NOVEL POSTHARVEST TREATMENTS FOR AMELIORATION OF ROTS IN 'HASS' AVOCADO

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ABSTRACT

Preliminary assessments were made of the disease response of 'Hass' avocados to fruit surface pH treatments (pH 5.0, 5.5, 6.0, 6.5, 7.0 and 8.0), cooling rates (18°C reduced to 5°C in either 24 or 96 h), heat treatments (hot air at 35, 45 or 55°C for either 2 or 5 min), CO_2 shock treatments (air or 30% CO_2 in N_2 at 20°C for 18 h), or UV treatments (exposure to UV-C radiation for 0, 1, 3 or 5 min). After treatments were applied all fruit were coolstored for 4 weeks at 5°C before removal to 20°C for ripening and assessment of rots on green fruit for fuzzy patches (FP), and on ripe fruit for stem-end rots (SER) and body rots (BR).

Treating fruit with more acidic buffer solutions (pH 5.0 or 5.5) markedly increased SER and BR (approx. 3 to 18%, and 30 to 60%, respectively) and reduced the rates of ripening compared to untreated fruit. Fast cooling delayed the expression of SER but did not affect total incidence of SER or BR, weight loss or ripening rates. Heat treatments trended to increase SER (from approx. 8 to 14%) with an increase in temperature from 35 to 55°C, but there was no effect of duration. The 55°C treatment reduced the rate of ripening of fruit compared to other treatments. Shock treatment with CO_2 slightly increased SER and BR, although for one orchard there was a 50% reduction in rots and this suggests CO_2 shock may have potential to reduce rots. UV treatment for 5 min significantly reduced SER and BR by 7-10% and reduced FP during shelf life without causing skin damage.

It is concluded that if the positive aspects of the individual treatments can be combined, there may a useful potential to control rots. For example, CO_2 shock or UV radiation (closer to the threshold of skin damage) could be combined with ozone fumigation.

Keywords: fuzzy patches, stem-end rots, body rots, surface pH, cooling rates, heat treatments, CO_2 shock, UV.

INTRODUCTION

The occurrence of stem-end rots (SER) and body rots (BR) during storage and/or shelf life is the major limitation to the quality of New Zealand avocados, and thereby, to market development. The occurrence of rots can vary from 0 to 80% in fruit from different orchards (Everett, 1999). Recent studies indicate that holding temperatures and conditions after harvest can influence the expression and incidence of rots during shelf life after storage, but that this effect of holding conditions on ripening rates and rots, which was through an effect on water loss, is small and approx. two to three times less than the natural level of rot occurrence (Lallu *et al*., 2002, 2003). Therefore, whilst holding conditions are important to fruit quality, the majority of rots are not affected. Additional postharvest treatments that are able to reduce the inherently high rot potential of avocados, are needed urgently if existing markets are to be expanded and /or new export markets are to be developed.

The ideal treatment to control rots should be chemical free since market access is often limited by restrictions on pesticide use and the global trend for residue free food. Several non-chemical post-harvest treatments or treatments that use chemicals that are generally regarded as safe (GRAS) have been investigated or are used for rot control in various fruit, and some of these may be suitable for avocados. Unsuccessful novel treatments tried on avocados include elicitors (chemicals that stimulate the plants natural defense system) such as methyl jasmonate, GRAS compounds, 76% ethanol, neem oil, 30% CO_2 shock treatments in air, and some food grade antioxidants (Everett, 2002).

In this report, results are presented from separate studies in which a preliminary assessment was made of the disease response of 'Hass' avocados to fruit surface pH treatments, cooling rate treatments, CO_2 shock treatments, heat treatments, or UV treatments. For pH treatments, fruit from three orchards were sprayed with buffer solutions (pH 5.0, 5.5, 6.0, 6.5, 7.0 and 8.0), or not treated, prior to coolstorage. For cooling rate treatments, fruit from six orchards were cooled to 5°C in either 24 or 96 hours. Heat treatments comprised exposure of fruit from three orchards to hot air at 35°, 45° or 55°C for 0, 2 or 5 min prior to coolstorage. For CO_2 shock treatments, fruit from six orchards were treated with air or 30% CO_2 in nitrogen for 18 hours prior to coolstorage. For UV treatments, fruit from three orchards were exposed to UV-C radiation for 0, 1, 3 or 5 minutes. After treatments all fruit were coolstored for 4 weeks at 5°C before removal to 20°C for assessment of rots during shelf life.

MATERIALS AND METHODS

Fruit for all treatments was commercially packed count 24 or 25 fruit collected from packhouses and transported to HortResearch (Mt Albert, Auckland) for treatments. Treatments were applied the same day as fruit were packed. Three fruit per tray were weighed for weight loss assessment. After treatment fruit from all treatments were held at 5°C for 4 weeks before being removed to 20°C for assessment of ripening and disorders during shelf life.

Surface pH treatments

Fruit from three Bay of Plenty orchards were sprayed with buffer solutions of citrate-phosphate (pH 5.0, 5.5, 6.0, 6.5, 7.0) or phosphate (pH 8.0) or not treated (control), dried for 2 hours, and then packed into two replicate trays per treatment.

Cooling rate treatments

Fruit from six orchards collected from packhouses in Whangarei, South Auckland or the Bay of Plenty and two replicate trays from each orchard placed into each of two cooling rate treatments (cooling from ambient temperature (approx 18°C) to 5°C over 24 hours (fast) or 96 hours (slow)). Air and fruit temperatures were recorded during each cooling treatment.

Heat treatments
Fruit from three Bay of Plenty orchards were exposed to hot air at 35, 45 or 55°C for 0, 2 or 5 minutes prior to coolstorage. A single tray of fruit was used at each temperature and time, and three fruit per tray were used for weight loss assessment. Air and fruit temperatures were recorded during each heat treatment.

CO_2 shock treatments
Fruit from six orchards were collected from packhouses in Whangarei and the Bay of Plenty and two replicate trays per orchard were held in air or 30% CO_2 in nitrogen for 18 hours at 20°C prior to coolstorage.

UV treatments
Fruit from three Bay of Plenty orchards were exposed to UV-C radiation for 0, 1, 3 or 5 minutes from four lamps (Phillips TUV 30W / G30 T8) positioned above the fruit. Fruit were rotated on brushes during the UV-C treatments. Two replicate trays were used for each orchard.

Shelf life assessment
Following completion of the treatments fruit were coolstored for four weeks at 5°C. After storage, fruit were transferred to 20°C and assessed at intervals for rate of ripening, the incidence and severity of rots and disorders, and weight loss. Subjective assessments of fruit firmness, skin colour, rots (fuzzy patches (FP), stem-end rots (SER), body rots (BR)) and other disorders were made according to the methods and using the 0-100% rating scales described in the NZ AIC Assessment Manual 2001, Version 2 (AIC, 2001).

Data analysis
Means for treatment effects were calculated based on the total fruit, and differences between treatments and/or orchards analysed by ANOVA at a $p<0.05$ level using untransformed data or arc sin square root transformed data. Least significant differences (LSD) were calculated for separating treatment means. The results presented are of untransformed data.

RESULTS AND DISCUSSION

Surface pH treatments
Treating fruit with pH 5.0 or 5.5 buffer solutions markedly increased the incidence of SER from approx. 4% to approx. 14-16% in untreated and treated fruit, respectively, and significantly increased BR from approx 32% to approx. 60% in untreated and treated fruit, respectively (Table 1). Fruit treated with pH solutions of 6.0 to 8.0 had slightly higher incidence of rots than untreated fruit, with a trend for an increase in rots with a decrease in pH. Treatment with the low pH solutions also significantly increased the severity of SER and particularly BR (data not shown).

The least amount of weight loss at the end of storage (3.09 and 2.86%) occurred in the control fruit or fruit treated with the pH 8 solution, respectively, and this was approx. 0.5% lower than in the lowest pH treatments (Table 1). Higher water loss has been related to higher incidence of rots (Lallu *et al*., 2002). Therefore, an effect of surface pH on rot incidence may possibly be through an effect on water loss, or the higher levels of weight loss in conjunction with a lower rate of ripening compared to control fruit (Table 1) may have predisposed the fruit to the higher incidence of rots in these treatments.

Table 1. Effect of treating 'Hass' avocado fruit with buffer solutions to alter surface pH on weight loss (%), and accumulative incidence (%) of ripe fruit, stem-end rots (SER), or body rots (BR). Fruit were treated and then coolstored for 4 weeks at 5°C before assessment at the ripe stage during shelf life at 20°C. Values for SER and BR are based on ripe and unripe fruit. n = 18 fruit for weight loss, and n = 6 trays of fruit for ripe fruit, SER and BR.

	Weight loss (%)		Ripe fruit (%)		SER (%)	BR (%)
Buffer pH	4 weeks	Day 3	Day 4	Day 6	Day 8	Day 8
5.0	3.52	5.10	17.4	100.0	16.0	59.7
5.5	3.43	5.15	22.2	99.3	13.9	58.3
6.0	3.36	5.10	20.8	96.5	8.3	44.4
6.5	3.64	5.75	17.4	98.6	7.6	49.3
7.0	3.32	5.01	10.4	98.6	7.6	35.4
8.0	2.86	4.67	16.0	96.5	8.3	43.1
Control	3.09	5.05	38.9	100.0	4.2	31.9
Statistical analysis:						
p value	*0.004*	*0.012*	*0.006*	*Not tested*	*0.074*	*0.022*
LSD	*0.39*	*0.53*	*13.33*	*Not tested*	*7.91*	*17.89*

The effects of pH solutions on BR severity suggest the effects of the solutions may extend beyond the skin or surface. Preliminary attempts were made to quantify changes in skin pH during ripening but no consistent changes were detected. If there were natural changes in the surface pH or within the skin during ripening and these changes were related to rot expression, then any rot control treatment based on pH manipulation should utilise solutions (and methods) that counter the changes and/or interfere in the relationship. At present, it appears that if surface pH is to be used as a rot control treatment, then solutions that prevent the surface from becoming acidic or maintain a neutral pH during ripening are likely to reduce rots.

Cooling rate treatments

The incidence or severity of SER or BR, weight loss and rate of ripening of fruit was not affected by cooling fruit at different rates, i.e. cooling from ambient temperatures (approx. 18°C) to 5°C over 24 hours compared to 96 hours (Table 2). Despite a high occurrence of SER and BR rots overall, (approx. 23% and 40%, respectively), the severity of rots was generally low in that most of the SER had a severity of less than 5% and 1%, respectively (data not shown). This is not unusual, nor is the degree of weight loss at the end of storage (approx. 3.1 %) or the rates of ripening during shelf life (Table 2). However, the lack of differences in weight loss and ripening rates may explain why no cooling rate effects were detected. Any effect of cooling rates on rot incidence can be expected to be through effects on water loss and ripening rates.

Table 2. Effect of cooling 'Hass' avocado fruit to 5°C in 24 or 96 hours, then coolstorage for 4 weeks at 5°C, on weight loss (%), and accumulative incidence (%) of ripe fruit, stem-end rots (SER; %), or body rots (BR; %). Fruit were assessed at the ripe stage during shelf life at 20°C. Values for SER and BR are based on ripe and unripe fruit. n = 18 fruit for weight loss, and n = 12 trays of fruit for ripe fruit, SER and BR.

	Weight loss (%)	Ripe fruit (%)		SER (%)	BR (%)
Cooling rate	4 weeks storage	Day 3	Day 5	Day 7	Day 7
24 h (½ time, 8.8 h)	3.09	16.7	81.3	23.0	42.3
96 h (½ time, 31 h)	3.26	13.0	87.0	22.7	38.0
Statistical analysis:					
p value	*0.413*	*0.568*	*0.340*	*0.961*	*0.516*

Heat treatments

Heat (hot air) treatments did not significantly affect the incidence or severity of SER or BR (Table 3). However, overall there was a trend for the incidence of SER to increase from approx. 8% to approx. 14% with an increase in treatment temperature from 35 to 55°C, but not with duration. In contrast, the incidence of BR increased from approx. 26% to approx. 37% with an increase in duration from 2 to 5 min, but was only marginally different in heat-treated fruit than untreated (Ambient) fruit. Fruit treated at 55°C also had a significantly decreased rate of ripening on day 4 (Table 3). Severity of SER and BR was generally less than 1% or 10%, respectively, and was not affected by heat treatments (data not shown). As expected, given the short durations of the treatments, weight loss after storage or after 3 days shelf life was not affected by the heat treatments (Table 3).

Table 3. Effect of heat treatment of 'Hass' avocado fruit for 2 or 5 minutes at 35°, 45°, 55°C or ambient (18°C) temperatures on weight loss (%), accumulative incidence (%) of ripe fruit, accumulative incidence of stem-end rots (SER) and body rots (BR). After heat treatment fruit were coolstored at 5°C for 4 weeks before assessment during shelf life at 20°C. Values for rots are based on ripe and unripe fruit. n = 9 fruit for weight loss, and n = 3 trays of fruit for ripe fruit, SER and BR.

Treatment	Weight loss (%)	Ripe fruit (%)		SER (%)	BR (%)
	4 weeks storage	Day 4	Day 6	Day 8	Day 8
Duration means					
2 min	3.23	19.4	96.7	12.5	25.9
5 min	3.19	31.9	96.1	9.7	37.0
Temperature means					
35°C	3.15	41.0	97.2	8.3	36.1
45°C	3.42	25.7	97.2	10.4	29.2
55°C	3.07	10.4	94.8	14.6	29.2
Ambient	3.09	35.4	99	4.2	31.9
Source of variation: p values[1]					
Duration	*0.714*	*0.073*	*0.876*	*0.603*	*0.084*
Temperature	*0.134*	*0.017*	*0.514*	*0.723*	*0.550*
Temperature × duration	*0.055*	*0.855*	*0.717*	*0.447*	*0.932*

[1] Based on arc sin square root transformed data.

No marked commercially useful or consistent decrease in rots has also been shown by previous studies with heat treatments, either using hot air or hot water (Kritzinger *et al.*, 1997, 1998; Hofman *et al.*, 2002a, 2002b). It appears that heat treatments in the range 45° to 55°C will decrease the rate of ripening and confer some protection from low temperature injury if fruit are to be stored at chilling temperatures, but a useful decrease in rots is unlikely to be achieved, and an increase in rots is more likely to result. The decreased rate of ripening is possibly why an increase in the incidence of SER or BR occurs with heat treatments. It should be noted that whilst fruit were exposed to the nominated air temperatures of 35°, 45° and 55°C, the fruit skin temperatures were approx. 25°, 35°, and 40°C, respectively. Achieving higher skin temperatures closer to the nominated air temperature is likely to increase the risk of skin damage and thereby increase rots. Ideally, a heat treatment should result in no skin damage, but result in the eradication of BR pathogens already present as infections in the skin.

CO_2 shock treatments

Overall, approx. 30% of fruit developed SER and 47% developed body rots but shock treatment with 30% CO_2 in nitrogen had no significant affect on the incidence of SER or BR, although there was a trend for SER and BR to be slightly higher and possibly more severe in shock-treated fruit (Table 4). However, for fruit from one of the six orchards the shock treatment had a marked reducing affect on rots: SER were reduced from approx. 40% to 20% and BR from approx. 54% to 36%. Therefore it appears that a beneficial effect on rots can be achieved by CO_2 shock treatments but that it is likely to be orchard specific.

Table 4. Effect on 'Hass' avocado fruit of treatment with air or 30% CO_2 (balance N_2) at 20°C for 18 hours on weight loss (%), and accumulative incidence (%) of ripe fruit, stem-end rot (SER; %), and body rots (BR; %). Fruit were treated and then coolstored for 4 weeks at 5°C before assessment at the ripe stage during shelf life at 20°C. Values for SER and BR are based on ripe and unripe fruit. n = 18 fruit for weight loss, and n = 12 trays of fruit for ripe fruit, SER and BR.

	Weight loss (%)	Ripe fruit (%)		SER (%)	BR (%)
Treatment	4 weeks storage	Day 3	Day 5	Day 7	Day 7
Air	3.60	11.2	91.3	28.0	42.6
30% CO_2	3.66	16.5	75.6	32.8	50.8
Statistical analysis:					
p values	*0.709*	*0.270*	*0.009*	*0.315*	*0.166*
LSD	*ns*	*ns*	*10.89*	*ns*	*ns*

The CO_2 shock treatment did not significantly affect weight loss, but did significantly delay the ripening of treated fruit (Table 4). The delay in ripening of CO_2 treated fruit may have contributed to the higher incidence of SER and BR. In unreported trials, high CO_2 in the storage atmosphere has increased rots in 'Hass' avocados, and may have contributed to the higher incidence of rots in this trial (Yearsley *pers comm.*). The timing of the application of a CO_2 shock treatment after harvest may be one of the factors determining the efficacy of the shock treatment, and may be more likely to have a beneficial effect on reducing rots when it is applied closer to the time of harvest.

UV treatments

Overall, approx. 4, 13 or 40% of fruit developed FP, SER or BR, respectively, but the severity of FP, SER or BR was generally less than 1, 1, or 5%, respectively. While there were no significant differences between treatments in the incidence of SER or BR on day 7 of shelf life (Table 5), SER and BR were consistently and significantly less by approx. 7-10% in fruit given the 5 min UV treatment when compared over days 4 to 7 (data not shown). Similarly, despite the very low incidence of FP there was a trend for FP to be less in the greatest UV treatments on day 3 (data not shown). UV treatments did not significantly affect weight loss or incidence of ripe fruit compared to non-UV treatments (Table 5). In the absence of any visible UV damage to the fruit skin, it is likely that the threshold of UV damage to the fruit surface was not reached in this trial. Consequently, it is possible that a higher intensity UV treatment that is applied for five or less minutes may have a greater beneficial effect on reducing rots than that observed in this trial.

Table 5. Effect on 'Hass' avocados of treatment with UV-C light (Phillips TUV 30W / G30 T8) whilst rotating on brushes for 0, 1, 3 or 5 mins, on weight loss (%), and accumulative incidence (%) of ripe fruit, fuzzy patches (FP), stem-end rots (SER), and body rots (BR). After treatment fruit were coolstored for 4 weeks at 5°C before assessment at the ripe stage during shelf life at 20°C. n = 18 fruit for weight loss, and n = 6 trays of fruit for FP, SER and BR.

Treatment (min)		Weight loss (%)	Ripe fruit (%)		FP (%)	SER (%)	BR (%)
UV	Brushing	4 weeks storage	Day 3	Day 5	Day 3	Day 7	Day 7
0	0	3.55	7.3	98.0	4.0	13.3	45.3
0	5	2.97	10.0	97.3	4.7	14.7	39.3
1	1	3.52	11.3	89.3	5.3	11.3	47.3
3	3	3.17	20.0	95.3	2.0	16.7	37.3
5	5	3.35	18.0	90.7	3.3	10.0	31.3
Statistical analysis:							
p value		*0.090*	*0.726*	*0.643*	*nt*	*0.537*	*0.069*

nt = not tested

Other prospects: Combination treatments.

Rather than a single treatment, a combination of treatments that singularly are inconsistent or marginally effective in reducing rots could be effective for rot control if the treatments were combined. For example CO_2 shock treatment may be combined with ozone fumigation, or UV treatment combined with ozone fumigation. Whilst ozone treatment of the wash water has been shown to be of no use for rot control, the use of ozone as a fumigant either prior to or after packing has not been studied with 'Hass' avocados (Pak and Dixon, 2001). The vulnerability of new infections and/or latent infections to treatments is likely to be different when combined treatments are applied together or in sequence. Accordingly, both dose and timing may differ in the combined treatment relative to their use as single treatments.

Exploiting any synergism or additive effects between treatments should be explored further.

CONCLUSIONS

None of the novel treatments assessed in the study gave an unequivocal reduction in rots. However, there were some positive aspects or trends in some treatments that if they were to be enlarged or made consistent, they could be translated into useful commercial protocols. It is concluded that treatments based on manipulation of the surface pH should focus on preventing acidification of the fruit surface since rots are likely to be higher in fruit treated with acid solutions. The final wash of avocados on the packing line should be with water with a neutral pH. Fast cooling rates will delay the expression of SER but have no effect on BR but any effect of different cooling rates on rots is most likely to be through an effect on water loss during cooling.

Heat treatments are most likely to increase rot incidence because of a delay in ripening. An increase in BR may be avoided if the temperatures during heat treatments are close to the heat injury temperature, but it is likely the inherent BR level will not be reduced. Shock treatments with 30% CO_2 in nitrogen have the potential to reduce rots but the potential is orchard specific, and for most orchards the treatment is likely to result in a slight increase in rots. The specific requirements for the treatment to be effective is not known but time of treatment after harvest, and rate of ripening or maturity at harvest may be factors that should be further investigated. UV-C treatment of fruit has the potential to reduce rots, and in particular, if appropriate doses can be delivered in a practical timeframe on the packing line. Doses up to the threshold for skin damage should be tested.

A combination of individual postharvest treatments may be needed to control rots, and specific combinations of the above treatments may be useful. In particular, the combination of CO_2 shock with ozone fumigation, and UV combined with ozone fumigation should be assessed.

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