Dry matter is an imperfect indicator of maturity and is an indirect way to measure oil content. Within the California avocado industry there is a difference of opinion as to what the minimum acceptable maturity standard is and how this relates to building a quality reputation in the market. The current California standard for minimum maturity of Hass avocados at 20.8 percent dry matter is too low to be a guarantee of good ripe fruit quality. The scientific research shows it should be raised to 23 percent. If not raised by regulation, then a new voluntary maturity standard could be set based on a broader definition of quality and not the minimum acceptable eating quality. Dry matter of individual fruit is also very variable for unknown reasons. The method used to measure dry matter in California uses a very small sample of fruit that is unlikely to be truly representative of all the fruit in a grove. The flesh of each fruit is pooled together into an aggregate sample for measurement. This hides fruit that are very immature which would indicate that the fruit will have uneven ripening and poor quality. The method used to measure dry matter should be used for individual fruit with no aggregation of fruit tissue. In this way the values can be analyzed for not just an average, but also the variability in maturity. Given uneven ripening is an important problem in the supply chain, having a standard that can determine when the variability is low would be helpful for improving quality. Customers could then be presented with fruit with a high degree of consistency and reliability.

The bottom line: maturity is very important in setting the inherent quality of the fruit and the current California standard for Hass avocados is too low. Raising the minimum maturity standard to 23 or 24 percent would result in improved ripe fruit quality. Finding a marker of over maturity would allow a harvest window for the best quality to be defined. Fruit harvested outside of the ideal maturity could then be handled in the supply chain as high risk. This would increase the reliability of a good ripening and eating experience of California avocado fruit for consumers.

Harvest Strategy

The monetary value of avocado fruit changes during the harvest sea-

Harvesting in the Heat

Historically, avocados harvested during a heat wave, as can sometimes occur during August and September, have poor quality. To maintain fruit quality, it is crucial that avocados are not harvested when air temperatures are above 90°F. This may mean starting crews early (sunrise) and stopping harvest by late-morning during heat waves, and monitoring of grove temperatures so that harvesting can be restricted to the cooler parts of a grove. Harvest bins should always be placed in complete shade, preferably under a structure, to prevent overheating the fruit. Fruit in bins that are not shaded can reach temperatures 20°F above ambient air temperature. Bins should not be left in the field more than 8 hours, whether shaded or not, and should be transported out of the grove as soon after harvest as possible so that the cooling process can begin.

Fruit exposed to high temperatures in the field are more susceptible to cold injury during storage and develop more decay and rot issues. The problems don't appear until fruit ripen, resulting in a poor eating experience for the consumer.

When forecasts call for temperatures approaching 90°F:

- Irrigate your trees the day before the heat starts to help the trees cope with the heat
- Monitor the air temperature in your grove
- Start and stop harvest crews early
- Handle fruit gently as they are more sensitive to damage due to the temperature stress
- Always shade or cover bins during harvest and transport
- Do not leave filled bins in the field more than 8 hours
- Monitor workers' health and be sure that adequate water, shade and breaks are available

son as the supply of California avocados goes from a few thousand pounds per week to millions of pounds per week. The price also varies with the time of the year and by how many pounds of imported fruit enter the market for sale. The variable price has encouraged many California growers to harvest according to the price of the fruit rather than at the best maturity for quality. If prices are high at the start of the season and the fruit have low maturity and less than ideal eating quality, growers are encouraged to harvest. Similarly, in the late season prices can be high and growers are encouraged to hold on to over mature fruit. Avocados continue to increase in size the longer they are held on the tree. This is often seen as beneficial as larger fruit usually demand higher prices. Chasing the price of fruit can be incompatible with the aim of harvesting at a maturity when the quality of the fruit will be best as it will restrict the options growers have in the timing of their harvest. Labor availability and potential oversupply of the market are further negative factors that reduce the value of a harvest window for best quality fruit.

Understanding the maturity harvest window for best quality allows for the fruit to be classified into high and low risk for developing disorders and poor quality. If such fruit could be identified, it may be possible through the appropriate postharvest handling to mitigate the negative effects of low maturity or high maturity fruit to maintain a consistent quality to the consumer.

The bottom line: chasing the price per pound or waiting for the fruit to reach a certain size can be incompatible with achieving high quality fruit. Systems are needed that identify the ideal harvest window based on quality, and that also identify if the fruit are high or low risk for developing ripe fruit disorders, so that the best returns can be achieved within a harvest season.

Fruit Mineral Composition

Dry matter represents the reciprocal of the amount of water present in the fruit and is a proxy for oil content. The amount of oil in the fruit is associated with maturity and fruit ripening to good texture and flavor for best eating quality. The storage life of the fruit and the sensitivity to cold temperatures also depends on the mineral content of the fruit. In particular, calcium has a strong influence on the ability of the fruit to resist ripe rots. There are also interactions with other fruit nutrients; high levels of fruit nitrogen have been associated with chilling injury and the development of rot. The fertilizer program used by a grower, the rootstock and soil type all combine to set the composition of the fruit to affect the quality of ripe fruit.

The bottom line: producing avocados with high levels of calcium and low nitrogen improves ripe fruit quality. More information is needed to establish the ideal levels in California avocado groves of calcium and nitrogen nutrition that give high yields of high quality fruit.

Handling

When harvested, avocados are hard and green giving the illusion they are resistant to bruising and can be dropped without damage. The unripe fruit are in fact sensitive to physical damage, and under wet, humid conditions this physical damage leads to higher numbers of ripe rots. High quality avocados require careful handling to minimize the expression of ripe rots. It is important to avoid dropping the fruit onto hard surfaces, bouncing bins of fruit on rough roads or allowing the fruit to rub together. When harvested, the fruit should be placed into bags and then placed into clean bins and not thrown onto the ground in a pile before being put into the bin. After harvesting, the fruit in bins should be covered to reduce water loss, start to cool the fruit, avoid contamination with leaves or other debris, and be sent to the packer as soon as possible to be packed and entered into the supply chain with the minimum fruit age.

When temperatures are high, over 90°F, the fruit should not be harvested. Fruit damaged on the tree that have dropped should not be placed into the supply chain. Fruit damaged by wind, heat stress or a freeze will ripen poorly and typically develop high levels of ripe rots due to internal or external damage. For the best quality fruit, the principle should be to only harvest fruit that are healthy and undamaged on the tree. A high quality standard and ethic is not just about the ideal maturity or mineral content of the fruit, but soft handling of blemish free fruit harvested directly from the tree is also needed.

The bottom line: physical damage lowers the quality of the fruit. For the best quality and safest fruit, the fruit should never touch the ground and only healthy fruit should be harvested and placed into the supply chain. Fruit that has fallen onto the ground through the effects of wind, heat stress or from a freeze should not be sent to market.

What Are Our Competitors Doing?

Avocados imported into the United States very often have quality problems. Fruit harvested early in the importing countries' harvest season and shipped long distances typically are less than perfect. Compared to California avocados, these fruit are inferior and achieve lower prices. However, with each season the exporters of avocados become more experienced and are learning from their mistakes. New technologies and understanding how quality is affected by cultural practices and the environment are constantly being

researched. The knowledge of how to grow, harvest, handle, ripen and sell avocados transported long distances while maintaining good quality is available. What is lacking is the implementation of systems to best use the knowledge. This is a situation that will not last forever. The closer imported avocado quality comes to the quality of California avocados, the more difficult it will be to argue for a premium position or price. This is the goal of the imports, for there to be no distinction in quality between California avocados and imported avocados. Therefore, it is vitally important that the California avocado industry continues to improve quality and the systems that ensure good quality is consistently delivered to the consumer for a reliable eating experience.

The bottom line: Is this statement, often heard at meetings and around the industry, always true? "California produces the best quality avocados. No other avocados are better." Is it true for early and late season California fruit? Is it also true after a freeze or Santa Ana winds, a heat wave and when the market is slow to move fruit through the supply chain?

Avocados grown in California, when compared to imported fruit, are better quality, and if handled correctly should always be better because of our freshness advantage and dry climate. But is the quality good enough to realize the values of the fruit needed to keep the California avocado grower in business? At present, the values look to be marginally on the positive side and they could easily slip to the negative. There is plenty that can be done to improve quality and establish a premium position that would assure California avocado consumers they will always have a reliable positive eating experience. To do this, California avocado growers and others in the industry will need a stronger quality ethic and to pay attention to nutrition, maturity, and harvest and postharvest handling to consistently produce high quality fruit. The rest of the supply chain - packers, handlers and retailers - also have to do their part to maintain quality through to the consumer.

A Quality-Based System

A lot of knowledge already exists about what influences and determines the eating quality of California avocados. This information is summarized above and can be used to consider what the components of a quality-based system would include. The starting point would be to have a clear, well-defined goal for customers and consumers of California avocados. This goal would be to guarantee a reliable, positive eating experience. To achieve this goal, it will be necessary to have fruit that when ripe are: free from rots and disorders when cut, the best soft and creamy eating texture, absent of off-flavor, free from chemical residues, and safe from contamination.

These fruit would constitute a new grade standard: California gold. This standard would be promoted as the ultimate avocado eating experience only available in the USA from California-grown avocados. The fruit have the greatest freshness, consistent ripeness and best food safety of avocados sold in the USA, backed by a sound system of monitoring and evaluation. Fruit that make the grade are not always available, so they command a premium position in the avocado market. The new grade is voluntary and as such carries the mystique and aura of extraordinary avocado fruit.

For the grower and the industry, the gold standard avocados will require a particular handling system backed by monitoring throughout the harvest season to define a harvest window based on the period when maturity is at its best. A minimum maturity, based on a dry matter value and other fruit characteristics that are based on a reliable positive eating experience rather than a minimum acceptable eating experience, will define the start of the gold standard harvest. A maximum maturity, based on measurements that delimit a decline in the reliability of the eating experience, will define the end of the gold standard harvest. As the harvest window will vary from season to season, district to district and by micro-climate, a system of monitoring before and throughout the harvest season checks and acts to assure customers the best harvest window is being used for each grove. The fruit are all from groves that are GAP compliant, ensuring the fruit are the safest available to eat. The fruit age is monitored and kept to a minimum so the fruit are always freshest, minimizing the opportunity for disorders to develop. The fruit are handled using soft handling systems in the supply chain, starting with harvest. Harvest conditions are taken into account, as are cultural management and fruit mineral contents in the decision for harvesting. Fruit that are damaged by windfall, freezes and heat stress are not part of the California gold standard as they represent a food safety hazard and have unacceptable levels of disorders.

The description above may not be entirely accurate as to what may be put in place with respect to quality, but it is an example of what a system could look like. If quality was to be based entirely on technical considerations, a system like that could best use the postharvest and quality knowledge available. Such systems don't come for free, or without effort, and must result in a premium for the fruit. This is the challenge: designing a quality system that is also a good return on investment.