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FRUIT AGE, STORAGE TEMPERATURE AND MATURITY EFFECTS ON HASS AVOCADO FRUIT QUALITY AND RIPENING

J. DIXON,
D. B. SMITH
T. A. ELMSLY

Avocado Industry Council Ltd, P.O. Box 16004, Bethlehem, Tauranga
E-mail: jonathandixon@nzavocado.co.nz

ABSTRACT

The influence of storage temperature and duration of storage was previously investigated in two trials in the 2002/2003 season. The month during which 'Hass' avocado fruit were harvested affected fruit quality with the lowest levels of rots and chilling injury occurring in mid season harvested fruit. In the 2003/2004 season a study combining storage temperature and duration was conducted on avocado fruit harvested early, mid and late season. For fruit stored at 5°C for 4 weeks the month of harvest where the incidence of sound fruit was greatest was about the same in 2003/2004 as in 2002/2003. The pattern of rot development also differed from one season to the next where February harvested fruit had better quality than December harvested fruit in 2003/2004 in contrast to fruit harvested in 2002/2003 where February harvested fruit had the poorest quality. This study confirmed results from the previous season where storage for longer than 4 weeks greatly reduced fruit quality. Similarly, fewer quality problems were found in fruit stored at 5°C compared to fruit stored at 2°C. It is suggested that for optimum quality during the export harvest season storage temperature and duration should be maintained according to harvest maturity appropriate to each season.

Keywords: *stem-end rot, body rot, chilling injury*

INTRODUCTION

A study was undertaken on fruit harvested in the 2002/2003 season that aimed to define the chilling injury response and fruit quality parameters of New Zealand 'Hass' avocados in relation to maturity as defined by harvest month or dry matter (DM), storage temperature and duration over the export harvest season (Dixon *et al.,* 2003). There were two trials in 2002/2003 examining the separate issues of storage temperature and storage duration. The findings were that month of harvest affected the incidence and severity of rots and chilling injury. Fruit harvested in late October/early November

generally had the lowest rots and the least chilling injury. Fruit harvested in January/February had the most rots and chilling injury. There was also a differential effect of storage temperature during the export harvest season with the suggestion that storage temperatures could be adjusted up or down from 5°C according to month of harvest for optimum quality. The study reported in this paper for fruit harvested over the 2003/2004 export season aims to confirm the trends seen in 2002/2003 harvested fruit through an experiment combining storage temperature and duration.

MATERIALS AND METHODS

Avocado fruit cultivar 'Hass' were carefully harvested from three commercial orchards in the Bay of Plenty region (37°S, 176°E) directly into trays. There were three harvests from each orchard in October (21-24/10/2003), December (16-18/12/2003) and February (9-11/2/2004). A total of five hundred fruit were taken at each harvest from each orchard. Within 4 hours of harvest the ungraded fruit, average weight 228.9g in October, 237.2g in December and 242.8g in February, were weighed and packed into trays of 20 fruit. The trays of fruit were placed into temperature controlled cabinets at 2°C ± 0.5°C or 5°C ± 0.5°C, 85% ± 5% RH. Fruit in trays were distributed within the shelving of the cabinets randomly to account for any possible temperature gradient effects within a cabinet. Cabinet temperatures were monitored continuously for the duration of the experiment using temperature loggers. A total of 100 fruit (5 trays of 20 fruit) per orchard per harvest were stored for 28 or 42 days at 2°C or 5°C before removal to 19.5°C ± 1°C, 60% ± 5% RH for ripening. At each harvest a non-stored control sample of 100 fruit per orchard per harvest was ripened at 19.5°C ± 1°C, 60% ± 5% RH, immediately after harvest. An additional 20 fruit sample from each harvest 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.

After removal from storage fruit were inspected for external disorders and once eating ripe were assessed for internal disorders. Each day over the ripening period the fruit were assessed for firmness by hand squeeze. Once the fruit had reached eating ripeness, determined 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.

The tray averages of the incidence and severity of disorders were analyzed as a repeated measures trial with storage times nested within storage temperatures nested within harvests nested within orchards using the General Linear Models function of MINITAB version 13.31.

RESULTS AND DISCUSSION

Non-stored fruit

The same trends in dry matter accumulation and ripening times were observed in fruit harvested in 2003/2004 as found for fruit harvested in 2002/2003 (Dixon *et al.,* 2003).

Fruit dry matter increased with each harvest from an average of 26.5% for the three orchards in October to 33.2% in February (Table 1). At the equivalent month of harvest dry matter in 2003/2004 was slightly less than in 2002/2003 suggesting fruit maturity may have been less advanced. The time for fruit to ripen to eating ripeness decreased ($p<0.001$) and fruit dry matter increased at each month of harvest (Table 1). In contrast to the previous season for fruit harvested in 2003/2004 the average incidence and severity of stem-end rot increased with each subsequent harvest and the incidence and severity of brown patches decreased with each harvest (Table 1). The incidence of stem-end rots and brown patches were not significantly different between orchards (Table 1). Overall the quality of the ripe fruit was good with greater than 90% of ripe fruit having disorders with less than 5% severity.

Table 1. The effect of harvest month and orchard on dry matter, time to ripen and fruit quality for non-stored avocados ripened after harvest. Numbers in the table are average values for five trays per harvest orchard combination.

Orchard	Harvest	Dry matter %	Time to ripen days	Stem-end rot		Brown patches		Sound fruit[c] %
				Inc[a] %	Sev[b] %	Inc %	Sev %	
1	October	27.4	13.0	4.0	0.1	46.0	1.3	93.0
	December	29.6	11.3	10.0	0.2	49.0	2.0	89.0
	February	33.8	10.7	9.0	0.3	29.0	0.9	92.0
2	October	25.8	12.9	6.0	0.2	58.0	1.8	87.0
	December	33.6	13.9	5.0	0.1	20.0	0.6	95.0
	February	34.4	10.1	11.0	0.5	29.0	0.8	94.0
3	October	26.2	12.5	0.0	0.0	45.0	1.2	95.0
	December	33.5	12.6	7.0	0.2	26.0	0.7	94.0
	February	31.6	12.7	14.0	0.7	14.0	0.4	91.0
	October	26.5	12.8	3.3	0.1	49.7	1.4	91.7
	December	32.2	12.6	7.3	0.2	31.7	1.1	92.7
	February	33.2	11.2	11.3	0.5	24.0	0.7	92.3
	ANOVA	Orchard	$p<0.01$	NS[d]	NS	NS	$p<0.05$	NS
		Harvest	$p<0.001$	$p<0.01$	$p<0.01$	$p<0.001$	$p<0.01$	NS

[a]Incidence; [b]Severity; [c]The incidence of ripe fruit with disorders less than 5% severity; [d]Not significant

Cool-stored fruit

In general, fruit stored at 5°C took less time to ripen ($p<0.001$) and had a lower incidence and severity of stem-end rot and brown patches than fruit stored at 2°C (Table 2). Such general effects of temperature are in agreement with results obtained for fruit harvested in 2002/2003 and stored at 2°C or 5°C (Dixon *et al*., 2003). Fruit stored for 6 weeks at either 2°C or 5°C had greater incidences and severity of stem-end rot and brown patches than fruit stored for 4 weeks (Table 2). When averaged over all harvests the fruit stored at 5°C for 4 weeks had a greater incidence of sound fruit than fruit stored at 2°C for 4 weeks and could be considered to be of better quality overall.

There was an anomalous result for fruit harvested in October and stored at 2°C for 4

weeks where the incidence and severity of stem-end rot and brown patches was very high (Table 2). These fruit also had a very high incidence and severity of discrete patches (cold damage) on the green fruit and a high incidence and severity of diffuse flesh discolouration (chilling injury) in the ripe fruit (Figures 1 and 2). An examination of the temperature records for the cabinet used to store the fruit reveals that the cabinet air temperature was about 1.5°C ± 0.5°C for 2 of the 4 weeks of storage. Although this temperature was only about 0.5°C lower than the storage temperature over the 4 week storage period it may have been sufficient to greatly enhance chilling damage to the fruit. Both Pinkerton and Fuerte avocados have been shown to have a greater sensitivity to chilling injury as the storage temperature is reduced below 2°C (Bower and Magwaza, 2004). A high incidence and severity of cold damage may have greatly enhanced the development of rots during ripening giving an unusual result. Due to the uncertainties of the impact of severe cold damage on the fruit ripening behaviour and pathogen development the fruit harvested in October and stored at 2°C for 4 weeks was excluded from the statistical analysis.

Table 2. The effect of harvest month, storage temperature and storage duration on time to ripen and fruit quality for avocado fruit ripened after storage. Numbers in the table are average values for five trays per harvest orchard combination.

Harvest month	Temperature °C	Storage time weeks	Time to ripen Days	Stem-end rot Inc[a] %	Stem-end rot Sev[b] %	Brown patches Inc %	Brown patches Sev %	Sound fruit[c] Inc %
October	2	4	8.8[d]	40.0	3.0	71.7	22.7	40.7
		6	9.0	30.7	1.0	46.3	2.3	81.3
	5	4	6.6	4.0	0.1	18.0	0.4	97.3
		6	5.5	18.0	1.0	44.0	4.3	72.7
December	2	4	4.8	7.0	0.2	12.7	0.5	93.7
		6	5.8	34.3	2.5	70.7	15.0	48.0
	5	4	3.3	7.3	0.2	22.7	0.8	85.0
		6	3.3	17.0	0.9	41.3	5.0	66.0
February	2	4	5.1	16.3	0.6	34.7	5.9	83.0
		6	6.4	63.0	4.8	88.7	34.9	23.0
	5	4	3.2	8.7	0.3	24.0	0.9	93.0
		6	3.1	22.7	1.1	54.3	3.4	62.0
	2	4	4.9	11.7	0.4	23.7	3.2	88.3
		6	7.0	42.7	2.8	68.6	17.4	50.8
	5	4	4.4	6.7	0.2	21.6	0.7	91.8
		6	3.9	19.2	1.0	46.6	4.2	72.2
	2		6.2	30.3	1.8	50.6	11.7	65.8
	5		4.2	12.9	0.6	34.1	2.5	76.0
ANOVA	Temperature		p<0.001	p<0.001	p<0.001	p<0.001	p<0.001	p<0.001
	Storage time		p<0.001	p<0.001	p<0.001	p<0.001	p<0.001	p<0.001
	Harvest		p<0.001	p<0.001	p<0.001	p<0.001	p<0.001	p<0.001

[a]Incidence; [b]Severity; [c]The incidence of ripe fruit with disorders less than 5% severity; [d]Dark line represents data that was excluded from the statistical analysis

At 2°C there was a general overall decrease in the incidence of sound fruit from one harvest to the next (Table 2). At 5°C the decline in the incidence of sound fruit

depended on storage duration (Table 2). Fruit stored at 5°C for 6 weeks had a general overall decline in the incidence of sound fruit with harvest month but the fruit stored at 5°C for 4 weeks had a higher incidence of sound fruit in February than in December (Table 2). Fruit stored at 5°C for 4 weeks had the highest incidence of sound fruit when harvested in October or February. These results contrast to fruit harvested in 2002/2003 where for fruit stored at 5°C for 4 weeks the highest incidence of sound fruit was for fruit harvested in September and late October with February harvested fruit having the lowest incidence of sound fruit (Dixon *et al.*, 2003).

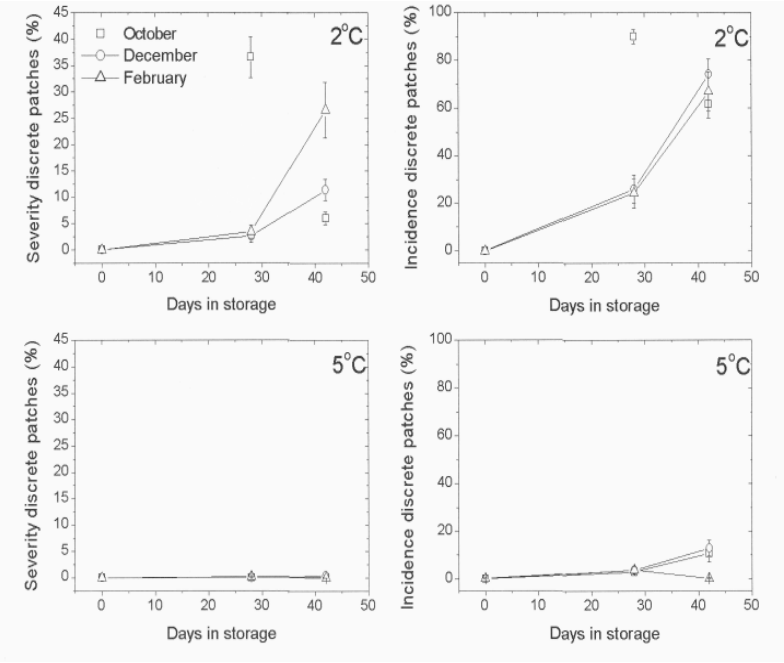

Figure 1. Changes in the severity and incidence of cold damage (discrete patches) after storage for 4 or 6 weeks at 2°C or 5°C for 'Hass' avocados harvested in October, December or February. Vertical bars represent the standard error of the mean of 15 trays of 20 fruit.

December harvested fruit stored at 2°C for 4 weeks was of good quality with a similar incidence of sound fruit as fruit harvested in October or February stored at 5°C for 4 weeks (Table 2). Fruit stored at 5°C for 4 weeks had the highest incidence of sound fruit when harvested in October or February. These results contrast to fruit harvested in 2002/2003 where for fruit stored at 5°C for 4 weeks the highest incidence of sound fruit was for fruit harvested in September and late October with February harvested fruit having the lowest incidence of sound fruit (Dixon *et al.,* 2003). December harvested fruit stored at 2°C for 4 weeks was of good quality with a similar incidence of sound fruit as fruit harvested in October or February stored at 5°C for 4 weeks (Table 2). The reason for this is not known but suggests that storage temperature could be adjusted in relation to the month of harvest as suggested previously (Dixon *et al.,* 2003). However, the same general trend observed in 2002/2003 of a decrease in fruit quality with late harvests was observed in the 2003/2004 harvest season. The authors previously proposed that there is a harvest month where fruit quality is optimum when avocado fruit are stored at 5°C for 4 weeks (Dixon *et al*., 2003). That the harvest month where quality was optimum did not follow the same pattern in fruit harvested in 2003/2004 as

in 2002/2003 suggests the degree of fruit maturity for optimum quality changes from year to year. The variance in results for optimum harvest month for 2002/2003 and 2003/2004 suggests that several years of data on fruit quality in relation to storage temperature and duration will be required to establish the relationship between maturity, storage temperature and duration.

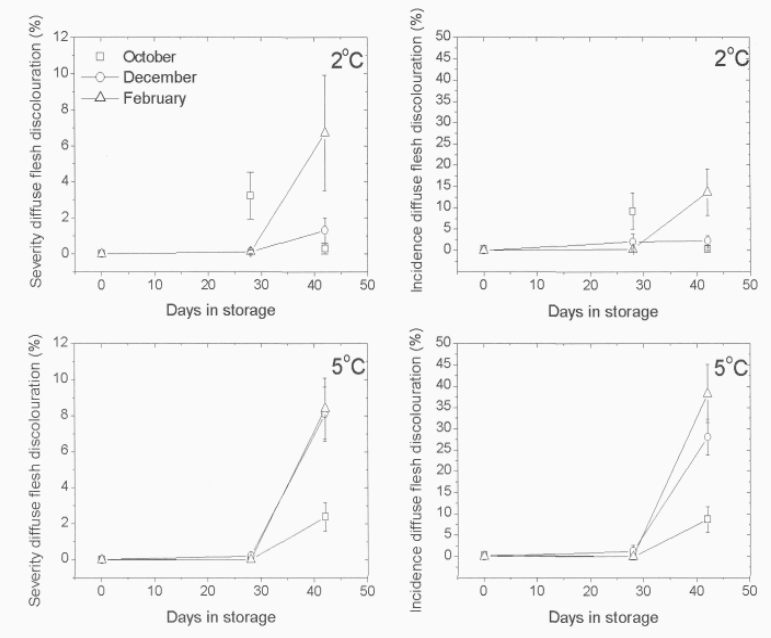

Figure 2. Changes in the severity and incidence of chilling injury in the flesh (diffuse flesh discoloration) after storage for 4 or 6 weeks at 2°C or 5°C for 'Hass' avocados harvested in October, December or February. Vertical bars represent the standard error of the mean of 15 trays of 20 fruit.

Chilling injury

Fruit stored at 2°C developed more discrete patches during storage in contrast to the fruit stored at 5°C that developed very few discrete patches (Figure 1). The incidence and severity of discrete patches increased with longer storage durations. The month of harvest only influenced the severity of discrete patches for fruit stored at 2°C for 6 weeks where the February harvested fruit had larger discrete patches than fruit harvested in October or December. The incidence of discrete patches was the same for fruit stored at 2°C regardless of storage duration. Internal chilling injury was related to both maturity and storage duration with the late season fruit having the greatest incidence and severity of diffuse flesh discolouration (Figure 2). The fruit stored for 6 weeks developed high levels of chilling injury while the fruit stored for 4 weeks had very little chilling injury in agreement with results obtained with fruit harvested in 2002/2003 (Dixon *et al*., 2003). The fruit stored at 5°C for 6 weeks developed greater incidence and severity of diffuse flesh discolouration compared to fruit stored at 2°C for 6 weeks. The reason for this is not known. These results would suggest that as long as the storage duration was kept to less than 4 weeks at 5°C internal chilling injury and cold damage will not be important quality disorders.

CONCLUSIONS

The month during which 'Hass' avocados were harvested affected fruit quality through changes to the incidence of chilling injury, ripening times, and the incidence and severity of rots in ripe fruit. For fruit stored at 5°C for 4 weeks the month of harvest where the incidence of sound fruit was greatest was about the same in 2003/2004 as in 2002/2003. February harvested fruit had better quality than December harvested fruit in 2003/2004 in contrast to fruit harvested in 2002/2003 where February harvested fruit had the poorest quality. The pattern of rot development in relation to maturity observed in 2003/2004 with increasing stem-end rots and decreasing body rots was opposite to that found in 2002/2003. For optimum quality for all months of harvest storage at 5°C for 4 weeks would be suitable. For fruit stored at 2°C for 4 weeks the optimum month of harvest was December. The duration of storage should not exceed 4 weeks to avoid chilling injury. Differences in the optimum month of harvest for fruit quality from year to year suggest that the ideal storage temperature and duration will change from year to year.

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