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QUALITY OF HASS AVOCADO (*PERSEA AMERICANA* MILL.) FRUIT AFTER HIGH HUMIDITY STORAGE IN POLYETHYLENE BAGS

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ABSTRACT

Understanding the role of water loss during ripening and storage on the quality of New Zealand 'Hass' avocado fruit will help the New Zealand avocado industry to improve its' post-harvest handling systems. Reduced water loss has been implicated as an important factor for the increased expression of post-harvest rots by increasing the ripening time of the fruit. The effects of reducing fruit water loss during storage and/or during subsequent ripening on the rate of ripening and rot development was investigated using polyethylene bags to generate high humidity storage conditions. There were four treatments: control (no bags in storage or ripening), high humidity during storage (bags in storage then ripened out of bags), high humidity during ripening (no bags in storage then in bags during ripening), high humidity during storage and ripening (bags in storage and in ripening). The fruit stored and/or ripened in high humidity (polyethylene bags) had the least weight loss and the most rots despite having no difference in ripening time between treatments. The expression of stem-end rots was equally enhanced by storage in bags either during cool storage or ripening while the expression of body rots was most affected by high humidity during ripening. Avoiding high humidity conditions during storage and/or ripening should result in fruit with the least amounts of post-harvest rots.

Keywords: *weight loss, stem-end rots, body rots, ripening*

INTRODUCTION

Rots that develop during the ripening of avocados are a major cause of postharvest losses. The role of fruit mass loss (principally water loss. Banks *et al*., 1999) and exogenous ethylene removal in promoting postharvest rot development was investigated in fruit stored in polyethylene bags (Dixon *et al*., 2003). Storing avocados in polyethylene bags raises the relative humidity around the fruit to near saturating levels (Sommer, 2002) and can be used to apply high humidity treatments. Low weight loss or removal of exogenous ethylene during storage increased ripening times after storage. The fruit that took the longest to ripen had the greatest incidence and severity of rots. The longer ripening time was related to a delay in the onset of ripening, after which the fruit ripened at the same rate as the control fruit, which resulted in greater levels of rots overall. While reduced water loss in storage appeared to play a role in ripening and the subsequent level of rots the role of water loss during ripening was not examined. The effects of reducing fruit weight loss either during cool storage and/or during subsequent ripening on the rate of ripening and rot development was investigated in the 2003/2004 harvest season.

MATERIALS AND METHODS

Avocado fruit cultivar 'Hass' were harvested from one commercial orchard in the Bay of Plenty (37°S, 176°E). Four hundred fruit were harvested on the 19 December 2003. Within 4 hours of harvest the ungraded fruit, average weight 246.7g, were weighed and packed into trays of 20 fruit.

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

Treatment 1 (trays, trays): control, fruit were stored and then ripened in standard single layer trays on cardboard plixes.

Treatment 2 (bags, trays): fruit were stored on their cardboard plixes within a standard single layer tray. Trays were placed into a 25 *pm* polyethylene bag, 605 mm wide by 705 mm long. After storage the trays were removed from the bags and the fruit were ripened. Bags were loosely sealed by folding over the open end of the bags before the trays were placed into storage. To reduce the potential for a modified atmosphere to 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 minimized.

Treatment 3 (trays, bags): fruit were stored on their cardboard plix trays within a standard single layer tray. During ripening trays were placed into a 25 µm polyethylene bag, 605 mm wide by 705 mm long. Bags were loosely sealed by folding over the open end of the bags before the trays were placed into storage. The bags were modified with holes as described for Treatment 2.

Treatment 4 (bags, bags): fruit were stored on their cardboard plix trays within a standard single layer tray. Trays were placed into a 25 µm polyethylene bag, 605 mm wide by 705 mm long before storage. Trays were left in bags during ripening. Bags were loosely sealed by folding over the open end of the bags before the trays were placed into storage. The bags were modified with holes as described for Treatment 2.

The fruit were placed into a commercial cool store at 4°C ± 0.5°C, 85% RH 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 in bags was removed from the bags as required, then placed back into trays which were then placed back into the bags as in Treatments 3 and 4 and ripened at 19.5°C ± 1°C, 60% RH. 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 gram weight, the fruit were cut and assessed for 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. 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 were analyzed as a complete randomised block design using tray average values for each treatment in MINITAB version 13.31.

RESULTS AND DISCUSSION

The fruit used in this experiment had an average dry matter content of 29.1% ± 2.5% (mean ± standard deviation). Storage in polyethylene bags reduced weight loss by about half during storage and/or ripening (Table 1). Total weight loss was greatest for the fruit stored and ripened in trays and lowest in fruit stored and ripened in bags (Table 1). The rate of weight loss during storage or ripening depended on the presence or absence of bags and there appeared to be no carry over effect of previous storage on the rate of weight loss, i.e. storage in bags reduced the rate of weight loss compared to storage in trays but the rate of weight loss was the same for fruit ripened in trays whether they had been stored in bags or trays.

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, then ripened at 19.5°C, 60% RH.

Treatment		% Weight loss			Rate of weight loss (percent per day)	
Storage	Ripening	Storage[1]	Ripening[2]	Total	Storage	Ripening
Trays	Trays	3.4a[3]	4.3a	7.7a	0.13a	2.3a
Bags	Trays	2.1b	4.2a	6.3b	0.08b	2.0a
Trays	Bags	3.2a	2.7b	5.9b	0.12a	1.3b
Bags	Bags	2.0b	2.2b	4.2c	0.07b	1.0b

[1]Weight loss of fruit on removal from storage, [2]Weight loss of fruit over the ripening period, fruit were retained in bags 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%.

There was no significant difference in the average ripening times between treatments (Table 2). Since ripening times were similar for all treatments this suggests that differences found in the development of rots were due to treatment effects rather than an indirect effect of longer ripening times as found in fruit stored in bags with ethylene adsorbent sachets (Dixon et al., 2003). The cumulative incidence of ripe fruit over time was similar for all treatments (Figure 1) although there was a tendency for fruit stored in bags to have a slightly slower rate of ripening. There was no difference in the onset of ripening of fruit between treatments despite large differences in weight loss between treatments. A lack of difference in ripening times between treatments is in agreement with the results for fruit harvested in 2002/2003 (Dixon *et* al., 2003).

Table 2. Average number of days to ripen, incidence and severity of stem-end and body rot and incidence of unsound fruit for avocado fruit stored for 28 days at 4°C, 85% RH or in high humidity, then ripened at 19.5°C, 60% RH.

Treatment Storage	Ripening	Days to ripen[1]	Stem-end rot Inc[2]	Sev[3]	Brown patches Inc	Sev	Unsound fruit Inc[4]
Trays	Trays	4.7a[5]	8a	0.1a	27a	0.7a	6a
Bags	Trays	5.0a	29a	1.7a	46ab	3.1ab	26a
Trays	Bags	4.9a	35a	1.4a	72b	3.6ab	33a
Bags	Bags	5.2a	68b	4.8b	79b	9.8b	59b

[1]The average number of days at 19.5°C after removal from coolstorage until ripe; [2]Incidence; [3]Severity; [4]Incidence of fruit with at least one disorder at greater than 5% severity; [5]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%.

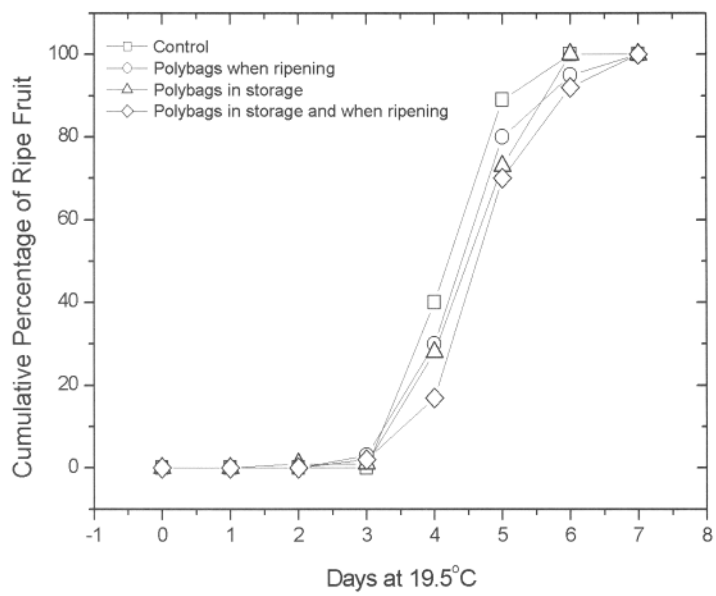

Figure 1. The effect of high humidity during storage and/or when ripening on the cumulative percentage of ripe fruit.

Storage and ripening in bags significantly ($p<0.05$) increased the severity and incidence of stem-end rots and brown patches (Table 2). There was a tendency for fruit that were stored only or ripened only in polyethylene bags to have increased severity and incidence of stem-end rot compared to the control. Storage in bags during ripening increased the incidence of brown patches (Table 2). Storage and ripening in bags increased the severity of brown patches to a level greater than for fruit either stored or ripened in bags separately. Fruit stored in bags during ripening had similar incidence of brown patches but severity of brown patches was greatest where the fruit had been stored and ripened in bags.

There were differences in the rate of expression of stem-end rot between treatments (Figure 2). Fruit stored and ripened in trays had the least stem-end rots. A period of storage in bags or during ripening resulted in fruit with an increased incidence and severity of stem-end rots. There appeared to an additive effect of storing fruit in bags where fruit maintained in bags during storage and ripening developed stem-end rots at about the same rate as the combined incidence of fruit stored or ripened in bags (Figure 2).

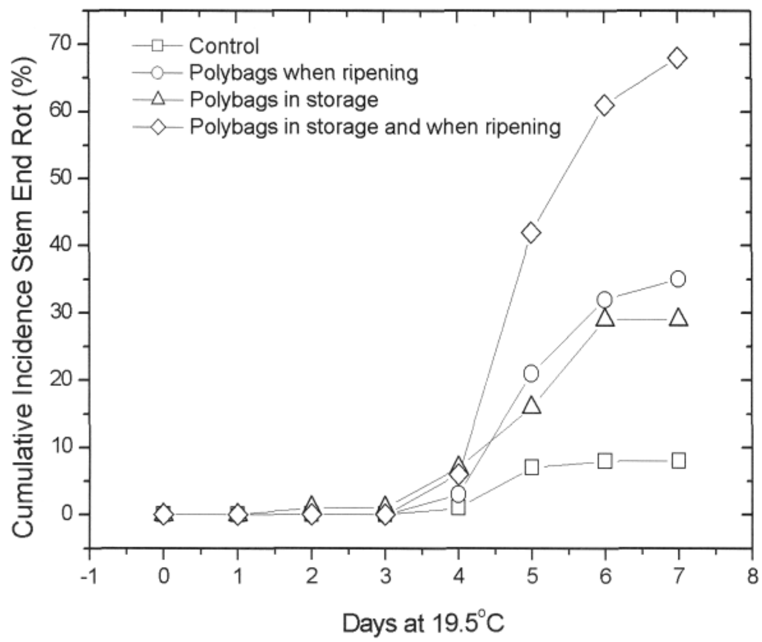

Figure 2. Influence of high humidity during storage and/or ripening on the development of stem-end rot.

The cumulative incidence of brown patches showed a different pattern to that for stem-end rots (Figure 3). The fruit stored and ripened in trays had the lowest incidence and severity of brown patches. The fruit stored in trays then ripened in bags developed about the same amount of brown patches as the fruit stored and ripened in bags. The fruit stored in bags then ripened in trays developed about half the numbers of brown patches compared to the fruit ripened in bags. The expression of brown patches appears to be related to the humidity conditions during ripening irrespective of previous storage conditions. Such results suggest that expression of brown patches is influenced predominantly by ripening conditions whereas expression of stem-end rots is equally affected by storage and ripening conditions.

In this trial reducing weight loss during storage and/or ripening through the use of polyethylene bags has not had a positive effect on ripe fruit quality. Maintaining a high humidity around the fruit has resulted in greater severity and incidence of ripe rots. The rate of expression of these rots has depended on whether the rots were stem-end rots or body rots (brown patches). These findings indicate that maintaining minimum water loss conditions during storage and ripening will be detrimental to fruit quality in contradiction to suggestions in other reports (Lallu *et al*., 2003).

In previous research the presence of ethylene adsorbing sachets inside polyethylene bags increased the ripening times of avocado fruit but also increased the incidence and severity of rots (Dixon *et al.,* 2003). Fruit stored in intact modified atmosphere bags also had increased ripening times and greater rots than fruit stored in perforated modified atmosphere bags (Dixon *et al.* 2004). In this trial there may have been confounding effects of ethylene accumulation and/or a modified atmosphere develop around the fruit. By perforating the polyethylene bags used to store or ripen the fruit the influence of a possible modified atmosphere and ethylene accumulation should have been minimized leaving just a humidity effect. Without a direct measurement of respiration gases or ethylene in the bag atmosphere it is not known if the storage environment for the fruit in bags was different to that if the fruit stored in trays in air. The best indication that there may have been a modified atmosphere effect on the fruit in bags would have been an increased ripening time as has been reported in a parallel trial to the one reported here (Dixon *et al*., 2004). That there was no increase in ripening time suggests that the effect of storage or ripening in bags was due primarily to the high humidity in the storage environment. Combining the findings of this trial and the other trials looking at the confounding effects of ethylene and modified atmospheres on ripening and post-harvest quality suggests that high humidity during storage and ripening has a major influence on promoting the expression of post-harvest rots in 'Hass' avocado fruit.

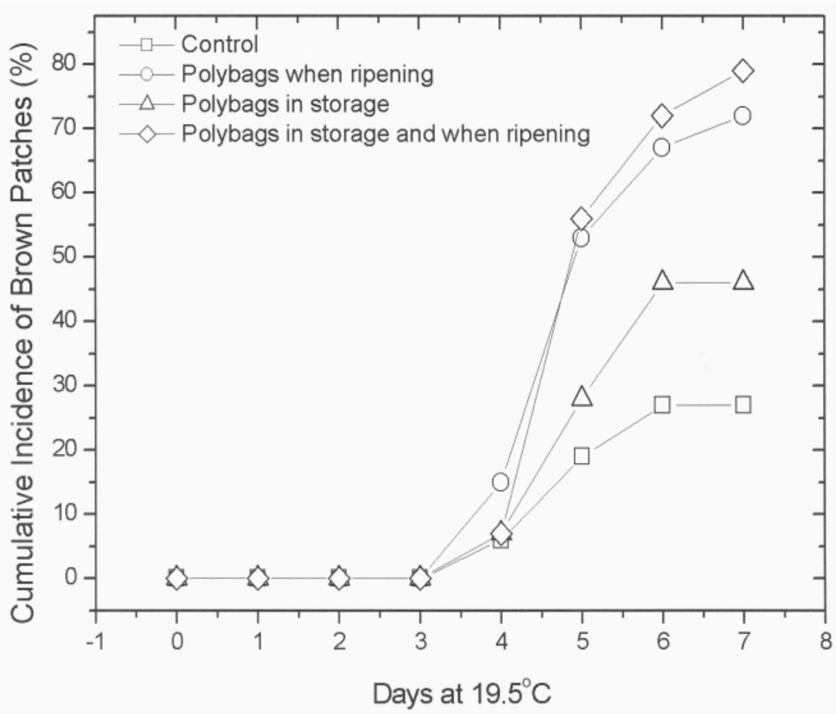

Figure 3. Influence of high humidity during storage and/or ripening on the development of brown patches.

CONCLUSIONS

Holding conditions during storage and ripening can have a large influence on rot development and subsequent fruit quality. High humidity during storage and/or ripening results in greater expression of post-harvest rots. Storage at about 85% RH and ripening at about 60-65% RH in the appropriate temperature conditions should result in fruit with the least amounts of post-harvest rots.

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