EFFECTS OF AIRFLOWS DURING STORAGE OR SHIPPING ON SHELF LIFE QUALITY OF HASS AVOCADOS

C. Yearsley, N. Lallu, J. Burdon, D. Billing, M. Punter and S. Osman

HortResearch, Private Bag 92 169, Auckland
Corresponding author: cyearsley@hortresearch.co.nz

ABSTRACT

The expression of rots and the ripening rate of fruit were influenced by airflow conditions in the range expected during commercial holding, storage and transport of avocados. In this study, fruit from the lowest airflow treatment (0.2 m/sec) were approx. 0.4°C warmer than in the fastest airflow treatment (1.2 m/sec). After 4 weeks storage at 5°C, fruit from the lowest airflow had the highest weight loss and tended to have a higher rate of ripening, and incidence of fuzzy patches during shelf life at 20°C. The effect of airflow treatments on the incidence of stem end rots and body rots was confounded by differences between orchards. However, in general, fruit from the orchard with the lowest weight loss during storage had the lowest incidence of rots during shelf life, and fruit from the orchard with the highest weight loss had the highest incidence of rots.

It is concluded that the effect of airflow on fruit quality will depend on how it affects fruit temperature and the degree of water loss. Either high or low airflow can lead to higher water loss and thereby an increase in fuzzy patches, stem end rots, or body rots. The effect of airflow on water loss can be negligible or less than the effect of storage temperature on water loss. Overall, an increase in water loss of 0.5% over the storage period is likely to increase fuzzy patches, stem end rots or body rots by approx. 0 to 15%, approx. 5 to 10%, and approx. 7 to 20%, respectively. As best practices guidelines, it is recommended that once fruit are cooled, airflow be maintained at 0.2 to 0.6 m/sec.

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

INTRODUCTION

During 1997 to 1999 avocados were exported to the USA in shipping containers and controlled atmospheres (CA's) were extensively used. In recent years, the use of containers and CA has lost favour, and reefer shipping has become the predominant or preferred transport mode because of costs and shorter transit times compared to container shipping. Whilst fruit are arriving in good condition and rots have been lower following reefer shipment than container shipment, fruit are often 'sprung' (i.e. slightly rubbery to the touch) indicating the fruit have started to ripen during transit. This is thought to be a consequence of higher weight loss resulting from high airflow and/or high rates of fresh air exchange during reefer shipping.

Given the generic nature of the best practice guidelines for handling and shipping avocados, further improvements in quality are likely to be achieved if optimum storage and reefer shipping conditions are defined. In this study the effects of airflow rates of 0.2, 0.8, 1.2 or 2.0 m/sec during simulated reefer vessel shipping on the shelf life quality of Hass avocados was determined.

MATERIAL AND METHODS

Commercially packed Hass avocados (count 20-25) from 4 orchards (designated O1, O2, O3 and O4) were obtained from a Bay of Plenty packhouse on 18/01/02 and transported to HortResearch (Mt Albert, Auckland). On arrival, fruit were allocated amongst 4 airflow treatments, and left to cool at 5°C. Five replicate trays were used per treatment for each orchard.

Nominal airflow treatments of 0.2, 0.5, 1.2, or 2.0 m/sec, meant to simulate exposure of fruit to airflows encountered during reefer shipping, were attained using a forced air tunnel arrangement. All fruit were exposed to the same RH and were in the same coolstore during treatment. Room air temperature and relative humidity and fruit temperature were recorded during the treatment period of 4 weeks at 5°C, then fruit were transferred to 20°C for shelf life evaluation.

Fruit were assessed at intervals during shelf life for rate of ripening, firmness (using an Anderson firmometer), skin colour, respiration and ethylene production rate, the incidence and severity 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 0 to 100% rating scales described in the AIC Avocado Assessment Manual (AIC, 2000). Results were analysed by ANOVA in order to identify significant effects of airflow, and/or orchard at a $p<0.05$ level.

RESULTS

Fruit temperatures

Although the nominated airflow rates were obtained, the different airflow rates resulted in different fruit temperatures such that fruit in the lowest airflow (0.2 m/sec) were approx. 0.4°C warmer than fruit in the fastest airflow (1.2 m/sec) (Figure 1). Typically over a 24 hour period, the mean fruit temperatures for fruit held at 0.2, 0.5, 1.2 or 2.0 m/sec were 5.03, 4.90, 4.85 or 4.80°C, respectively, but in general, the fruit temperature followed more closely the coolstore air temperature with increasing airflow. Thus the temperature of fruit held in 1.2 or 2.0 m/sec airflow tended to fluctuate in parallel pattern to that of the coolstore air.

Weight loss

At the end of 4 weeks storage at 5°C, mean weight loss was in the range 2.4 to 2.6% with a trend for fruit held in the highest airflow to have less weight loss than fruit held in the lowest airflow throughout storage (Table 1). After 3 days shelf life at 20°C, the weight loss difference (approx. 0.6%) between the highest and lowest airflow rates was significant.

Table 1. Weight loss of fruit from 4 Hass avocados orchards during storage for 4 weeks at 5°C in airflows of 0.2, 0.5, 1.2, or 2.0 m/sec, and then 3 days shelf life at 20°C, n = 60.

Airflow (m/sec)	Orchard	Weight loss (%) after 4 weeks	Weight loss (%) after 3 days 20°C
0.2	O1	2.8	5.7
	O2	2.9	5.2
	O3	2.3	5.0
	O4	2.2	4.6
	Mean	***2.5***	***5.1***
0.5	O1	3.1	6.1
	O2	2.9	5.0
	O3	2.3	4.8
	O4	2.0	4.2
	Mean	***2.6***	***5.0***
1.2	O1	3.1	6.0
	O2	2.2	4.2
	O3	2.4	5.0
	O4	2.0	4.4
	Mean	***2.4***	***5.0***
2.0	O1	3.2	5.7
	O2	2.3	4.3
	O3	2.1	4.5
	O4	1.8	3.8
	Mean	***2.4***	***4.6***

Source variation	DF	*p values* 4 weeks	*p values* 3 days 20°C
Airflow	3	0.116	0.006
Orchard	3	<0.001	<0.001
Airflow x Orchard	9	0.019	0.302
Residual	224		
Total	239		

Differences between orchards were significant such that the highest weight loss occurred in fruit from orchard 1 and the lowest in fruit from orchard 4. Depending on airflow, differences in weight loss between orchards O1 and O4 at the end of 3 days shelf life ranged from approx. 1.0% at the lowest flow rate to approx. 1.9% at the highest flow rate. The differences in weight loss between orchards were apparent after 1 week of storage.

The interaction between airflow rate and orchard was significant during storage but not shelf life, and the effect of flow rate was dependent on the orchard. Overall, O2 and O3 responded similarly, whereas relative to these orchards there was more weight loss from O1 and less from O4.

Firmness

Average firmometer values for airflow treatments ranged between 1.87 to 2.00 mm after storage and 7.28 to 8.17 mm after 3 days shelf life at 20°C. Airflow had no significant effect on firmness of fruit during shelf life although there was a trend for fruit to be firmer with higher flow rate (data not shown). Differences between orchards were significantly different ($p = <0.001$) such that orchards O2 and O3 were firmer than orchards O1 and O4. However, there was no consistent effect of orchards across airflow rates.

Rates of ripening

Most of the fruit reached the eating ripe stage within 3-6 days of shelf life (Figure 2). Airflow rate during storage had a significant effect on days 4 to 6 when fruit reached the ripe eating stage. On day 4 of shelf life, approx. 81% of the fruit held in an airflow rate of 0.2 or 0.5 m/sec had reached the ripe stage whereas approx. 70% of the fruit held in an airflow of 1.2 or 2.0 m/sec had reached the ripe stage. However, there was no overall trend of ripening rate with increasing flow rate: the highest and lowest proportions of fruit at the ripe stage on day 4 were for fruit held in an airflow of 1.2 m/sec and 0.5 m/sec, respectively.

Orchard effects were significant on day 4 and day 6. On day 4, approx. 63% of the fruit from O1 and O2 were at the ripe stage whereas approx. 88% of the fruit from O3 and O4 were ripe. Most of the remaining fruit from these orchards then reached the ripe stage on day 6. Fruit with greater weight loss during coolstorage tended to ripen slightly earlier during shelf life at 20°C (Figure 3).

Fuzzy patches

On day 3 of shelf life, the incidence of fuzzy patches amongst airflow treatments was in the range 19 to 33% with approx. 30% of the fruit held in a flow of 0.2 or 0.5 m/sec and approx. 22% of the fruit held in a flow of 1.2 or 2.0 m/sec were affected by fuzzy patches (Table 3). In contrast, there was a greater difference between orchards where the incidence was approx. 45%, 25%, 22% and 14% for O1, O2, O3 and O4 respectively. The effect of airflow within orchards was not consistent but there was a trend for all orchards to have a higher incidence of fuzzy patches when fruit were held at lower airflows. There was also a trend for fruit with higher weight loss during coolstorage to have a higher incidence of fuzzy patches after 3 days shelf life compared to fruit with lower weight loss during coolstorage (Figure 4).

Table 3. Incidence of fuzzy patches amongst Hass avocado fruit, obtained from 4 orchards, on day 3 of shelf life at 20°C following storage for 4 weeks at 5°C in airflows of 0.2, 0.5, 1.2, or 2.0 m/sec, n = 5.

	Incidence (%) of fuzzy patches on day 3 in				
Airflow (m/sec)	Orchard 4	Orchard 5	Orchard 6	Orchard 7	***Mean***
0.2	41.0	30.4	34.1	9.2	***28.7***
0.5	66.1	19.1	24.9	20.9	***32.7***
1.2	39.5	23.4	9.1	5.9	***19.5***
2.0	33.8	26.0	19.0	20.0	***24.7***
Mean	***45.1***	***24.7***	***21.8***	***14.0***	
Source of variation	DF	SS	MS	F	*p values*
Airflow	3	1924.1	641.4	4.3	0.008
Orchard	3	10528.3	3509.4	23.5	<0.001
Airflow x Orchard	9	4006.5	445.2	3.0	0.005
Residual	64	9540.9	149.1		
Total	79	25999.8	329.1		

Stem end rots

Approx. 14 to 25% of the fruit developed stem end rots during shelf life (Figure 5). The lowest incidence (14.1%) occurred in fruit held at 2.0 m/sec, and the highest incidence (25%) in fruit held in an airflow of 1.2 m/sec. The effect of airflow was not significant except on days 5 and 6 of shelf life when fruit held in 0.2 and 1.2 m/sec, respectively had a higher incidence of stem end rots than fruit held at other airflows.

Differences between orchards were as large as or greater than between airflows. In general, fruit from O2 tended to have a lower incidence of stem end rots, and fruit from O1 a higher incidence than fruit for other orchards, although on days 5 and 6, O1 and O2 tended to have a higher level of stem end rots than fruit from orchards O3 and O4.

There was a trend for fruit with higher weight loss during coolstorage to have a higher incidence of stem end rots after 4 or 6 days shelf life compared to fruit with lower weight loss during coolstorage (Figure 6).

Body rots

At the end of 6 days shelf life, up to 52% of the fruit had developed body rots (Figure 7). On day 4, approx. 30% of the ripe fruit had developed body rots, and this incidence was not significantly affected by airflow rates. However, on days 5 and 6, the incidence of body rots was affected by airflow rates but not consistently. On day 5 the highest incidence occurred with fruit held in airflow of 0.2 m/sec, whereas on day 6, the highest incidence was in fruit held in airflow of 1.2 or 2.0 m/sec.

Orchard differences were significant, and overall, fruit from O1 tended to have the highest incidence (up to 74%) and fruit from O4 the lowest incidence (approx. 16 to 37%) of body rots. There was also a trend for fruit with higher weight loss during coolstorage to have a higher incidence of body rots after 4 or 6 days shelf life compared to fruit with lower weight loss during coolstorage (Figure 8).

Orchards

If the responses of fruit from different orchards to airflow treatments are considered collectively, O1, which had the highest weight loss tended to have the highest incidence of rots, and O4 that had the lowest weight loss the lowest incidence of rots during shelf life (Table 4). The pattern of weight loss between orchards during shelf life had already been established after 1 week of storage.

Table 4. Orchards O1, O2, O3, O4, 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 at the end of the holding period, ripe fruit and FP on day 3 of shelf life, on day 5 for SER and BR.

Airflow	Incidence	WL	Ripe	FP	SER	BR
0.2 m/sec	Highest	O1	O4	O1	O1	O1
	Lowest	O4	O1	O4	O2	O4
0.5 m/sec	Highest	O1	O4	O1	O1	O1
	Lowest	O4	O2	O4	O2	O4
1.2 m/sec	Highest	O1	O3	O1	O1	O1
	Lowest	O4	O2	O4	O4	O4
2.0 m/sec	Highest	O1	O3	O1	O1	O1
	Lowest	O4	O2	O4	O2	O4

DISCUSSION

Whilst overall the responses of orchards to airflow 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. Some interactions between treatment and orchards were statistically significant, indicating the effect of treatment is not consistent at all combinations of the other treatments. Therefore, orchard 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.

In general, water loss did explain airflow and orchard effects. The orchard that had the highest water loss had the highest occurrence of rots and tended to ripen earlier and concentrated mostly over one day, whereas with lower water loss there was a lower rot incidence and ripening was less uniform and was spread over several days. However, it was expected that with higher airflow, a higher water loss would have occurred rather than the opposite. This apparent anomaly between water loss and airflow rate can be explained by the effect of the high airflow rate on fruit temperature. At the higher airflow, fruit temperatures "cycled' with the air temperature and fruit temperatures were approx. 0.4°C cooler than fruit held in the lowest airflow. Given that water loss is mostly driven by the difference between fruit temperature and air temperature and the RH of the air, and less by air velocity, higher water loss would occur under low airflow conditions than the high airflow conditions. Had the fruit temperatures been the same, a higher water loss would have occurred at higher rather than lower airflows if the same RH were also maintained, since any differences in water loss would now be due largely to airflow alone. Therefore, whilst the design used in this study to establish different airflows was successful, it confounded the effects of airflow because of an effect on fruit temperatures.

The airflow rates used in the present study are in the range that would be expected during commercial holding, storage and transport of avocados. However, air temperatures in relation to airflow are likely to be more variable than in this experiment. Where low airflow occurs it is most likely that air temperatures will be higher than the air delivery temperature, and this in turn will lead to a higher water loss. The degree of water loss would depend on how RH was affected under the low airflow conditions. With reduced flow but higher fruit temperatures, RH of the surrounding air may be increased or decreased relative to the delivery air, which is typically 86-92%. In contrast under high airflow conditions, RH around the fruit will be similar to the RH of the delivery air, and therefore, water loss will always be higher than under low airflow conditions except when RH under low airflow conditions is at the lower end of the delivery air RH range.

SUMMARY

It is concluded that:

- The inherent rot potential and ripening rate of fruit at harvest can be influenced by airflow conditions during storage.
- The effect of airflow during storage and / or transport is dependent on the effect of airflow on fruit temperature and the degree of water loss that occurs under the airflow condition.
- Either high or low airflow can lead to higher water loss and thereby an increase in fuzzy patches, stem end rots, or body rots.
- The effect of airflow on water loss can be negligible or less than the effect of storage temperature.
- Overall, an increase in water loss of 0.5% over the storage period is likely to increase fuzzy patches, stem end rots or body rots by approx. 0 to 15%, approx. 5 to 10% , and approx. 7 to 20%, respectively.

As best practices guidelines, it is recommended that once fruit are cooled, airflow is maintained at 0.2 to 0.6 m/sec.

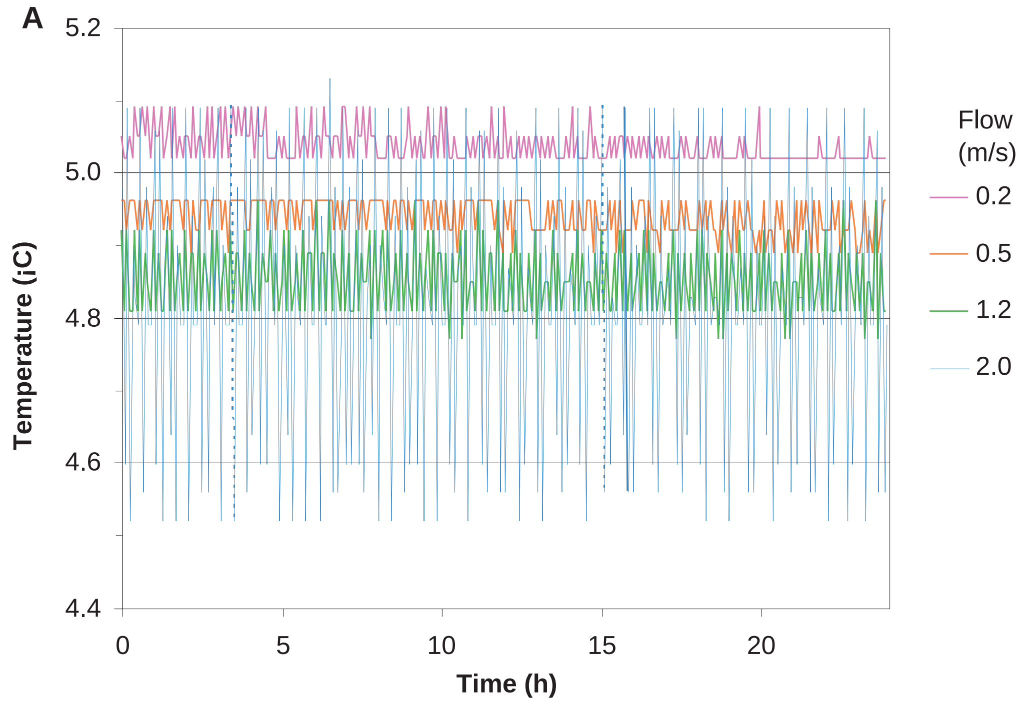
REFERENCES

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.



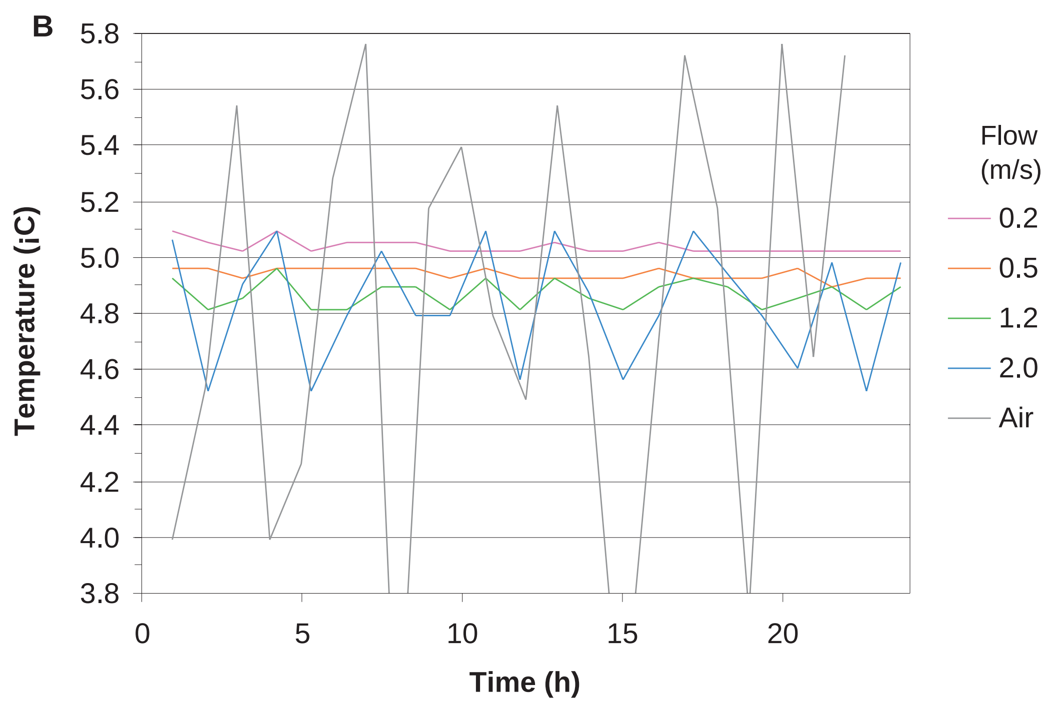


Figure 1. Fruit temperatures during a 24 hour period for fruit held in different airflow rates when logged at 5 minute intervals (A) or when 10 minute readings are averaged per hour (B).

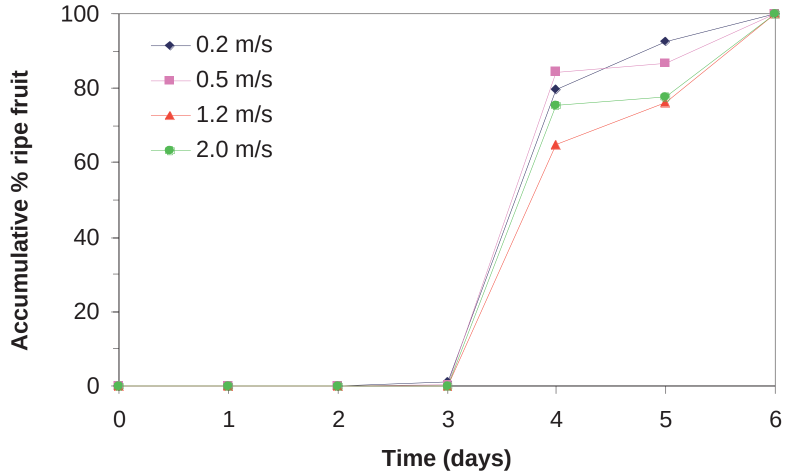


Figure 2. Accumulative number (%) of fruit at the ripe stage during shelf life at 20°C following storage for 4 weeks at 5°C in airflows of 0.2, 0.5, 1.2 or 2.0 m/sec; n = 20.

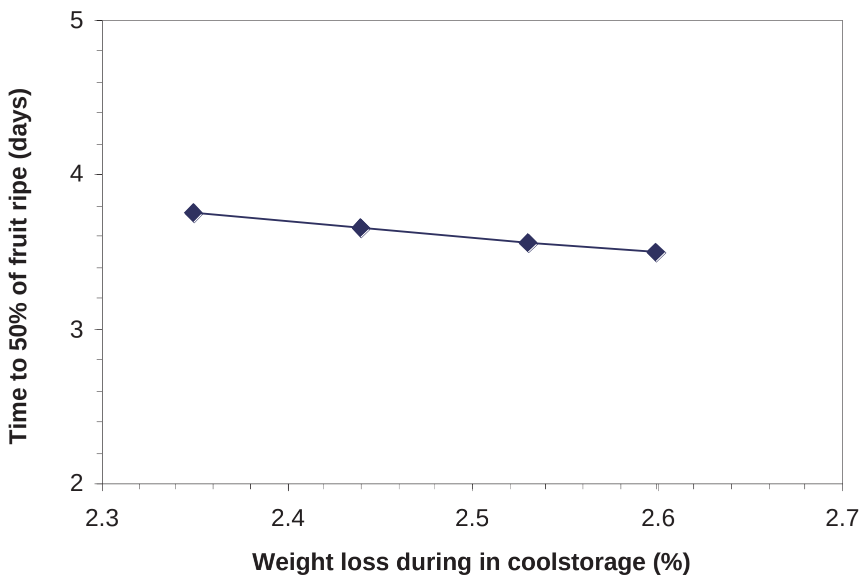


Figure 3. The relationship between the time when 50% of Hass avocado reach the ripe stage during shelf life at 20°C and weight loss from fruit during coolstorage for 4 weeks at 5°C, n = 15 (R^2 = 0.98).

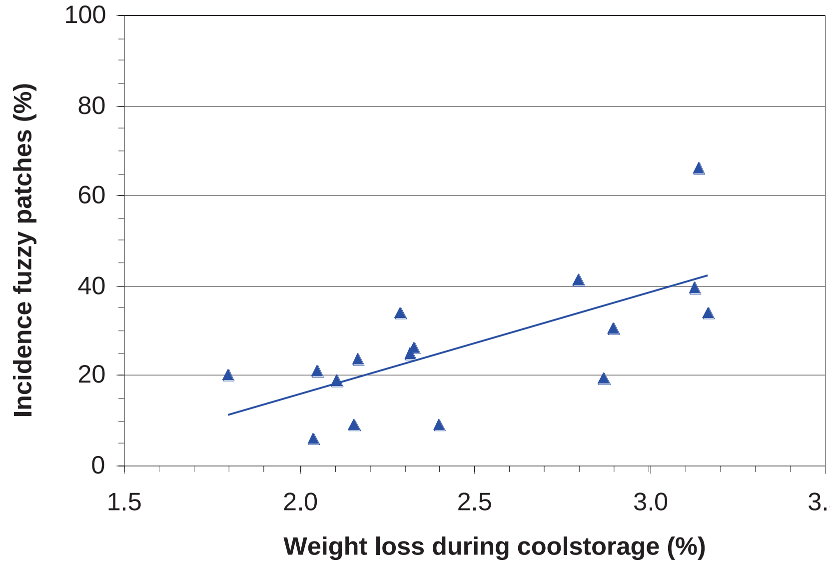


Figure 4. Relationship between the incidence of fuzzy patches on Hass avocados on day 3 of shelf life at 20°C, and weight loss from fruit during coolstorage for 4 weeks at 5°C, n = 18 (R^2 = 0.47).

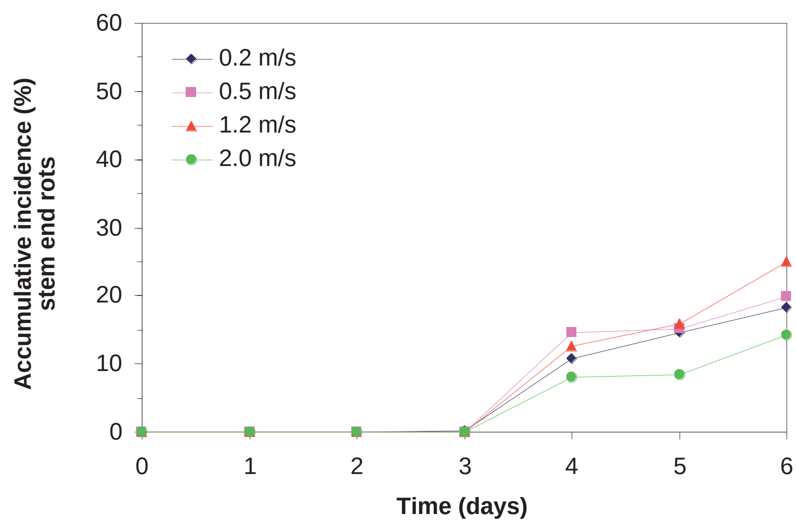


Figure 5. Accumulative incidence of stem end rots amongst Hass avocado fruit during shelf life at 20°C following storage for 4 weeks at 5°C in airflows of 0.2, 0.5, 1.2, or 2.0 m/sec. Values are based on ripe and unripe fruit, n = 20.

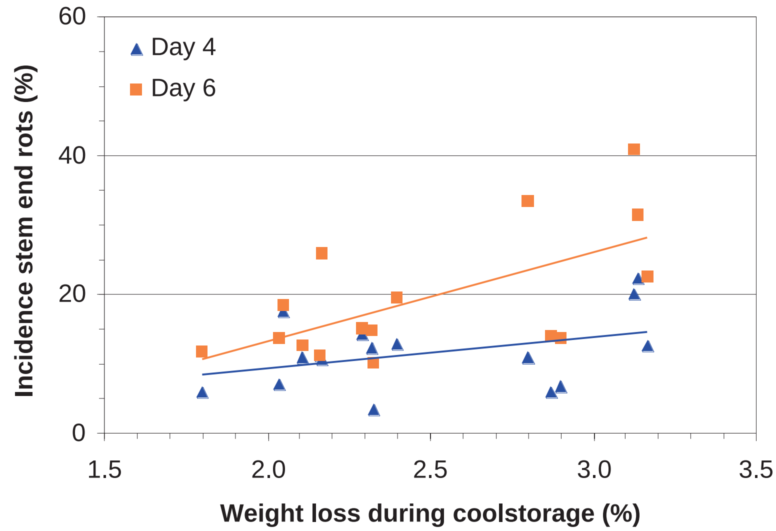


Figure 6. Relationship between percentage incidence of stem end rots in Hass avocados on days 4 and 6 of shelf life at 20°C and weight loss from fruit during coolstorage for 4 weeks at 5°C, n = 18 (Day 4, R^2 = 0.14 and Day 6, R^2 = 0.39).

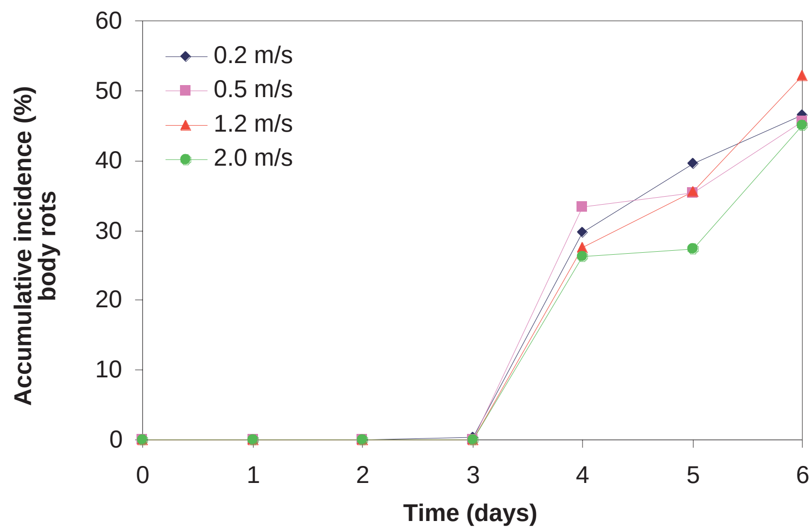


Figure 7. Accumulative incidence of body rots amongst Hass avocado fruit during shelf life at 20°C following storage for 4 weeks at 5°C in airflows of 0.2, 0.5, 1.2, or 2.0 m/sec. Values are based on ripe and unripe fruit, n = 20.

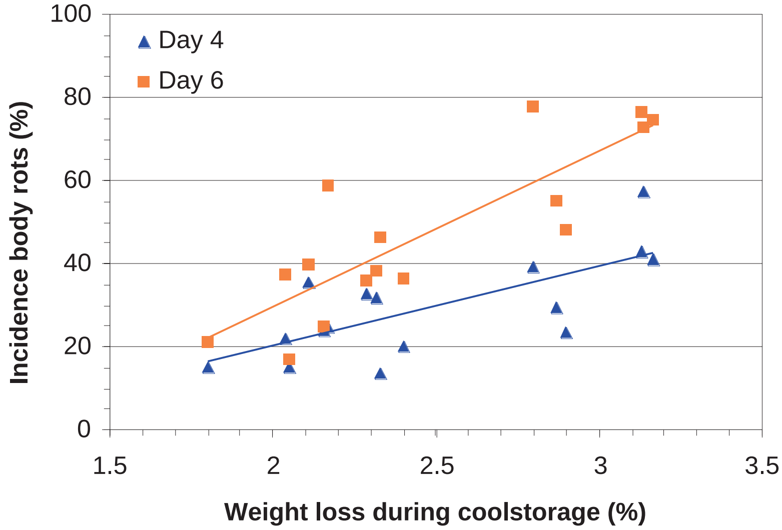


Figure 8. Relationship between the incidence of body rots in Hass avocados on days 4 and 6 of shelf life at 20°C and weight loss from fruit during coolstorage for 4 weeks at 5°C; n = 18 (Day 4, R^2 = 0.52 and Day 6, R^2 = 0.72).