INCREASING PICK TO PACK TIMES INCREASES RIPE ROTS IN 'HASS' AVOCADOS.

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ABSTRACT

Rots that develop during the ripening of exported avocados limit the marketability of the fruit for the importer. Fruit weight loss during the initial stages of ripening influences the ripening time and the incidence and severity of ripe rots. The first ripening stage is the inhibition stage where the fruit have not started to ripen. Water loss during the inhibition stage can reduce the time in this stage by about 2 days. Therefore fruit that have had increased water loss with pick to pack times greater than 24 hours could be expected to have more advanced ripeness after storage and more ripe rots. To test the impact of long delays after harvest before packing have on ripe fruit quality holding times of up to three days in low or high humidity were investigated over two harvest seasons, 2003/2004 and 2004/2005, for their effect on the rate of ripening and rot development. Fruit lost more weight the longer the holding time before storage. The fruit stored in high humidity had less weight loss after 48 and 72 hours than similar fruit in low humidity. The rate of weight loss during storage and ripening was similar for fruit from each holding time. As the holding time increased before storage the average ripening time of fruit decreased. Increasing the holding time before storage from 24 to 48 or 72 hours under low or high humidity conditions increased the incidence and severity of stem end rot and brown patches. Placing the fruit into high humidity conditions before storage to reduce weight loss did not decrease ripe rots but increased ripe rots. The increase in ripe rots could be attributed to an increase in pre-storage weight loss leading to fruit leaving the inhibition ripening stage early. Despite the faster ripening times of fruit held for more than 24 hours than fruit held for 24 hours or less the incidence and severity of ripe rots was greater. This study suggests that fruit coolstored after increased weight loss at the inhibition stage had advanced ripeness. To minimise the potential for development of a high incidence and severity of ripe rots after storage, freshly harvested avocado fruit should be placed into storage within 24 hours of harvest as a best practice goal.

Keywords: *ripening times, weight loss, delaying storage*

INTRODUCTION

Rots that develop during the ripening of exported avocados limit the marketability of the fruit for the importer (Mandemaker, 2004). Previous research has established that fruit weight loss during the initial stages of ripening influences the ripening time which in turn influences the incidence and severity of ripe rots (Dixon *et al*., 2004a; Lallu *et al*., 2004). Avocado fruit just after harvest go through a series of ripening stages that last for different lengths of time which may be influenced by fruit maturity. The first ripening stage after harvest is the inhibition stage where the fruit are considered to be insensitive to exogenous ethylene and have not started to ripen. Following the inhibition stage is the pre-climacteric stage where the fruit initiate a number of biochemical changes that lead to ripening. The inhibition stage is considered important for fruit quality in that if the fruit can be packed and placed into coolstorage before entering the pre-climacteric stage they will have a greater storage life and have less advanced ripeness when removed from storage. The inhibition stage has been reported to last for 4 days (Lallu *et al*., 2004). Increased water loss during the inhibition stage can reduce the time in this stage about 2 days. Therefore fruit that have had increased water loss with longer pick to pack times than 24 or 48 hours could be expected to have

more advanced ripeness after storage and poorer ripe fruit quality. Packers report that a constraint on their business is the industry requirement that the pick to pack time be no longer than 48 hours and ideally be 24 hours. A longer pick to pack time would allow greater quantities of fruit to be accumulated resulting in greater efficiencies when packing the fruit. The results of research reported in earlier issues of the New Zealand Avocado Growers' Association Annual Research Report (Dixon *et al*., 2003; 2004a; 2004b; Lallu *et al*., 2003; 2004; Yearsley *et al*., 2002) indicate that having a long delay between harvest and storage would increase water loss and alter ripening times leading to more ripe rots. Maintaining the fruit in high humidity before storage may allow less weight to be lost before storage so that the fruit are held in the inhibition ripeness stage. This would allow longer pick to pack times than 24 hours provided the weight loss of the fruit was minimised. To test what the impact of long delays after harvest before packing may have on ripe fruit quality delays of up to three days in low or high humidity were investigated over two harvest seasons 2003/2004 and 2004/2005 for their effect on the rate of ripening and rot development.

MATERIALS AND METHODS

Avocado fruit cultivar 'Hass' were harvested from one commercial orchard in the Bay of Plenty (37ºS, 176ºE). Eight hundred fruit were harvested each on the 19/1/2004, 13/12/2004, and 14/2/2005. Within 30 minutes of harvest the ungraded fruit, average weight 226.72g, 260.91g, 254.57g respectively, were weighed and packed into trays of 10 fruit. The trays were randomly divided into two lots of 40 trays each. One lot of 40 trays was not placed into bags. One lot of 40 trays was placed into high humidity where the fruit stored on their cardboard plix trays within a single layer tray. The trays were placed into a 25µm polyethylene bag, 605mm wide by 705mm long before storage (Figure 1). Trays were left in bags until placed into storage. Bags were loosely sealed by folding over the open end of the bags and securing with

Figure 1. Trays of avocados in polyethylene bags before removal and placement into storage.

cellotape. To reduce the potential for a modified atmosphere build up, bags were modified by cutting 18 6mm diameter holes (9 per side of bag) using a no. 2 cork borer. Holes were positioned at the top and bottom of trays to ensure that a high humidity was maintained but a likely modified atmosphere minimised (Dixon *et al*., 2004b).

There were four treatments each consisting of 20 trays of 10 fruit (10 trays in bags and 10 trays not in bags) where the trays were maintained at 20ºC±1ºC, 65%±5% relative humidity:

Treatment 1: 4 hours after harvest, trays in bags were removed from bags and both bagged trays and non-bagged trays were placed into storage.

Treatment 2: 24 hours after harvest, trays in bags were removed from bags and both bagged trays and non-bagged trays were placed into storage.

Treatment 3: 48 hours after harvest, trays in bags were removed from bags and both bagged trays and non-bagged trays were placed into storage.

Treatment 4: 72 hours after harvest, trays in bags were removed from bags and both bagged trays and non-bagged trays were placed into storage.

The trays were placed into a commercial coolstore at 4ºC±0.5ºC, 85%±5% relative humidity for 28 days. After removal from storage all fruit was weighed and assessed for disorders according to the Avocado Industry Council Fruit Assessment Manual (Dixon, 2003). The fruit were ripened at 19.5ºC±1ºC, 60%±5% relative humidity. The fruit were assessed daily for firmness by hand squeeze. Once the fruit had reached eating ripeness as assessed by hand squeeze, equivalent to a firmness reading of at least 85 using a firmometer with a 300 g weight, the fruit were cut and assessed for ripe fruit disorders according to the Avocado Industry Council Fruit Assessment Manual (Dixon, 2003). Weight loss was calculated as the percentage difference of fruit mass when removed from storage or when cut as ripe from fruit mass when harvested and before placement into storage. An additional 20 fruit sample from each orchard of fruit harvested within 1 to 3 days of the experimental fruit was assessed for percentage dry matter by drying flesh peelings from the inside face of one quarter of each fruit after the seed, seed coat and skin were removed.

The results were analysed as a complete randomised block design with harvests nested within orchards using tray average values for each treatment in MINITAB version 13.31. Where required the data was square root transformed to meet the assumption of normality for Analysis of Variance.

RESULTS

The fruit each harvest season had similar dry matter content when harvested (Table 1).

Weight loss before storage

The fruit lost more weight the longer the holding time before storage (Figure 1). The weight loss increased in a linear manner reaching over 2% after 72 hours for fruit in low humidity conditions (Table 2, Figure 1). The fruit stored in high humidity had greatly reduced weight loss after 48 and 72 hours than similar fruit maintained in low humidity (Figure 1, Table 2). After 48 and 72 hours in low humidity fruit had lost 64% to 65% more weight than high humidity fruit. By contrast the fruit 24 hours in low humidity lost 29% more weight the high humidity fruit. The fruit held 4 hours after harvest before storage had similar weight loss irrespective of humidity conditions.

Table 1. Average dry matter content of the fruit harvested in 2004 and 2005.

Date	DM
18/1/2004	33.72
8/12/2004	31.55
20/12/2004	33.46
11/2/2005	34.30

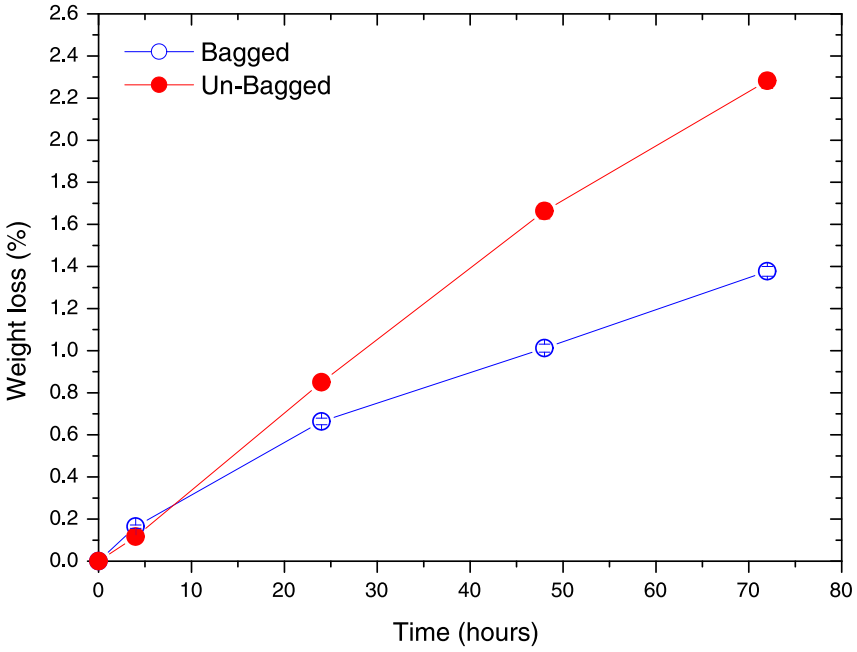

Figure 1. Weight loss from Hass avocado fruit during holding at 20°C ± 1°C, 65% ± 5% RH. Values are the means of 300 fruit (30 trays). Vertical bars represent the standard error of the mean.

Ripening time

As the holding time increased before storage the average ripening time after storage of fruit at each holding time decreased (Table 2). The pattern of the number of fruit ripe on each day after removal from storage changed between the different holding times before storage treatments (Figure 2). For the 4 and 24 hour delay most fruit were ripe on day 5 while for the 48 and 72 hour delay most fruit were ripe on day 4. Pre-storage weight loss and ripening time appeared to be related as the slowest ripening times had the least pre-storage weight loss but similar storage and ripening weight loss. The fruit with the longest delays before storage had the fastest ripening times despite up to 4 days less coolstorage (Table 2).

Disorders

Increasing the holding time before storage from 24 to 48 or 72 hours under low or high humidity

Table 2. Weight loss and ripening time of 'Hass' avocado fruit maintained in high or low humidity for different times before storage.

Treatment	Delay	Pre-storage	Storage Time	Storage	Ripening time	Ripening	Total fruit age	Total
	hours	Weight loss (%)	days	Weight loss (%)	days	Weight loss (%)	days	Weight loss (%)
High humidity	4	0.16a[1]	27	2.36a	4.52a	3.73a	31.52	6.25
	24	0.66b	26	2.29a	4.46a	3.80a	30.46	6.75
	48	1.01c	25	2.20ab	4.00b	3.38ab	29.00	6.59
	72	1.38d	24	2.00b	3.89b	3.10b	27.10	6.48
Mean		0.80		2.21	4.22	3.50		6.52
Low humidity	4	0.12a	27	2.22a	4.64a	3.69a	31.64	6.02a
	24	0.85b	26	2.09a	4.29ab	3.38b	30.29	6.32a
	48	1.66c	25	2.13a	3.96bc	3.38b	28.96	7.17b
	72	2.28d	24	1.89b	3.79c	3.05c	27.79	7.22b
Mean		1.23		2.08	4.17	3.37		6.68

[1]*Means followed by the same letter within a column are not different according to a One-way analysis of variance using a Tukey's family error rate of 5%.*

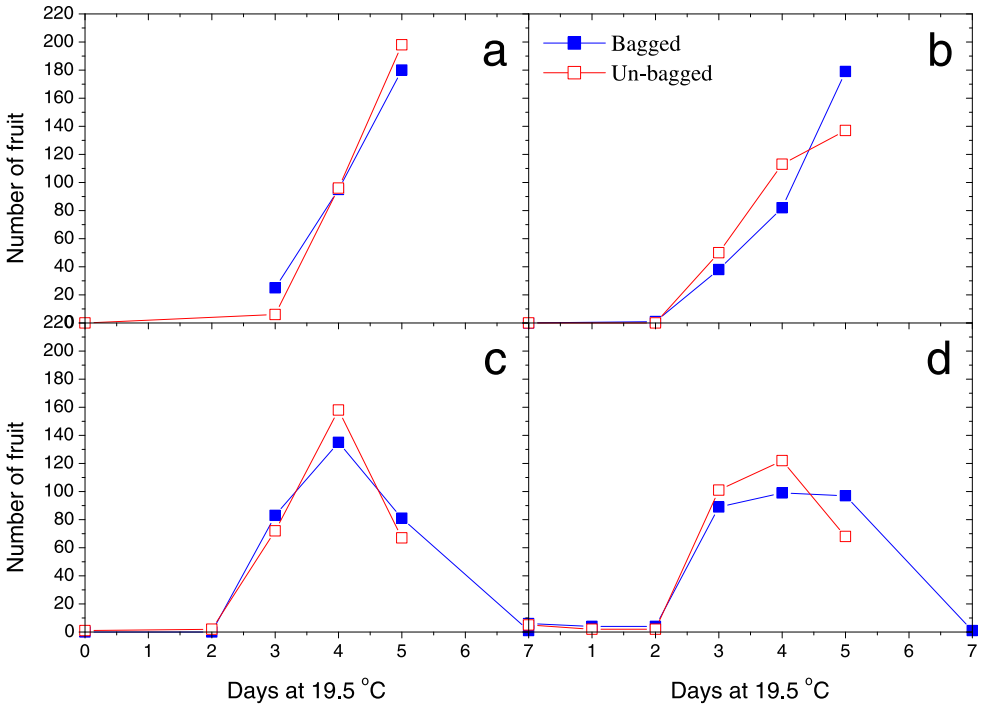

Figure 2. Number of fruit ripe each day after removal from storage at 4°C ± 0.5°C, 85% ± 5% RH following holding after harvest at 19.5°C ± 1.0°C, 65% ± 5% RH for a) 4 hours, b) 24 hours, c) 48 hours or d) 72 hours. Each panel represents the number of fruit ripe out of 300 on each day.

conditions generally increased the incidence and severity of stem end rot and brown patches (Table 3). The incidence of sound fruit decreased significantly from a 24 hour delay to 48 or 72 hours delay in high or low humidity conditions (Table 3). Under high humidity conditions before storage the incidence and severity of rots tended to be greater than the fruit maintained under low humidity conditions before storage. Once the holding time before storage exceeded 24 hours there appeared

Table 3. Incidence of stem end rot and brown patches and severity of fruit with stem end rot and brown patches held for different times before storage.

Treatment	Delay hours	Inc SER %	Sev[1] SER %	Inc BP %	Sev BP %	Inc Sound Fruit[3] %
High humidity	4	11.3a[2]	2.1	44.3	5.7	90.7a
	24	21.0ab	3.0	50.0	5.3	84.7a
	48	24.0ab	3.4	47.0	5.7	83.0ab
	72	35.3b	3.4	57.3	7.4	70.7b
Mean		22.9	3.0	49.7	6.0	82.2
Low humidity	4	11.0a	1.2a	36.0a	3.0a	94.3a
	24	11.3a	2.7ab	35.0a	2.9a	91.3a
	48	23.3b	3.2ab	46.3ab	6.4b	81.3b
	72	26.0b	4.7b	51.7b	6.2b	80.3b
Mean		17.9	2.92	42.3	4.6	86.8

[1]Severity of fruit with the disorder; [2]Means followed by the same letter within a column are not different according to a One-way analysis of variance using a Tukey's family error rate of 5%; [3]Number of fruit with disorders less than 5% severity.

to be a greater increase in rots and decrease in sound fruit compared to the increase in disorders from 4 hours to 24 hours. Holding avocados for 72 hours after harvest had the greatest effect on the incidence and severity of rots with up to 20% less sound fruit than fruit held less than 24 hours (Table 3).

DISCUSSION

The fruit used in this study had poorer ripe fruit quality when storage was delayed by more than 24 hours with a significant increase in the number of unsound fruit after storage. The results reported here confirm the findings of previous research (Yearsley *et al*., 2002; Lallu *et al*., 2003) that the expression of ripe rots and fruit ripening can be influenced by the holding time before packing. The increase in ripe rots was a consistent pattern over the two harvest seasons, 2003/2004 and 2004/2005, in this study. The increase in ripe rots most likely can be attributed to an increase in pre-storage weight loss leading to fruit entering the preclimacteric ripening phase as described by Lallu *et al*. (2004) for non-stored fruit.

A high humidity treatment used to reduce the pre-storage weight loss did not reduce the initial weight loss before storage and therefore had little effect on the expression of ripe rots. The high humidity treatment increased the incidence and severity of rots compared to the low humidity treatment. Fruit held in high humidity had slightly increased ripening times than fruit held in low humidity. The increase in ripe rots under high humidity may have been due to the high humidity treatment being a more suitable environment for the development of fungal rots that the low humidity treatment. In kiwifruit, for example, a low humidity treatment after harvest and before storage can reduce postharvest rots (Fukiage *et al*., 1997) through a curing effect. A slight curing effect of low humidity may be possible with avocados as the incidence of stem end rot and brown patches was slightly lower in fruit held in low humidity. This difference was not significant, however. The severity of stem end rot and brown patches also tended to be less in fruit held in low humidity than fruit held in high humidity before storage. The greatest difference between low and high humidity fruit in ripe rots was for the fruit held 24 hours or less. There may be a potential curing treatment that reduces ripe rots by maintaining the fruit in low humidity before storage for 24 hours or less.

The main effect of delaying the placement of fruit into storage after harvest appears therefore to be advancing the fruit past the inhibition ripeness stage into the pre-climacteric ripeness stage. When freshly harvested avocados at the inhibition stage were moved from a high to a low humidity weight loss increased the rate of ripening by advancing ethylene biosynthesis (Lallu *et al*., 2004). This implies that the fruit came out of coolstorage in an advanced state of ripeness compared to fruit placed into storage as soon as possible after harvest. Despite the faster ripening times of fruit held for more than 24 hours than fruit held for 24 hours or less the incidence and severity of ripe rots was greater. Therefore, the increased ripeness appears to be more important than a curing effect induced by low humidity. Slow to ripen fruit generally develop more disorders than fast to ripen fruit (Dixon *et al*., 2003). The reduced ripening times after holding the fruit for 48 or 72 hours before storage did not counteract the increased development of ripe rots. This finding would appear to further indicate that advancing the ripening stage of avocado fruit as proposed by Lallu *et al*., (2004) has an important role in the expression of ripe rots. Therefore, to minimise the potential for development of a high incidence and severity of ripe rots, freshly harvested avocado fruit should be placed into storage within 24 hours.

CONCLUSION

Delaying storage of New Zealand ‘Hass’ avocado fruit after harvest for more than 24 hours ncreases the incidence and severity of ripe rots. Placing the fruit into high humidity conditions before storage to reduce weight loss did not decrease ripe rots but increased ripe rots. ‘Hass’ avocado fruit should be picked and packed and placed into storage within 24 hours of harvest as a best practice goal.

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