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IS RIPENING AND POST HARVEST QUALITY OF HASS AVOCADOS AFFECTED BY FRUIT WATER STATUS?

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SUMMARY

Fruit placed into storage delayed longer than 48 hours after picking have a significant increase in ripe rots. This is thought to be due to the delayed fruit being at a more advanced physiological stage of ripening after storage. Our working hypothesis was that high rates of water loss before storage affected fruit quality. Imbibing fruit with water had the opposite effect of water loss slowing down ripening. As the amount of water imbibed could be considered as a measure of fruit water status experiments were conducted to investigate if the fruit water status or changes in fruit water status were affecting ripe fruit quality. Fruit water status was increased after rain or by irrigation but the effect on ripening times differed depending on how the fruit water status was changed or maintained. Irrigation would be expected to keep fruit water status at a higher level while rain causes large rapid changes in fruit water status. Minor changes in fruit water status over the course of a day had little effect on ripening times. The amount of sound fruit when ripe depended on ripening times. The water loss or infusion at the inhibition stage of ripening had the most effect of fruit quality.

Key words: weight loss, imbibing, rain, irrigation

INTRODUCTION

Over the past several seasons we have been investigating factors that influence the ripening and development of disorders after storage. One factor that has had a consistent negative effect on fruit quality has been a pick to pack time longer than 48 hours. An increase in ripe rots has been observed in the library trays (DIXON and PAK, 2002) and in controlled experiments (YEARSLEY et al, 2002; LALLU et al, 2003). We are particularly interested in what is happening in the first 48 hours after harvest that has such a negative effect on fruit quality.

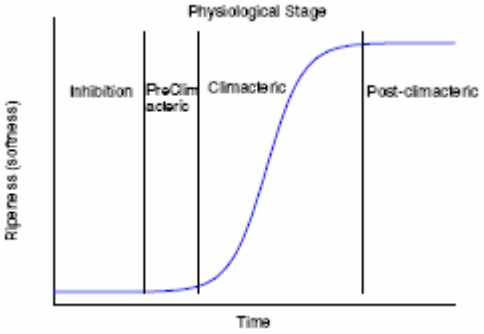

Figure 1. Typical ripening pattern of non-stored avocados.

RIPENING OF NON-STORED FRUIT

To understand what factors may be that affecting ripe rots just after harvest a consideration of the first principles with regard to avocado Figure 1. Typical ripening pattern of non-ripening physiology of our basic stored avocados understanding of the avocado ripening process is required. When avocados ripen they go through four main physiological and biochemical stages which soften the fruit and make it edible (Figure 1). The stages are: inhibition where the fruit are relatively insensitive to ethylene (a gas often referred to as the ripening hormone), pre-climacteric where the fruit become sensitive to ethylene and initiate the biochemical processes involved in ripening, climacteric where the fruit ripen rapidly by softening and changing colour, followed by the post climacteric stage where the fruit move from being eating ripe to overripe (Figure 1). For freshly harvested non-stored fruit this process takes from 17 to 10 days depending on the time of year (DIXON et al, 2003).

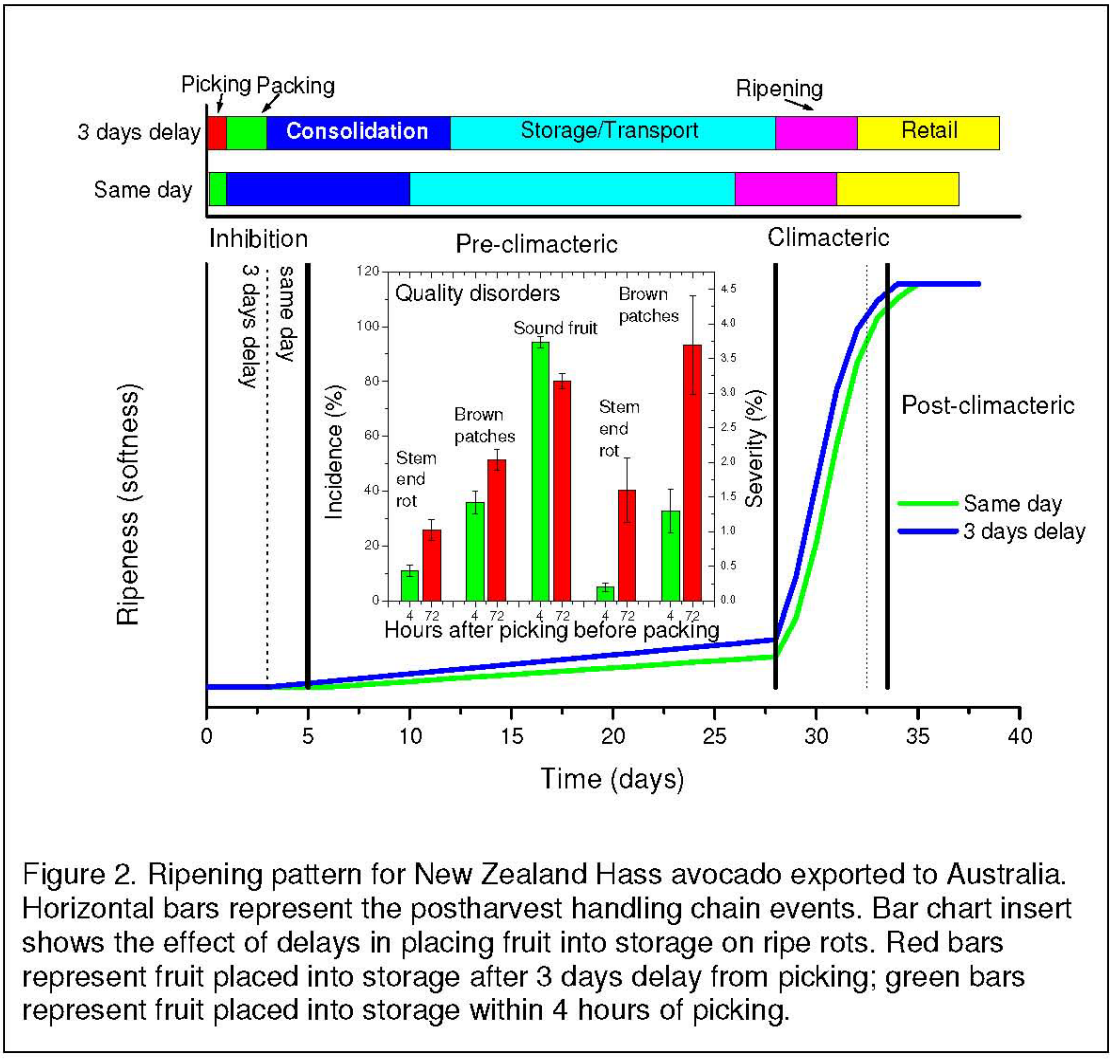

Figure 2. Ripening pattern for New Zealand Hass avocado exported to Australia. Horizontal bars represent the postharvest handling chain events. Bar chart insert shows the effect of delays in placing fruit into storage on ripe rots. Red bars represent fruit placed into storage after 3 days delay from picking; green bars represent fruit placed into storage within 4 hours of picking.

RIPENING OF EXPORTED FRUIT

Exported fruit experience the following handling: picked and packed then consolidated

after placement into coolstorage then transported to the market where they are ripened and sold (Figure 2). This series of events means that coolstorage takes place during the inhibition and pre-climacteric ripening stages. The effect of coolstorage is to greatly extend the time the fruit are in the inhibition and pre-climacteric stages thereby delaying ripening. It is expected that if there is a delay after harvest before the fruit are packed the inhibition stage will be shortened and fruit come out of coolstorage slightly softer and more advanced in ripeness than the fruit packed without delay. Ripening times were slightly faster after storage for the delayed fruit as they were softer than fruit packed on the same day of harvest.

This has important implications as to what the fruit are like when they are being handled in the market. The bars above the graph show the timelines of handling events for fruit exported to Australia. When there is no delay there is a longer period where the fruit are firmer during the retail period. The small difference in ripening results in a greater incidence and severity of stem end rot and brown patches and fewer marketable or sound fruit. We are interested to know why what seems like a trivial difference in the time taken to place fruit into storage after picking matters so much.

WATER LOSS AND RIPENING

Based on previous research (BOWER and CUTTING, 1988) we hypothesized that the rates of water loss after harvest may be a significant influence on ripening and ripe fruit quality. Therefore the amount of water loss after harvest may be inducing earlier ripening because high water loss rates result in faster ripening and more rots (BOWER and CUTTING, 1988; LALLU et al, 2002, 2003, 2004) while conversely low water loss rates result in slower ripening (DIXON et al, 2003, 2004).

RIPENING TIME AND ROTS

The time the fruit take to ripen has a strong influence on ripe fruit quality as the longer the fruit take to ripen the greater the numbers of fruit with ripe rots (Figure 3). The incidence of unsound fruit increases for each individual date of ripening. It is therefore reasonable to suggest that treatments that increase ripening time will result in more ripe rots. However, delays longer than 48 hours after picking before packing before placement of avocados into storage results in faster ripening and more ripe rots (YEARSLEY et al, 2002). This would suggest that water loss and ripening could be separate influences on the

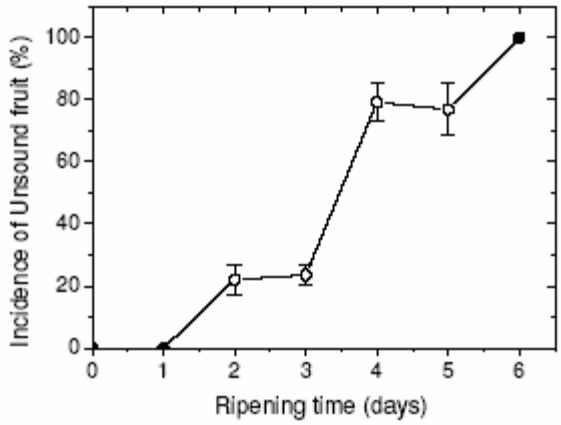

Figure 3. Relationship between time to ripen at 20°C and the number of unsound fruit on each day of ripening.

development of ripe rots. When analyzing experiments it is important to also review fruit ripening times.

EFFECT ON RIPENING AND QUALITY OF DELAYING PACKING

To investigate the relationship between quality, ripening and water loss the fruit ripening was manipulated by a series of experiments that: increased and decreased water loss after harvest and adding water to the fruit (by imbibing) at different physiological stages. By changing the ripening characteristics we sought to better define what was the effect of water loss on ripening and quality from that of faster or slower ripening.

Fruit were carefully harvested into polythene bags containing wet paper towels or into single layer trays. The fruit were then either removed from the bags then placed into coolstorage within 4 hours of harvest or were left 72 hours either in bags (high humidity) or in trays at 60% RH before placement into coolstorage. Weight loss was greatest after 72 hours and was almost 1% greater in fruit at low RH compared to the fruit in bags. Ripening times were faster for fruit left 72 hours before storage but there was no effect of high or low humidity. Even though ripening times were the same the fruit kept in trays had more sound fruit after coolstorage than the fruit kept in bags.

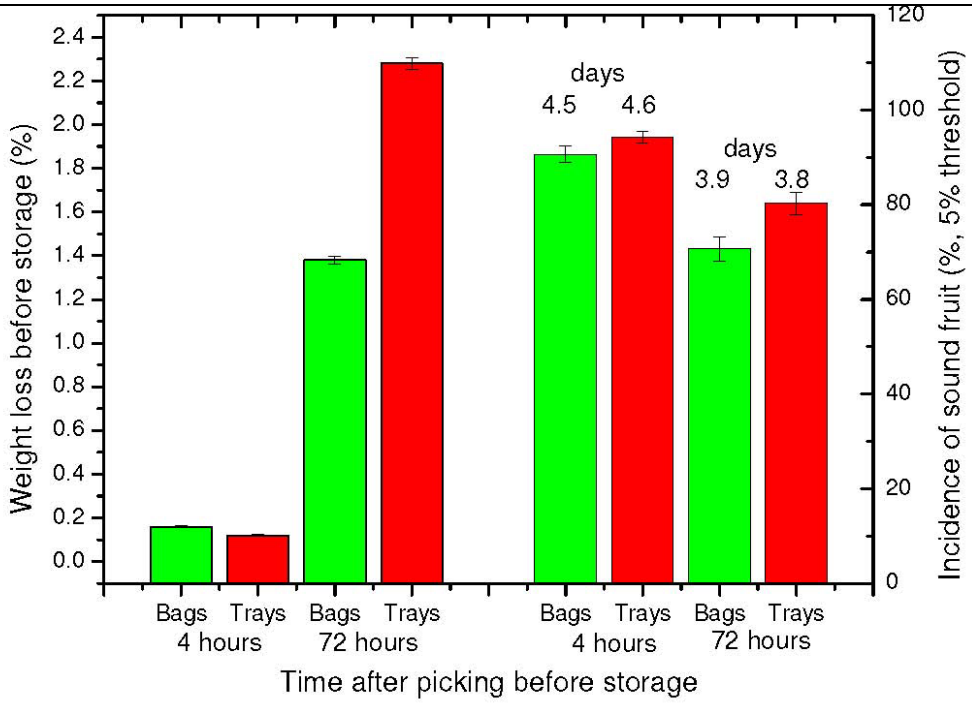

Figure 4. Effect of delays before packing on the amount of water loss, ripening and the numbers of sound fruit following coolstorage for 28 days at 4 °C, 85% RH. Before storage fruit were placed into either polyethylene bags (green bars) or trays (red bars). The bags were removed when the fruit were placed into storage. The numbers above the bars represent the average number of days taken to ripen.

These results led to a number of unanswered questions: is high humidity having a

separate influence on quality to weight loss and ripening times? Could this be a confounding factor affecting the results?

EFFECT OF RIPENING AND QUALITY OF ADDING WATER TO THE FRUIT

To establish if the loss of water from the fruit is a key factor affecting ripening times and ripe rots experiments were conducted where water was infused into the fruit. The hypothesis was that reversing the loss of water from fruit should then result in slower ripening times and increased ripe rots.

Fruit with long stalks were imbibed with water over 24 hours at 20°C in high humidity (Figure 5). This fully saturated the fruit with water. After imbibing the stalks were cut to normal length (5mm) and the fruit placed into coolstorage at 4°C or left to ripen at 20°C. At the same time a similar batch of non-imbibed fruit were left to lose weight at low RH before storage or ripening.

Imbibing and weight loss treatments were imposed on non-stored fruit at the inhibition, pre-climacteric and climacteric stage of ripening. Imbibing after the climacteric stage was not possible as the stalks fell off. Fruit in the inhibition stage imbibed and lost the most water while the fruit in the pre-climacteric and climacteric stages imbibed progressively less water presumably as the vascular tissue was broken down as part of the fruit softening process (Figure 6).

Imbibing fruit at the inhibition and climacteric stages increased ripening times and reduced the number of sound fruit when ripe (Table 1). Imbibing at the pre-climacteric stage gave faster ripening and more sound fruit than non-imbibed fruit. These results established that imbibing avocado fruit leads to changes in ripening and quality that are, in general, the opposite to those found with weight loss.

Figure 5. System used to imbibe the fruit. The freshly trimmed stalk was placed into clean water while the fruit was enclosed in a sealed polyethylene bag for 24 hours at 20 °C.

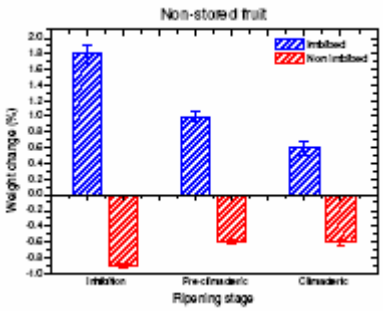

Figure 6. Change in weight for avocado fruit either imbibed with water or left to lose weight at 60% RH or lose weight at different ripening stages. Treatment was carried out at 20 °C.

MEASURING FRUIT WATER STATUS

The amount of water imbibed may also be a measure of fruit water potential as it

measures how readily water moves into the fruit. The fruit water potential could be considered to indicate fruit water status that when changed may be related to the changes in quality disorders. The fruit water potential may also indicate how easily the fruit will lose water thereby affecting ripening and quality.

We examined the effect on ripening and quality of imbibed fruit in relation to the time of day when harvested, irrigated and non-irrigated orchards and before and after rain. These experiments were to establish if differences in fruit water status at harvest affect ripe fruit quality.

Table 1. Ripening time and incidence of sound fruit for imbibed or non-imbibed non-stored Hass avocado fruit at different ripeness stages. Control fruit were stored in polyethylene bags or in trays.

Stage	Ripening Time (days)		Sound fruit (%)	
	Imbibed	Non -Imbibed	Imbibed	Non-Imbibed
Inhibition	10.6	9.4	79.3	91.7
Pre-climacteric	9.7	10.3	93.3	87.3
Climacteric	11.7	10.2	90.0	96.2
Control				
Humidity (95%+)		11.2		93.3
Humidity (60%)		10.5		95.0

INFLUENCES ON FRUIT WATER STATUS: TIME OF DAY WHEN HARVESTED

Avocado fruit were harvested from dawn through to dusk on a fine sunny day over three orchards. These fruit were imbibed before storage at 4°C for 28 days then ripened at 20°C. There was a trend for mid afternoon fruit to imbibe the most water with dawn and dusk fruit the least. Ripening times were unaffected by the time of day when harvested after imbibing irrespective of the weight increase. The severity of ripe rots did not follow the same pattern as the amount of water imbibed where they increased from a low level at dawn to be the greatest in the fruit harvested from the mid-afternoon to dusk. It would appear that the fruit water status at different times of the day is not affecting ripening times or ripe rots.

IRRIGATION

Fruit water status of fruit harvested at dawn or mid-afternoon from irrigated orchards was compared to fruit from non-irrigated orchards. Fruit harvested at dawn had no difference in the amount of water they imbibed (Figure 8). Non-irrigated fruit harvested mid afternoon imbibed more water than fruit from irrigated orchards. This would suggest that fruit from non-irrigated orchards had a different fruit water status to fruit from irrigated orchards.

Imbibing non-irrigated fruit changed the ripening times of the fruit harvested in the mid-afternoon (Table 2). The ripening times of imbibed and non-imbibed but irrigated fruit

were similar. Non-irrigated imbibed fruit ripening times were slower than non-imbibed non-irrigated fruit. Infusing fruit with water changed the ripening characteristic of the fruit and suggests that fruit water status may be important in determining ripening rates of avocado fruit.

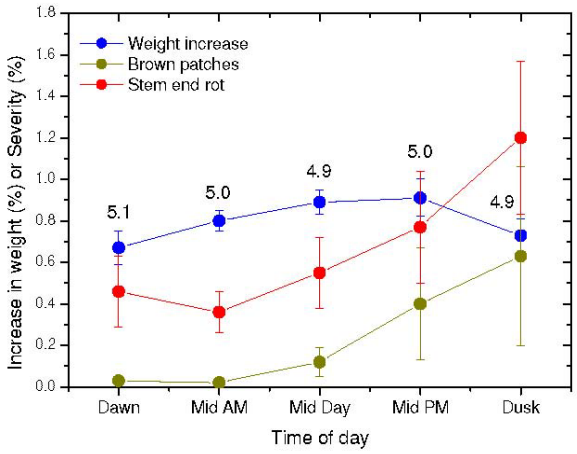

Figure 7. Increase in weight of fruit imbibed after harvest and severity of stem end rot and brown patches over the course of a day. The numbers above a data point represent the average time to ripen.

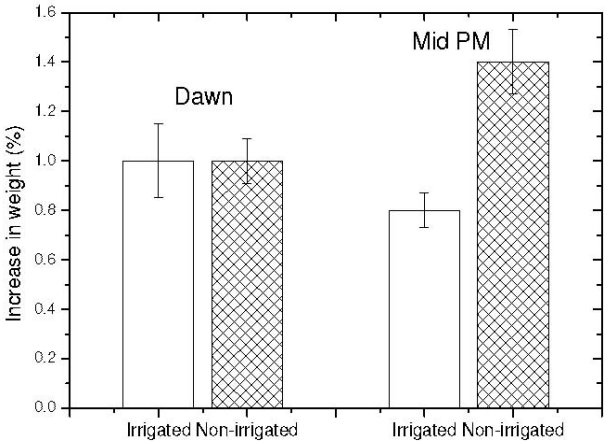

Figure 8. Increase in weight of avocados harvested at dawn or during the mid afternoon after imbibing for 24 hours for Hass avocados from irrigated and non-irrigated orchards.

Table 2. Ripening time of imbibed and non-imbibed fruit harvested from irrigated and non-irrigated orchards in the mid afternoon. Stem end rot and brown patches severity of imbibed fruit harvested in the mid afternoon.

Ripening time (days)	Imbibed		Non-imbibed	
Time of day	Irrigated	Non-irrigated	Irrigated	Non-irrigated
Mid PM	4.4	4.1	4.7	3.6

RAINFALL

Rainfall greater than 5mm has been shown to increase the incidence and severity of rots (PAK et al, 2003). The rain was thought to increase the amount of water in the fruit altering the fruit water status. The increase in the water content of the peel especially was thought to increase the susceptibility to mechanical damage providing an entry point for fungal rots (EVERETT et al, 2001). Avocado fruit were harvested before and after 10mm of rain to determine if imbibing the fruit would show a change in the fruit water status of the fruit and if the change in fruit water status was related to a change in the incidence of sound fruit. There was considerably less water imbibed by the fruit after rain suggesting that the fruit had a higher fruit water status (Figure 9). Ripening times of

fruit harvested after rain was shorter than ripening times of the fruit harvested before rain. The post rain fruit had fewer rots than the more slowly ripening pre rain fruit. These results would suggest that ripening times have had more influence on the incidence of sound fruit than rain. Pre rain fruit took more than 1.5 days longer to ripen than the post rain fruit. The results reported previously (PAK et al, 2003) were for fruit that had very similar ripening times. The results presented here indicate that ripening time may have been a confounding factor affecting the incidence of sound fruit.

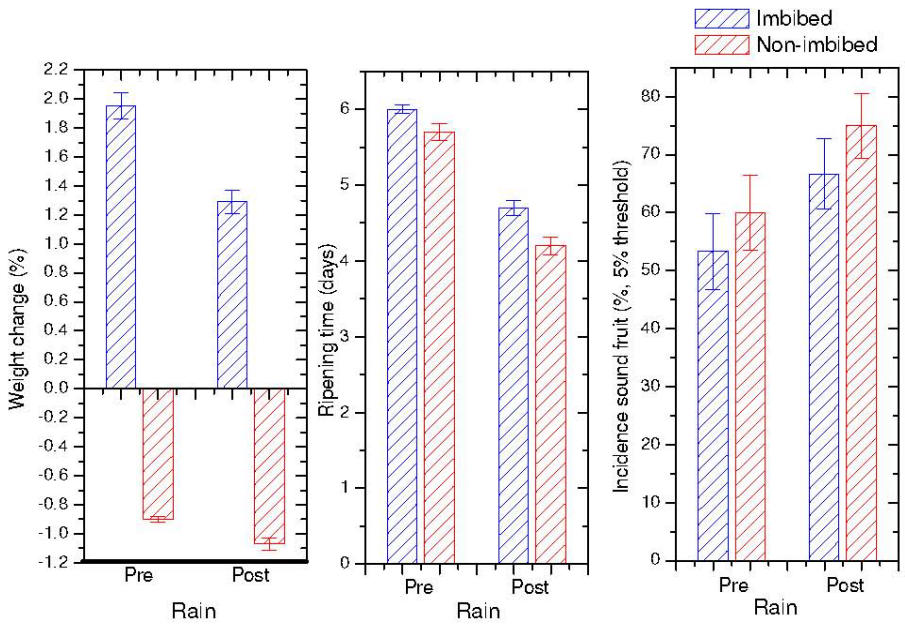

Figure 9. Change in weight, ripening time and incidence of sound fruit for fruit imbibed with water or weight loss harvested before and after 10 mm of rain. Left panel: weight change of imbibed and non-imbibed fruit; middle panel: ripening times after storage; right panel: incidence of sound fruit after storage at 4 °C for 28 days then ripened at 20 °C.

CONCLUSIONS

Is the question as to why fruit delayed for 72 hours before storage have poorer ripe fruit quality answered? Only partially, the main reason the fruit have increased ripe rots appears to be that they move from the inhibition stage of ripening to the pre-climacteric stage in which water loss has a large influence on ripening time and rot development. Infusing the fruit with water slows down ripening and is the opposite effect of water loss. How water loss or gain affects ripening physiology remains unknown. Ripening times have a major influence on ripe fruit quality. High humidity conditions before storage also influence ripe rots separately. Rapid changes in fruit water status during the course of the day or after rainfall appear to influence ripening and ripe rots differently to long term influences such as irrigation. Our understanding of the main drivers and sources of variation in the development of ripe rots is far from complete at present. However, it is clear that both pre-harvest and post-picking but pre-storage handling have a large

influence on final fruit quality.

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