# Developing appropriate ripening protocols for the avocado 'ripe and ready' programmes

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**ABSTRACT**

*As result of the perception amongst certain English ripeners that South African avocados have ripening difficulties, a study was conducted to investigate this aspect. Two trials were conducted encompassing the major commercial techniques used to retard ripening and ensure that avocados arrive hard on the European market after export by sea. These techniques included temperature control, Controlled Atmosphere (CA), SmartFresh™ and waxing.*

*The results confirmed that all the mentioned procedures contribute towards reducing the risk of fruit softening in transit. The procedures were, however, also found to retard ripening during subsequent forced ripening. Compared to the other procedures, the effect of waxing was relatively small and cessation will only slightly contribute towards accelerating ripening. It may also result in more black cold injury and less attractive fruit. Unfortunately, a significantly higher incidence of fungal infections was recorded in fruit that were washed and waxed in the packinghouse compared to fruit that were washed in the laboratory. This aspect requires immediate attention. Preconditioning for 10 hours at 35°C before ripening at 20°C was found to effectively condense the ripening time of all treatments without impairing quality. The laboratory preconditioning trials must, nevertheless, be continued over a number of seasons with fruit from various producers, so as to establish what effect climate and horticultural practices have on the incidence of physiological and pathological disorders.*

**INTRODUCTION**

There is a perception amongst certain English ripeners that South African avocados fruit take longer to ripen, and ripen more unevenly than fruit from certain other countries. Although this aspect has not been scientifically investigated in the UK, it requires attention from South African researchers.

Due to the long storage period, considerable research has gone into the development of appropriate export procedures for South African avocados. The result is that the cold chain is very well managed and the incidence of fruit softening during shipment (soft landings) is effectively minimized. Because of this, the possibility exists that South African avocados take longer to ripen. It is therefore our responsibility to research procedures that will assist our clients to appropriately ripen South African avocado fruit.

A number of techniques are used to stop South African avocados from softening whilst being shipped to the UK. The most important of these is temperature management. Considerable research has gone into this aspect and the fruit are exported at a maturity related 'low as possible' temperature regime, but with a minimized risk of black cold injury.

A second aspect in which South African fruit differ from that of other countries concerns the use of wax. The natural waxes currently being used are thought to reduce the risk of black cold injury while providing an attractive shiny appearance to the fruit.

The third technique being employed is controlled atmosphere storage (CA). This service became available to the South African industry during the mid-nineties and has since been intensively used on avocados.

Finally, the ethylene inhibitor 1-methyl cyclopropene (SmartFresh™) has become available during the last few seasons. SmartFresh™ was found to lesson the risk of soft landings, while also reducing grey pulp, especially during the late season.

This paper deals with 2 trials. In the first we aimed to establish whether waxed fruit take longer to ripen than unwaxed fruit when stored under Regular Atmosphere (RA), CA or SmartFresh™ conditions. In the second, we aimed to establish whether preconditioning the fruit for a relatively short period at a comparatively high temperature will improve ripening without compromising quality.

**MATERIAL AND METHODS**

**Trial 1**

Early season waxed 'Hass' fruit (count 18) was obtained from the packing line of a Mpumalanga packinghouse during the early season. Unwaxed fruit of the same batch was washed in the lab using the same protocol as the packinghouse. The fruit was then either stored under CA or treated with SmartFresh™ and stored under RA. Both treatments were stored for 21 days. The CA fruit was stored at 6°C only, while the control and SmartFresh™ treated fruit was stored at temperatures of either 6, 7 or 8ºC. The fruit was then ripened at 20°C and evaluated upon ripening using the standard set of evaluation criteria including: number of days to ripen, physiological disorders (grey pulp, lenticel damage, black cold damage) and pathological disorders (stem-end rot, anthracnose).

**Trial 2**

Mid season waxed Hass fruit (count 18) was obtained from a second Mpumalanga packinghouse and stored under either RA, CA or SmartFresh™ conditions for 28 days at 5°C. After storage, one third of the fruit (6 box replicates) in each treatment was ripened at 18°C, while the second third was forced ripened with ethylene (100 ppm) at 20-21ºC. The forced ripening protocol included:

- A conditioning period of 24 hours at 20-22ºC before applying the ethylene.
- Ethylene: 100 ppm was applied for 12 hours every 2nd day until fruit started to break (i.e. until the onset of softening).
- The room was ventilated twice daily to prevent $CO_2$ build-up.

The last third of fruit was subjected to a 10 hour conditioning

period at 35°C before being ripened at 18°C. The fruit was evaluated upon ripening using the standard set of evaluation criteria including: number of days to ripen, physiological disorders (grey pulp, lenticel damage, black cold damage) and pathological disorders (stem-end rot, anthracnose).

## RESULTS AND DISCUSSION

### Trial 1

The ripening profiles of the fruit are shown in Fig. 1 a - c, while the mean number of days required to ripen the fruit as well as the incidences of the different physiological and pathological disorders are listed in Table 1a – e.

When stored at 6°C, unwaxed control fruit took on average 9.2 days to ripen (Table 1a). The number of days slightly increased to 9.8 when applying wax. In fruit that had been stored under CA conditions, the mean ripening time of unwaxed fruit increased by 2 days to 11.2 days and this further increased to 12.5 days in waxed fruit. In the case of SmartFresh™ treated fruit, both unwaxed and waxed fruit took 13.2 days to ripen. From the results it would therefore appear that both CA and SmartfFresh™ significantly increased the ripening time of Hass avocados and that waxing caused a less important further delay in CA stored fruit but not in SmartFresh™ treated fruit.

From a commercial perspective, three aspects need to be taken into consideration, namely, the day on which ripening starts, the day on which the majority of the fruit ripen (the ripening peak), and the period required to ripen all fruit. In terms of the onset of ripening, it would appear that in all 3 cases, the waxed and unwaxed fruit started to ripen on the same day (day 7 for control fruit and day 8 for CA and SmartFresh™ treated fruit). However, as far as the ripening peak is concerned, considerable variation existed between the control (Fig. 1a), CA (Fig. 1b) and SmartFresh™ (Fig. 1c) treatments. Control fruit peaked on either day 8 (unwaxed fruit) or day 9 (waxed fruit) during which approximately a third of the avocados ripened. In contrast, CA fruit peaked over a 3 day period (days 11 to 13) during which between approximately 70% (unwaxed) and 50% (waxed) of the fruit ripened. In the case of SmartFresh™ treated fruit, the peak was 2 days later (days 13 to 15) during which between 70% (waxed) and 60% (unwaxed) of the fruit ripened.

There were also differences between the various treatments in terms of the last fruit to ripen. All unwaxed control fruit reached the ready to eat stage by day 12 while the waxed fruit were all ripe by day 14. In the cases of CA and SmartFresh™ treated fruit, there was no difference between waxed and unwaxed fruit. The last of the CA fruit ripened on day 17 and the SmartFresh™ fruit on day 18.

The incidence of grey pulp is shown in Table 1b. There was no difference between waxed and unwaxed fruit as far as this disorder is concerned. The results, nevertheless, again demonstrated the powerful grey pulp reduction potential of SmartFresh™.

The percentages of fruit with black cold damage symptoms are shown in Table 1c. The results clearly show unwaxed fruit to be significantly more prone to chilling injury than waxed fruit. When stored at 6°C, between 7% and 19% of unwaxed fruit developed black cold injury symptoms, while virtually no waxed fruit developed symptoms.

The incidences of stem-end rot and anthracnose are shown in Tables 1d & e. In most cases, waxed fruit were found to have considerably higher rates of infection than unwaxed fruit.

This is an extremely worrying trend. However, as mentioned before, the waxed fruit were washed and waxed at the packinghouse while the unwaxed fruit were washed in the laboratory. It is therefore possible that the higher incidence of fungal infections may be attributable to the packinghouse procedure rather than the wax. We will most certainly follow up on this aspect.

### Trial 2

The mean number of days required to ripen early season Hass avocados is shown in Table 2. When ripened at 18°C, the control fruit took on average seven and a half days to ripen. CA and SmartFresh™ treatments added another 3 and 4 days respectively. When adding ethylene and increasing the temperature to 20°C, the average ripening time of control fruit was reduced by two and a half days, that of CA by three and a half days and that of SmartFresh™ by nearly 3 days.

When applying a 10 hour preconditioning treatment at 35°C, the mean ripening time of control and CA fruit was reduced by about 2 and 3 days respectively and that of SmartFresh™ by more than four and a half days.

The ripening profiles of the different treatments are shown in Fig. 2. When ripened at 18°C, the control fruit ripened over a 7-day period (days 5 to 11).

**Table 1. Average number of days to ripen Hass fruit (a) and the incidences of grey pulp (b), black cold damage (c), anthracnose (d) and stem-end rot (e). Waxed and non-waxed fruit of all treatments were stored at 6,7 and 8ºC. Averages marked with the same symbol are not significantly different (Student t-test (P<0.05) was used for days to ripen, while the $\chi^2$-test, (P<0.05), was used for the disorders. The statistics apply separately for each treatment temperature).**

a)

| Average days to ripen | 6°C | | 7°C | | 8°C | |
|---|---|---|---|---|---|---|
| | **Waxed** | No Wax | **Waxed** | No Wax | **Waxed** | No Wax |
| **Control** | 9.8 [a] | 9.2 [b] | 10.58 [b] | 9.666 [a] | 9.54 [b] | 8.54 [a] |
| CA | 12.5 [c] | 11.212 [d] | * | * | * | * |
| SmartFresh™ | 13.24 [e] | 13.21 [e] | 12.92 [c] | 13.02 [c] | 11.92 [c] | 12.23 [c] |

b)

| % Fruit with grey pulp | 6°C | | 7°C | | 8°C | |
|---|---|---|---|---|---|---|
| | **Waxed** | No Wax | **Waxed** | No Wax | **Waxed** | No Wax |
| **Control** | 0.00 [a] | 1.8 [a] | 5.45 [b] | 7.4 [b] | 5.71 [b] | 5.47 [b] |
| CA | 0.00 [a] | 2.08 [a] | * | * | * | * |
| SmartFresh™ | 0.00 [a] | 0.00 [a] | 0.00 [a] | 0.00 [a] | 0.00 [a] | 0.00 [a] |

c)

| % Fruit with black cold damage | 6°C | | 7°C | | 8°C | |
|---|---|---|---|---|---|---|
| | **Waxed** | No Wax | **Waxed** | No Wax | **Waxed** | No Wax |
| **Control** | 1.85 [a] | 18.51 [c] | 0.00 [a] | 4.71 [a] | 0.00 [a] | 0.00 [a] |
| CA | 0.00 [a] | 14.28 [c] | * | * | * | * |
| 300ppb SF | 0.00 [a] | 7.40 [b] | 1.85 [a] | 0.00 [a] | 0.00 [a] | 0.00 [a] |

d)

| % Fruit with anthracnose | 6°C | | 7°C | | 8°C | |
|---|---|---|---|---|---|---|
| | **Waxed** | No Wax | **Waxed** | No Wax | **Waxed** | No Wax |
| **Control** | 17.64 [e] | 1.85 [a] | 18.51 [d] | 7.40 [b] | 14.28 [b] | 5.5 [a] |
| CA | 6.66 [bd] | 3.7 [ab] | * | * | * | * |
| 300ppb SF | 9.09 [d] | 0.00 [a] | 12.9 [c] | 0.00 [a] | 1.85 [a] | 1.88 [a] |

e)

| % Fruit with stem end rot | 6°C | | 7°C | | 8°C | |
|---|---|---|---|---|---|---|
| | **Waxed** | No Wax | **Waxed** | No Wax | **Waxed** | No Wax |
| **Control** | 19.6 [c] | 3.7 [a] | 20.37 c | 11.11 [b] | 20.00 [b] | 5.47 [a] |
| CA | 23.3 [c] | 12.9 [b] | * | * | * | * |
| 300ppb SF | 21.2 [c] | 0.00 [a] | 16.66 [bc] | 5.66 [a] | 16.66 [b] | 3.77 [a] |

The CA fruit ripened over a 9-day period (days 6 to 14) while the SmartFresh™ fruit ripened over a 10-day period (days 7 to 16). The highest proportion of fruit ripening on any day for control fruit was approximately 30% (day 8) while that of CA and SmartFresh™ fruit was only about 20% on, respectively, days 11 and 13.

When applying ethylene and increasing the storage temperature, the first control fruit ripened one day earlier and the span shrunk to 4 days.

In the cases of CA and SmartFresh™ fruit, the onset of ripening was advanced by 2 days but the span shrunk by respectively 1 and 2 days.

Although the procedures resulted in more control fruit ripening during the early stages of the ripening period, the maximum number of CA or SmartFresh™ fruit ripening on any given day remained at around 20%.

Conditioning the fruit at 35°C for 10 hours before ripening, gave very good results. The onset of ripening was fairly similar to the above (4-5 days).

However, the ripening span of the CA and SmartFresh™ fruit was considerably reduced (around 6 days from start to finish). The SmartFresh™ treatment further yielded the highest percentage of fruit on any given day, namely around 40% on day 7. This procedure would therefore seem to be quite beneficial for the ripening of, especially, SmartFresh™ treated fruit.

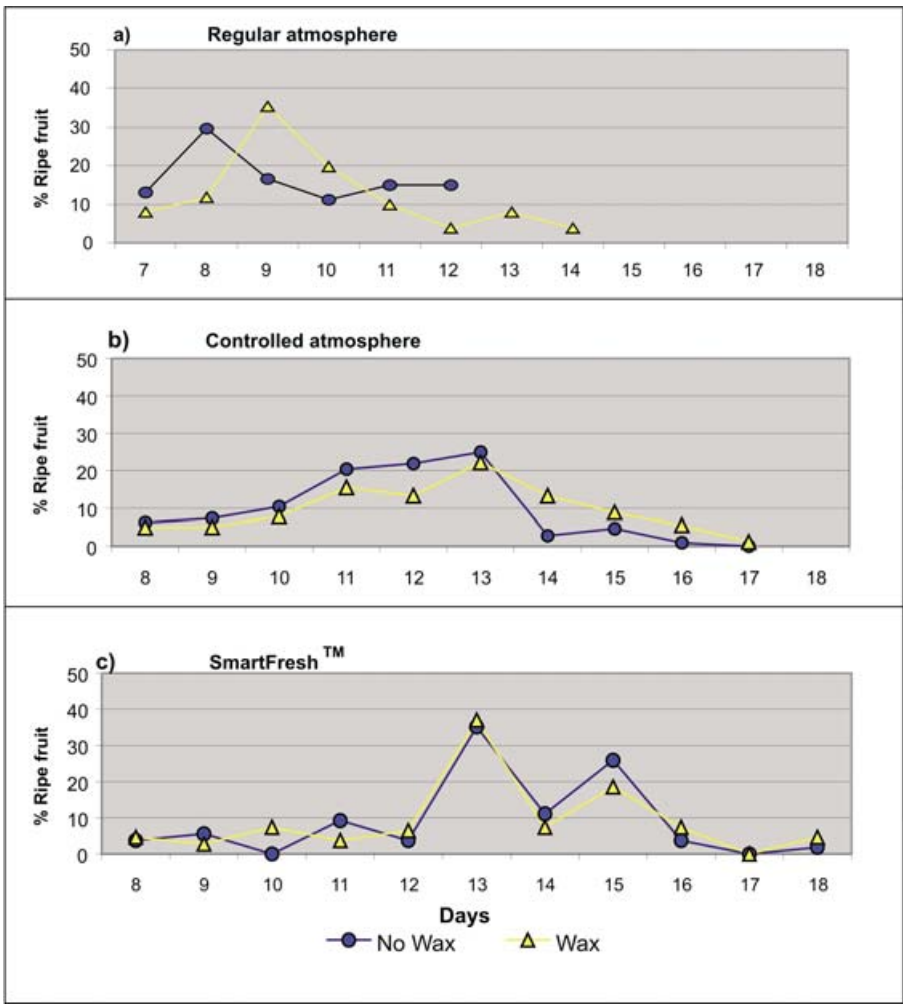



**Figure 1. Ripening profiles of early season count 18 Hass fruit. Waxed and non-waxed fruit were stored under either regular atmosphere (a), controlled atmosphere (b) or SmartFresh™ (c) conditions for a period of 21 days at 6ºC, before being ripened at 18ºC.**

**Table 2. Average number of days to ripen early season Hass fruit, as well as the percentage fruit with the following disorders: grey pulp, black cold damage, anthracnose and stem-end rot. Averages marked with the same symbol are not significantly different (Student t-test (P<0.05) was used for days to ripen, while the $\chi^2$-test, (P<0.05), was used for the disorders. The statistics apply separately for each ripening protocol).**

| Ripening protocol | Treatment | no. of days to ripen | % Fruit with | | | |
|---|---|---|---|---|---|---|
| | | | Grey pulp | Black cold damge | Anthracnose | Stem-end rot |
| Ripened @ 18°C | Untreated | 7.40 $^{a}$ | 0.00 $^{a}$ | 5.50 $^{a}$ | 0.00 $^{a}$ | 0.00 $^{a}$ |
| | Controlled atmosphere | 10.20 $^{b}$ | 0.00 $^{a}$ | 13.80 $^{C}$ | 0.00 $^{a}$ | 0.00 $^{a}$ |
| | SmartFresh™ | 11.40 $^{c}$ | 0.00 $^{a}$ | 11.11 $^{b}$ | 0.00 $^{a}$ | 0.00 $^{a}$ |
| Ripened @ 20°C + Ethylene | Untreated | 4.90 $^{a}$ | 0.00 $^{a}$ | 16.67 $^{c}$ | 0.00 $^{a}$ | 0.00 $^{a}$ |
| | Controlled atmosphere | 6.60 $^{b}$ | 0.00 $^{a}$ | 0.00 $^{a}$ | 0.00 $^{a}$ | 0.00 $^{a}$ |
| | SmartFresh™ | 8.60 $^{c}$ | 0.00 $^{a}$ | 5.50 $^{b}$ | 0.00 $^{a}$ | 0.00 $^{a}$ |
| 10h @ 35°C, then Ripened @ 18°C | Untreated | 5.60 $^{a}$ | 0.00 $^{a}$ | 0.00 $^{a}$ | 0.00 $^{a}$ | 0.00 $^{a}$ |
| | Controlled atmosphere | 7.20 $^{b}$ | 0.00 $^{a}$ | 0.00 $^{a}$ | 0.00 $^{a}$ | 0.00 $^{a}$ |
| | SmartFresh™ | 6.78 $^{c}$ | 0.00 $^{a}$ | 5.50 $^{b}$ | 0.00 $^{a}$ | 0.00 $^{a}$ |

## RECOMMENDATIONS AND FURTHER RESEARCH

The present results confirmed that the currently used storage temperature regimes as well as CA, SmartFresh™ and waxing all contribute towards reducing the risk of soft landings.

These procedures do, however, retard the ripening of the fruit during subsequent forced ripening as performed for the English 'ripe and ready' programmes.

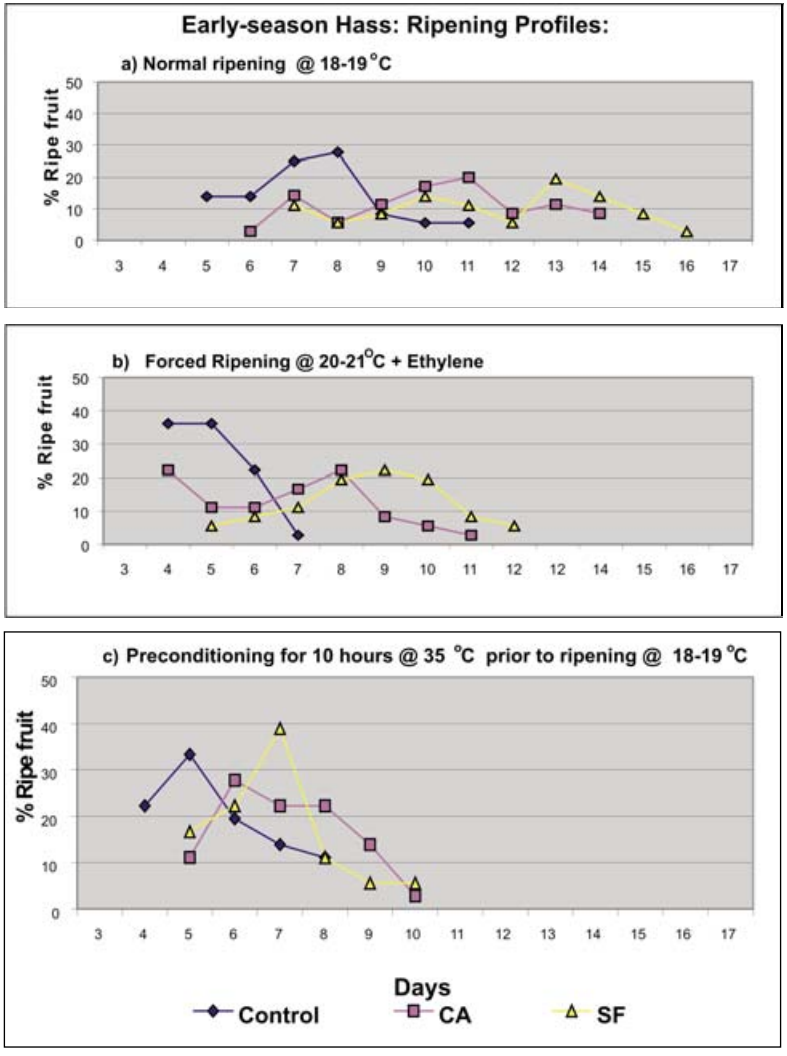
Compared to the other procedures, the effect that waxing has on ripening is relatively small. Discontinuation of waxing will therefore only slightly accelerate ripening.

It may also result in more black cold injury and less attractive fruit. The significantly higher incidence of fungal infections in fruit washed and waxed, in the packinghouse (compared to laboratory washed fruit) nevertheless requires immediate attention.

Preconditioning for 10 hours at 35°C before ripening at 20°C effectively condensed the ripening periods of all treatments, but the SmartFresh™ treatment benefited most from preconditioning. Although the present study did not show conditioning to impair quality, it is doubtful whether the English ripeners will apply preconditioning based on the present results only. It may therefore be fitting to send a representative to England to conduct such trials under commercial conditions.

During the last season, we have arranged to have a less drastic preconditioning treatment done on fruit that were experimentally bulk shipped to the UK (Ivin & Stanley, 2004). No adverse effect was noticed here either.

The laboratory trials should, however, be continued over a number of seasons with fruit from various producers, so as to establish what effect climate and horticultural practices have on the ultimate quality of preconditioned forced ripened fruit.




**EDITORIAL NOTE**

Since submitting the present article for publication, the preconditioning research has been continued during the 2005 avocado export season.

Unfortunately, the more drastic procedures (e.g. 35°C for 10 hours on day 25 followed by ripening at 18°C) did not meet expectations.

On the other hand, the less drastic intermittent preconditioning treatments (e.g. 20°C for 25 hours on day 21, followed by 5 days at 5°C and ripening at 18°C) consistently rendered good results.

These procedures further have the advantage that they can be applied by a South African exporter at an import facility in Europe, before dispatching the fruit to a prepacker who will then ripen the fruit as normal. A detailed report regarding these 'triggering' procedures will be published in the next issue of this journal.

**REFERENCE**

IVIN, C. & STANLEY, R. 2004. Quality evaluation of avocado's following bulk shipment from South Africa to Europe. Unpublished report.

**Figure 2. Ripening profiles of waxed Hass fruit that had been stored under regular atmosphere, controlled atmosphere and SmartFresh™ conditions. The fruit were either ripened at 18-19ºC (a), forced ripened with ethylene at 18-19ºC (b) or at 18-19ºC after a preconditioning period of 10 hours at 35ºC (c).**