# Semi-commercial trials to determine the risk of shipping 'Hass' at 1°C for 30 days

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## INTRODUCTION

With the every growing competition between South Africa and other avocado producing countries for good prices in Europe, a need for accessing new markets has arisen. However, countries such as the U.S.A. require certain mitigation treatments be conducted to eliminate the potential entry of phytosanitary pests into their country. Cold sterilization is one of the treatments that have received much attention by South African entomologists in recent years. Certain fruit fly species have been found to be quite cold tolerant and indications are that temperatures as low as 1°C may be required (for 20 days) to meet phytosanitary requirements. While preliminary trials, under controlled research conditions, have indicated that this temperature may render fruit of an acceptable quality, more research was required to test the treatment under commercial conditions.

Zauberman and Jobin-Dėcor (1995) previously reported that they could successfully store 'Hass' for up to five weeks at 2°C without developing any external chilling injury or abnormal ripening. In similar studies Van Rooyen and Bower (2006) found that the severity of internal quality problems, associated with the 'Pinkerton' avocado, could be reduced by storing fruit at 2°C, without negatively affecting the external quality. Similar success was attained when storing 'Hass' at temperatures as low as 1°C (Van Rooyen and Bower, unpublished). In most of these studies the date of harvest (Kritzinger and Kruger, 1997; Van Rooyen and Bower, 2006), stage of fruit ripeness (Kosiyachinda and Young, 1976), and the origin of the fruit (Kruger *et al.*, 2000; Van Rooyen and Bower, 2006) was found to play a significant role in both chilling injury and disorder susceptibility.

It was thus important that additional research be conducted, using fruit picked at different dates and farms, in order to determine the potential risk periods/areas for the development of external chilling injury when storing fruit at 1°C. Research would also be needed to evaluate the logistical problems associated with conditioning and shipping fruit at 1°C.

| | Front | Middle | Back |
|---|---|---|---|
| Top | Export 1 | Export 1 | Export 1 |
| | Export 2 | Export 2 | Export 2 |
| | Export 3 | Export 3 | Export 3 |
| | Export 4 | Export 4 | Export 4 |
| | Export 5 | Export 5 | Export 5 |
| | Factory 6 | Factory 6 | Factory 6 |
| | Factory 7 | Factory 7 | Factory 7 |
| | Factory 8 | Factory 8 | Factory 8 |
| | Factory 9 | Factory 9 | Factory 9 |
| Middle | Export 10 | Export 6 | Export 10 |
| | Export 11 | Export 7 | Export 11 |
| | Export 12 | Export 8 | Export 12 |
| | Export 13 | Export 9 | Export 13 |
| | Export 14 | Factory 10 | Export 14 |
| | Factory 15 | Factory 15 | Factory 15 |
| | Factory 16 | Factory 16 | Factory 16 |
| | Factory 17 | Factory 17 | Factory 17 |
| Bottom | Export 18 | Export 18 | Export 18 |
| | Export 19 | Export 11 | Export 19 |
| | Export 20 | Export 12 | Export 20 |
| | Export 21 | Export 13 | Export 21 |
| | Export 22 | Export 14 | Export 22 |

**Figure 1. Side view of the three pallets used for 'Hass' fruit quality determinations for each period in the season (Early, Mid or Late). Only the export fruit layers were evaluated (shaded)**

## MATERIALS AND METHODS

### Fruit source and numbers

'Hass' fruit were obtained from Westfalia Fruit Estates at three dates in the 2008 avocado season, thought to represent "Early" (2008-05-28), "Mid" (2008-07-03) and "Late" (2009-08-11) season fruit. For each date two pallets of export-quality fruit, count 14, were sourced from the Westfalia pack house after fruit had passed through the packline (i.e. after the standard washing, waxing, grading and palletizing). Each "export quality" pallet was made up of fruit picked from between three and five different orchards. The orchard codes were recorded and the moisture content of the fruit determined. Eighteen pallets of factory grade fruit (various cultivars and sizes all picked on same dates as export fruit) were packed into export quality cartons and used to fill up the remainder of the container in order to simulate commercial airflow conditions.

The two "export quality" pallets were then divided into three pallets, as per **Figure 1**, and placed into the static container as shown in **Figure 2**. Each layer and pallet position was cleared marked on the carton so that the effect (if any) of carton position on fruit quality could be determined. Fruit were conditioned for low temperature storage before the storage temperature was dropped to 1°C (air delivery temperature) for a minimum of 21 days (to meet USDA-APHIS requirements), making the total storage period 28 days.

### Storage container

In order to improve the temperature uniformity of the "regular atmosphere" container used, a few small structural modifications were made within the container. These modifications are still in the experimental phase; however, the container is generally referred to as a "Modified airflow" or "Directed airflow" container.

### Parameters recorded

#### a) Temperature monitoring

Data loggers were used to monitor both the air and fruit pulp temperature, and the relative humidity at various layers and positions in the container (the same pallets were used for fruit quality ratings, **Figure 2**).

#### b) Fruit quality

Immediately after removal from the storage container, the severity of the following external quality parameters were rated on all the "export quality" fruit: chilling injury, lenticel damage, discolouration and softening. To determine fruit quality on ripening, cartons from each "export-quality" layer (**Figure 1**) were taken and left at ambient room temperature (±22°C) until "eating ripeness" was attained. "Eating ripeness" was determined using a hand-held densimeter (Bareiss, Oberdischingen, Germany) using a scale of 0 (soft) to 100 (hard), where a reading of 55 to 60 was deemed to indicate "eating ripeness" (Köhne *et al.*, 1998). At "eating ripeness" the following was determined: exocarp colour, shrivelling, appearance, internal disorders (grey pulp, pulp spot), pathological infections, vascular browning, taste and days to ripening.

### Commercial export container

At the end of the season a commercial container of 'Hass' (using the modified airflow adaptations) was shipped to Rotterdam at 1°C (delivery air temperature). Data loggers were placed at various locations in the container (as in the static trials) to monitor air and pulp temperature, and relative humidity. The same ratings, as were done in the static trials, were done on three pallets positioned exactly as in the static trials (**Figure 2**). The fruit in the container were subjected to the conditioning treatment while at the train station in Tzaneen and then the air delivery temperature was dropped to 1°C for the remainder of the journey to the Cape Town and Rotterdam harbours.

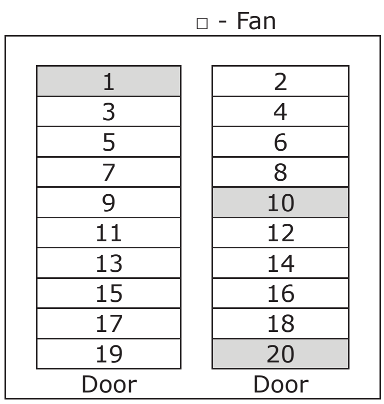


**Figure 2. Top view of the pallet positions in the container. Shaded blocks indicate "export quality" pallets which were used for fruit evaluations (1=Front, 10=Middle and 20=Back)**

## RESULTS AND DISCUSSION

### Fruit maturity

The average moisture content of fruit, from the various orchards used to make up the experimental pallets, was obtained from the pack house records. The average moisture content of the fruit was found to decrease with each consecutive trial date (**Table 1**).

### Temperature and relative humidity

Static containers

The middle pallet, on average, logged slightly higher pulp temperatures for all three dates. The front and back containers were fairly similar in temperature readings; however, the temperature spikes were greater for the front pallet closest to the cooling/heating unit. Generally the top layers were the "warmest", and the bottom layers the "coolest". The relative humidity was fairly constant for all three dates and averaged at about 91% (±1.5).

Export container

Contrary to the static container trends the "warmest" pallet was located at the back closest to the door. The front pallet averaged the "lowest" temperatures, however, with much less dramatic spikes, once the container was loaded onto the ship, than the static trials. The only temperature spikes that were experienced were when the container was loaded onto the train in Tzaneen and then once again when the container was loaded onto the ship. The "cold sterilization" period would thus only come into affect once the fruit were loaded onto the ship as the cold treatment requires that the pulp temperature stay below 2°C for 21 consecutive days. The "warmest" temperatures were recorded for the top layers of all three pallets while the bottom layers logged the "coolest" temperatures. The relative humidity averaged at 89% (±3.3).

### External chilling injury

Static containers

For all three trial dates very little severe chilling injury was recorded (<2% on average, **Table 2**). No clear re-

**Table 1. Average moisture content of fruit, from various orchards, used to determine the sensitivity of 'Hass' fruit to storage at 1°C throughout the season**

| | Early season | Mid season | Late season | Export |
|---|---|---|---|---|
| Average moisture content (%) | 73 | 71 | 66 | 65 |

lationship was thus found between harvest date or carton position and chilling injury severity. The fact that pallets were made up of fruit from various orchards, did also not appear to make a significant difference in terms of external chilling injury development.

Export container
A greater percentage of fruit was rated as having "severe chilling injury" in the export container (<6% on average, **Table 4**), compared to the static trials (viz. <2%). The worst chilling injury was recorded in cartons positioned at the bottom of the various pallets, which was generally identified as being the coldest area of the export container. However, with regard to pallet position, the pallet at the back of the container was found to have the highest percentage of fruit with "severe chilling injury" while being identified as the "warmest" pallet. This would seem to indicate that temperature is not the

**Table 2. Percentage 'Hass' fruit (Count 14) rated as having "severe chilling injury", in the static containers, for the various trial dates**

| % Fruit rated as "severe" | | Front | Middle | Back | Mean |
|---|---|---|---|---|---|
| **Early season** | Top | 0.5 (0.3)* | 0.0 (0.0) | 0.0 (0.0) | 0.2 (0.2) |
| | Middle | 0.1 (0.1) | 0.4 (0.2) | 0.0 (0.0) | 0.2 (0.2) |
| | Bottom | 0.4 (0.2) | 0.2 (0.2) | 0.0 (0.0) | 0.2 (0.2) |
| | *Mean* | 0.3 (0.2) | 0.2 (0.2) | 0.0 (0.0) | 0.2 (0.2) |
| **Mid season** | Top | 0.1 (0.1) | 0.4 (0.2) | 0.1 (0.1) | 0.2 (0.2) |
| | Middle | 0.6 (0.3) | 0.0 (0.0) | 2.0 (0.5) | 0.9 (0.4) |
| | Bottom | 0.5 (0.3) | 0.0 (0.0) | 3.2 (0.6) | 1.2 (0.4) |
| | *Mean* | 0.4 (0.3) | 0.1 (0.1) | 1.8 (0.5) | 0.8 (0.3) |
| **Late season** | Top | 0.2 (0.2) | 0.5 (0.3) | 0.5 (0.3) | 0.4 (0.2) |
| | Middle | 0.2 (0.2) | 0.3 (0.3) | 0.6 (0.3) | 0.3 (0.3) |
| | Bottom | 1.3 (0.4) | 1.3 (0.5) | 0.8 (0.3) | 1.2 (0.4) |
| | *Mean* | 0.6 (0.3) | 0.7 (0.4) | 0.6 (0.3) | 0.7 (0.3) |
| **Number of fruit/date** | Total | 2520 | 2352 | 2520 | 7392 |

*Figures in brackets denote the standard error

**Table 3. Percentage 'Hass' fruit (Count 14) rated as having "severe lenticel damage", in the static containers, for the various trial dates**

| % Fruit rated as "severe" | | Front | Middle | Back | Mean |
|---|---|---|---|---|---|
| **Early season** | Top | 7.1 (1.6)* | 4.2 (0.7) | 2.3 (1.0) | 4.5 (1.2) |
| | Middle | 7.1 (1.1) | 7.9 (1.0) | 2.6 (1.4) | 5.9 (1.2) |
| | Bottom | 6.8 (1.1) | 8.7 (10) | 4.0 (1.5) | 6.5 (1.3) |
| | *Mean* | 7.0 (1.3) | 6.8 (0.9) | 3.0 (1.3) | 5.6 (1.2) |
| **Mid season** | Top | 21.0 (1.8) | 32.5 (3.0) | 5.7 (1.1) | 19.7 (2.6) |
| | Middle | 23.5 (1.3) | 14.3 (1.9) | 7.4 (1.3) | 15.0 (1.8) |
| | Bottom | 36.4 (2.9) | 14.8 (2.2) | 13.5 (2.9) | 21.5 (3.1) |
| | *Mean* | 26.9 (2.3) | 21.0 (2.7) | 8.8 (2.0) | 18.9 (2.5) |
| **Late season** | Top | 34.6 (2.6) | 39.9 (3.9) | 47.2 (2.3) | 40.6 (3.1) |
| | Middle | 19.8 (1.5) | 5.1 (1.1) | 53.3 (2.2) | 26.1 (3.3) |
| | Bottom | 28.3 (1.7) | 15.1 (2.0) | 46.0 (2.8) | 29.8 (2.8) |
| | *Mean* | 27.5 (2.2) | 20.7 (3.3) | 48.8 (2.5) | 32.3 (3.1) |
| **Number of fruit/date** | Total | 2520 | 2352 | 2520 | 7392 |

*Figures in brackets denote the standard error

**Table 4. Percentage 'Hass' fruit rated as having "severe chilling injury" and "severe lenticel damage" in the export container sent to Rotterdam, in August 2008, at 1°C storage temperature**

| % Fruit rated as "severe" | | Front | Middle | Back | Mean |
|---|---|---|---|---|---|
| **Chilling injury** | Top | 3.6 (1.0)* | 2.4 (0.7) | 8.5 (1.3) | 4.9 (1.1) |
| | Middle | 2.1 (0.7) | 3.4 (0.9) | 6.5 (1.3) | 3.9 (1.0) |
| | Bottom | 5.8 (0.9) | 8.3 (1.4) | 8.6 (1.3) | 7.2 (1.2) |
| | *Mean* | 3.9 (0.9) | 4.9 (1.2) | 7.5 (1.3) | 5.4 (1.1) |
| **Lenticel damage** | Top | 13.3 (1.3) | 14.4 (1.3) | 20.8 (1.4) | 16.0 (1.4) |
| | Middle | 15.6 (1.3) | 19.5 (1.5) | 21.2 (1.3) | 18.7 (1.4) |
| | Bottom | 17.9 (1.1) | 21.0 (1.6) | 21.9 (1.2) | 20.2 (1.3) |
| | *Mean* | 15.7 (1.3) | 18.4 (1.6) | 21.3 (1.3) | 18.5 (1.4) |
| **Number of fruit** | Total | 5280 | 5280 | 4752 | 14784 |

*Figures in brackets denote the standard error main contributing factor in the cause of chilling injury but rather that fruit origin could also play a role.

## Lenticel damage

Static containers

The percentage of fruit affected by severe lenticel damage was seen to increase as the season progressed (**Table 3**). For the first two trial dates the percentage fruit affected by lenticel damage was least in the pallet positioned at the back of the container. However, for the last trial date the fruit in the pallet positioned at the back of the container were rated as the most severely affected. No clear trend could be seen regarding the severity of the lenticel damage in relation to the position of the carton in the pallet. The large differences noted between the various pallet position categories (i.e. top, middle and bottom) was ascribed to fruit from various orchards often being packed together in layers on a pallet and thus differences are due to fruit origin and not carton position. If fruit origin was found to play a role, then this would indicate that fruit handling at harvest, and perhaps conditions at/or prior to harvesting (e.g. wetness of fruit), need special attention.

Export container

The percentage fruit with severe lenticel damage followed the same trend as the severe chilling injury data (**Table 4**), in terms of the fact that the bottom layers of each pallet, and back pallet experienced the most lenticel damage, although differences were not as significant.

## Fruit ripening

Static containers

General 'Hass' fruit ripening was not affected by storage at 1ºC. Fruit were found to have excellent internal quality (i.e. no mesocarp discolouration or vascular browning) and taste on ripening. Fruit colour development was also very attractive, with fruit turning black and masking the external chilling injury or lenticel

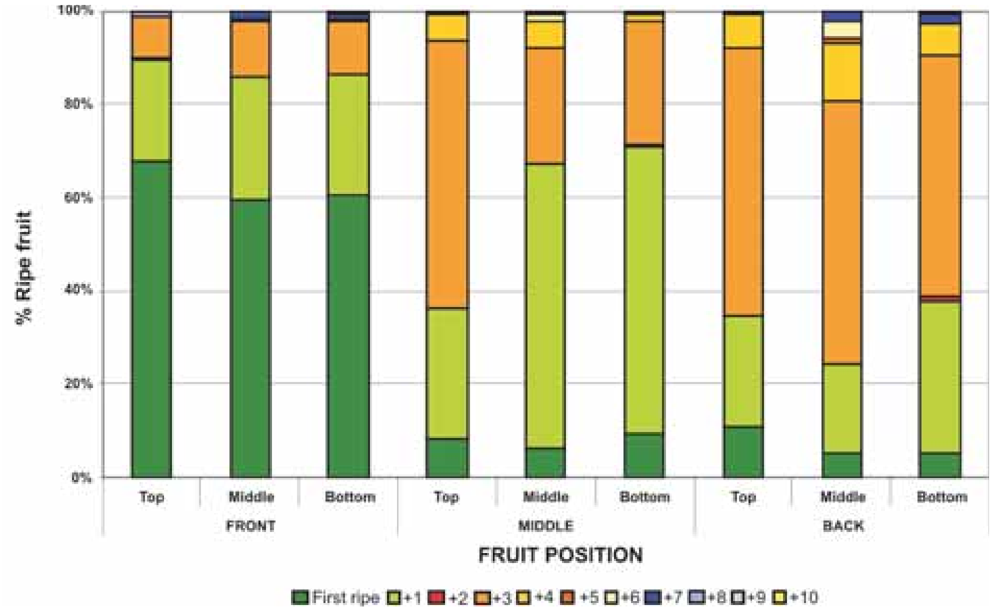


**Figure 3. Ripening uniformity of 'Hass' fruit harvested in May 2008 and stored at 1ºC (DAT). Data depicts percentage fruit ripe when first fruit reached "eating ripeness" (Densimeter reading 55 to 60) and each consecutive day thereafter**

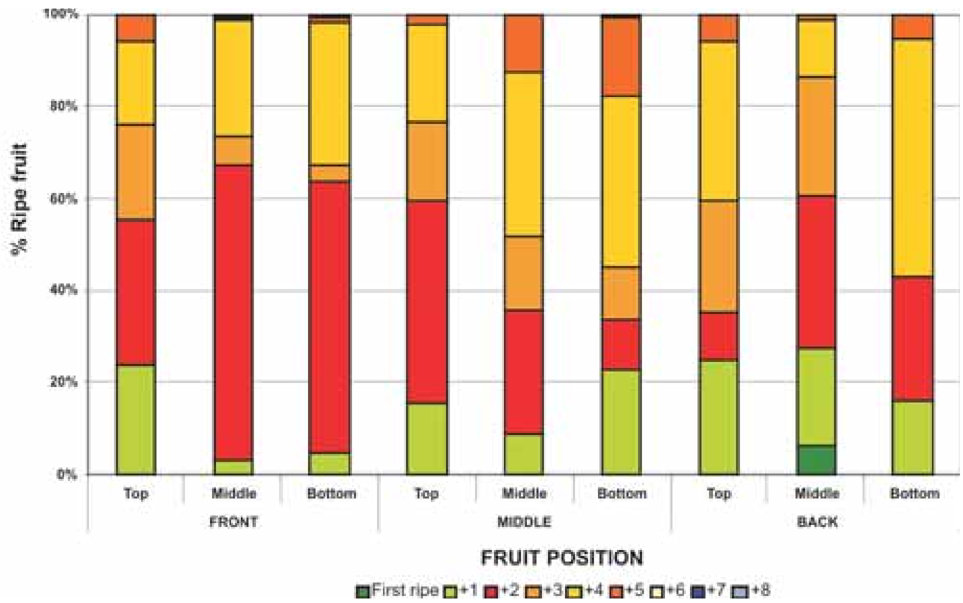


**Figure 4. Ripening uniformity of 'Hass' fruit harvested in July 2008 and stored at 1ºC (DAT). Data depicts percentage fruit ripe when first fruit reached "eating ripeness" (Densimeter reading 55 to 60) and each consecutive day thereafter**

damage. Ripening uniformity was, however, found to be better with the early season fruit with 93.4% of the fruit reaching "eating ripeness" within three days of the first fruit ripening (**Figure 3**), but the mid and late season fruit averaged 64.4% (**Figure 4**) and 67.3% (**Figure 5**) respectively for the same period. The pallet position in the container appeared to play a role in the uniformity of fruit ripening for the early (**Figure 3**) and late season (**Figure 5**) fruit but, on closer inspection, it was found that the origin of fruit appeared to have the most significant effect. For each trial date a component of each pallet was made up of fruit from the same orchards, however, the percentage of cartons varied. For the early season fruit the front pallet was made up almost fully by one orchard, whereas the other two pallets had a more even distribution of sources. The mid season pallets were made up more evenly whereas for the late season trial the front and middle pallets were made up similarly but the back pallet was again made up almost solely of one fruit source. Thus it was concluded that fruit origin played a significant effect in ripening uniformity. The more uniform ripening of fruit at the early part of the season may also indicate that maturity or orchard conditions play a role and this will need to be established.

## CONCLUSION

Cold sterilization does not appear to render 'Hass' of an unacceptable quality and, should this treatment be found to achieve the right degree of insect mortality, should soon offer South African avocado producers a few new market alternatives. However, before this treatment can be implemented commercially, additional research needs to be done to confirm this season's results and to elucidate the effect of fruit origin vs fruit position on chilling injury and lenticel damage. Additional container modifications also need to be tested in the next season to further increase the temperature uniformity within the container.


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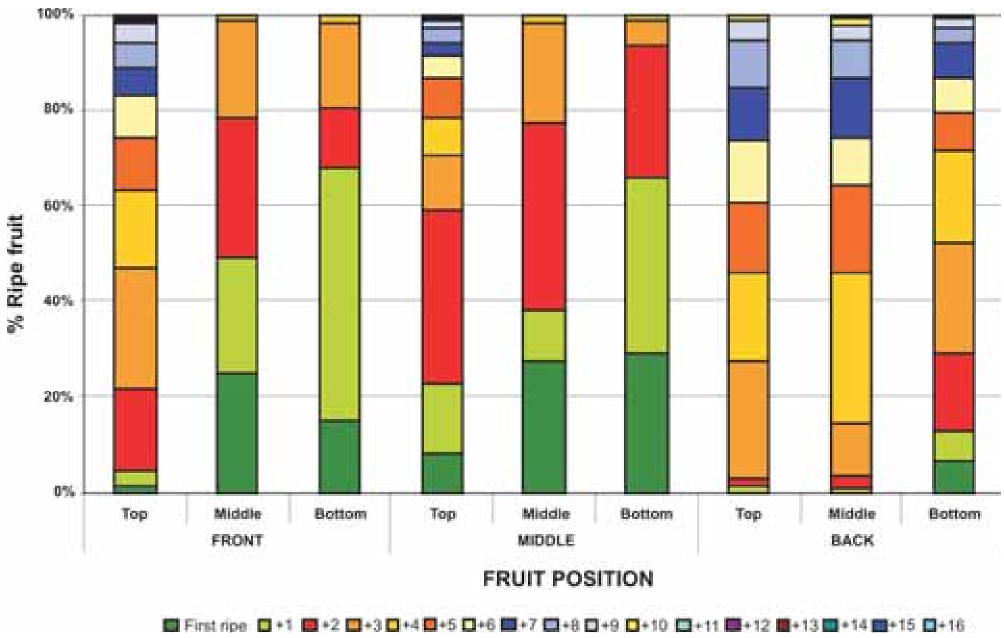


**Figure 5. Ripening uniformity of 'Hass' fruit harvested in August 2008 and stored at 1°C (DAT). Data depicts percentage fruit ripe when first fruit reached "eating ripeness" (Densimeter reading 55 to 60) and each consecutive day thereafter**