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NEW ZEALAND AVOCADO FRUIT QUALITY: THE IMPACT OF STORAGE TEMPERATURE AND MATURITY

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SUMMARY

New Zealand (NZ) 'Hass' avocados are exported from August to March. Little is known about the effect of maturity on NZ avocado fruit quality and sensitivity to chilling injury. We report on two trials, avocados were harvested early, mid and late season and stored either at temperatures ranging from 2°C to 7.5°C for 28 days or at 4°C for different storage durations with fruit removed every seven days for up to 42 days. The maturity of the fruit affected the incidence and severity of rots and chilling injury with mid season fruit were the least sensitive to chilling injury and generally had the lowest levels of rots. Late season high maturity fruit had the greatest levels of rots and chilling injury. It is suggested that for optimum quality NZ 'Hass' avocados should be stored at temperatures and durations appropriate to fruit maturity.

Key Words: time to ripen, body rot, stem end rot, chilling injury

INTRODUCTION

The NZ avocado industry is based on exporting fresh 'Hass' avocados (*Persea americana* Mill) over long distances to Australia and the USA. To achieve good quality outturns the post-harvest handling procedures must include effective temperature management through the post-harvest handling chain. Avocados in NZ are harvested for export for 8 months from late August (late winter) until early March (late autumn). The impact of increasing fruit maturity on the response of avocado fruit to storage temperature has not been fully defined for NZ 'Hass' avocados. Hopkirk *et al* (1994) recommended for NZ 'Hass' avocados is storage at 4 to 6°C for up to 4 weeks for optimal quality while fruit maintained at 0 or 2°C develop chilling injury symptoms and a high incidence of rots after 2 weeks storage. Research in South Africa has suggested that the sensitivity of avocado fruit to

chilling injury changes as the harvest season progresses (Toerien, 1986). However, the influence of maturity on chilling sensitivity characteristics of NZ 'Hass' avocados is not known. Storage temperature and duration of storage affects ripening time, the duration of which may influence the incidence and severity of rots (Hopkirk *et al*, 1994). The studies reported in this paper aim to define the chilling injury response of NZ Hass avocado fruit to temperature and time in storage and to characterise the response of fruit quality parameters to temperature during the NZ avocado export harvest season.

MATERIALS AND METHODS

There were two trials: the effect of storage temperature on fruit quality and the effect of fruit age and maturity on fruit quality. Avocado fruit (cv. 'Hass') were harvested from three commercial orchards in the Bay of Plenty region (37°S, 176°E), North Island of NZ. There were three harvests from each orchard for the storage temperature trial (harvest 1: 2-5/9/2002, harvest 2: 29/10-1/11/2002, harvest 3: 10-14/2/2003) and three harvests (fruit age harvest 1: 4/9/2002, fruit age harvest 2: 31/10/2002, fruit age harvest 3: 7/1/2003) for the fruit age and maturity trial. In the storage temperature trial fruit were transported to the laboratory within 4 h of harvest and placed at 2°C, 3°C, 4°C, 5°C or 7.5°C, 85% RH. A total of 100 fruit per orchard per harvest were stored for 28 days before removal to 20°C for ripening. In the fruit age trial fruit were placed into a commercial cool store at 4°C where a sample of 100 fruit per orchard per harvest was removed from storage every seven days to 20°C for ripening. In each trial a non-stored control sample of 100 fruit per orchard per harvest was ripened at 20°C, 60% RH, immediately after harvest. A 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 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. Ripeness was determined by firmometer when the fruit reached a softness reading of 85 using a 300g weight or by hand feel after calibration to a firmometer. Fruit were assessed for disorders according to the Avocado Industry Council Fruit Assessment Manual (2001). Disorders were rated by assessing the percentage (scale 0 to 100) of the cut surface of the fruit or skin surface area that was affected by disorders. Green fruit were rated for discrete patches (brown to black sunken lesions with sharp discrete edges). The cut surface of ripe fruit was rated for stem end rot (discoloured flesh from the stem button down) and diffuse flesh discolouration (greying of the flesh with indistinct edges). The under side of the peeled skin was rated for brown patches (body rot as circular brown coloured patches).

Each trial was analysed as a repeated measures trial with harvests nested within orchards. Binary logistic regression analysis (MINITAB) was used to determine differences in incidences.

RESULTS AND DISCUSSION

Non-stored fruit

Fruit dry matter increased with each harvest from an average of 24.2% in September, to 34.3% in February. The time to ripen decreased ($p<0.001$) with each harvest and increasing dry matter (Table 1). The average incidence of stem end rot tended to decrease with each harvest but was not significantly different between orchards (Table 1). By contrast the average incidence of body rots was lowest for the early harvest. Average severity of stem end rot was low across all harvests while the severity of body rots was lowest in the early harvest. Overall quality of the ripe fruit was good with greater than 90% of ripe fruit having disorders with less than 5% severity.

Cool-stored fruit

As in non-stored fruit the average incidence and severity of stem end rot tended to decrease with harvest ($p<0.001$) and temperature ($p<0.001$) while the average incidence and severity of body rot tended to increase with temperature ($p<0.001$) and harvest ($p<0.001$, Table 2). Time to ripen decreased with increasing temperature ($p<0.001$) and harvest ($p<0.001$, Table 2). Overall, quality of ripe fruit was good with the incidence of sound fruit changing with harvest. The best quality fruit were in harvest 2 with the earlier and later harvests having poorer quality in agreement with Cutting and Wolstenholme (1992). This suggests there may be a maturity where fruit quality is optimum when fruit are stored for 28 days. The incidence of sound fruit was similar for harvests 1 and 2 at temperatures of 5 to 7.5°C and but was lower at 2°C for harvest 3 fruit. The difference in behaviour of stem end and body rots as the season progressed may be related to a differential effect of temperature and duration of storage on spore survival and fungal growth rates. Storage at temperatures between 4 to 10°C has been shown to kill spores of avocado rot fungi but latent infections were unaffected (Everett, 1998 unpublished results).

Chilling injury

The incidence and severity of discrete patches on avocado skin depended on the storage temperature, duration of storage and fruit maturity (Figures 1 and 2). The fruit harvested early and late in the export season had the greatest levels of discrete patches at temperatures below 5°C and had the lowest levels of discrete patches in the middle of the harvest season (Figure 1). Diffuse flesh discolouration was related to fruit maturity with no symptoms apparent until harvest 3 (Figure 1). Discrete patches appeared after 21 days storage at 4°C for fruit age harvest 3 but were at very low levels in fruit age harvests 1 and 2 (Figure 2). By contrast diffuse flesh discolouration appeared after 35 days storage for fruit age harvests 2 and 3 as has been reported for South African avocados (Vorster et al, 1988). The increased incidence of discrete patches and diffuse flesh discolouration in late season NZ avocados is in contrast to the decreased chilling sensitivity of late season South African avocados (Toerien, 1986) and would suggest that for NZ 'Hass' avocados storage temperatures could be adjusted up or down in relation to maturity over the export harvest season for optimal fruit quality.

There was a differential effect of ripening time on rot incidence and severity over the different harvests. Cool-stored fruit from harvest 1 had ripening times that were longer than for harvests 2 and 3 (Table 2). The fruit from harvest 1 had greater incidence and severity of stem end rot than fruit from harvests 2 and 3 (Table 2). However, cool-stored fruit from harvest 3, despite ripening in about half the time of fruit from harvest 1, had greater incidence and severity of body rot than fruit from harvest 1. If rot development proceeds at a rate dependant on temperature then short ripening times should result in fruit with fewer and less severe rots independent of other factors. That the relationship between ripening time and incidence and severity of rots was not consistent for all harvests suggests that fruit maturity factors may override the influence of ripening time late in the harvest season. Further experimentation is required to identify the interaction between ripening time, maturity and rot development.

CONCLUSIONS

Maturity of NZ Hass avocados affected fruit quality by changing the sensitivity of the fruit to chilling injury and the incidence and severity of fruit with rots. There was a differential effect of ripening time on rot incidence and severity with maturity. The relationship between fruit ripening times and the development of fruit quality disorders needs to be further defined to allow ripening factors, such as maturity, to be isolated from ripening time. For optimum quality it is suggested NZ Hass avocados be stored at about 5°C in the early season, the temperature could then be lowered to

4°C mid season but should be raised late season to 7°C. In addition, the duration of storage should not exceed 28 days to avoid chilling injury.

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Table 1. The effect of orchard and harvest month on dry matter, time to ripen and fruit quality for non-stored avocados from the storage temperature trial ripened immediately after harvest.

Orchard	Harvest	Dry Matter %	Time to ripen days	Stem end rot		Body rot		Sound fruit[b] %
				Inc[a] %	Sev %	Inc %	Sev %	
1	1	23.3	16.5	6.0	0.1	16.0	0.7	96.0
	2	27.7	16.8	2.0	0.0	19.0	0.8	97.0
	3	32.7	10.0	5.0	0.1	26.0	0.9	96.0
2	1	25.0	15.0	11.0	0.1	17.0	0.8	96.0
	2	30.3	12.0	3.0	0.2	34.0	1.1	91.0
	3	36.2	8.0	0.0	0.0	25.0	1.0	95.0
3	1	24.2	17.0	10.0	0.2	16.0	0.6	96.0
	2	27.1	15.0	9.0	1.1	42.0	3.4	76.0
	3	34.0	8.7	1.0	0.1	43.0	1.6	97.0
ANOVA		Orchard	NS[c]	NS	p<0.05	p<0.001	p<0.01	p<0.001
		Harvest	p<0.001	p<0.001	p<0.05	p<0.001	p=0.01	NS

[a] Significance levels estimated using binary logistic regression analysis; [b] The incidence of ripe fruit with disorders less than 5% severity; [c] Not significant

Table 2. The effect of storage temperature on time to ripen at 20°C and fruit quality of avocados stored for 28 days then ripened at 20°C

Temperature Cº	Harvest	Time to ripen days	Stem end rot		Body rot		Sound fruitc[b] %
			Inc[a]	Sev	Inc	Sev	
2	1	8.9	19.1	1.4	22.1	1.7	83.0
	2	7.7	8.7	0.3	21.7	1.1	91.0
	3	4.9	6.3	0.2	42.7	4.8	75.3
3	1	10.4	26.3	1.2	20.3	1.0	83.7
4	2	6.6	8.0	0.2	16.0	1.0	92.3
	3	3.9	5.3	0.1	39.0	1.6	92.0
5	1	8.8	12.3	0.4	7.3	0.3	94.3
	2	4.9	9.0	0.1	16.0	0.7	95.3
	3	3.1	5.0	0.2	45.0	3.1	86.0
7.5	1	4.3	5.7	0.1	10.0	0.4	96.3
	2	3.1	2.0	0.0	5.7	0.2	96.7
	3	1.2	7.0	0.2	47.3	2.1	88.0
ANOVA	Temp	p<0.001	p<0.001	p<0.001	p<0.001	p<0.01	p<0.001
	Harvest	p<0.001	p<0.001	p<0.001	p<0.001	p<0.001	p<0.001

[a] Significance levels estimated using binary logistic regression analysis; [b] The incidence of ripe fruit with disorders less than 5% severity

Figure 1. Changes in incidence and severity of cold damage (discrete patches) and chilling injury in the flesh (diffuse flesh discolouration) after 28 days storage at various temperatures for each harvest. Vertical bars represent the standard error of the mean of 300 fruit.

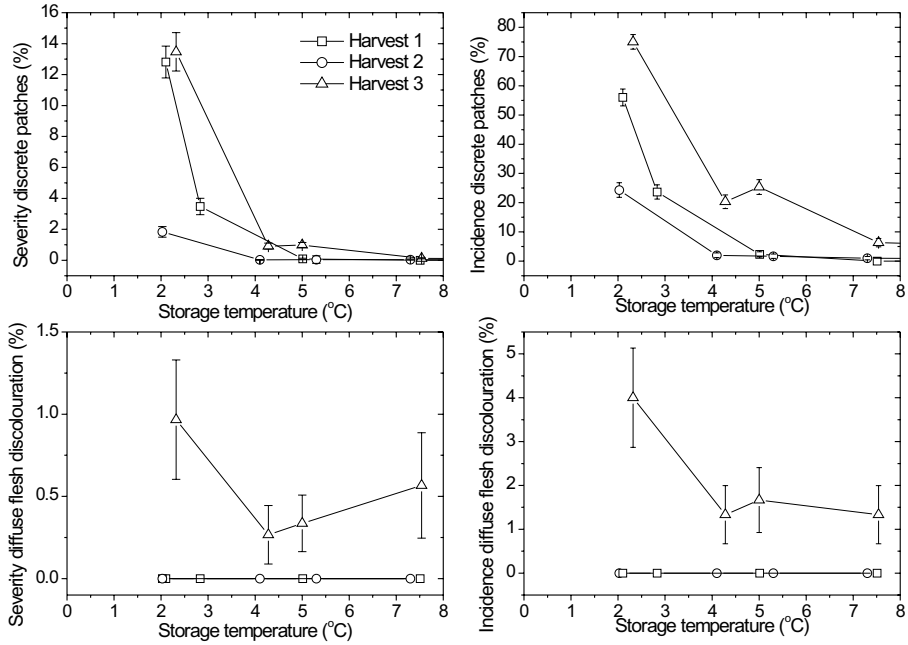

Figure 2. Changes in incidence and severity of cold damage (discrete patches) and chilling injury in the flesh (diffuse flesh discolouration) after storage at 4°C for different time periods for each harvest. Vertical bars represent the standard error of the mean of 300 fruit.