QUALITY OF AVOCADO (*PERSEA AMERICANA* MILL.) FRUIT AFTER HIGH HUMIDITY STORAGE AND/OR EXOGENOUS ETHYLENE REMOVAL.

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ABSTRACT

Identifying factors that promote fruit ripening while at the same time also inhibit rot development will help to improve avocado ripe fruit quality. Two factors implicated in both ripening and rot development are water loss and ethylene. The effect on ripening and rot development of water loss and exogenous ethylene removal during coolstorage for 28 days at 4ºC followed by ripening at 19.5ºC was investigated using polybags and ethylene adsorbent sachets. There were four treatments: control (no bags or sachets), high humidity (polybags), high humidity and exogenous ethylene removal (polybags+sachets) and exogenous ethylene removal only (sachets only). The fruit stored in polybags had the least weight loss and the longest ripening times but also the most rots. Low weight loss and/or removal of exogenous ethylene during storage inhibited ripening after storage. Water loss during storage appears to play a role in ripening. The effect on ripening and subsequent fruit quality appeared to be an increase in the lag time after removal from storage before fruit are ripe rather than slowing the rate of softening.
Keywords: weight loss, stem-end rots, body rots, rates of ripening

INTRODUCTION

The principal causes of post harvest losses in New Zealand avocados are fungal rots that develop during fruit ripening (Dixon, 2001). In New Zealand avocados, postharvest rots are caused by a complex of five fungi (*Colletotrichum gloeosporioides, Colletotrichum acutatum, Botryosphaeria parva, Botryosphaeria dothidea* and *Phomopsis* spp.) commonly referred to by their location on the fruit as either body rots or stem-end rots (Everett and Pak, 2001). Rots are thought to develop once ripening has proceeded sufficiently to reduce the concentration of antifungal dienes in the fruit (Prusky *et al.*, 1983). The rate at which the fruit ripen is dependant on temperature with higher temperatures favouring faster fruit ripening but also faster fungal rot development (Hopkirk *et al.*, 1994). Conditions that promote fruit ripening may also favour faster growth of fungal rots, conversely slowing fruit ripening may inhibit rot development. Identifying factors that promote ripening while at the same time inhibiting rot development will enhance avocado fruit handlers' ability to present avocado fruit of high quality when ripe.

Avocado fruit are unusual in that they only ripen once removed from the tree (Dixon and Partridge, 2001). The key driver that sets off the ripening process is not known. One possible candidate may be water loss (Akkaravessapong *et al.*, 1996). In persimmons, for example, water loss in the calyx induces ethylene biosynthesis, subsequent fruit ripening is meditated by an autocatalytic response to the ethylene produced first in the calyx (Nakano *et al.*, 2003). Avocado fruit typically ripen over 4 to 8 days at 20ºC after storage (Dixon, 2001). Treatment with ethylene is often used to accelerate ripening (Dixon and Partridge, 2001) and the presence of ethylene in the storage environment often promotes faster ripening (Hofman *et al.*, 2002). Preventing water loss in fruit or removing ethylene from the storage environment should therefore delay or inhibit avocado fruit ripening thereby increasing the shelf-life of the fruit. There is little published information that relates water loss to ripening and post harvest rot development of avocado fruit. Experiments investigating the role of water loss during ripening are complicated by the confounding interaction between water loss and ethylene on the fruit ripening process. By isolating water loss from the effect of ethylene a greater understanding of the ripening process can be developed that will allow rot expression during ripening to be better understood. The effects on avocado fruit ripening and rot development in relation to water loss and exogenous ethylene removal during coolstorage were investigated in the 2002/03 New Zealand avocado harvest season.

MATERIALS AND METHODS

Avocado fruit were harvested from three commercial orchards in the Bay of Plenty (37°S, 176°E). Four hundred fruit were harvested from each orchard on 16 December 2002. Within 4 hours of harvest the ungraded fruit were weighed and packed into trays of 20 fruit.

There were four treatments each consisting of 100 fruit (5 trays of 20 fruit) per orchard:

- Treatment 1: control, fruit were stored "naked" in standard single layer trays with plixes but without without polyliners or ethylene adsorbent sachets.
- Treatment 2: fruit were stored on their cardboard plix trays within a 25 µm thickness polyethylene bag, 605 mm width by 705 mm length. Bags were loosely sealed by folding over the open end before the trays were placed into standard single layer trays for storage.
- Treatment 3: fruit were stored as in Treatment 2 with the addition of 5 sachets of Hydrosil® HS-600 (6% potassium permanganate impregnated onto zeolite enclosed in a DuPont Tyvek[R] moisture resistant bag) distributed evenly throughout the tray before the bags were loosely sealed by folding over the open end. The bags and trays of fruit were placed into standard single layer trays.
- Treatment 4: fruit were stored "naked" in single layer trays with the addition of 5 sachets of the ethylene adsorbent Hydrosil® distributed evenly throughout the tray.

The fruit were then placed into a commercial coolstore at 4°C ± 0.5°C, 85% RH for 28 days. After removal from storage the fruit was removed from bags, weighed and assessed for disorders according to the Avocado Industry

Council Fruit Assessment Manual (Dixon, 2002) then ripened at 19.5°C ± 1°C, 60% RH. Once the fruit had reached eating ripeness as assessed by hand squeeze as having a firmness reading of at least 85 using a firmometer with a 300 gram weight the fruit were cut and assessed for disorders according to the Avocado Industry Council Fruit Assessment Manual (Dixon, 2002). 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. An additional 20 fruit sample from each orchard 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 from trays were analysed as a complete randomised block design using MINITAB version 13.31.

RESULTS AND DISCUSSION

The fruit used in this trial had an average dry matter content of 31.4% and ripened in a manner consistent with other avocado fruit harvested at about the same time.

Storage of avocados inside polybags in trays reduced weight loss to about one third that of fruit stored without polybags (Table 1). When ripe, the fruit stored in polybags had greater weight loss after ripening than the fruit stored without polybags. The greater weight loss after ripening was due to the fruit taking longer to ripen than fruit stored without polybags (Table 2) as the rate of weight loss during ripening was the same (Table 1). Weight loss during storage was not significantly affected by ethylene adsorbent sachets although the average ripening time was longest for the polybag+sachets treatment.

Table 1. Average weight loss and rate of weight loss of avocado fruit stored for 28 days at 4°C, 85% RH or in high humidity (polyliners), with and without removal of exogenous ethylene, then ripened at 19.5°C, 60% RH.

Treatment	% Weight loss			Rate of weight loss (percent per day)	
	Storage[1]	Ripening[2]	Total	Storage	Ripening
Control	3.0a[3]	3.1a	6.1a	0.11a	0.84a
Polybag	1.0b	4.0bc	5.0b	0.03b	0.86a
Polybag + Sachets	1.3b	4.5b	5.8ab	0.04b	0.80a
Sachets	3.1a	3.6ac	6.6a	0.11a	0.84a

[1]Weight loss of fruit on removal from storage, [2]Weight loss of fruit over the ripening period, fruit were removed from polybags for ripening, [3]Means followed by the same letter are not different according to a One-way analysis of variance using a Tukeys family error rate of 5%.

The incidence of stem-end rot, in ripe fruit, was highest in the fruit stored in polybags (Table 2). While the incidence of brown patches was highest in the polybags+sachets treatment it was not significantly different to the other treatments. However, the severity of brown patches was greatest in the polybags+sachets treatment and may be related to the longer ripening time compared to other treatments (Table 2). The incidence of unsound fruit at a 5% disorder threshold was highest in the polybags+sachets treatment (Table 2). These results suggest reducing weight loss during storage slows avocado fruit ripening after storage leading to poorer quality when ripe through a greater incidence and severity of rots.

Table 2. Average number of days to ripen, incidence and severity of stem-end and body rot and incidence of unsound fruit using a 5% disorder threshold for avocado fruit stored for 28 days at 4°C, 85% RH or in high humidity (polyliners), with and without removal of exogenous ethylene.

Treatment	Days to ripen[1]	Stem-end rot		Brown patches		Incidence of Unsound fruit, at a 5% disorder threshold
		Inc[2]	Sev[3]	Inc	Sev	
Control	3.9a[4]	1.7a	0.0a	21.0a	0.4a	2.0a
Polybags	4.8ab	11.7ab	0.5a	22.3a	1.0ab	8.7ab
Polybags+Sachets	5.6b	18.3b	1.0a	36.0a	3.6b	19.3b
Sachets	4.4ab	3.0a	0.6a	22.0a	0.8ab	4.7ab

[1]The average number of days at 19.5°C after removal from coolstorage until ripe. [2]Incidence. [3]Severity. [4]Means followed by the same letter are not different according to a One-way analysis of variance using a Tukeys family error rate of 5%.

When the fruit were removed from storage there was a lag period of 2-3 days before the fruit started to ripen (Figure 1). There was also a lag period before the fruit started to show symptoms of rots that was the same as the ripening lag for brown patches (body rots) but the appearance of stem-end rot symptoms were delayed an extra day (Table 3, Figures 2 and 3). The differences observed in the incidence and severity of brown patches and stem-end rot may be related to changes in the ripening time of the fruit rather than a direct effect of weight loss during storage or removal of exogenous ethylene.

Table 3. Lag time before ripening and development of rots for avocados stored at 4°C in high humidity (polyliners), with and without removal of exogenous ethylene.

	Lag phase before ripening or development of rots (days)		
Treatment	Ripening	Brown patches (body rots)	Stem-end rot
Control	2	2	3
Polybags	2	2	3
Polybags+Sachets	3	3	4
Sachets	2	2	3

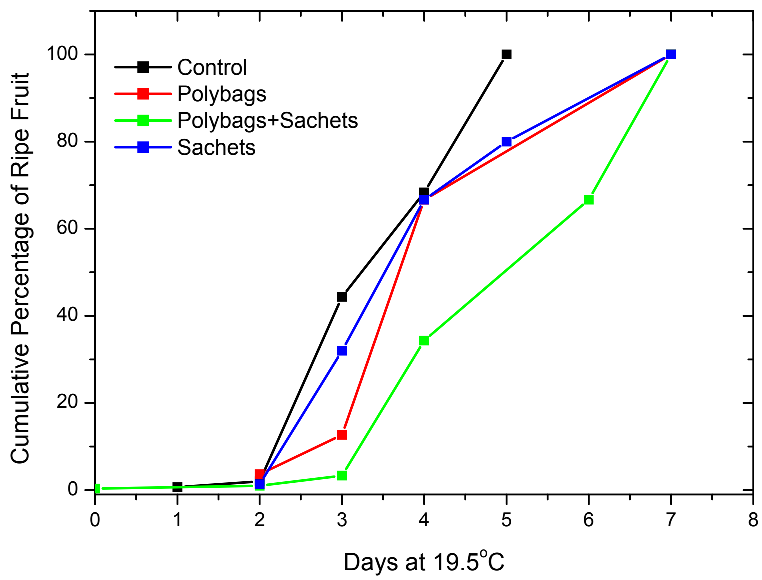

Figure 1. Cumulative percentage of fruit at the ripe stage during ripening at 19.5°C, 65% RH after storage for 28 days at 4°C, 85% RH.

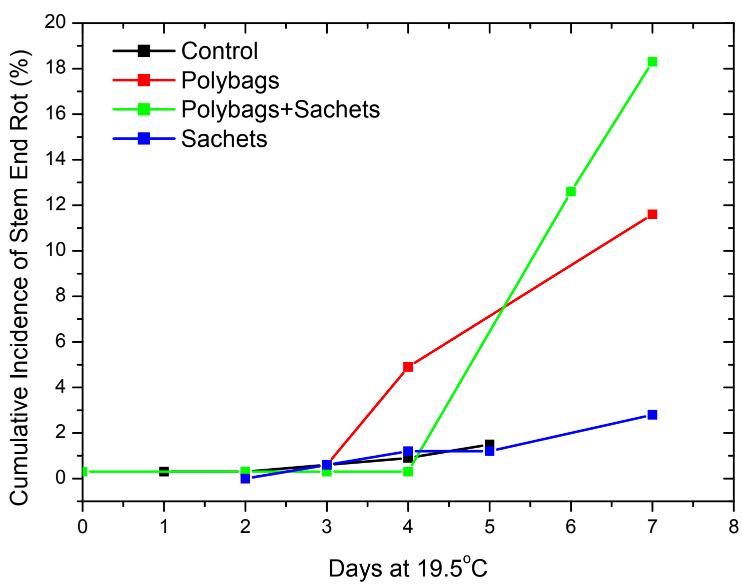

Figure 2. Cumulative incidence of stem-end rot in fruit at the ripe stage during ripening at 19.5°C, 65% RH after storage for 28 days at 4°C, 85% RH.

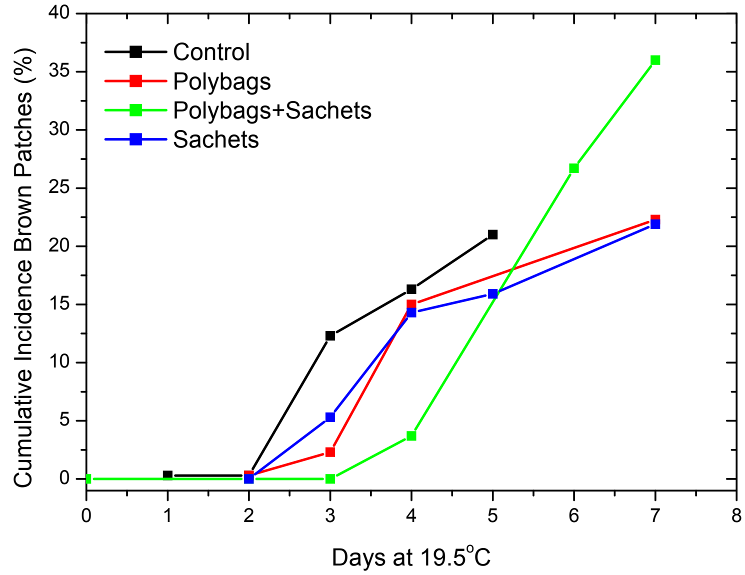

Figure 3. Cumulative incidence of brown patches (body rots) in fruit at the ripe stage during ripening at 19.5°C, 65% RH after storage for 28 days at 4°C, 85% RH.

In general, following the lag period there was a linear phase between the ripening time and the cumulative incidence of ripe fruit (Figure 1). Once the lag period had passed, the rate of softening and ripening was fastest for control fruit while fruit in polybags+sachets had the slowest rate of softening (Table 4). The fruit stored in polybags with or without sachets had similar rates of ripening despite different lag periods before ripening. While individually both exposure to high humidity and removal of exogenous ethylene in storage reduced the rate of ripening and softening the greatest decrease in softening was found with both polybags and sachets. This would suggest that both weight loss and exogenous ethylene during storage have an additive effect on reducing the rate of ripening after storage (Table 2).

Table 4. Ripening and softening rates for avocados stored at 4°C, 85% RH or in high humidity (polyliners), with and without removal of exogenous ethylene. Linear regression coefficients, correlation coefficients (r) and probability levels (p) were calculated using the data in Figure 1.

Treatment	Rate of ripening % ripe per day	r	p	Rate of softening Hand firmness per day
Control	31.8[1]	0.994	0.006	25.7a[2]
Polybags	20.0	0.947	0.053	21.7ab
Polybags+Sachets	22.6	0.990	0.010	18.0b
Sachets	19.5	0.956	0.011	23.4ab

[1]Calculation is based on ripening after the lag phase. [2]Means followed by the same letter are not different according to a One-way analysis of variance using a Tukeys family error rate of 5%

The ripening rate of the avocados in this trial was highly correlated with the incidence of brown patches (body rots) and stem-end rot (Tables 5 and 6). There were different rates of development of brown patches and stem-end rot in relation to ripening as indicated by their regression slopes (Tables 5 and 6). Incidence of brown patches increased fastest in the polybags+sachets treatment and was similar for the other treatments. By contrast the incidence of stem-end rot increased more slowly than the incidence of brown patches. The fruit stored in polybags had the fastest increase in the incidence of stem-end rot compared to the control fruit (Table 6).

Table 5. Linear regression coefficients, correlation coefficients (r) and probability levels (p) for the cumulative number of fruit ripe with the cumulative incidence of fruit with brown patches (body rot) for avocados ripening at 19.5°C, 65% RH after storage at 4°C, 85% RH or in high humidity (polyliners), with and without removal of exogenous ethylene. Regression analysis used the data presented in Figures 1 and 2.

Treatment	Slope (% Brown patches/% ripe)	r	p
Control	0.217	0.989	0.0013
Polybags	0.231	0.999	0.0003
Polybags+Sachets	0.376	0.971	0.0011
Sachets	0.220	0.995	0.0003

Table 6. Linear regression coefficients, correlation coefficients (r) and probability levels (p) for the cumulative number of fruit ripe with the cumulative incidence of fruit with stem-end rot for avocados ripening at 19.5°C, 65% RH after storage at 4°C, 85% RH or in high humidity (polyliners), with and without removal of exogenous ethylene. Regression analysis used the data presented in Figures 1 and 3.

Treatment	Slope (% Stem-end rot/% ripe)	r	p
Control	0.011	0.973	0.0052
Polybags	0.114	0.972	0.0277
Polybags+Sachets	0.184	0.951	0.0036
Sachets	0.024	0.917	0.0287

CONCLUSIONS

A longer ripening time resulted in poorer fruit quality with the fruit with the slowest ripening times having the greatest incidence and severity of brown patches and stem-end rots. Low weight loss or removal of exogenous ethylene during storage inhibits ripening after storage. A combination of low weight loss and removal of exogenous ethylene during storage had the greatest effect on increasing the ripening time after storage. Water loss during storage appears to play a role in ripening. The effect on ripening appears to be in increasing the lag time before fruit are ripe rather than slowing the rate of softening.

ACKNOWLEDGEMENTS

The authors wish to thank Kevin McPheat, FilterCorp International, Auckland for the donation of the ethylene adsorbent sachets and Geoff Grieg, Ag-Brokers New Zealand Limited for the donation of the tray polybags. Thanks also to Alex Barker, Brian and Jan Robinson and Rob Bayly for fruit.

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