Quantification of the respiration and softening rates of South African avocados of increasing maturity stored at different temperatures

D Lemmer, TR Malumane and FJ Kruger

Postharvest Technologies Division,
Agricultural Research Council – Institute for Tropical and Subtropical Crops,
Private Bag X11208, Nelspruit 1200, South Africa
E-mail: fransk@arc.agric.za

ABSTRACT

A study was launched to quantify the respiration and softening rates of South African export avocados. During the 2008 season baseline information was generated by storing Hass fruit under regular atmosphere (RA) at three moisture content levels (75, 70 and 65%) and four temperatures (7, 6, 5 and 4°C) for fifty days. The respiration rate of the fruit was determined every second day, while the firmness was measured every four days. An appropriate data base was established regarding the pace at which the respiration rate increases and the firmness decreases during the storage period. The results further indicated that, under RA conditions, the firmness of the fruit began decreasing before the respiration rate started to increase. These observations have important commercial ramifications, and appropriate management guidelines will be formulated after another season's data has been generated. In addition to these repetitive trials, breaks that may occur during different stages of the commercial cold chain will be simulated. Controlled atmosphere and 1-MCP will also be introduced to the study.

INTRODUCTION

This report deals with the first year's results of a three year project jointly sponsored by the Postharvest Innovation Program and the South African Avocado Growers' Association. The project proposal (Lemmer *et al.*, 2008) contains a relevant literature survey.

The first aim of this project is to quantify the respiration and softening rates of South African avocados of increasing maturity stored at currently prescribed temperature regimes. The second aim is to establish what effect temperature deviations of varying magnitude have on the respiration and in-transit softening rates of the fruit stored under regular atmosphere (RA), controlled atmosphere (CA) and SmartFresh conditions. The third aim is to record the post-storage ripening patterns of the above fruit.

The project is being conducted over a three year period, as from the 2008/09 season. During the planning stage it was decided that, during the first year, Hass fruit will be harvested at three maturity stages and stored at four different storage temperatures. During the second year, the most relevant maturity x temperature combinations will be selected and the temperature manipulated so as to simulate temperature deviations/breaks of varying magnitudes and intervals that may occur at specific stages of the commercial chain. During the third year, the most essential trials performed with 'Hass' will be repeated with the Fuerte and Pinkerton cultivars.

MATERIALS AND METHODS

The twelve treatments included during the 2008 season are listed in **Table 1**. For each individual treatment, 24 boxes of count 18 'Hass' were sampled from the HL Hall and Sons Packhouse in Nelspruit. Twenty of the boxes were used for respiration rate measurements (2 replications of 10 boxes each) while the remaining

Table 1. Maturity and storage temperature settings applied during the 2008 season

Treatment number	Moisture content (%)	Storage temperature (°C)
1	75	4
2	75	5
3	75	6
4	75	7
5	70	4
6	70	5
7	70	6
8	70	7
9	65	4
10	65	5
11	65	6
12	65	7

four were used for firmness measurements.

The respiration rate measurements were done every second day over a 50 day storage period. To do this, 10 boxes of fruit were enclosed in a 210 litre drum for one and half hours before measuring the CO_2 level inside the drum. The reading was hereafter processed and expressed as mg CO_2/kg/h.

The firmness measurements were done every four days. A desktop electronic Sinclair IQ firmness meter was used to take four measurements per fruit. The apparatus automatically calculated a representative value per fruit which was expressed in iQ units. The mean of the 72 fruit per sample was hereafter determined.

RESULTS AND DISCUSSION

The respiration rate measurements of the 12 combinations (3 maturity levels x 4 storage temperatures) are depicted in **Figure 1** while the firmness of the fruit is shown in **Figure 2**. The respiration rate and firmness measurement readings of the four storage tempera-

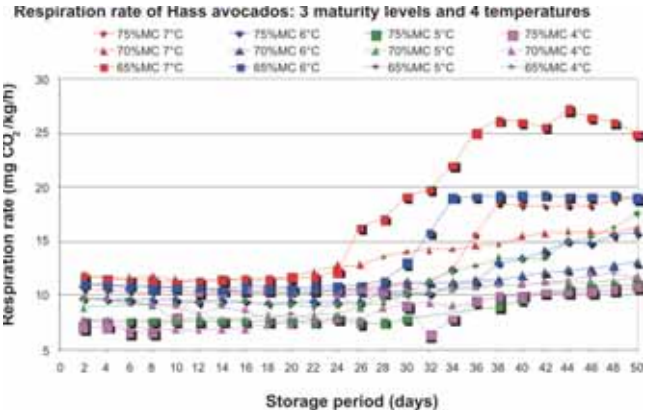

Figure 1. Respiration rates of 'Hass' avocado fruit of increasing maturity stored at different temperatures

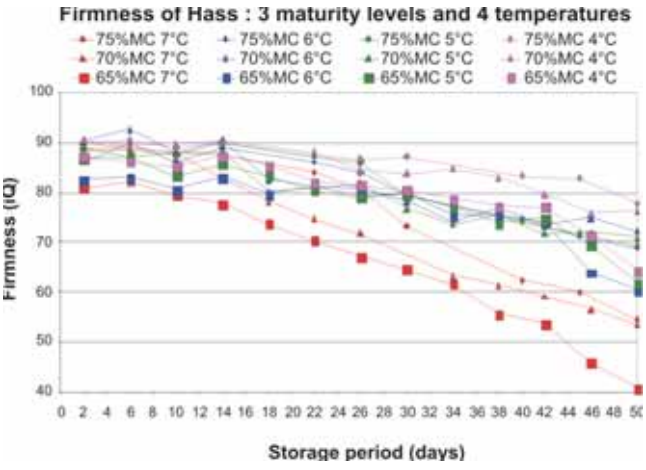

Figure 2. Softening rates of 'Hass' avocado fruit of increasing maturity stored at different temperatures

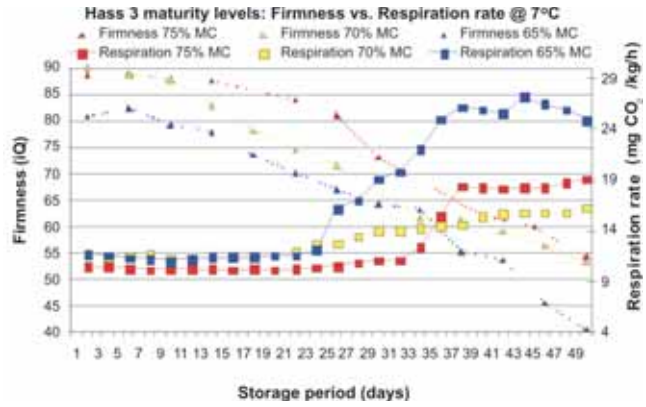

Figure 3. Respiration and softening rates of 'Hass' avocado fruit stored at 7°C

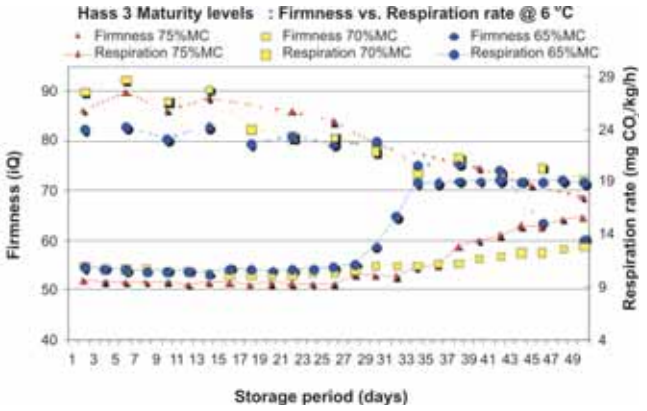

Figure 4. Respiration and softening rates of 'Hass' avocado fruit stored at 6°C

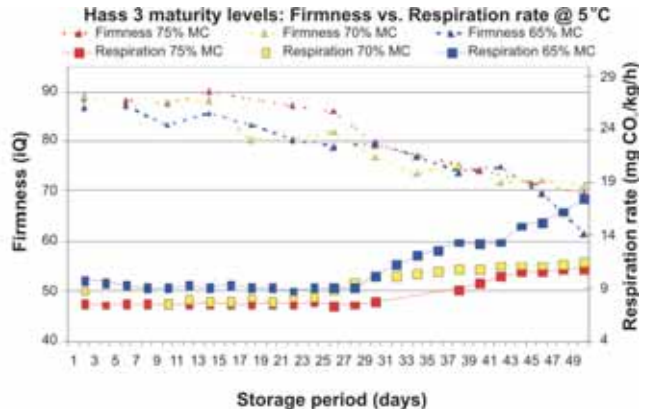

Figure 5. Respiration and softening rates of 'Hass' avocado fruit stored at 5°C

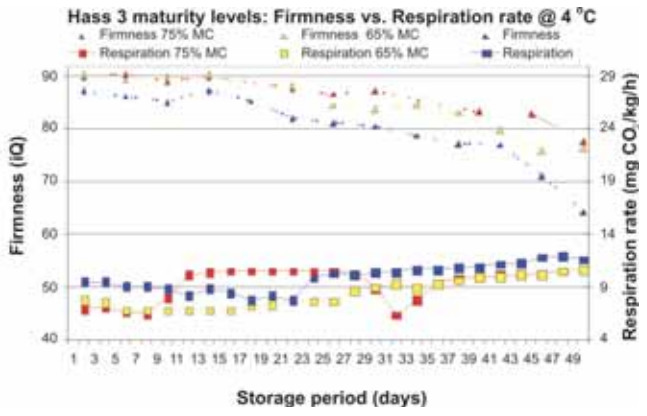

Figure 6. Respiration and softening rates of 'Hass' avocado fruit stored at 4°C

tures are compared in **Figure 3** (7°C), **Figure 4** (6°C), **Figure 5** (5°C) and **Figure 6** (4°C).

The mean respiration rates recorded during the first three weeks of storage are shown in **Table 2**. The day on which the respiration rates of each of the treatments started to increase and the maximum rate registered are shown in **Table 3**. The linear regression determined softening rates of the fruit are shown in **Table 4**.

The following conclusions can be drawn from the graphs and tables:

- With early season fruit, the respiration rates of the 6°C and 7°C treatments were around 10 mg CO_2kg/h at the beginning of the storage period and this increased to between 15 and 20 CO_2/kg/h after approximately one month.
- At the end of the season, the initial respiration rates of the fruit kept at the above temperature settings were around 11 mg CO_2/kg/h. It increased to between 20 and 30 mg CO_2/kg/h after approximately three weeks.
- At the beginning of the season, the respiration rates of the 4°C and 5°C treatments were around 7 mg CO_2/kg/h. However, they did not show the drastic increases observed with the 6 and 7°C settings and only gradually increased to around 11 mg CO_2/kg/h by the end of the storage period. (Interestingly, cold damage caused a temporary increase in respiration rate of about 5 mg CO_2/kg/h for approximately three weeks in the 4°C treatment. Although the respiration rate then returned to its original levels, this observation may have commercial importance, especially with sensitive cultivars stored at higher temperatures.)
- By the end of the season, the initial respiration rates of the 4°C and 5°C treatments were around 9 mg CO_2/kg/h. The 4°C then exhibited a gradual increase to around 12 mg CO_2/kg/h. In contrast, the 5°C treatment showed a marked increase, not dissimilar to the 6°C and 7°C treatments, as from day 28 to reach 18 mg CO_2/kg/h by day 50.
- The initial respiration rates of the samples harvested at the 70% moisture content level were halfway between those of the early and late season samples. However, the respiration rates of these fruit, which were harvested in the middle of winter, did not show the subsequent sharp increases in respiration rate observed in the 75% and 65% MC fruit.
- The firmness of all samples was around 90 iQ units before storage.
- The firmness of the samples stored at 7°C decreased at the fastest rate. At the end of storage these fruit were between 55 iQ units (75 and 70% MC treatments) and 40 iQ units (65% MC treatment).
- The 75 and 70% MC samples stored at 4°C remained the firmest and were between 75-80 iQ units at the end of the 50 day storage period.
- All other samples were in between the above two levels and reached between 60 and 75 iQ units at the end of the storage period.
- Most importantly, the firmness of most samples started to decrease before a significant increase

Table 2. Mean respiration rates recorded for 'Hass' avocados during the first 3 weeks of storage

Storage temperature (°C)	Respiration rate (mg CO_2/kg/h)		
	75% MC	70% MC	65% MC
7	10.35 d	11.56 a	11.4 a
6	9.45 e	10.58 cd	10.72 c
5	7.55 h	8.13 g	9.22 e
4	6.78 i	7.04 i	8.69 f

Table 3. Day on which a drastic increase in respiration rate was initiated and the maximum respiration rate recorded for 'Hass' avocados

Storage temperature (°C)	Day of increase and maximum rate (mg CO_2/kg/h)					
	75% MC		70% MC		65% MC	
	Day	Max	Day	Max	Day	Max
7	32	19.12	Gradual	16.27	24	27.8
6	36	15.68	Gradual	13.01	28	19.22
5	Gradual	10.5	Gradual	11.57	Gradual	17.49
4	Gradual	10.75	Gradual	10.69	22	11.97

Table 4. Mean daily softening rates of 'Hass' avocados of increasing maturity stored at different temperatures

Storage temperature (°C)	Mean daily softening rate per maturity category					
	75% MC		70% MC		65% MC	
	iQ/day	R^2	iQ/day	R^2	iQ/day	R^2
7	0.77	0.93	0.82	0.99	0.85	0.96
6	0.42	0.88	0.44	0.9	0.48	0.75
5	0.44	0.88	0.42	0.92	0.44	0.88
4	0.23	0.88	0.31	0.9	0.4	0.85

in respiration rate was recorded. For instance, the firmness of the 65% MC fruit stored at 7°C exhibited a marked decrease in firmness as from day 10 while the respiration rates of the same samples only started to increase as from day 24. This observation has important commercial ramifications as it implies that, under RA conditions, an exporter will only pick up increases in return air temperature (RAT) after the fruit has lost a significant proportion of firmness. Remedial delivery air temperature (DAT) adjustments may therefore very well be too late.

- The rate at which the loss of firmness took place depended on the interaction between fruit maturity and the storage temperature. The least mature fruit (75%) stored at the lowest temperature (4°C) exhibited the slowest softening rate (0.23 iQ units per day) while the most mature fruit (65%), stored at the highest temperature (7°C), had the highest softening rate (0.85 iQ units per day). The respiration rates of the intermediate combinations were distributed between the latter values. If proven to be consistent, these values may be of great value to prepackers who supply the 'ready to eat' market as it may enable them to order fruit at a specific firmness.

FURTHER RESEARCH

During the 2008 avocado season sound baseline information was generated regarding the respiration and softening rates of 'Hass' avocado fruit stored under export simulation conditions. The consistency of the observed trends will be verified during the 2009 season. The effect that complementary ripening inhibition techniques such as CA and SmartFresh has on the respiration and softening rates of the fruit, will also be determined. So will the influence of storage breaks of varying magnitude and duration.

ACKNOWLEDGEMENTS

The authors would like to thank the Postharvest Innovation Program and the South African Avocado Growers' Association for financial support as well as HL Hall and Sons for supplying the fruit.

LITERATURE CITED

LEMMER, D., MALUMANE, T.R. AND KRUGER, F.J. 2008. Project proposal for the quantification of the respiration and softening rates of South African avocados of increasing maturity stored at different temperatures. Unpublished document: Postharvest Innovation Program, Cape Town.