How to store partially ripened 'Hass' avocado fruit

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Abstract

The Australian industry is based on providing ripened fruit to the consumer, but there is little information on how to hold these fruit during periods of inconsistent flows from the ripener to the retailer. To develop appropriate recommendations, 'Hass' fruit were ripened up to the 'sprung' stage and stored for 3, 5, 10 and 15 days at either 2, 4, 6, or 8°C. In the next season, fruit were ripened to either the 'rubbery', 'sprung', or 'softening' stages (firmness of 1, 2, or 3 respectively on a 0-7 scale), then stored for 7 or 14 days at either 2, 5, or 8°C. After holding, ripening was completed at 20°C until the 'soft ripe' stage (firmness of 5), and quality assessed. The proportion of sound fruit (i.e. <10% of the flesh affected by all internal defects) held at 2°C after the 'rubbery' stage was reduced by 37-67% compared to non-stored fruit. Diffuse discolouration was the main cause of quality loss, and generally increased with longer storage of riper fruit, especially when stored at 2°C. The results suggest that 'Hass' fruit ripened up to the 'softening' stage can be stored for up to 10 days at 5-8°C with low risk of quality loss at eating ripe. However, 8°C may be a safer option for 10-15 days holding. Storage below 5°C should be avoided, especially after the 'rubbery' stage.

Como almacenar frutos de aguacates 'Hass' parcialmente maduros

La industria Australiana esta basada en proveer fruta madura al consumidor, pero existe poca información de como mantener la fruta de aguacate en aquellos períodos de bajo flujo en el mercado desde el madurador hasta el minorista. Para desarrollar recomendaciones apropiadas, se pusieron a madurar frutos de aguacate 'Hass' hasta la etapa 'maduro firme' y almacenadas durante 3, 5 10 y 15 días a 2, 4, 6 u 8°C. En la siguiente cosecha se puso a madurar el fruto hasta las etapas 'rubbery', 'maduro firme' y 'listo para consumir' (firmeza de 1, 2 o 3 respectivamente en escala de 0 a 7) y almacenada durante 7 o 14 días a 2, 5, u 8°C. Después del almacenamiento, la maduración fue terminada a 20°C hasta la etapa 'maduro suave' (con una firmeza de 5) y se evalúo su calidad. La proportión de fruto sano (I.e. ı10% de la pulpa afectada por defectos internos) mantenidas a 2°C después la etapa 'inicio de la maduración' fue reducido entre el 37-67% comparado con el fruto no almacenado. La decoloración fue la principal causa de la pérdida de calidad en el aguacate la cual aumenta generalmente con los largos períodos de almacenamiento de la fruta madura especialmente cuando es almacenada a 2°C. Los resultados sugieren que la fruta 'Hass' parcialmente madurada hasta la etapa 'listo para consumir' puede ser almacenada hasta 10 días entre 5-8°C con un bajo riesgo de pérdida de la calidad. Sin embargo, el almacenamiento a 8°C podría ser una opción más segura para períodos más largos de 10-15 días. El almacenamiento por debajo de los 5°C se debe evitar, especialmente después de la etapa 'inicio de la maduración'.

Key words: avocado, ripening, storage

Introduction

Ripening practices can affect avocado fruit quality (Hofman *et al.* 2002), including fruit susceptibility to flesh diseases and disorders (Hopkirk et al. 1994). Ripening can be described as the processes resulting in changes in colour, texture and flavour, which make the fruit acceptable for consumption (Biale and Young 1971). Flesh softening and skin colour change from green to purple or black are the most obvious events of ripening in 'Hass' avocado fruit, the main cultivar in Australia. It has a climacteric pattern in which the ripening process is preceded by sharp increases in respiration and ethylene production (Adato and Gazit 1974).

The Australian avocado industry is based on providing ripened fruit to the consumer. Sometimes ripening fruit have to be held to help match the flow of fruit from the supplier, via the ripener to the retailer. However, there is little information on the appropriate temperatures and durations for holding partially ripened fruit. Early work suggested that susceptibility of Hass and other cultivars to internal chilling damage increases as the fruit soften (Kosiyachinda and Young 1976; Zauberman et al. 1973), but specific recommendations are required.

To develop recommendations for handling partially ripe avocado, commercially picked and packed Hass fruit were partially ripened with ethylene to several stages of ripeness (based on fruit firmness), including the stage at which fruit are normally dispatched to retail. Fruit were then held for 3-15 days at 2-8°C. After holding, fruit were ripened at 20°C until the eating ripe stage, and external and internal quality assessed.

Materials and methods

Commercially picked and packed Hass fruit were collected (within 24 hours of picking) in mid July 2009 and mid Jun 2010 from farms in the Childers and Bundaberg areas in south east Queensland. One P-84 tray (count 20) was sampled per treatment per farm. Immediately after packing, fruit were transported to the Maroochy Research Station at Nambour. Fruit dry matter (DM) was determined on 15 fruit per farm by taking a core of flesh (using the Hofshi plugger) from each fruit, which were diced and mixed to provide five composite samples of about 12 g each per farm. Samples were weighed before and after drying at 65°C until constant weight (about three days).

To simulate commercial transport conditions, all fruit were first held at 5°C for 4 days, then at 8°C for 1 day before being treated with 10 ppm ethylene for 2 days at 20°C. Fruit were then held at 20°C and carefully assessed daily for firmness both by hand and with the 'Firmometer' (White et al. 2009). The Firmometer was used (with a 200 g weight) on 10 fruit per treatment, and the test area marked to allow any potential bruising caused by the test to be excluded during quality assessment. Firmness was monitored until 80% of the fruit in each tray reached the firmness stages of about 2 ('sprung', corresponding to a Firmometer value of 25-30) in 2009. In 2010, the following three stages were targeted: 1-2 ('rubbery' to 'sprung', Firmometer value of 10-25); 2-3 ('sprung' to 'softening', Firmometer value of 30-40); 3-4 ('softening' to 'firm ripe', Firmometer value of 45-65).

Once the desired firmness (ripeness) was reached (generally 1-2 days between each stage), the following treatments were applied: in 2009, fruit were held at either 2, 4, 6 or 8°C for either 3, 5, 10 or 15 days. In 2010, fruit were held for either 2, 5 or 8°C for either 7 or 14 days. After removal from each treatment, fruit were held at 20°C and regularly assessed for firmness until stage 5 ('soft-ripe', corresponding to a 'Firmometer' value around 80). External and internal fruit quality was then assessed based on the 'International Avocado Quality Manual' (White et al. 2009). The days from removal to ripe were recorded for each fruit. Skin colour at ripe was visually assessed on a 1 to 6 (green to black) scale. Each fruit was then cut in halves, peeled, the seed removed, and the severity of flesh diseases and internal disorders assessed as the percentage of flesh volume affected. Flesh diseases were described based on the location of the disease on the fruit, for example stem-end rots or body rots. The percentage of sound fruit (based only on flesh appearance) was calculated based on the number of fruit with 10% or less of all flesh defects combined in relation to the total number of fruit per treatment per farm.

Statistical analyses were performed by Genstat® 11 for Windows™ (VSN International Ltd., UK). Analysis of variance used the 'General Analysis of Variance' model, with treatment factors (holding temperature/time and stage of ripeness) as 'treatments' structure and the farm as 'block' structure. The protected least significant difference (LSD) procedure at $P = 0.05$ was used to test for differences between treatment means.

Results and discussion

In 2009, the days from removal to ripe were generally shorter at higher holding temperatures and longer holding times (Table 1). In 2010, the days from removal to ripe were generally less 14 days holding compared with 7 days, and as expected, days to ripe after removal was less when riper fruit were placed into storage (Table 2). There was little variation in days from removal to ripe among different storage temperatures after 7 days storage, and a reduction of 1-2 days in firmer ('rubbery' or 'sprung') fruit stored at 5 and 8°C compared to 2°C after 14 days storage.

Table 1: The effects of holding temperature (2, 4, 6, or 8°C) and duration (0, 3, 5, 10, or 15 days) on days from removal to ripe at 20°C and the % of sound fruit (based on flesh defects) at eating ripe (the 'soft ripe' stage) of "sprung" 'Hass' avocado

Holding temperature (^{o}C)	Holding time (days)				
	0	3	5	10	15
Days from removal to ripe at 20^{o}C					
Nil	7.4 [a]				
2		5.5 [c]	5.0 [cde]	6.7 [b]	4.4 [fgh]
4		5.1 [cde]	5.2 [cde]	5.4 [cd]	4.1 [gh]
6		4.8 [def]	4.6 [efg]	4.3 [fgh]	3.4 [i]
8		5.0 [cde]	4.1 [h]	4.0 [h]	2.6 [j]
% of sound fruit (flesh defects) [1]					
Nil	93 [a]				
2		85 [ab]	80 [abc]	63 [cde]	37 [f]
4		80 [abc]	76 [abcd]	70 [bcde]	54 [ef]
6		72 [abcde]	89 [ab]	80 [abc]	57 [def]
8		87 [ab]	91 [ab]	80 [abc]	80 [abc]

[1]Sound fruit = percentage of ripe fruit with a severity rating of 10% or less for all flesh defects combined.

For either days from removal to ripe or % of sound fruit, means with different letters are significantly different (P = 0.05) as tested by least significant difference (LSD).

Table 2: The effects of ripeness stage (rubbery-sprung, sprung-softening, or softening to firm-ripe) of 'Hass' avocado at the start of storage, holding temperature (2, 5, or 8°C) and duration (7 or 14 days) on days from removal to ripe at 20°C and the % of sound fruit (based on flesh defects) at eating ripe (the 'soft ripe' stage).

Holding temperature (^{o}C)	Holding time (days)						
	0	7			14		
		Rubbery-sprung	Sprung-softening	Softening-firm ripe	Rubbery-sprung	Sprung-softening	Softening-firm ripe
Days to ripe at 20^{o}C after ethylene and storage							
No Storage	6.3 [b]						
2		7.0 [a]	5.4 [d]	3.7 [fg]	6.8 [a]	4.3 [e]	2.0 [i]
5		7.0 [a]	5.2 [d]	3.5 [g]	5.8 [c]	2.4 [i]	2.4 [i]
8		6.9 [a]	5.3 [d]	4.0 [ef]	5.1 [d]	2.9 [h]	2.4 [i]
% sound fruit (flesh defects)[1]							
No Storage	100 [a]						
2		93 [ab]	63 [cd]	55 [d]	83 [ab]	58 [d]	33 [e]
5		88 [ab]	90 [ab]	82 [abc]	88 [ab]	88 [ab]	84 [ab]
8		88 [ab]	87 [ab]	82 [abc]	93 [ab]	85 [ab]	80 [bc]

[1]Sound fruit = percentage of ripe fruit with a severity rating of 10% or less of the flesh affected by all defects combined.

For either days from removal to ripe or % of sound fruit, means with different letters are significantly different (P = 0.05) as tested by LSD.

The storage treatments generally resulted in fruit with greener skin colour at ripe (ratings of 3.4 to 4.5) compared with control (4.7-5.0) in both years, and skin colour was generally darker at higher storage temperatures (data not shown). This suggests that holding partially ripened Hass fruit reduces de-greening of the skin, especially when held at 2°C.

Diffuse discolouration (DD) was the main cause of quality loss in both years. In 2009, the severity of DD generally increased with longer storage and at lower temperatures (Figure 1). In 2010, the severity of DD increased markedly in fruit stored at 2°C after the rubbery-sprung stage, with little difference between 5 and 8°C (Figure 2; Figure 3). For those fruit, there was more DD with 14 days storage compared to 7 days, and fruit stored at a softer stage. These results confirm previous work with partially ripened and stored Hass, in which fruit susceptibility to chilling damage (including internal disorders) increased with fruit softening, which was associated with the progression of the climacteric to the peak (Kosiyachinda and Young 1976). Interestingly though, these results contrast with the storage of unripe (green) fruit, in which the severity of DD is usually lower in fruit stored at 2°C compared to 5°C (van Rooyen and Bower 2006).

There was very little vascular leaching or vascular browning in both years (data not shown). The differences among storage temperatures and times were not significant for rots in either year (data not shown), with an average across all treatments of about 2% or less for body rots, and 1% or less for stem end rots.

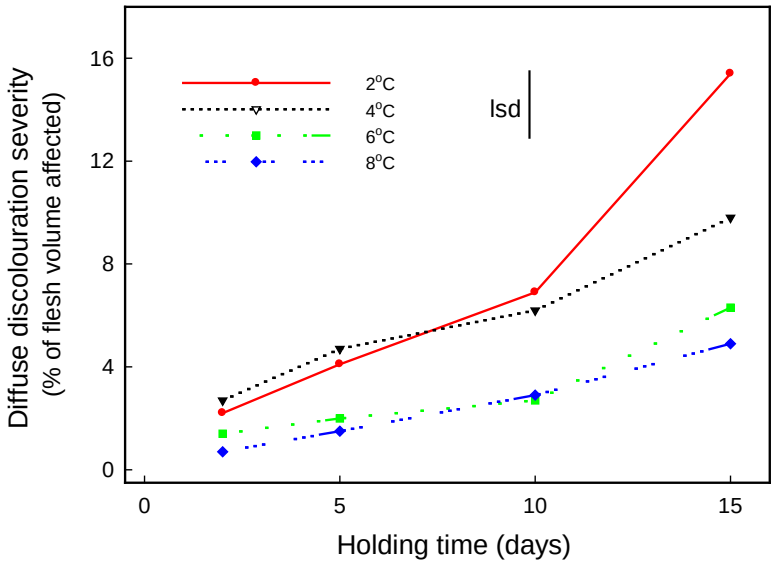

Figure 1: Diffuse discolouration severity (% of flesh volume affected) in ripe 'Hass' avocado fruit that were partially ripened (until the 'sprung' firmness stage) then held at either 2, 4, 6, or 8ºC for either 0, 3, 5, 10, or 15 days before ripening fully. The vertical bar indicates the least significant difference (lsd) at P=0.05.

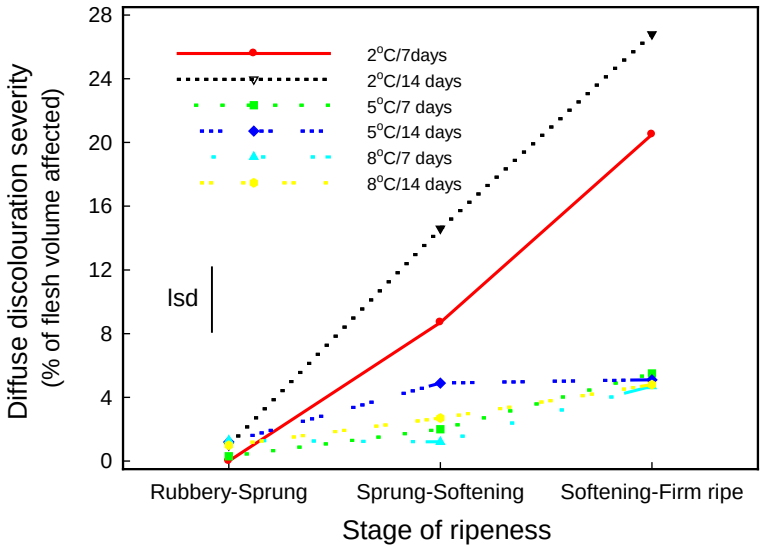

Figure 2: Diffuse discolouration severity (% of flesh volume affected) in ripe 'Hass' avocado fruit that were partially ripened with ethylene (until the 'rubbery' to 'sprung', 'sprung' to 'softening' or 'softening' to 'firm ripe' firmness stages) and then held at either 2, 5, or 8°C for either 7 or 14 days before ripening fully . The vertical bar indicates the least significant difference (lsd) at P=0.05.

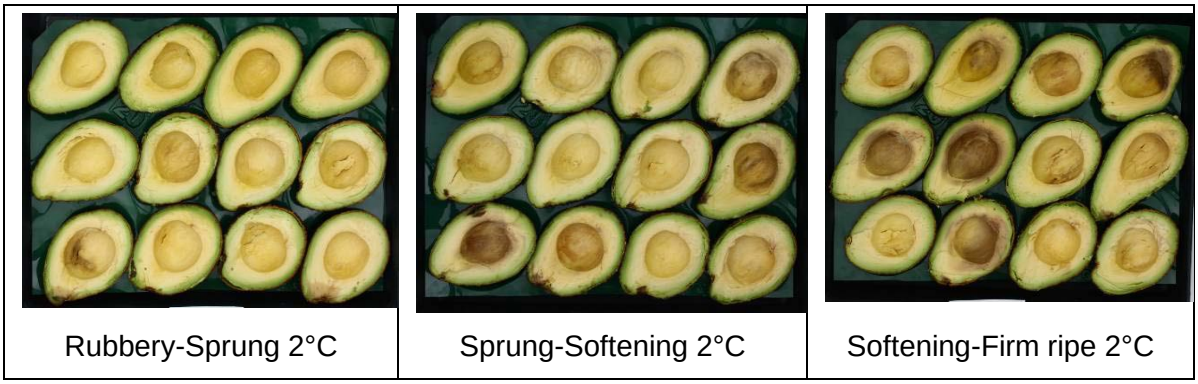

Figure 3: Internal quality (at eating ripe) of 'Hass' avocado fruit ripened to either the 'rubbery' to 'sprung', 'sprung' to 'softening' or 'softening' to 'firm ripe' firmness stages, then held for 7 days at 2°C.

Compared to control, the percentage of sound fruit (those with a severity rating of 10% or less for all flesh defects combined) was not significantly reduced in fruit stored up to 5 days between 2-8°C, or up to 10 days between 6-8°C, or up to 15 days at 8°C in 2009 (Table 1). This suggests that the longer the storage of partially ripened fruit, the higher the temperature required to avoiding significant loss of quality. However, after removal from storage, the ripening time may reduce with higher storage temperatures, as the fruit stored at higher temperatures reached eating soft more quickly after removal (Table 1).

In 2010, fruit at the rubbery-sprung stage held at 2-8°C for up to 14 days showed no significant reduction in the % of sound fruit (Table 2). However, holding riper fruit at 2°C for even 7 days resulted in loss of quality compared with no storage. In comparison, fruit from rubbery to firm ripe can be held at 5-8°C for up to 14 days with little loss. This confirms results from the 2009 trial, indicating that partially ripened Hass fruit that have reached the 'sprung' stage should not be stored below 5°C for periods longer than 3 days. However, in 2009 fruit ripened up to the 'sprung' stage and held at 6°C for 15 days had significant quality loss compared to 8°C, suggesting the effect of seasonal or production

factors in the response of partially ripened fruit to longer storage periods. Based on the results from both years, partially ripened Hass fruit should be held at 8°C when stored for longer than 10 days.

On average, dry matter was 27.7% in 2009 and 27.9% in 2010. Across all treatments, there was significant variation between farms for days from removal to ripe, skin colour at ripe, DD, and rots on both years, and on the % of sound fruit in 2010 (data not shown).

Conclusions and recommendations

Both trials confirm that holding sprung fruit at 2°C for more than three days increases the risk of fresh defects (mainly diffuse discolouration), but this risk can be reduced by holding firm fruit, or holding at 5-8°C. If partially ripened fruit is to be held for longer periods (7-14 days), fruit should be only rubbery-sprung, while sprung-firm ripe fruit should be stored at 5-8°C for not longer than 10 days. There seems to be no benefit in holding partially ripe fruit at 2°C to increase days to ripe after removal, and 2°C storage should be avoided for fruit past the rubbery-sprung stage. The relevance of these recommendations to fruit of different maturity still needs to be tested.

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