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The Effect of Intransit and Storage Conditions on the Quality of Avocados -1997 Season

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INTRODUCTION

The European market demands hard avocados without any external and internal disorders. All these characteristics are influenced by horticultural aspects, preshipment handling procedures and voyage conditions.

These conditions and market quality were monitored over seven seasons. Present handling and transport procedures are based on this research. Most of the available data and recommendations however, are based on the behaviour of Fuerte avocados shipped in ducted containers. This season however, Hass and Pinkerton varieties as well as CA containers were also evaluated on a limited scale.

Important aspects confirmed during previous seasons can be summarised as follows:

- Fuerte avocados older than 28 days between picking and arrival in the market develop more chilling injury (longer low temperature exposure) and were softer than younger fruit irrespective of optimum postharvest temperature management procedures.

- Freshly picked avocados can be transported and shipped warmer than older fruit and will arrive in a firm condition provided optimum voyage temperatures were maintained.

- For different age categories of fruit to arrive on the market with firmo readings of 30 units and less, the following maximum loading temperature tolerances must apply:

• Fruit which will be approximately 20 days old on arrival (i.e. so called dead line fruit) can be loaded up to 4°C warmer than the specified optimum holding store intake temperature.

• Fruit of the "medium category" that will be approximately 24 days old on arrival at the market; can be loaded up to 3°C warmer than the specified optimum holding store intake temperature.

• "Old fruit" that will be older than 28 days on arrival at the market must not be loaded warmer than 2°C than the specified optimum holding store intake temperature.

- "Too fast" cooling and holding at too low temperatures prior to shipment resulted in more black and brown cold development.

A temperature management system to ensure a constant downward trend in pulp temperature reduced the rate of softening during the voyage and drastically reduced the incidence of chilling injury and physiological disorders.

Fruit condition pre-harvest and post-harvest discharge as well as road transport and voyage temperatures for the 1997 season again were analysed. These results and conclusions are discussed in this report.

1. PROCEDURES

Evaluation of fruit condition

A total of 185 containers of avocados, sampled from commercial shipments, from various packhouses in South Africa to arrival at the Rungis market in Paris, Belgium and England were monitored. The 185 containers included 104 containers of Fuerte avocados and 17 containers of Hass and Pinkerton avocados. It is important to note that one sample represents a 20 ft container containing two thousand one hundred 5 kg cartons of avocados.

Definitions

The following definitions and abbreviations for quality parameters were used in the text and statistical tables.

AGE **Age** of the fruit in days from time of picking and the event. eg. Age arrival = number of days between picking and arrival at the Rungis market in Paris.
ANTH **Anthracnose** ie. fungal disease characterised as black spots (lesions) on the skin of fruit.
ARR **Arrival** of fruit on the market.
BLC **Black cold** - a chilling injury resulting in a brown to black discolouration of the skin.
BRC **Brown cold** - a chilling injury that normally develops after storage and transport at colder temperatures, ie. normally first seen at the market.
BRS **Internal bruising**
CA **Controlled Atmosphere** - ie. the oxygen and carbon dioxide concentrations are controlled to certain levels in the container.
CERC **Cercospora spot**
DC **Dothiorella**
DSK **Dusky cold** - a senescent discolouration that develops on the skin of Fuerte and sometimes on Edranol - normally at the eating ripe stage.
F-AV **Average firmness** - fruit firmness as measured with a densi-meter
GP **Grey pulp** - greyish pulp discoloration that develops in the mesocarp of the avocado fruit a few minutes after cutting the fruit, exposing tissue to oxygen.
INT **Internal** - ie. internal quality or internal defects.
LD **Lentidamage** - External discolouration of mainly the lenti-cels. This defect is not related to low temperatures during storage. It is a type of mechanical damage and develops during subsequent transport and storage.
MD **Mechanical damage**
PS **Pulp spot** - discoloured (greyish) spots developing in the mesocarp soon after the fruit has been cut.
RA **Regular atmosphere storage.**
RIPE Fruit evaluated at eating ripe storage.
SER **Stem end rot**. A fungal decay starting at the stem end.
SM **Sooty mould** - a fungus disease on the skin of the fruit.
VB **Vascular browning** - A brown discolouration of the vascular tissue starting from the stem end spreading into the fruit.

2. RESULTS AND DISCUSSIONS

The results of the statistical analysis of Fuerte avocado indices shipped by sea from South Africa to the Rungis market in Paris are summarised in tables 1 to 4. The quality indices for Hass are summarised in tables 5 to 7 and for Pinkerton in table 8 and 9.

It was decided, in an effort to keep the discussions focused on the major industry problems only, to summarise the quality indices. This is done in table 10.

This data indicates that fruit firmness and black cold were the two most important quality problems during the 1997 avocado season.

2.1 Fruit firmness

Fruit firmness is one of the most important quality parameters. Avocado importers and distributors require hard fruit. This means that avocados must arrive in the market place with a firmness reading of at least 90 units for Hass and 85 units for Fuerte as determined with the densimeter.

Table 1. Summary statistics for Fuerte in porthole containers during 1997

Variable	Age	F-AV	BLC-ARR
Sample size	185.	185.	185.
Average	24.1	79.3	1.1
Standard error	0.272508	0.641805	0.1713
Minimum	4.	45.	0.
Maximum	40.	95.	17.
Lower quartile	21.	76.	0.
Upper quartile	26.	85.	1.
Variable	**LD-ARR**	**BRC-ARR**	**DSK-ARR**
Sample size	185.	185.	185.
Average	2.944108	0.622703	3.254443
Standard error	0.260869	0.206327	0.484313
Minimum	0.	0.	0.
Maximum	22.2	25.	40.
Lower quartile	0.5	0.	0.
Upper quartile	4.	0.	3.13
Variable	**SM-ARR**	**MD**	**DC-ARR**
Sample size	185.	185.	185.
Average	0.826005	39.499586	0.552719
Standard error	0.155516	1.627804	0.243037
Minimum	0.	0.	0.
Maximum	12.5	100.	33.333
Lower quartile	0.	22.22	0.
Upper quartile	0.1	50.	0.
Variable	**ANTH-X-A**	**SER-X-ARR**	**CERC**
Sample size	185.	185.	185.
Average	1.367535	0.045027	5.759191
Standard error	0.290249	0.045027	0.707127
Minimum	0.	0.	0.
Maximum	30.	8.33	54.5
Lower quartile	0.	0.	0.
Upper quartile	0.	0.	8.333
Variable	**SM-RIPE**	**BLC-RIPE**	**LD-RIPE**
Sample size	184.	185.	185.
Average	1.781957	5.246141	8.536012
Standard error	0.390082	1.873222	0.582586
Minimum	0.	0.	0.
Maximum	56.25	329.	50.
Lower quartile	0.	0.	3.57
Upper quartile	1.4	2.8	11.
Variable	**BRC-RIPE**	**DSK-RIPE**	**TOTAL-COLD**
Sample size	185.	185.	185.
Average	2.319569	7.914061	20.784822
Standard error	0.402723	0.770271	1.354121
Minimum	0.	0.	0.
Maximum	43.	81.25	92.
Lower Quartile	0.	0.	8.
Upper quartile	2.1	11.	26.5
Variable	**ANTH-X-RIPE**	**SER-X-RIPE**	**DC-RIPE**
Sample size	185.	185.	185.
Average	8.770982	8.065694	3.320719
Standard error	0.997824	1.067489	0.732382
Minimum	0.	0.	0.

Table 1. Continued

Variable	ANTH-INT-RIPE	SER-INT-RIPE
Sample size	185.	185.
Average	4.700112	5.695789
Standard error	0.736094	0.758498
Minimum	0.	0.
Maximum	58.33	56.25
Lower quartile	0.	0.
Upper quartile	6.25	8.333

Variable	VB	GP	PS
Sample size	185.	185.	185.
Average	8.678285	18.648265	19.617198
Standard error	1.138704	1.648441	1.65101
Minimum	0.	0.	0.
Maximum	92.	100.	100.
Lower quartile	0.	0.	0.
Upper quartile	12.5	28.57	31.

Variable	BRS-INT
Sample size	185.
Average	2.201666
Standard error	0.484871
Minimum	0.
Maximum	57.14
Lower quartile	0.
Upper quartile	0.

2.1.1. *Fuerte firmness*

The industry average firmness readings (F-AV) for Fuerte avocados shipped in RA containers was 79.3 units (table 1) and for Fuerte shipped in CA containers was 88.9 units (table 3).

If all the quality reports (local and overseas) and marketing comments are considered, then it can be concluded that:

• The 1997 avocado season can be characterised as a "soft fruit" season.

• Avocados transported under CA conditions arrived much harder (firmer) than avocados shipped in RA containers.

• Avocado fruit firmness on arrival of the seven "port hole vessels" were compared (table 4). No statistical differences in fruit firmness on arrival could be found between the different vessels sailing from Cape Town to Zeebrugge (Belgium)

Fruit firmness categories as measured with a Firmometer and densimeter are as follows:

Category	Firmometer	Densimeter (Fuerte)	Densimeter (Hass)
VERY HARD	≤ 20	≥ 90	≥ 96
HARD	21 - 30	85 - 89	92 - 95
FIRM	31 - 35	82 - 84	90 - 91
BREAKING	36 - 45	77 - 81	86 - 89
SOFT	46 - 75	61 - 76	74 - 85
VERY SOFT	76 - 99	49 - 60	65 - 73
EAT-RIPE	≥ 100	≤ 48	≤ 64

The abovementioned quality and shipping parameters were correlated with the condition of the avocados on arrival on the Rungis market in Paris. This data was statistically analysed using the STATGRAPHICS computer programme. Analysis of variance, multiple regression and simple correlation techniques were used.

If the data for fruit firmness (F-AV) in tables 1 and 3 are compared, it can also be seen that:

• Average firmness for RA was 79.3 units compared to 88.7 units for CA fruit.

• Minimum firmness for RA Fuerte was 45 units compared to 76 units for CA Fuerte. Fruit firmness of the hardest fruit shipped RA and CA did not differ (95 units versus 96 units).

If fruit firmness of Fuerte avocados on arrival in Paris is considered over the total season, then it can be stated that:

• Especially the first six shipments (± first 6 weeks) of RA fruit arrived too soft.

• Firmness of RA fruit improved later (from ± 7th week) during the season.

• CA shipped Fuerte arrived in a firm condition throughout the season.

It can therefore be concluded that, especially conditions of inherent softer fruit, shipping under CA conditions can retain fruit firmness better than RA shipping. This was especially true for the first six Fuerte shipments of the 1997 season.

Table 2 Continued. Sample correlation between the variable for Fuerte in porthole containers during 1997

	AGE	F-AV	BLC-ARR	LD-ARR	BRC-ARR	DSK-ARR	SM-ARR	MD	DC-ARR	ANTH-X-A	SER-C-ARR
AGE	1.0000 (185) 0.0000	0.2544 (185) 0.0005	0.0517 (185) 0.4844	-0.0163 (185) 0.8253	0.1885 (185) 0.0102	-0.0021 (185) 0.9777	0,1427 (185) 0.0526	0.0028 (185) 0.9694	-0.0238 (185) 0.7475	0.0124 (185) 0.8668	0.1973 (185) 0.0071
F-AV	-0.2544 (185) 0.0005	1.0000 (185) 0.0000	-0.0021 (185) 0.9777	0.0464 (185) 0.5304	-0.1140 (185) 0.1224	-0.2009 (185) 0.0061	-0.0830 (185) 0.2615	-0.0939 (185) 0.2038	-0.0743 (185) 0.3151	-0.2385 (185) 0.0011	-0.2061 (185) 0.0049
BLC-ARR	0.0517 (185) 0.4844	-0.0021 (185) 0.9777	1.0000 (185) 0.0000	0.1509 (185) 0.0403	0.1486 (185) 0.0436	0.2532 (185) 0.0005	0.0533 (185) 0.4715	-0.0828 (185) 0.2624	-0.0411 (185) 0.5784	0.1247 (185) 0.0908	-0.0358 (185) 0.6284
LD-ARR	-0.0163 (185) 0.8253	0.0464 (185) 0.5304	0.1509 (185) 0.0403	1.0000 (185) 0.0000	0.0739 (185) 0.3173	0.1474 (185) 0.0453	-0.0191 (185) 0.7962	0.0949 (185) 0.1989	-0.0498 (185) 0.5006	0.1766 (185) 0.0162	-0.0405 (185) 0.5841
BRC-ARR	0.1885 (185) 0.0102	-0.1140 (185) 0.1224	0.1486 (185) 0.0436	0.0739 (185) 0.3173	1.0000 (185) 0.0000	0.1256 (185) 0.0884	0.1679 (185) 0.0223	0.0003 (185) 0.9967	-0.0373 (185) 0.6142	0.1732 (185) 0.0184	-0.0164 (185) 0.8246
DSK-ARR	-0.0021 (185) 0.9777	-0.2009 (185) 0.0061	0.2532 (185) 0.0005	0.1474 (185) 0.0453	0.1256 (185) 0.0884	1.0000 (185) 0.0000	0.0552 (185) 0.4559	-0.0015 (185) 0.9836	-0.0628 (185) 0.3959	0.0838 (185) 0.2568	-0.0365 (185) 0.6216
SM-ARR	0.1427 (185) 0.0526	-0.0830 (185) 0.2615	0.0533 (185) 0.4715	-0.0191 (185) 0.7962	0.1679 (185) 0.0223	0.0552 (185) 0.4559	1.0000 (185) 0.0000	-0.0778 (185) 0.2923	-0.0601 (185) 0.4164	-0.0179 (185) 0.8090	-0.0289 (185) 0.6965
MD	0.0028 (185) 0.9694	-0.0939 (185) 0.2038	-0.0828 (185) 0.2624	0.0949 (185) 0.1989	0.0003 (185) 0.9967	-0.0015 (185) 0.9836	-0.0778 (185) 0.2923	1.0000 (185) 0.0000	0.0695 (185) 0.3475	0.0660 (185) 0.3723	-0.0551 (185) 0.4564
D-C-ARR	-0.0238 (185) 0.7475	-0.0743 (185) 0.3151	-0.0411 (185) 0.5784	-0.0498 (185) 0.5006	-0.0373 (185) 0.6142	-0.0628 0.3959	-0.0601 (185) 0.416	0.0695 (185) 0.3475	1.0000 (185) 0.0000	0.2122 (185) 0.0037	0.0124 (185) 0.8674
ANTH-X-A	0.0124 (185) 0.8668	-0.2385 (185) 0.0011	0.1247 (185) 0.0908	0.1766 (185) 0.0162	0.1732 (185) 0.0184	0.0838 (185) 0.2568	-0.0179 (185) 0.8090	0.0660 (185) 0.3723	0.2122 (185) 0.0037	1.0000 (185) 0.0000	0.1304 (185) 0.0769
SER-X-ARR	0.1973 (185) 0.0071	-0.2061 (185) 0.0049	-0.0358 (185) 0.6284	-0.0405 (185) 0.5841	-0.0164 (185) 0.8246	-0.0365 (185) 0.6216	-0.0289 (185) 0.6965	-0.0551 (185) 0.4564	-0.0124 (185) 0.8674	0.1304 (185) 0.0769	1.0000 (185) 0.0000

Coefficient (sample size) significance level

Recommendation for Fuerte avocados

It is recommended that CA shipping is considered for at least the first four weeks (based on results of previous seasons) but preferably for the first six weeks (based on 1997 results) of the Fuerte export season.

2.1.2 *Hass firmness*

The industry average firmness (F-AV) of Hass avocados shipped in RA containers (table 5) was 90.2 units and for CA container shipments (table 6) was 92.3 units. This means that, on average, all Hass avocados arrived in Paris in firm to hard condition irrespective of RA and CA shipping conditions.

Recommendation for Hass avocados

Hass avocados need not to be shipped under CA conditions to retain fruit firmness.

Table 2. Sample correlations between the variables for Fuerte in porthole containers during 1997

	AGE	F-AV	SM -RIPE	BLC-RIPE	LD-RIPE	BRC-RIPE	DSK-RIPE	V-B	GP	PS
AGE	1.0000 (184) 0.0000	-0.2568 (184) 0.0004	0.1118 (184) 0.1308	0.1119 (184) 0.1305	0.1434 (184) 0.0521	0.1928 (184) 0.0087	-0.1506 (184) 0.0413	0.0920 (184) 0.2141	0.1266 (184) 0.0868	0.1869 (184) 0.0111
F-AV	-0.2568 (184) 0.0004	1.0000 (184) 0.0000	-0.1111 (184) 0.1333	0.0090 (184) 0.9035	-0.1407 (184) 0.0568	-0.1414 (184) 0.0556	-0.1587 (184) 0.0314	-0.0645 (184) 0.3846	0.0140 (184) 0.8500	0.0271 (184) 0.7152
SM-RIPE	0.1118 (184) 0.1308	-0.1111 (184) 0.1333	1.0000 (184) 0.0000	0.0059 (184) 0.9365	0.1352 (184) 0.0673	0.0831 (184) 0.2619	0.0572 (184) 0.4407	0.1017 (184) 0.1695	0.1267 (184) 0.0865	0.0505 (184) 0.4958
BLC-RIPE	0.1119 (184) 0.1305	0.0090 (184) 0.9035	0.0059 (184) 0.9365	1.0000 (184) 0.0000	-0.0143 (184) 0.8476	0.0142 (184) 0.8478	-0.0165 (184) 0.8241	0.1351 (184) 0.0675	0.1151 (184) 0.1197	0.1545 (184) 0.0363
LD-RIPE	0.1434 (184) 0.0521	-0.1407 (184) 0.0568	0.1352 (184) 0.0673	-0.0143 (184) 0.8476	1.0000 (184) 0.0000	0.1403 (184) 0.0575	0.1668 (184) 0.0237	0.2225 (184) 0.0024	0.2466 (184) 0.0007	0.2385 (184) 0.0011
BRC-RIPE	0.1928 (184) 0.0087	-0.1414 (184) 0.0556	0.0831 (184) 0.2619	0.0142 (184) 0.8478	0.1403 (184) 0.0575	1.0000 (184) 0.0000	0.0435 (184) 0.5575	0.1517 (184) 0.0398	0.0388 (184) 0.6012	0.0593 (184) 0.4238
DSK-RIPE	-0.1506 (184) 0.0413	-0.1587 (184) 0.0314	0.0572 (184) 0.4407	-0.0165 (184) 0.8241	0.1668 (184) 0.0237	0.0435 (184) 0.5575	1.0000 (184) 0.0000	0.0607 (184) 0.4129	-0.0338 (184) 0.6485	0.0762 (184) 0.3036
V-B	0.0920 (184) 0.2141	-0.0645 (184) 0.3846	0.1017 (184) 0.1695	0.1351 (184) 0.0675	0.2225 (184) 0.0024	0.1517 (184) 0.0398	0.0607 (184) 0.4129	1.0000 (184) 0.0000	0.6434 (184) 0.0000	0.6525 (184) 0.0000
GP	0.1266 (184) 0.0868	0.0140 (184) 0.8500	0.1267 (184) 0.0865	0.1151 (184) 0.1197	0.2466 (184) 0.0007	0.0388 (184) 0.6012	-0.0338 (184) 0.6485	0.6434 (184) 0.0000	1.0000 (184) 0.0000	0.5992 (184) 0.0000
PS	0.1869 (184) 0.0111	0.0271 (184) 0.7152	0.0505 (184) 0.4958	0.1545 (184) 0.0363	0.2385 (184) 0.0011	0.0593 (184) 0.4238	0.0762 (184) 0.3036	0.6525 (184) 0.0000	0.5992 (184) 0.0000	1.0000 (184) 0.0000

Coefficient (sample size) significance level

2.1.3. *Pinkerton firmness*

Pinkerton avocado fruit firmness on arrival in Paris in RA containers averaged 88.2 units (table 8) with a minimum of 83 and a maximum of 94 units. This means that Pinkerton avocados arrived, on average, in a "breaking" condition measured on the Hass densimeter scale. Pinkerton shipped in CA containers (table 9) arrived at an average firmness of 87.9 which on the Hass scale also means a "breaking condition". Pinkerton fruit shipped CA were comparable with RA but CA fruit developed 41% pulp spot compared to 18% when shipped RA.

Fruit softening of Pinkerton shipped under RA/CA conditions was therefore not an industry problem during 1997.

Recommendation for Pinkerton avocados

More experimental data is required before recommendations on RA and CA shipping conditions and fruit firmness can be made.

2.2 Black cold injury

Black cold injury develops during storage at too low a temperature. It is therefore a chilling injury that becomes more severe when the storage temperature is reduced to counteract fruit softening. Although a very important market quality disorder, it is considered more important to deliver hard fruit and that the market can "absorb" some cold injury if the fruit is hard.

The incidence of black cold (as summarised in table 10) varied between cultivars and ripeness. A maximum incidence of 2.5% should however not be exceeded. With this as a criterium, it can be seen that Black cold was a problem with ripe Fuerte and Pinkerton and not with Hass. It can also be seen that:

• Black cold on arrival of Fuerte avocados shipped RA was only 1.1%. (table 1 BLC-ARR) and for CA it was 1.9% (table 3). This indicates a tendency for CA shipped Fuerte to develop more black cold injury than RA shipped Fuerte.

• The data in Tables 1 and 3 also indicates a maximum black cold incidence for Fuerte avocados of 17% when shipped RA but this increased to 66.7% for Fuerte shipped under CA conditions.

• **Black cold at the eating ripe** stage increased to 5.2% for Fuerte and 5.9% for Pinkerton avocados. This increase is not acceptable and needs further investigation.

• Possible increases in the incidence of Black cold during ripening are not available for CA Fuerte and for both RA and -CA Hass.

It can however be concluded that, in an attempt to maintain fruit firmness, transport temperatures were maintained at levels that could have resulted in more black cold than previous seasons.

Table 3. Summary statistics for Fuerte in CA containers during 1997

Variable	Age	F-AV	BLC-ARR
Sample size	129.	129.	129.
Average	24.589147	88.868217	1.994853
Standard error	0.263587	0.32282	0.807757
Minimum	20.	76.	0.
Maximum	35.	96.	66.
Lower quartile	22.	88.	0.
Upper quartile	27.	91.	0.4
Variable	**LD-ARR**	**BRC-ARR**	**DSK-ARR**
Sample size	129.	129.	129.
Average	2.867752	0.083721	0.62907
Standard error	0.339214	0.051289	0.147275
Minimum	0.	0.	0.
Maximum	28.	6.	13.33
Lower quartile	0.5	0.	0.
Upper quartile	3.	0.	0.3
Variable	**SM-ARR**	**MD**	**DC-ARR**
Sample size	129.	129.	129
Average	0.518682	37.049177	0
Standard error	0.145188	1.929814	0
Minimum	0.	0.	0
Maximum	14.	83.333	0
Lower quartile	0.	20.	0
Upper quartile	0.	50.	0
Variable	**ANTH-X-A**	**SER-X-ARR**	**CERC**
Sample size	129.	129	
Average	0.409504	0	
Standard error	0.169913	0	
Minimum	0.	0	
Maximum	12.5	0	
Lower quartile	0.	0	
Upper quartile	0.	0	

Recommendations

• The effect of CA on the incidence of black cold on Fuerte and other cultivars needs to be investigated.

• The increase in black cold incidence during ripening needs to be investigated to ensure correct post discharge handling.

2.3 Other quality defects

One of the reasons why it is important to present the trade with firm to hard avocados is that softer fruit tends to develop more external and internal quality related disorders. Fruit age (days between picking and arrival in the market place) is one of the major factors determining fruit firmness (other factors eg. picking maturity and temperature management are as important). It is therefore very important to deliver avocados to the consumer as soon as possible (24 days on average for Fuerte table 1 AGE) to maintain fruit firmness.

Fuerte quality

The correlation between different quality parameters for RA shipped Fuerte avocados for the 1997 season is given in table 2. This data confirm that:

• Older fruit (more days between picking and marketing) resulted in softer fruit with more black cold and brown cold. (Mainly due to the longer storage period of the older fruit).

• Older fruit also developed more quality disorders when ripened eg. more dusky cold, vascular browning, grey pulp and pulp spot.

• Softer fruit also developed more disorders such as dusky, cold, mechanical damage and anthracrose decay during transport.

• Quality deterioration (as sumarised in table 9) took place during the past shipment storage and ripening period. Some of these disorders (grey pulp and pulp spot) increased from 0.0% on arrival to more than 18% at eating ripe stage.

Unfortunately insufficient data is available on CA shipped Fuerte avocados. It can only be stated that:

• CA shipped Fuerte arrived significantly more firm than the RA shipped Fuerte.

• CA shipped Fuerte avocados developed more black cold than RA shipped fruit.

It was reported by the Institute for Tropical and Subtropical Crops (ITSC) that rainy conditions prior to harvest may result in fruit softening and other quality defects for as long as six weeks after the rain. It is suspected that the heavy rains before the start of the Fuerte season could have affected the quality of the fruit of the first six shipments. This aspect needs further research.

Table 4. Table of means for Fuerte firmness in porthole containers, 1997 season

Levels: Ships		Variable: Firmness at arrival				
Source of variation		SS	df	MS	F-ratio	Sig. level
Between Groups		622.46	6	103.73	1.378	0.2258 not sign.
Within Groups		13399.15	178	75.28		
Total Corrected		14021.61				

Levels: Ships	Count	Average	Std. Error (internal)	Std. Error (pooled s)	95% LSD Intervals for mean	
K	24	80.416667	2.0850717	1.7710179	77.944855	82.888478
H	45	78.511111	1.1719026	1.2933686	76.705955	80.316267
S	33	78.030303	1.4971468	1.5103292	75.922335	80.138271
C	24	78.375000	2.1726332	1.7710179	75.903188	80.846812
W	23	79.260870	1.8556797	1.8091087	76.735894	81.785845
I	19	78.789474	1.9019518	1.9904523	76.011397	81.567550
L	17	84.647059	1.0979298	2.1042829	81.710109	87.584009
Total	185	79.340541	0.6378855	0.6378855	78.450243	80.230838

K = DAL KALAHARI
H = HEEMSKERCK
S = SEDERBERG
C = CITY OF CAPE TOWN
W = WATERBERG
I = WINTERBERG
L = HELDERBERG

Table 5. Summary statistics for Hass in porthole containers during 1997

Variable	Age	F-AV	BLC-ARR
Sample size	337.	349.	322.
Average	23.827893	90.174785	0.97993
Standard error	0.185111	0.258	0.091205
Minimum	3.	58.	0.
Maximum	40.	98.	18.
Lower quartile	22.	88.	0.1
Upper quartile	26.	93.	1.2

Variable	LD-ARR-RIPE	BRC-ARR-RIPE	DSK-ARR-RIPE
Sample size	334.	320.	319.
Average	9.946177	0.019656	0.119812
Standard error	0.466099	0.016399	0.05862
Minimum	0.	0.	0.
Maximum	43.	5.2	16.
Lower quartile	3.8	0.	0.
Upper quartile	15.	0.	0.

Variable	MD	ANTH-X-ARR	SER-X-ARR
Sample size	349.	347.	347.
Average	14.665395	0.21268	0.086455
Standard error	0.731205	0.110804	0.086455
Minimum	0.	0.	0.
Maximum	75.	30.	30.
Lower quartile	6.25	0.	0.
Upper quartile	21.	0.	0.

Variable	V-B	GP	PS
Sample size	347.	347.	347.
Average	4.457427	13.460725	12.369688
Standard error	0.590423	1.055458	0.932709
Minimum	0.	0.	0.
Maximum	81.	100.	100.
Lower quartile	0.	0.	0.
Upper quartile	5.55	18.75	21.

Hass quality

CA shipment of Hass avocados did not result in better fruit firmness or lower incidences of lenticel damage, vascular browning, grey pulp or pulp sport (table 9).

It must however be noted that Hass avocados developed more lenticel damage, vascular browning, grey pulp and pulp spot than Fuerte (and much less of these and other disorders than Pinkerton.)

Pinkerton quality

Pinkerton avocados shipped in RA porthole or CA integral containers arrived in an average "breaking" condition in Paris. The average fruit firmness of 88 units was in the same range as CA shipped Fuerte and CA and RA Hass but much better than RA shipped Fuerte.

Pinkerton fruit however developed severe lenticel damage (17.9%), vascular browning (37.7%) and pulp spot 29.4%). Grey pulp was also a problem in both RA and CA containers during the entire season. The incidence of grey pulp increased rom 18.4% in RA to 41.0% in CA containers.

More data is required before any firm conclusions can be drawn regarding factors affecting the market quality of Pinkerton avocados shipped in RA and CA containers.

Table 6. Summary statistics for Hass in CA containers during 1997

Variable	Age	F-AV	BLC-ARR
Sample size	102.	104.	101.
Average	24.990196	92.259615	1.062248
Standard error	0.356185	0.272253	0.18521
Minimum	18.	84.	0.
Maximum	37.	98.	9.6
Lower quartile	22.	91.	0.
Upper quartile	27.	94.	1.
Variable	**LDD-ARR**	**BRC-ARR**	**DSK-ARR**
Sample size	103	101	101
Average	10.101068	0	0.014851
Standard error	0.807003	0	0.014851
Minimum	0.6	0	0
Maximum	38	0	1.5
Lower quartile	3.9	0	0
Upper quartile	13	0	0
Variable	**SM-ARR**	**ANTH-X-A**	**SER-X-ARR**
Sample size	101.	104	104
Average	0.036634	0	0
Standard error	0.024524	0	0
Minimum	0.	0	0
Maximum	2.2	0	0
Lower quartile	0.	0	0
Upper quartile	0.	0	0
Variable	**V-B**	**GP**	**PS**
Sample size	104.	104.	104.
Average	3.624382	10.42504	10.863382
Standard error	0.876162	1.752112	1.566624
Minimum	0.	0.	0.
Maximum	66.666	100.	64.
Lower quartile	0.	0.	0.
Upper quartile	2.7775	12.5	18.4659

Recommendations

- Fruit age and transport temperatures need to be carefully controlled to ensure hard fruit on arrival in the market place. The procedures developed over the past decade cannot be faulted and must be applied to ensure optimum quality.
- The effect of the environment (especially rain and associated conditions) must be studied to enable the industry to modify handling procedures (eg. RA vs CA shipments).
- More data is required to evaluate the effect of post-harvest conditions on the quality of Pinkerton avocados.

2.4 General comments

The authors of this report are all members of the South African Avocado Growers' Association (SAAGA) temperature research committee. In this capacity they have accumulated much experience that may be subjective to a certain degree but, is still more valuable than empirical data. A special effort was made during the 1997 season to identify some important factors to be considered by the avocado industry. These factors are:

- *Preshipment temperatures*

Delays in cooling after picking, too slow cooling, too low relative humidity warming and recooling, warm RMT temperatures intransit to the port and temperature increases during port handling cannot be corrected by a strict temperature management system during the voyage.

Most of the quality problems experienced during 1997 are directly related to inadequate preshipment temperature control.

Table 7. Sample correlation between the variables for Hass in porthole containers during 1997

	AGE	F-AV	SM -RIPE	BLC-RIPE	LD-RIPE	BRC-RIPE	ANTH-INT	SER-INT- R	V-B	GP	PS
AGE	1.0000 (306) 0.0000	-0.2647 (306) 0.0000	0.1083 (306) 0.0585	-0.0704 (306) 0.2196	0.2804 (306) 0.0000	0.2115 (306) 0.0002	0.0711 (306) 0.2147	0.0012 (306) 0.9833	0.0941 (306) 0.1005	0.0617 (306) 0.2821	0.0686 (306) 0.2318
F-AV	-0.2647 (306) 0.0000	1.0000 (306) 0.0000	-0.1822 (306) 0.0014	0.1736 (306) 0.0023	-0.3923 (306) 0.0000	-0.3455 (306) 0.0000	-0.2510 (306) 0.0000	-0.1443 (306) 0.0115	-0.1998 (306) 0.0004	-0.1859 (306) 0.0011	-0.0806 (306) 0.1594
BLC-ARR	0.1083 (306) 0.0585	-0.1822 (306) 0.0014	1.0000 (306) 0.0000	0.2264 (306) 0.0001	0.0767 (306) 0.1810	0.2723 (306) 0.0000	0.2312 (306) 0.0000	0.0601 (306) 0.2946	0.0738 (306) 0.1977	0.1836 (306) 0.001 3	0.1372 (306) 0.0163
LD-ARR	-0.0704 (306) 0.2196	0.1736 (306) 0.0023	0.2264 (306) 0.0001	1.0000 (306) 0.0000	0.0115 (306) 0.8408	-0.0043 (306) 0.9407	0.0416 (306) 0.4687	0.0154 (306) 0.7882	0.0225 (306) 0.6954	0.1092 (306) 0.0563	0.1207 (306) 0.0348
BRC-ARR	0.2804 (306) 0.0000	-0.3923 (306) 0.0000	0.0767 (306) 0.1810	0.0115 (306) 0.8410	1.0000 (306) 0.0000	0.8494 (306) 0.0000	0.1127 (306) 0.0489	0.1277 (306) 0.0255	0.1264 (306) 0.0270	0.0761 (306) 0.1844	0.0878 (306) 0.1256
DSK-ARR	0.2115 (306) 0.0002	-0.3455 (306) 0.0000	0.2723 (306) 0.0000	-0.0043 (306) 0.9407	0.8494 (306) 0.0000	1.0000 (306) 0.0000	0.1038 (306) .0697	0.0959 (306) 0.0941	0.1150 (306) 0.0444	0.0440 (306) 0.4431	0.0742 (306) 0.1958
ANTH-INT	0.0711 (306) 0.2147	-0.2510 (306) 0.0000	0.2312 (306) 0.0000	0.0416 (306) 0.4687	0.1127 (306) 0.0489	0.1038 (306) 0.0697	1.0000 (306) 0.0000	0.5215 (306) 0.0000	0.3784 (306) 0.0000	0.2306 (306) 0.0000	0.1888 (306) 0.0009
SER-INT-R	0.0012 (306) 0.0012	-0.1443 (306) 0.9833	0.0601 (306) 0.2946	0.0154 (306) 0.7882	0.1277 (306) 0.0255	0.0959 (306) 0.0941	0.5215 (184) 0.0000	1.0000 (306) 0.0000	0.2767 (306) 0.0000	0.0538 (306) 0.3486	0.1499 (306) 0.0086
V-B	0.0941 (306) 0.1005	-0.1998 (306) 0.0004	0.0738 (306) 0.1977	0.0225 (306) 0.6954	0.1264 (306) 0.0270	0.1150 (306) 0.0444	0.3784 (306) 0.0000	0.2767 (306) 0.0000	1.0000 (306) 0.0000	0.4653 (306) 0.0000	0.5937 (306) 0.0000
GP	0.0617 (306) 0.2821	-0.1859 (306) 0.0011	0.1836 (306) 0.0013	0.1092 (306) 0.0563	0.0761 (306) 0.1844	0.0440 (306) 0.4431	0.2306 (306) 0.0000	0.0538 (306) 0.3486	0.4653 (306) 0.0000	1.0000 (306) 0.0000	0.5871 (306) 0.0000
PS	0.0686 (306) 0.2318	-0.0806 (306) 0.1594	0.1372 (306) 0.0163	0.1207 (306) 0.0348	0.0878 (306) 0.1256	0.0742 (306) 0.1958	0.1888 (306) 0.0009	0.1499 (306) 0.0086	0.5937 (306) 0.0000	0.5871 (306) 0.0000	1..0000 (306) 0.0000

Coefficient sample size significance level

• *Loading temperature tolerances*

The 2.3 and 4°C temperature tolerances for "old", "medium" and "dead line" fruit were developed some 6 years ago and were applied commercially with much success. It is very clear that this "fruit age and temperature" formula will have to be applied strictly or perhaps if not, be changed to force colder arrival and loading pulp temperature.

The concept that so called "dead line" fruit may be 4°C warmer than the carrying temperature suits the avocado industry and the suppliers of infrastructure very well. It is however very clear that a lack of efficient cooling and temperature maintenance of "dead line" avocados totally cancelled the positive effect of having fresher fruit in the market.

In many cases it would have been better to ship fruit on the next vessel 8 days later, than to have rushed "dead line" fruit through the process.

Dead line avocados must arrive in the port colder than 4°C above the specified container loading temperature.

• *Early season loading temperatures*

The first few (up to 4) shipments are normally loaded and shipped at 7.5°C for up to 7 days after departure before the temperature is reduced to 7°C. This procedure is followed to reduce the incidence of chilling injury (especially black cold). It is however clear that the initial temperature of 7.5°C is still too warm and conducive to soft fruit on arrival. This is also (possibly) the main reason why the first shipments of Fuerte did better in CA containers because the CA minimised softening at 7.5°C or even at 7.0°C.

The temperature regime must start at 7.0°C (and not 7.5°C) for the first shipments and the step down procedure be based on feedback from the vessels and the market.

• *Increased volumes*

The big increase in export volume expected for 1998 will definitely cause new problem areas that will have to be solved. Some of these problems will require further research but a number of aspects should be considered before the season starts. Most important aspects are:

- Proper planning by individuals but also by the total industry to ensure deliveries of adequately pre-cooled fruit. Avocados that are on temperature can be shipped immediately into containers or conventional decks.

- Accurate estimates and timeous bookings of shipping space to avoid disappointment of fruit not being shipped as a result of insufficient space being available.

Table8. Summary statistics for Pinkerton in porthole containers during 1997

Variable	Age	F-AVXX	BLC-RIPE
Sample size	5.	5.	5.
Average	24.	88.2	5.94
Standard error	1.140175	2.083267	2.478225
Minimum	22.	83.	0.3
Maximum	28.	94.	13.
Lower quartile	22.	85.	1.
Upper quartile	25.	92.	10.
Variable	**LD-RIPE**	**BRC-RIPE**	**DSK-RIPE**
Sample size	5.	5	5.
Average	17.9	0	1.22
Standard error	3.318132	0	0.96871
Minimum	7.5	0	0.
Maximum	27.	0	5.
Lower quartile	14.	0	0.
Upper quartile	21.	0	1.1
Variable	**ANTH-X-RIPE**	**SER-X-RIPE**	**D-C-RIPE**
Sample size	5	5	5
Average	0	0	0
Standard error	0	0	0
Minimum	0	0	0
Maximum	0	0	0
Lower quartile	0.	0	0
Upper quartile	0	0	0
Variable	**V-B**	**GP**	**PS**
Sample size	5.	5.	5.
Average	37.6888	18.4222	29.428
Standard error	7.010852	7.111846	7.067332
Minimum	21.	0.	7.14
Maximum	60.	42.	50.
Lower quartile	25.	11.111	25.
Upper quartile	44.444	25.	37.

3. TECHNICAL EVALUATION

The avocado industry has a well planned research programme going. Some handling and temperature management aspects however, will have to be investigated. Most important factors are:

3.1 Integral container loading temperature

An integral refrigerated container is fitted with a cooling unit to maintain product temperature. Almost all of the new generation integral containers are fitted with:

• Electronic temperature control resulting in very accurate temperature control and data logging.

• Bigger cooling capacity to handle warmer loads effectively.

• More even air distribution in both the horizontal and vertical planes to improve uniform product temperature.

The maximum PPECB loading temperature tolerance of 0.5°C above the specified carrying temperature therefore needs to be re-evaluated for the new series of integral containers.

Tab le 9. Summary statistics for Pinkerton in CA containers during 1997

Variable	Age	F-AVXX	SM-RIPE
Sample size	16.	17.	17.
Average	24.75	87.882353	0.123529
Standard error	0.6129153	1.550338	0.123529
Minimum	21.	70.	0.
Maximum	31.	94.	2.1
Lower quartile	22.	90.	0.
Upper quartile	26.5	91.	0.

Variable	BLC-RIPE	LD-RIPE	BRC-RIPE
Sample size	17.	17	17.
Average	3.052941	13.29	0
Standard error	0.862754	2.257018	0.
Minimum	0	2.14	0.
Maximum	13.	36	0.
Lower quartile	0.6	7.1	0.
Upper quartile	3.5	22	0

Variable	DSK-RIPE	ANTH-X-RIPE	SER-X-RIPE
Sample size	17	16	17
Average	1.891765	1.93475	1.960765
Standard error	0.639318	1.326128	1.960765
Minimum	0	0	0
Maximum	8.6	16.666	33.333
Lower quartile	0.	0	0
Upper quartile	3.8	0	0

Variable	V-B	GP	PS
Sample size	5	5	5
Average	18.133294	40.990529	27.588235
Standard error	5.46444	7.338513	6.94837
Minimum	0.	0.	0.
Maximum	80.	100.	100.
Lower quartile	0.	16.666	0.
Upper quartile	25	71.4	42.

The following tests are considered urgent:

- Determine the (pre) cooling characteristics of the new series of containers.

- Determine the commercial procedures and tolerances required for inland container loading and external power supply (Genset) to maintain en route product temperature.

- Determine the requirements and optimum conditions for the so called "high cube" integral container (i.e. carton strength, air circulation, temperature deviations and effect on fruit quality.)

3.2 CA container loading temperature

During the early stages of CA shipments of avocados it was possible to apply the PPECB 0.5°C tolerance above the specified loading temperature. Increased volumes and limited infrastructure in the port required a re-evaluation of this concept. It was eventually decided on almost an ad hoc basis to increase the maximum loading temperature tolerance to 1.5°C.

Reasons were:

- All CA containers used to date were of the new series and brand new and therefore assumed to have better cooling capacities than the "old" containers.

- CA containers drastically lower the respiration rate and therefore the heat generated by fruit. The total heat load is therefore reduced.

Table 10. Summary of the incidence of the most important post-harvest quality parameters for three avocado cultivars shipped in RA can CA containers (Refer tables 1,3,5,6 and 8)

QUALITY PARAMETER	WHEN EVALUATED	FUERTE		HASS		PINKERTON	
		RA	CA	RA	CA	RA	CA
Fruit age days	arr.	24.1	24.6	23.8	24.9	24	24.7
Firmness	arr.	79.3	88.9	90.1	92.2	88	87.8
Black cold	arr.	1.1	2.0	1.0	1.0		
	ripe	5.2				5.9	3.0
Leaf damage	arr.	2.9	2.9	9.9	10.1		
	ripe	8.5				17.9	13.3
Brown cold	arr.	0.6	0.0	0.0	0.0		
	ripe	2.3				0.0	0.0
Dusky cold	arr.	3.2	0.6	0.1	0.0		
	ripe	7.9				1.2	1.8
Anthracrose	arr.	1.4	0.4	0.2	0.0		
	ripe	4.7				0.0	1.9
Stem end rot	arr.	0.0		0.0	0.0		
	ripe	5.7				0.0	0.0
Vascular browning	arr.	0.0		4.4	3.6		
	ripe	8.7				3.7	18.1
Grey pulp	arr.	0.0		13.4	10.4		
	ripe	18				18.4	41.0
Pulp spot	arr.	0.0		12.4	10.8		
	ripe	19				29.4	27.6

Factors requiring further investigation are:

- All the cooling factors regarding the container listed under par. 3.1.
- The CA effect on the cooling rate of the fruit.

3.3 Air circulation in integral containers

Avocados and also other fresh produce are very temperature sensitive. This requires maintenance of the correct air temperature, within the specified tolerance (±0.5°C), throughout the load. A universal problem is heat leakage through the door seals resulting in (slightly) warmer air temperatures at the door end. Short circuiting of air and mixing of cold and warm air due to turbulance also contribute to this problem.

A "splitter board" was developed by Cambridge Refrigeration Technology (CRT) in the UK to solve the problem. Design specifications were obtained from CRT and some shipping lines are keen to have this concept tested.

SUMMARY

• The 1997 season was characterized by soft fruit. This resulted in more Fuerte avocados being shipped under CA conditions than was planned originally.

• Black cold injury was a problem mainly because carrying temperatures had to be maintained in the colder ranges to avoid softening. More black cold was found in CA than RA shipped Fuerte avocados.

• External and internal quality disorders were, on average, very low in Fuerte and Hass avocados while Pinkerton suffered more from lenticel injury, vascular browning and pulp spot.

• Most quality problems experienced during the 1997 season were directly related to inadequate preshipment temperature control. Warmer loading temperatures cancelled the benefit of shipping fresh fruit.

• Early season shipping temperatures were approximately 0.5°C too warm.

RECOMMENDATIONS

The following is a summary of the recommendations made in the text. Paragraph references are given should it be necessary to refer to the reasons for these recommendations.

• CA shipping of Fuerte is recommended for at least the first four weeks of the season (par. 2.1.1)

• Hass avocados need not be shipped CA (par. 2.1.2)

• More data is required to evaluate post-harvest conditions on the quality of Pinkerton avocados, (par. 2.1.3)

• The effects of CA on the incidence of black cold needs to be invest! gated, (par. 2.2)

• The effect of post discharge handling conditions on the incidence of black cold must be investigated to reduce quality losses, (par. 2.2)

• Studies on the effect of climate (rain etc.) prior to harvest on avocado fruit quality must continue, (par. 2.3)

• Loading temperature tolerances must be determined for integral refrigerated and CA containers, (par. 3.1 and 3.2)

• Improved air circulation methods must be developed and tested to ensure more uniform temperature distribution, (par. 3.3)

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THIS IS A GREAT INDUSTRY!