EFFECTS OF PREPACKING HOLDING TEMPERATURES ON SHELF LIFE QUALITY OF HASS AVOCADOS

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ABSTRACT

The effect of holding temperature (7°C, just above dew point temperature (16°C), 20°C and ambient temperature) prior to packing on fruit quality after subsequent storage was investigated. Holding fruit at just above the dew point temperature (approx. 16°C) for 24 or 48 hours before packing resulted in minimal water loss and decreased the potential for rots compared to holding fruit at 7°C which resulted in the lowest weight loss, rate of ripening and stem end rots, but higher levels of fuzzy patches and body rots. Holding fruit at 20°C or at ambient temperature conditions enhanced the incidence of fuzzy patches, stem end and body rots, and resulted in faster ripening than holding fruit at 7 or 16°C.

Irrespective of holding conditions, rot incidence was higher when fruit were held for 48 hours compared to 24 hours prior to packing. With each additional days delay approximately. a 3 to 10% increase in rots can be expected. Overall, orchards and treatments with higher weight loss tended to have higher incidence of rots. While holding conditions prior to packing can influence the inherent rot potential and ripening rate of fruit, there is no standard holding condition that optimises fruit quality as holding time and temperature had differential and interacting effects on fruit quality. However, as best practice guidelines it is recommended that fruit are packed within 24 hours of harvest, and when fruit are held prior to packing they are held at temperatures slightly above the dew point and not at low temperature (7°C).

Keywords: holding temperatures, weight loss, firmness, ripening, fuzzy patches, stem end rots, body rots

INTRODUCTION

Following major problems with fruit quality in the USA market in 1999, the AIC introduced a series of best practice guidelines for postharvest handling and storage of New Zealand avocados destined for export markets (AIC 2000a, USA Best Practice Manual). In the absence of specific studies, much of the guidelines for best postharvest practices were based on general principles rather than on specific data. Nevertheless, the quality of New Zealand fruit in the USA market has improved but the occurrence of rots continues to be an issue and it is not clear whether the improvement in quality is due to the changes in best practice that were introduced, or to other factors that have also changed such as seasonal factors and shipping methods.

Currently, packhouse operators are encouraged to hold fruit after harvest for no longer than 48 hours before packing but holding conditions are not strictly defined, and in practice, vary from storage temperatures to ambient conditions. Handling prior to packing may impact on the quality of ripe avocados, and in particular the temperatures that fruit are exposed to for varying lengths of time may have a "curing" effect. In order to determine best practice more specifically, the effect of holding temperatures and periods prior to packing on the quality of Hass avocados during shelf life was studied.

MATERIAL AND METHODS

Freshly harvested fruit (approx. 20 count) were selected from field bins from 3 Bay of Plenty orchards (designated O1, O2 and O3) on 21/1/02, placed into WP47 crates and transported to HortResearch (Mt Albert, Auckland).

Four crates from each orchard were randomly allocated to each of four holding temperature treatments: 7°C, just below the dew point (16°C), 20°C, or at ambient temperatures. After 24 or 48 hours, fruit were passed across brushes and packed into single layer trays. Fruit and air temperatures, relative humidity and weight loss were recorded during the holding period.

Packed fruit were stored at 5°C for 4 weeks, and then transferred to 20°C for shelf life assessments. Fruit were assessed for rate of ripening, firmness (using an Anderson firmometer), skin colour, respiration and ethylene production rate, the incidence of rots (fuzzy patches, stem end rots and body rots) and weight loss. Subjective assessments of fruit firmness, skin colour, rots and disorders were made using the method and 0 to 100% rating scales described in the AIC Avocado Assessment Manual (AIC, 2000b). Results were analysed by ANOVA in order to identify significant effects of duration, holding temperature, and/or orchard at a $p<0.05$ level.

RESULTS

The ambient temperatures fruit were exposed to during the holding periods ranged from approx. 14°C to 28°C, whereas for the 7°C, 16°C (dew point) or 20°C treatments, air temperatures remained within 1°C throughout the holding periods (Figure 1). Relative humidity changed with the change in ambient temperature and ranged from approx. 40 to 80 % in the ambient temperature treatment, from approx. 60 to 80% for the 20°C treatment, and from approx. 85 to 95% for the 7 and 16°C treatments (Figure 1).

Weight loss

Over the 48 hour holding period weight loss was in the approx. range 0.45 to 1.80% and was least when fruit had been held at 7°C and highest for fruit held at ambient conditions (Table 1). In general, this pattern was maintained throughout 4 weeks coolstorage. After 2 days shelf life, accumulative weight loss was approximately 2.65% and similar between the holding treatments. Although weight loss was significantly different for fruit from different orchards, orchards responded to holding treatments in a similar pattern.

Table 1. Weight loss from Hass avocados after holding at different emperatures for 24 or 48 hours, coolstorage for 4 weeks at 5 °C, and subsequent 2 days shelf life at 20°C. Fruit were held in crates prior to coolstorage and the packed into trays for storage; n = 45.

Duration	Holding temperature	Weight loss (%) after		
		Holding period	4 weeks storage	2 days shelf life
24 hours	7°C	0.34	1.70	2.61
	16°C	0.47	1.85	2.66
	20°C	0.78	1.72	2.65
	Ambient	0.92	1.92	2.68
	Mean	***0.63***	***1.80***	***2.65***
48 hours	7°C	0.45	1.83	2.53
	16°C	0.70	1.86	2.83
	20°C	1.31	1.77	2.46
	Ambient	1.77	1.94	2.73
	Mean	***1.06***	***1.85***	***2.64***
Statistical analysis:				
p values	*Duration*	*<0.001*	*0.176*	*0.860*
	Temperatures	*<0.001*	*<0.004*	*0.045*

Firmness

In general, after storage, fruit held at 7°C tended to be firmer (lower firmometer value) but not significantly firmer than fruit held at higher temperatures (Table 2). Similarly, fruit held at ambient tended to be softer than fruit held at other temperatures. Fruit held for 24 hours prior to storage were significantly firmer than fruit held for 48 hours and this difference was maintained during shelf life. Orchard 2 was significantly softer than fruit from O1 and O3.

Rates of ripening

Fruit reached the ripe stage after 2 days at 20°C following removal from storage (Figure 2). Holding treatments had a significant effect on the initial ripening rates of fruit (for duration on day 3, and temperatures on days 3, 4 and 5), but after 5 days of shelf life, the numbers of fruit at the ripe stage was not different between holding treatments. In the first 3-4 days of shelf life, fruit held for 24 hours ripened more slowly than fruit held for 48 hours, and fruit held at 7°C ripened more slowly than fruit held at 16°C, 20°C or ambient. Fruit held at ambient tended to ripen faster than other fruit.

In general, there was no relationship between the time for 50% of fruit to reach the ripe stage and weight loss during the holding period, or only a slight trend for fruit that had greater weight loss to ripen earlier.

Table 2. Firmometer readings from Hass avocados during shelf life at 20°C after holding at different temperatures for 24 or 48 hours prior to coolstorage for 4 weeks at 5°C, n = 15.

Duration	Holding temperature	Firmometer (mm) value on shelf life	
		Day 0	Day 3
24 hours	7°C	1.84	7.36
	16°C	1.89	7.96
	20°C	1.93	8.31
	Ambient	1.89	7.87
	Mean	***1.89***	***7.89***
48 hours	7°C	2.06	8.43
	16°C	1.97	8.63
	20°C	1.97	8.88
	Ambient	2.12	8.08
	Mean	***2.03***	***8.50***
Statistical analysis:			
p values	*Duration*	*0.015*	*0.004*
	Temperatures	*0.828*	*0.081*

Fuzzy patches

After 3 days of shelf life, more than 40% of the fruit had developed fuzzy patches (Table 3). Although, the effects of holding temperature were not consistent over the holding periods, there was a trend for fruit held at 7°C to have higher levels of fuzzy patches than fruit held at other temperatures, and for a significantly higher incidence of fuzzy patches when fruit were held for 48 hours compared to 24 hours.

Table 3. Incidence of fuzzy patches on Hass avocados after 3 days shelf life at 20°C, following holding at different temperatures for 24 or 48 hours, prior to coolstorage for 4 weeks at 5°C, n = 18.

Holding temperature	Incidence of fuzzy patches after holding for	
	24 hours	48 hours
7°C	51.0	57.2
16°C	41.2	49.8
20°C	32.7	53.7
Ambient	51.4	43.0
Mean	*44.1*	*50.9*
LSD	*12.50*	*NS*

Fruit from O1 tended to have similar levels of fuzzy patches irrespective of the holding treatment, and the effect of a holding temperature was not consistent across orchards (data not shown). There was no significant relationship between the amount of weight loss during the holding period and the incidence of fuzzy patches (data not shown).

Stem end rots

Stem end rots became apparent in ripe fruit after 3 days shelf life, and up to approx. 40 to 50% of the fruit had developed stem end rots after 6 days (Figure 3). Both duration and holding temperature had a significant effect on the incidence of stem end rots. Overall, fruit held at 7°C tended to have lower incidence of stem end rots compared to fruit held at other temperatures, although initially on day 3 and 4 of shelf life, fruit from both 7°C and 20°C had lower stem end rots than fruit held at 16°C or at ambient temperatures. Stem end rots were significantly higher for fruit held for 48 hours compared to fruit held for 24 hours.

There was also a trend for fruit with higher weight loss during the holding period to have a higher incidence of stem end rots during 3 and 6 days shelf life compared to fruit with lower weight loss during the holding period (Figure 4).

Body rots

Body rots were visible externally on some unripe fruit but most body rots developed as fruit softened and ripened and the skin became black. Approx. 60 to 70% of the fruit had developed a body rot at the end of 6 days of shelf life at 20°C (Figure 5). Initially, both duration and holding temperature had significant effects on the incidence of body rots, but on days 5 and 6, the effects of duration or holding temperature were not significant.

On day 3, the incidence of body rots amongst fruit held for 24 hours was approx. half that amongst fruit held for 48 hours but over the next 3 days this difference was reduced to nil. Fruit held at 7°C or 20°C tended to have a lower incidence than fruit held at ambient or 16°C on days 3 and 4, but these differences were not consistent throughout shelf life, and on days 5 and 6 fruit held at 16°C for 24 hours had the lowest incidence of body rots.

There was a trend for fruit with higher weight loss during the holding period to have a higher incidence of body rots after 3 days shelf life compared to fruit with lower weight loss (Figure 6). The relationship between weight loss during the holding period and body rots was not as strong after 4 or 5 days shelf life (data not shown) and there was no relationship after 6 days.

Orchards

When orchards are compared overall, O2 had the highest weight loss during the holding period and subsequently had the highest incidence of fuzzy patches, stem end rots and body rots and the more ripe fruit on a specific day of shelf life (Table 5). Orchard 1 and O3 had similar levels of ripe fruit and disorders during shelf life, but there was a trend for O3 to have the lowest incidence of ripe fruit and disorders.

Table 4. Orchards O1, O2, O3 identified with the highest or lowest incidence of weight loss (WL), ripe fruit, fuzzy patches (FP), stem end rots (SER) or body rots (BR) during shelf life at 20°C after holding at different temperatures for 24 or 48 hours and then coolstorage at 5°C for 4 weeks. Identification is based on values for WL on day 2 of shelf life, FP on day 3, ripe fruit on day 4, and days 4 and 6 for SER and BR.

Duration	Temp	Incidence	WL	Ripe	FP	SER	BR
24 hours	7 °C	Highest	O2	O1	O2	O2	O1
		Lowest	O1	O2	O3	O1	O3
	16 °C	Highest	O2	O2	O2	O2	O2
		Lowest	O1	O3	O3	O3	O3
	20 °C	Highest	O2	O1	O2	O2	O2
		Lowest	O3	O3	O3	O3	O3
	Ambient	Highest	O2	O2	O2	O2	O2
		Lowest	O3	O1	O1	O3	O3
48 hours	7 °C	Highest	O2	O2	O2	O2	O2
		Lowest	O1	O3	O3	O3	O3
	16 °C	Highest	O2	O2	O2	O2	O2
		Lowest	O1	O3	O3	O3	O3
	20 °C	Highest	O2	O2	O2	O2	O2
		Lowest	O3	O3	O3	O1	O1
	Ambient	Highest	O2	O1	O2	O2	O2
		Lowest	O3	O3	O3	O3	O3

DISCUSSION

Temperatures during the holding period prior to packing significantly affected water loss from fruit, and although these effects were not always clearly related to the incidence of rots during shelf life after storage, overall, there was a trend for more rots to be associated with higher rates of water loss during the holding period. For example, early in shelf life fruit with double the weight loss during the holding period could have approx. 10% higher incidence of stem end or body rots. The variability in the relationship between water loss and rot incidence may be accounted for by several factors including orchard differences, the occurrence of ripening and development of rots over several days, and storage time.

Whilst overall the responses of orchards to holding treatments were similar, within specific treatments and specific days of shelf life, ranking between orchards varied, and the incidence between orchards was often greater than the difference between treatments. In addition, some interactions between treatment and orchards were statistically significant, which indicates that the effect of treatment is not consistent at all combinations of the other treatments, and therefore, an unambiguous interpretation of the main effects was not always possible. Therefore, orchards factors and in particular the inherent rot potential may have overridden postharvest treatment effects, especially where the rot potential and hence incidence was very high. The use

of late season fruit in this study and the generally wet season was favourable to high disease expression. A shorter storage duration than 4 weeks may have been more useful to detect treatment differences in orchards where the rot incidence was relatively high, i.e. with lesser storage time, differences between treatments may have been greater than between orchards.

Typically, based on logistics, fruit are harvested between 2 to 11 days prior to shipping. Therefore, packhouse handling and storage conditions will vary and various permutations of holding temperatures and storage conditions can be anticipated. Aside from fluctuating ambient conditions, the time fruit are held in a specific condition is likely to be the next most important variable given that coolstores are all set at the same temperatures (although cooling rates will vary according to the airflows present in the coolstores).

Holding fruit for 48 hours resulted in more rots than when fruit were held for 24 hours irrespective of the holding temperature prior to packing. More rots could be expected if the duration was longer than 48 hours but this would need further evaluation with respect to the specific holding conditions. However, given the limited permutations studied to date, prediction of the effect of various combinations of holding conditions on incidence of rot is not readily possible, although based on current data, a 5 to 10% increase in rots can be expected for each additional day before packing.

The effects of the different holding conditions assessed in this study tended to become similar once fruit were held for 48 hours. This suggests that beyond a set time and/or degree of water loss, the impact of the holding condition was overridden, and the chances of reducing the inherent potential of the fruit to rot are reduced or negated irrespective of the holding permutation. However, it should be noted that fluctuating ambient temperature conditions and holding fruit at 7°C resulted in a higher incidence of body rots, and therefore, when holding permutations are being considered, time in these conditions should be avoided or minimised.

SUMMARY

It is concluded that:

- The inherent rot potential and ripening rate of fruit at harvest can be influenced by holding conditions prior to packing. However, overall there is no standard holding condition that optimises fruit quality because time and temperature have differential effects on fruit quality parameters and there is some interaction between them.
- Holding fruit at high temperatures and low RH, (e.g. 20°C or ambient summer conditions), enhances incidence of fuzzy patches, stem end and body rots, and results in faster ripening. Holding fruit at lower temperatures (5-7°C) decreases stem end rots and body rots but increases fuzzy patches, and ripening may be slower.
- Water loss from fruit during the holding period is related to rot incidence during shelf life but is also related to the temperature under which water loss occurs.

- Holding fruit at just above the dew point, which will be in the range 12-16°C, will result in minimal water loss and decrease the potential for rots during shelf life.
- Irrespective of the holding condition, rot incidence is higher when fruit are held for 48 hours than 24 hours prior to packing, and with each additional days delay approx. a 3-10% increase in rots can be expected.
- The study should be repeated as: orchard differences and interactions with treatment effects confounded the interpretation of results; the effects were tested on late season fruit only; only limited permutation of the holding conditions were tested; and it was not possible to establish whether there was an effect on rots through ripening or an effect on rots *per se*.

As best practices guidelines, it is recommended that:

- fruit are packed within 24 hours of harvest
- fruit are held at temperatures slightly above dew point when held prior to packing
- fruit are not held fruit at 7°C before packing.

REFERENCES

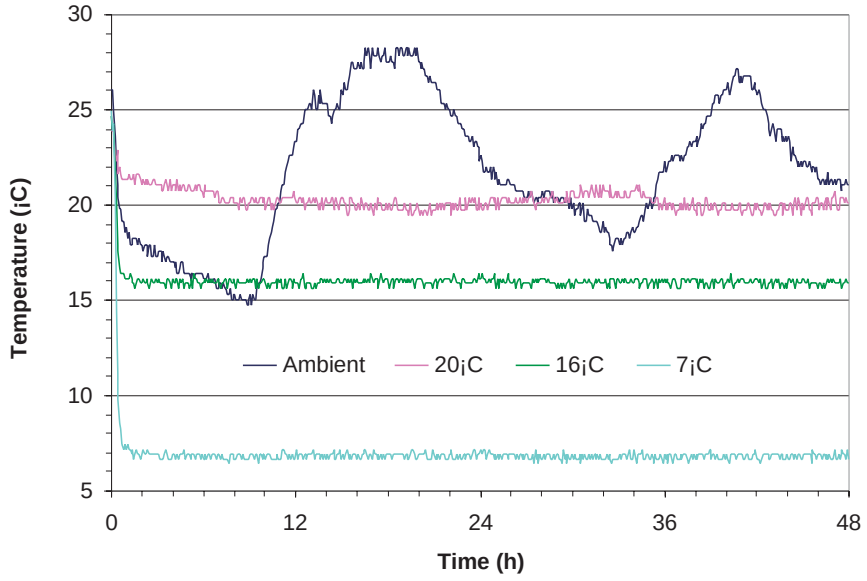
AIC, 2000a. USA Best Practice Manual, NZ Avocado Industry Council Ltd., July 2000, 18 pp.

AIC, 2000b. Avocado Assessment Manual, NZ Avocado Industry Council Ltd., 2000, 32 pp.

ACKNOWLEDGEMENTS

We are grateful to AIC for financial support for the trial, Henry Pak, Jonathon Dixon and Jonathon Cutting for discussions on trial design and results, and Global Fresh, Bridgecool, Aongatete, Katipak and Apata for assistance with fruit supply.

A)



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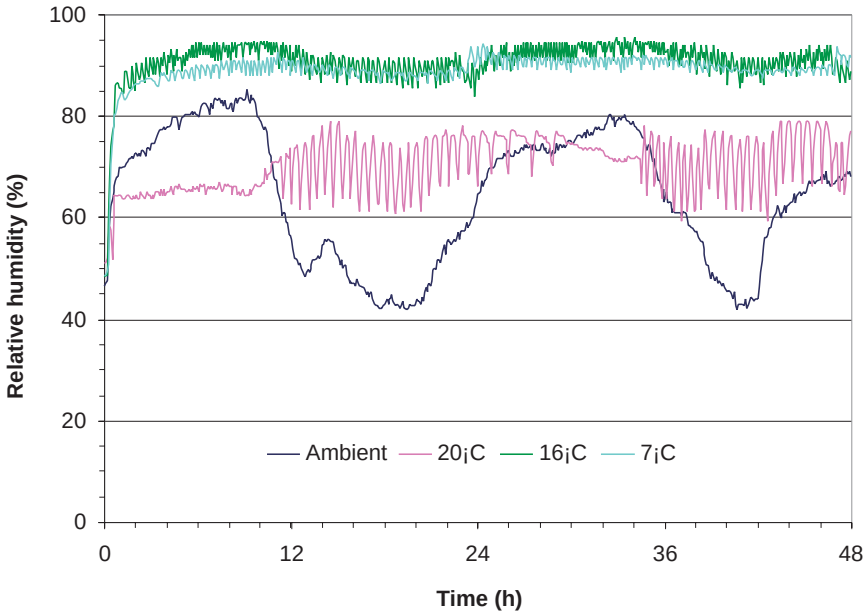

Figure 1. Temperature (A) and relative humidity (B) of the air during holding of fruit at 7°C, 16°C, 20°C, or ambient conditions for up to 48 hours.

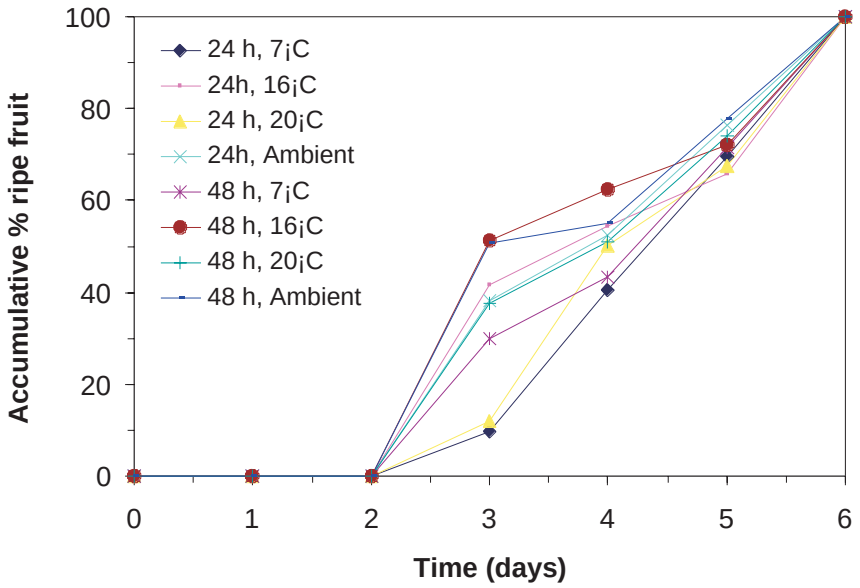

Figure 2. Accumulative number (%) of Hass avocados at the ripe stage during shelf life at 20°C after holding for 24 or 48 hours at different temperatures (7°C, 16°C, 20°C, ambient) prior to coolstorage for 4 weeks at 5°C, n = 15.

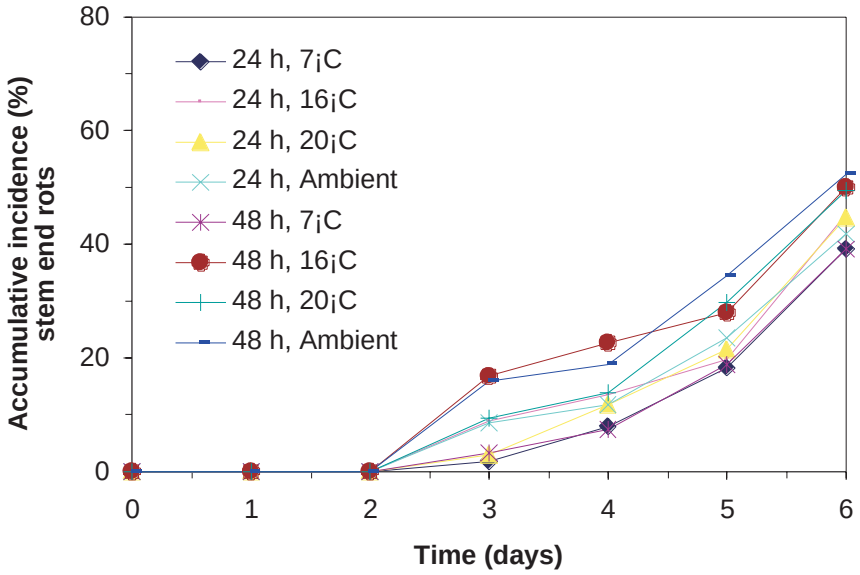

Figure 3. Accumulative incidence (%) of stem end rots in Hass avocado fruit assessed at the ripe stage during shelf life at 20°C after holding at different temperatures for 24 or 48 hours prior to coolstorage for 4 weeks at 5°C. Values are based on ripe and unripe fruit per treatment, n = 18.

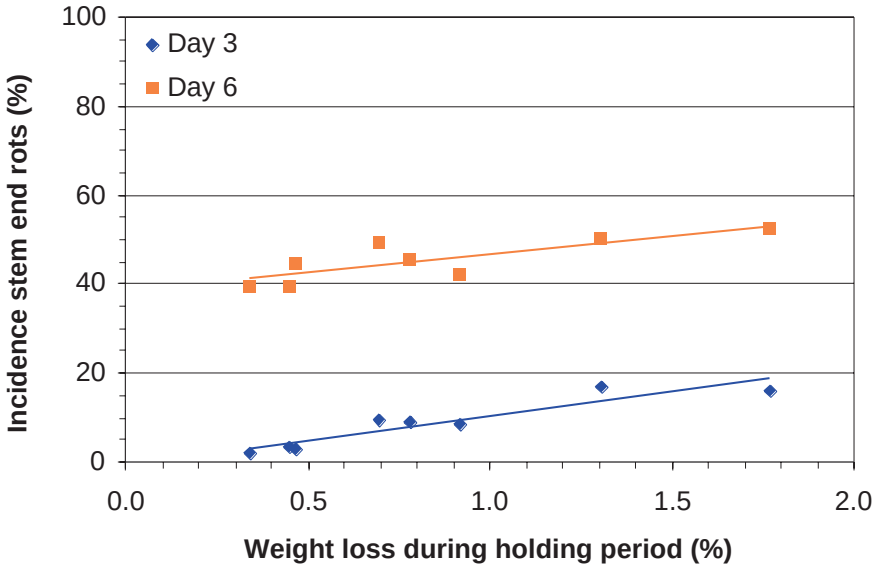

Figure 4. Relationship between the incidence of stem end rots in Hass avocados on days 3 and 6 of shelf life at 20°C and weight loss from fruit during holding at different temperatures for 24 or 48 hours prior to coolstorage for 4 weeks at 5°C, n = 18 (Day 3, R^2 = 0.86, and Day 6, R^2 = 0.64).

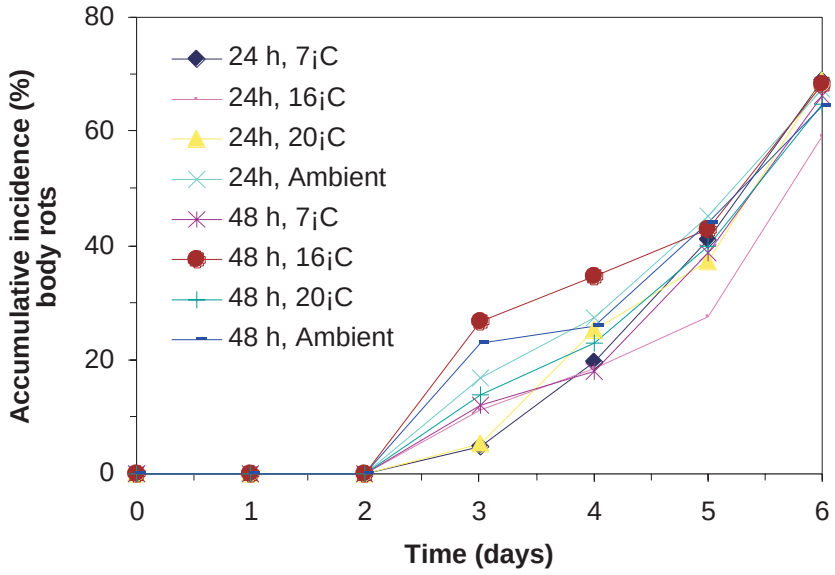

Figure 5. Accumulative incidence (%) of body rots in Hass avocado fruit assessed at the ripe stage during shelf life at 20°C after holding at different temperatures for 24 or 48 hours prior to coolstorage for 4 weeks at 5°C. Values are based on ripe and unripe fruit per treatment, n= 18.

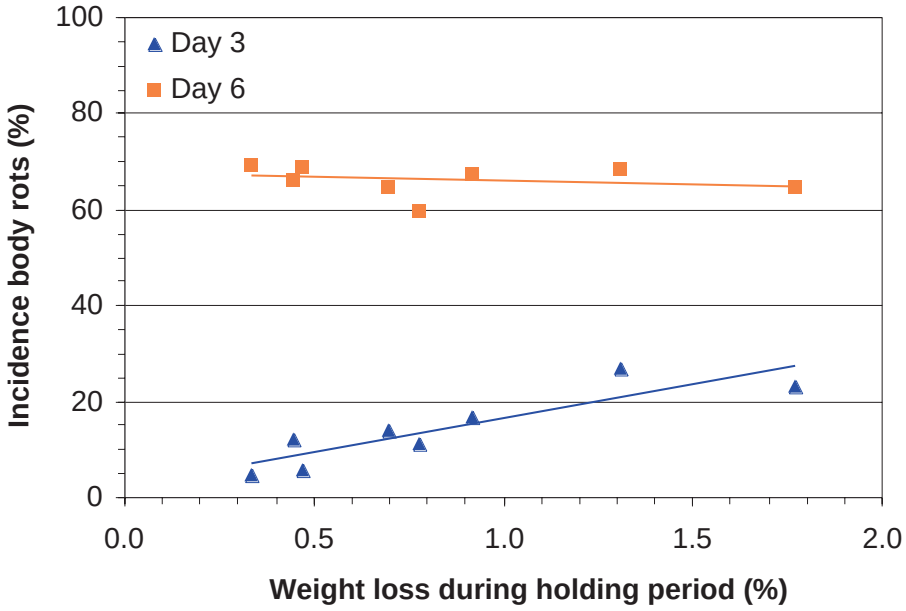

Figure 6. Relationship between the incidence of body rots in Hass avocados on days 3 and 6 of shelf life at 20°C and weight loss from fruit during holding at different temperatures for 24 or 48 hours prior to coolstorage for 4 weeks at 5°C, n = 18 (Day 3, R^2 = 0.78, and Day 6, R^2 = 0.04).