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AVOCADO POSTHARVEST QUALITY – AN OVERVIEW

Mary Lu Arpaia

Department of Botany and Plant Sciences
University of California, Riverside, CA 92521
arpaia@uckac.edu

Summary

This paper discusses the role of the preharvest environment on postharvest quality of the avocado. The role of the environment, rootstock/scion, planting design, pruning practices, pest management, irrigation, plant growth regulators and plant nutrition is discussed.

Keywords**:** quality, chilling injury, postharvest losses

The quality of avocados at the market place is a result of a continuum from the grower to the consumer. Along the way, many factors can exert an influence over the ultimate ripe quality of the fruit. Avocado fruit quality relates to several factors and may mean different things at different points along this continuum. The consumer may perceive quality as it relates to appearance, flavor, and dollar value. The packinghouse handler, wholesale distributor, and retailer, in contrast, may perceive quality as ease of handling, uniformity of packaging, and freedom from physical and physiological defects as well as pathological breakdown. In turn, the grower may perceive quality as the overall freedom from defects, optimum size distribution and overall packout and return upon investment. Little attention, traditionally, has been placed on optimization of fruit quality from the field through handling to the consumer.

Several factors limit the postharvest shelf life of avocados and thus quality. The avocado is considered to be a climacteric fruit, that is, during the course of ripening, the fruit will experience an increase in respiration and ethylene production. During ripening, the fruit can produce large amounts of carbon dioxide (CO_2), on the magnitude of 80 to 300 mg CO_2/kg·hr at 20ºC. Associated with the increase in respiration, is an increase in heat production, one of the byproducts of respiration. The heat of respiration of an avocado is considered to be quite high, on the magnitude of 4.9 – 18.3 x 10^3 kcal/metric ton per day. Ethylene production in a ripening avocado is also quite high (>100 µl/kg·hr at 20ºC).

In general, the avocado is considered to be a chilling sensitive fruit, that is with prolonged low temperature storage (generally near 5ºC) the fruit will develop chilling injury symptoms. On the other hand, if avocados are held at warmer temperatures, premature softening may occur, thus limiting options for marketing. The avocado can develop 2 types of chilling injury, internal and external. Internal chilling injury manifests itself as a grayish-brown discoloration of the flesh, particularly at the base of the fruit around the seed. This can be associated with vascular browning which starts at the base of the fruit. There is considerable variability between varieties in terms to chilling injury susceptibility. Internal chilling injury can be detected after approximately 3 to 4 weeks storage and is most evident in softening or ripe fruit. External damage to the peel may also occur when fruit are held at very low temperatures (generally <5 ºC). Symptoms of external chilling injury occur as irregular patches of blackening on the skin (similar to apple scald) that can be observed during storage. Symptoms may develop within 1 to 2 weeks after harvest, depending on the temperature. In varieties that darken during ripening, external chilling injury can be partially masked as the fruit darkens, but if damage is severe it may render the peel brittle, thus affecting fruit peelability. The susceptibility of the avocado to both types of chilling injury is influenced by a number of postharvest handling factors including maturity at harvest, duration of storage and storage temperature. It is possible to reduce fruit sensitivity to chilling by using controlled or modified atmosphere during long-term storage, or intermittent warming or stepped-down cooling. For a more thorough discussion of avocado postharvest biology see Woolf *et al* (2004).

Table 1. Preharvest factors involved in postharvest fruit quality.

Climate/environment
Rootstock/scion
Planting design
Pruning practices
Pest management
Irrigation
Plant growth regulators
Plant nutrition

Other sources of fruit loss during the postharvest handling chain can be associated with mishandling of the fruit during ripening. Often times, fruit ripening is not done at the proper temperature or fruit are allowed to excessively soften. This may result in losses due to excessive decay and bruising occurring during handling of soft fruit. Work is underway in California and elsewhere to examine ways to optimize fruit ripening in the postharvest environment and thus minimize quality problems at the consumer level.

The remainder of this paper will examine the role of the preharvest environment and how it may affect the postharvest life of avocado. Essentially, preharvest factors can influence both the rate of fruit development and maturation. The preharvest environment can also have a physical impact on fruit quality: for example, wind or insect scarring may reduce the packout percentage. Finally and most important, but much more difficult to quantify, are those effects that influence susceptibility to physiological and pathological breakdown in the postharvest environment.

The avocado tree exists in a dynamic environment and therefore can respond to changes to that environment in an interactive fashion. The factors listed in Table 1 are neither all inclusive nor mutually exclusive. Several examples will illustrate the interaction between one or more preharvest factors on postharvest fruit quality.

ENVIRONMENT

Environmental factors include climate (temperature, wind and rainfall), air quality, and positional effects both within a planting and within the tree. Elements such as wind, heavy precipitation, and frost may result in direct loss of the fruit from the postharvest chain due to fruit scarring; increased incidence of plant pathogens associated with high rainfall, especially during flowering (i.e., anthracnose); and loss of fruit related to freeze damage. Temperature during fruit growth and maturation may also influence fruit quality by either hastening or delaying horticultural maturity.

Avocado fruit shape is influenced by growing environment. Fruit grown in cooler environments tend to be more rounded as compared to fruit grown in warmer conditions which tend to be more elongate. In California we have noted that the ‘Harvest’ variety (a recent release from the UC Breeding program) will be almost completely round when grown in the relatively cool coastal environment of southern California. Contrasted with this, is the much more elongated fruit shape one observes when the variety is grown in the hot San Joaquin Valley of California. Fruit shape is more tear-dropped in intermediate environments. The effect of climate on fruit shape is also evident when examining fruit shape in relation to bloom/fruit set in a given tree. Fruit resulting from “off-bloom” are typically more round then their counterparts set during the main flowering period.

In South Africa the incidence of grey pulp or mesocarp discoloration following storage changes with time between growing districts and time within a harvesting season (Rowell, 1988; Kruger, F.J. and Kritzinger, M., 1999; Dixon *et al*., 2003).

After mild freezes in California, avocado fruit, although exhibiting no external damage, may become more susceptible to decay, weight loss, and chilling injury following storage. Relative susceptibility can be correlated to pedicel appearance following exposure to temperatures below -1C in the field. This characteristic can be used as a marker of fruit quality at harvest following mild freezes (Arpaia, unpublished data). Conversely, Woolf *et al* (1999) demonstrated that exposed sun fruit which are exposed to higher temperatures have a higher tolerance to postharvest heat (50°C hot water treatments) and cold (0°C storage). Several researchers have illustrated the impact of inoculum load and rainfall on the subsequent severity of postharvest decay (Smilanick and Margosan, 2002; Everett *et al*., 2003, Pak *et al*., 2003).

ROOTSTOCK/SCION AND POLLINIZER EFFECTS

Kremer-Köhne and Köhne (1992) illustrated the influence of ‘Fuerte’ vs. ‘Hass’ avocado on susceptibility to chilling injury. They observed that ‘Hass’ had a higher percentage of fruit free from physiological disorders following storage than did ‘Fuerte’. The use of clonal or “copy” rootstocks for avocado is a relatively recent development (Brokaw, 1987) and subsequently the influence of rootstock on postharvest quality is poorly understood. In spite of this, Marques (2002) demonstrated that rootstock can also influence the incidence and severity of postharvest disease. He demonstrated that ‘Hass’ trees grown on Velvick clonal rootstock had a lower incidence of postharvest decay as compared to ‘Hass’ grown on the Duke 7 rootstock under Australian conditions. The work of Degani *et al* (1990) has shown that pollinizer may also influence both fruit size and seed size in ‘Fuerte’. More recently (Arpaia, unpublished data) observed that ‘Hass’ seed length to width ratio was also influence by the proximity to different pollinizer varieties.

PLANTING DESIGN AND PRUNING

A critical consideration for tropical and subtropical fruits is also the timing of pruning. If pruning or girdling occurs at a time that promotes vegetative growth at the expense of fruit growth, a Ca imbalance and reduction in overall fruit size may occur. Whiley *et al*. (1992) reported higher fruit Ca levels during the first 8 weeks of 'Hass' avocado fruit growth when the spring vegetative flush was controlled with the growth regulator β-[(4-chlorophenyl)methyl]-α-(1,1-dimethyl)-1H-l,2,4-triazole-l-ethanol (paclobutrazol). Cutting and Bower (1992) demonstrated, under the subtropical growing conditions of South Africa, that avocado fruit borne on trees where vegetative growth was controlled by pruning had higher Ca, Mg, K, and P levels at harvest. Hoffman (unpublished data, 2002) also found that any pruning treatment that stimulates vegetative growth near or during fruit set/growth will reduce quality, and that growth regulators that reduce growth can reduce defects. In Australia, current recommendations it is now believed that canopy management treatments need to avoid increasing vegetative growth during fruit growth otherwise fruit quality will be compromised.

PEST MANAGEMENT

Pest management practices may result in direct fruit loss from scarring and in indirect losses from changes in fruit composition. Thrips scarring, caused by second instar feeding of the avocado thrips on young, developing fruit, is a major concern for growers and is the number one pest controlled in avocados in California. The occurrence of thrips scarring on the fruit results in direct fruit loss as a result of downgrading at the packinghouse. The occurrence of greenhouse thrips in avocado groves also influence not only fruit grade but may also influence the ripening behavior of fruit by slowing or retarding fruit ripening.

IRRIGATION

Irrigation effects on postharvest fruit quality are difficult to quantify. However, Bower (1988) found that preharvest water stress influenced polyphenol oxidase (PPO) levels in ripe avocado fruit after 30 days in storage at 5.5°C. PPO has been associated with mesocarp discoloration in avocados. He also found that preharvest water stress influences the fruit's ability to withstand low O_2 and high CO_2. Fruit from stressed trees exhibited more physiological disorders following storage and ripening than fruit from nonstressed trees.

PLANT GROWTH REGULATORS

As noted above, the use of plant growth regulators that reduce vegetative vigor may have influence postharvest fruit quality, presumably by influencing the distribution of plant nutrients within the tree. Bower and Cutting (1988) reviewed the literature surrounding endogenous plant growth regulators and their effects on fruit quality. With the exception of ethylene and ABA (via its role in water stress) there is little current evidence that cultural processes greatly influence plant growth regulators and postharvest fruit quality.

PLANT NUTRITION

The influence of nutritional practices on avocado fruit quality is confusing but overall, research has indicated that the nutritional status of the fruit can impact the postharvest quality of the fruit. Previous work suggested that avocado fruit quality appears to be primarily affected by calcium (Kremer-Köhne *et al*. (1993) and secondarily by nitrogen (Arpaia *et al*., 1996), boron (Smith *et al*., 1997), magnesium, potassium (Koen *et al*., 1990; Witney *et al*., 1990), and zinc (Vorster and Bezuidenhout, 1988).

Extensive research on 'Fuerte' avocado has been conducted in South Africa. This research focuses on the relationship of postharvest avocado fruit quality and the role of plant nutrition. Witney *et al*. (1990) demonstrated the impact of fruit Ca levels on fruit ripening duration. They reported a significant interaction between these two variables, with high-Ca fruit taking longer to ripen. They also reported on fruit Ca levels during fruit growth from vigorous vs. nonvigorous trees for both 'Hass' and 'Fuerte'. In both instances, fruit borne on nonvigorous trees had higher Ca levels, especially during the early stages of fruit growth. This period also correlates with the time of maximal vegetative flushing. They suggest that it is the early levels of Ca in the fruit that influence subsequent postharvest fruit quality. The work of Whiley *et al*. (1992) confirmed this observation.

Postharvest problems of avocados in South Africa are a combination of several disorders. Swarts (1984) differentiates between pulp spot and mesocarp discoloration or grey pulp. Pulp spot is a blackening of the pulp region surrounding cut vascular bundles and is localized in nature and more prevalent in early season fruit. Mesocarp discoloration or grey pulp is an overall grey-brown flesh discoloration that normally increases with fruit maturity. Vorster and Bezuidenhout (1988) reported lower Zn and Ca levels in fruit exhibiting pulp spot. Smith and Köhne (1992) surveyed a large population of 'Fuerte' avocado trees in which low-yielding trees had poorer fruit quality following storage and lower Ca and Zn levels and higher B levels in flesh tissue. This picture is complicated by the multi-year study of du Plessis and Koen (1992). They concluded that the incidence of grey pulp (or mesocarp discoloration) is strongly correlated with the subsoil Ca and Mg: K ratio. They also reported a significant reduction in the incidence of pulp spot with high levels of subsoil K, which, however, was found to aggravate grey pulp.

An approach recently taken by Van Rooyen and Bower (2004, unpublished data) is to integrate through stepwise multiple regression the nutritional status of the fruit. Their work on 'Pinkerton' avocado demonstrates that excessive nitrogen plays the most significant role in mesocarp discoloration. They also found that decreasing levels of copper, manganese and boron can also contribute to mesocarp discoloration. Their findings show that the interactions of various plant nutrients can be more important than the individual status of a specific element. For example the nitrogen:calcium ratio was found to significantly influence the development of postharvest disorders whereas the level of calcium by itself did not.

POSTHARVEST FACTORS UNDER THE CONTROL OF THE GROWER

The grower can also play an important role in the postharvest quality of fruit in the manner in which the fruit is handled following harvest prior to delivery to the packinghouse. Eaks (1978) demonstrated that continual temperatures in excess of

25°C following harvest were detrimental to fruit quality from the perspective of fruit ripening. He found that ripening was inhibited when fruit were continuously held at 40°C and abnormal ripening (hard spots) were observed when fruit were held continuously at 30°C. Subsequently Arpaia (1994) observed that cooling delays of 12 or 24 hours when pulp temperature was maintained at 30°C or 40°C during the delay affected ripe fruit quality following storage at 5°C. Woolf *et al*. (1995) observed an increase in avocado tolerance to low temperature following hot air treatments of even 34°C. The rate of ripening was also slowed (decreased shelf life). Such effects have also been noted for fruit exposed to high temperatures (sun exposure) on the tree (Woolf *et al*., 1999, 2000). It is therefore critical for the grower to protect fruit following harvest from high temperatures. Fruit in the bin can warm rapidly following harvest (Arpaia, unpublished data) reaching temperatures in excess of 25°C within a matter of an hour or two.

CONCLUSIONS

There is ample evidence in current literature that preharvest factors may influence the postharvest fruit quality of avocado. Preharvest factors are perhaps especially critical to the success of handling avocados destined for the export market since typically long transit times to market are required. Understanding the effects of the preharvest environment on growth and maturation processes and susceptibility to physiological and pathological disorders will help to explain inconsistencies in postharvest fruit performance. There will also be an indirect benefit of this line of research. Typically, growers do not usually understand the postharvest biology of their particular commodity nor do they particularly care since they perceive that "postharvest" is anything past the farm gate. Efforts toward understanding the role of preharvest factors on postharvest quality brings growers into actively controlling the quality of their product and helps to make them willing participants in the quest for optimizing product quality.

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