Laboratory investigation into the effect that the time period between harvest and the application of a balanced atmosphere has on the quality and ripening patterns of South African export avocado fruit (with some comparative SmartFresh results)

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ABSTRACT

The primary aim of this project is to determine what effect the balanced atmosphere (BA) to regular atmosphere (RA) storage period ratio has on the storage potential and ripening patterns of 'Hass' and 'Maluma' avocado fruit stored under export simulation conditions. The results indicated that the quality of 'Hass' was excellent during the 2018 season and very few disorders occurred. Certain ripening pattern related results, that were linked to the relative lengths of the BA and RA storage periods, were nevertheless observed. In addition, the ripening patterns of SmartFresh treated fruit were found to be in line with those of the BA treatments during the 2018 season. In the case of 'Maluma', a definite advantage was observed when starting BA within 4 days after harvest.

INTRODUCTION

Presently, most South African avocado consignments are only placed under controlled atmosphere (CA) in Cape Town harbour. Current regulations stipulate that the fruit may be kept under regular atmosphere (RA) conditions in cold rooms and refrigerated trucks for a maximum of 14 days before having to be containerised and shipped.

In a minority of instances, "door to door" CA is employed. That is, the containers are transported to the packing house where they are loaded and the atmosphere build-up initiated. The atmosphere then establishes itself during the road transport and harbour storage phases. This works well, but higher costs, smaller consignment sizes and the extra logistical arrangements have caused the procedure to be primarily used during the late season only by most exporters.

CA consignments are generally set at a ratio of 6% CO_2; 4% O_2. Active scrubbing, filtering and purging are required to maintain this ratio. However, during the last number of seasons, the use of a balanced atmosphere (BA) system where the O_2 + CO_2 rates add up to 21% has been tested with success. The reduced complexity of managing BA made it much easier to conduct experiments, both in the laboratory and under commercial conditions.

The present project represents the laboratory phase of a study aiming to establish whether it will be possible to create intermittent atmospheres in tents and trucks without having to transport CA containers from the harbour to the packhouse. It aims to quantify the maximum period 'Hass' and 'Maluma' fruit of increasing maturity may be held at regular atmosphere before having to be placed under CA/BA.

Since the project offered an opportunity to make comparisons between the ripening inhibition effects of BA and SmartFresh, this treatment was also included in the study.

MATERIALS AND METHODS

A series of trials was performed during the 2018 season. Two cultivars ('Hass' and 'Maluma') and two fruit sizes (count 18 and jumble-packed fruit) were used.

The balanced atmosphere currently used by certain service providers (8% CO_2; 13% O_2) was employed for the BA treatments.

The fruit were stored under RA conditions for either 1, 4, 8, 12 or 16 days before being placed into BA for the balance of the 30-day storage period. During certain experiments, the above 3-4 day intervals were shortened to 1-2 days so as to generate more refined data for, especially, the 'Maluma' cultivar.

Referential SmartFresh applications were further included in certain of the trials. These included different application rates and periods that are specified in the results and discussion section.

Upon removal from storage, the firmness of ten fruit from each treatment was determined with a penetrometer. A carton of each count was then ripened and the number of days required to ripen each fruit recorded. The fruit were thereafter dissected and the internal quality scored.

RESULTS AND DISCUSSION

'Hass'

None of the 'Hass' fruit had a firmness lower than 15 kg upon removal from cool storage after 30 days at 5.5°C. No instances of "soft arrivals" therefore occurred. The incidences of physiological and pathological disorders were further negligible in this cultivar.

The results from two trials are shown in Tables 1-4. It is important to take note of the higher degree of ripening related variation that was recorded in the jumble fruit (Tables 2 and 4) compared to the Count 18 fruit (Tables 1 and 3). This is probably due to higher incidences of dead seeds in the jumble fruit that pre-disposed them to faster ripening.

In the case of Count 18 fruit (Tables 1 and 3), the RA treatments' ripening was more synchronised (3 day span) than that of the BA treatments' (4-7 day span). This was also evident in the jumble fruit in the first trial (Table 2). However, the opposite was true for the second trial performed with jumble fruit (Table 4) where the BA fruit ripening was more synchronised than the RA fruit.

In the first trial (Tables 1 and 2), the BA application period reached its optimal effectiveness when applied for 22 days or longer, while in the second (Tables 3 and 4) there was a dose response up to the 30-day mark.

In the second 'Hass' trial (Tables 3 and 4), the commercially used SmartFresh application rate/period combination (300 ppb) gave very similar ripening rate results to the longer BA storage periods while the lower rates (100 and 200 ppb) were equitable to the shorter BA periods. This supports our current application rate/period recommendation (300 ppb for 16 hours) for mid-season fruit destined for ripening programmes.

Table 1. Ripening rate of Count 18 'Hass' avocado fruit (dry matter 27.2%) stored for 30 days at 5.5°C under regular atmosphere (RA) and balanced atmosphere (BA) conditions for a total of 30 days

Treatment	Ready to eat fruit per day (%)										
	Day 2	Day 3	Day 4	Day 5	Day 6	Day 7	Day 8	Day 9	Day 10	Day 11	Day 12
RA 30 days	71	14	14								
RA 16 days BA 14 days		14	29	14	14	21	7				
RA 12 days BA 18 days			7	21	21	21	14	14			
RA 8 days BA 22 days				21	29	36	14				
RA 4 days BA 26 days				36	36	29					
BA 30 days				14	29	21	14	21			

Table 2. Ripening rate of Count Jumble 'Hass' avocado fruit (dry matter 27.2%) kept for six different time periods under, respectively, RA and BA conditions for a total of 30 days.

Treatment	Ready to eat fruit per day (%)												
	Day 3	Day 4	Day 5	Day 6	Day 7	Day 8	Day 9	Day 10	Day 11	Day 12	Day 13	Day 14	Day 15
RA 30 days	29	21	6	17	21	4	2						
RA 16 days BA 14 days			15	4	25	33	23						
RA 12 days BA 18 days		8	10	6	35	25	13	2					
RA 8 days BA 22 days			13	23	19	15	23	4	4				
RA 4 days BA 26 days			8	10	27	25	2	10	2	6	4	2	2
BA 30 days				13	31	8	8	6	6	2	10	8	6

Table 3. Ripening rate of Count 18 'Hass' avocado fruit (dry matter 28.2%) stored for 30 days at 5.5°C under regular atmosphere (RA) and balanced atmosphere (BA) conditions for different time periods or treated with three SmartFresh application rates.

Treatment	Ready to eat fruit per day (%)										
	Day 3	Day 4	Day 5	Day 6	Day 7	Day 8	Day 9	Day 10	Day 11	Day 12	Day 13
RA 30 days			11	67	22						
RA 16 days BA 14 days			22	28	50						
RA 12 days BA 18 days				22	56	22					
RA 8 days BA 22 days					61	17	6	17			
RA 4 days BA 26 days					11	22	28	17	11	6	6
BA 30 days							33	11	28	22	6
SmartFresh 100 ppb				39	22	6	6	27			
SmartFresh 200 ppb						17	27	6	22	11	17
SmartFresh 300 ppb								17	28	28	28

Table 4. Ripening rate of Count Jumble 'Hass' avocado fruit (dry matter 32.5%) treated with three SmartFresh application rates or kept for four different lengths of time under BA. The fruit were stored for 30 days at 5.5°C.

Treatment	Ready to eat fruit per day (%)										
	Day 3	Day 4	Day 5	Day 6	Day 7	Day 8	Day 9	Day 10	Day 11	Day 12	Day 13
RA 30 days	25	20	15	10	10	5	5	5	5		
RA 16 days BA 14 days			20	30	5	10	35				
RA 12 days BA 18 days				35	15	30	20				
RA 8 days BA 22 days				10	5	15	30	20	10	10	
RA 4 days BA 26 days						15	30	30	15	10	
BA 30 days						25	15	20	30	10	
SmartFresh 100 ppb		15	30	5	15	15	20				
SmartFresh 200 ppb				15	15	30	10	15	15		
SmartFresh 300 ppb								25	20	15	40

The first of the above trials were performed with mid-season fruit (mid-June), while the second was performed with mid-late season fruit (mid-August) from a higher altitude orchard. The results from a third, SmartFresh rate/period, trial conducted with very-late season fruit from a high-altitude orchard (DM 30%) rendered quite interesting results (Table 5).

The above trial consisted of 21 treatments. In addition to a RA control, there were 5 SmartFresh rates (100, 200, 300, 400 & 500 ppb) and 4 application periods (12, 24, 36 & 48 hours). The first observation to be made is that the RA control represented a soft landing in that a proportion of the fruit were already ripe on day 1. The second is that the control fruit ripened over an extended period of 8 days. This premature and diffuse ripening pattern was corroborated by a similar pattern in the two shortest period/lowest rate (100 ppb for 12 and 24 hours) SmartFresh applications which also ripened from day 1 to day 8. The third observation is that both the application rate and the application period showed clear dose effects in so far as the start of ripening is concerned. What is, however, important is that, although the higher rate/longer period applications took longer to start ripening, they ripened over a shorter period. The 500 ppb rate recommended for this time of the year did especially well.

'Maluma'

In contrast with 'Hass', only fruit put under BA within 4 days after harvest had consistent firmness readings higher than 15 kg upon removal from cool storage. This was true for both Count 18 fruit (Table 6) as well as for jumble packs (Table 7). This was reflected in the physiological disorder profile of Count 18 fruit, but not jumble packs where fruit with dead stones were only free of grey pulp when stored for the whole 30-day storage period under BA conditions (Fig. 1).

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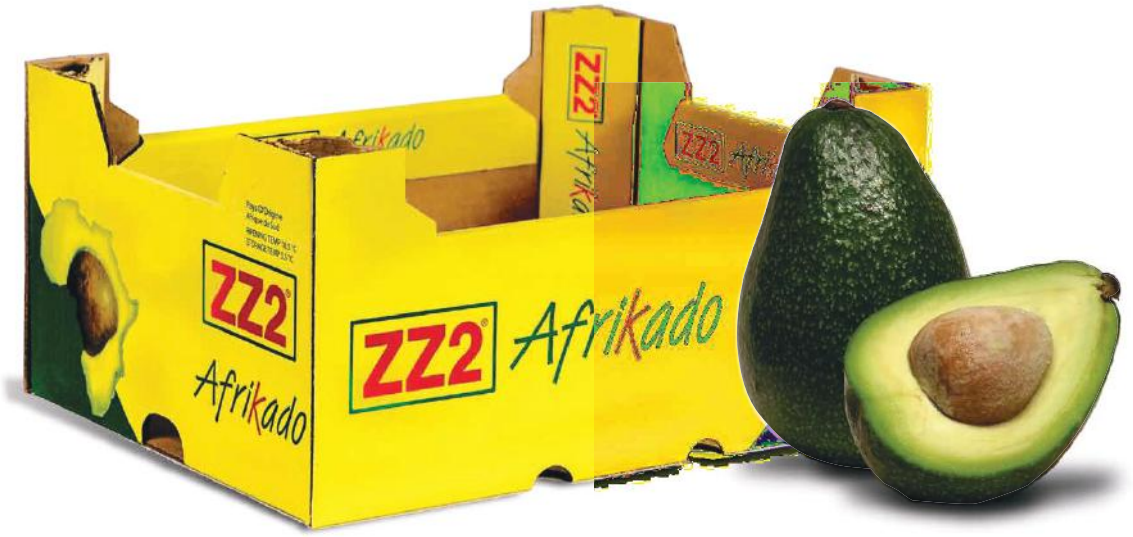

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Table 5. Ripening rate of late season (October 2018) 'Hass' avocado fruit after storage for 21 days at 4°C followed by ripening at 20°C. Except for the odd bruise, there were no physiological or pathological disorders.

	Percentage of ripe fruit per day no													
Day no	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**
Treatment														
Control	5		45		25	15	5	5						
100 ppb 12 hrs	35	30	5	5		10	10	5						
100 ppb 24 hrs	10	10		20	30	20	5	5						
100 ppb 36 hrs				15	45	15	15	10						
100 ppb 48 hrs					20	15	10	35	10	10				
200 ppb 12 hrs			30	30	15	15	10							
200 ppb 24 hrs				15	5	5	5	15	25	10	20			
200 ppb 36 hrs				20	20	5	5	5	15	10	10	5	5	
200 ppb 48 hrs						10	15	15	5	25	20	5	5	
300 ppb 12 hrs							10	20	15		15	25	15	
300 ppb 24 hrs						10	10	10	20		15	15	10	10
300 ppb 36 hrs									25	5	30	10	10	20
300 ppb 48 hrs										10	30	15	20	25
400 ppb 12 hrs						10	20	30	30	5	5			
400 ppb 24 hrs								15	25	10	20	10	10	10
400 ppb 36 hrs								5	15	20	30	15	5	10
400 ppb 48 hrs										20	30	25	15	10
500 ppb 12 hrs								25	15	10	30	20		
500 ppb 24 hrs								25	25	35	5	5	5	
500 ppb 36 hrs									30	20	25	10	5	10
500 ppb 48 hrs										25	40	20	10	5

Table 6. Firmness of Count 18 'Maluma' fruit (dry matter 29%) directly after storage for 30 days at 5.5°C under regular atmosphere (RA) and balanced atmosphere (BA) conditions for different time periods.

Storage period		Firmness per fruit (kg)									
RA	**BA**	1	2	3	4	5	6	7	8	9	10
1	29	15+	15+	15+	15+	15+	15+	15+	15+	15+	15+
4	26	15+	15+	15+	15+	15+	15+	15+	15+	15+	15+
8	22	15+	14	13,7	12,1	12	11,9	11,6	10,2	9,6	9,1
12	18	15+	15+	15+	15+	14	13,3	11,6	11,5	6,6	6
16	14	15+	15+	15+	13,5	6,9	6,5	6,4	5,9	5,7	3,9
30	0	11	8,1	7,7	5,1	4,4	3,5	2,1	2	1,6	1,5

Table 7. Firmness of jumble packed 'Maluma' fruit (dry matter 28.5%) directly after storage for 30 days at 5.5°C under regular atmosphere (RA) and balanced atmosphere (BA) conditions for different time periods.

Storage period		Firmness per fruit (kg)									
RA	**BA**	1	2	3	4	5	6	7	8	9	10
1	29	15+	15+	15+	15+	15+	15+	15+	15+	15+	15+
4	26	15+	15+	15+	15+	15+	15+	15+	15+	15+	15+
8	22	15+	15+	15+	15+	14,2	11,2	10,2	9,7	9,6	7,3
12	18	15+	15+	15+	15+	15+	15+	11,7	10,5	6,1	5,1
16	14	9,2	8,9	8,2	7,8	5,4	4,7	4,4	2,4	2,4	2,3
30	0	13,5	5,6	3,9	2,8	2,6	2,6	2,5	2,3	2,2	1,9

In certain trials, both Count 18 and jumble fruit were only free of vascular stains when placed under BA within four days after harvest (Fig. 2). Due to the specialised approach required to explain the aetiology of the 'Maluma' disorders, a separate report has been compiled for the purpose (Kruger *et al*., 2019a).

RECOMMENDATIONS

The present results indicate that 'Maluma' must preferably be placed into BA storage within 4 days of picking.

Due to orchard and climate induced variations, it is important to perform more trials with the 'Hass' cultivar over a number of seasons before a definitive recommendation is made regarding the maximum period from harvest to BA application. It would, nevertheless, seem justified to continue with our sister project aimed at developing alternative strategies to lengthen the BA period making use of trucks and tents in place of door to door containers (Kruger *et al*., 2019b).

The results again showed that, during certain seasons, SmartFresh ripens as well, if not better than fruit stored under BA. The decision was therefore taken to institute a ripening prediction service so as to establish in advance whether a specific season will pose ripening related problems or not.

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Storage period (days)		Appearance after 30 days at 6°C and 2.5 days at 20°C
RA	BA	
1	29	
2	28	
4	26	
5	25	

Figure 1. Internal quality of jumble packed 'Maluma' fruit after storage for 30 days at 5.5°C under regular atmosphere (RA) and balanced atmosphere (BA) conditions for different time periods.

Storage periods (days)		Appearance	
RA	BA	Count: 18	Count: Jumble
1	29		
4	26		
8	22		

Figure 2. Internal quality of Count 18 and jumble packed 'Maluma' fruit after storage for 30 days at 5.5°C under regular atmosphere (RA) and balanced atmosphere (BA) conditions for different time periods.