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Factors Affecting the Quality of Fuerte Avocados — 1994 Season

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INTRODUCTION

The European market requires hard avocados without any external chilling injury and internal physiological defects. All these characteristics are influenced by pre-shipment handling and voyage conditions.

Pre-shipment quality, handling, cooling and transport data as well as voyage temperatures and market condition of Fuerte avocados were monitored on an industry basis during the past five seasons. The results and conclusions for the 1994 season are discussed in this report.

PROCEDURES

Evaluation of fruit condition

A total of 421 sample containers (398 ex Transvaal and 23 ex KwaZulu/Natal) were evaluated.

Parameters:

- Moisture: Percentage moisture content at time of picking (maturity) as related to oil content and maturity.
- Average pulp temperatures taken in pallets loaded at the door, centre and end of the truck at arrival in Cape Town and the outside of the pallet plus a pulp temperature reading taken on the inside of a randomly selected pallet.
- Pulp temperature (°C) on the outside of the pallet at loading at packhouse.
- DAT: Delivery air temperature in cold store, truck, holding store or ship.
- RAT: Return air temperature in cold store, RMT, container holding store or ship.
- Difference in pulp temperature between truck on arrival and specified container loading temperature.
- Actual pulp temperature at loading of container.
- Difference in pulp temperature between RMT arrival and specified holding store intake temperature.

- Difference in pulp temperature between the arrival pulp temperature and the specified initial container DAT.
- Difference between the actual pulp temperature and DAT (set point) of the cold store at time of containerisation at packhouse in KwaZulu/Natal.
- Age of fruit in days between packing and arrival at the Rungis market.

Indicators of fruit condition:

- Firmness at picking as measured with a firmometer. Lower readings indicate harder fruit:
- Fruit firmness in the Rungis market as measured with a firmometer.
- Black cold damage on arrival at the Rungis market.
- Lenticel cold injury on arrival at Rungis market.
- Dusky coloured external cold damage on arrival at Rungis market (possible late brown cold injury).
- Black cold damage, pulp spot and grey pulp that developed after arrival at the Rungis market.

Table 1
Statistical correlations of different fruit quality indexes for Transvaal avocado's

		Age	*Firmo*	*Black-arr*	*Lent-arr*	*Dusk-arr*	*Grey*	*Pulp*
Age	(a)	1.0000	0.1810	0.0724	–0.0470	0.0077	0.0554	–0.0872
	(b)	(398)	(398)	(398)	(398)	(398)	(398)	(398)
	(c)	0.0000	0.0003	0.1494	0.3501	0.8779	0.2700	0.0823
Firmo	(a)	0.1810	1.000	0.0157	–0.1060	0.1244	0.2947	0.1382
	(b)	(398)	(398)	(398)	(398)	(398)	(398)	(398)
	(c)	0.0003	0.0000	0.7542	0.0344	0.0130	0.0000	0.0058
Black-arr	(a)	0.0724	0.0157	1.0000	0.0078	–0.0220	0.0152	–0.0108
	(b)	(398)	(398)	(398)	(398)	(398)	(398)	(398)
	(c)	0.1494	0.7542	0.0000	0.8774	0.6612	0.7624	0.8293
Lent-arr	(a)	–0.0470	–0.1060	0.0078	1.0000	0.0012	–0.0124	–0.0574
	(b)	(398)	(398)	(398)	(398)	(398)	(398)	(398)
	(c)	0.3501	0.0344	0.8774	0.0000	0.9808	0.8054	0.2529
Dusk-arr	(a)	0.0077	0.1244	–0.0220	0.0012	1.0000	0.0013	–0.0218
	(b)	(398)	(398)	(398)	(398)	(398)	(398)	(398)
	(c)	0.8779	0.0130	0.6612	0.9808	0.0000	0.9801	0.6652
Grey	(a)	0.0554	0.2947	0.0152	–0.0124	0.0013	1.0000	0.2741
	(b)	(398)	(398)	(398)	(398)	(398)	(398)	(398)
	(c)	0.2700	0.0000	0.7624	0.8054	0.9801	0.0000	0.0000
Pulp	(a)	–0.0872	0.1382	–0.0108	–0.0574	–0.0218	0.2741	1.0000
	(b)	(398)	(398)	(398)	(398)	(398)	(398)	(398)
	(c)	0.0823	0.0058	0.8293	0.2529	0.6652	0.0000	0.0000

a = Coefficient
b = Sample size
c = Significance level

Table 2
Correlations between post-harvest handling factors and fruit quality indexes for Everdon (Natal Fuerte)

	Age	*Firmo*	*Black-arr*	*Lent-arr*	*Dusk-arr*	*Black*	*Grey*	*LTemp*	*Moist*	*PFirmo*	*Diffph*
Age	1.0000 (13) 0.0000	–0.3225 (13) 0.2825	0.3387 (13) 0.2576	0.2439 (13) 0.4219	0.0000 (13) 1.0000	0.3387 (13) 0.2576	–0.1045 (13) 0.7340	–0.2398 (13) 0.4301	0.7187 (13) 0.0056	0.4815 (13) 0.0958	–0.5007 (13) 0.0813
Firmo	–0.3225 (13) 0.2825	1.0000 (13) 0.0000	0.5713 (13) 0.0414	–0.2160 (13) 0.4785	–0.0309 (13) 0.9203	0.5713 (13) 0.0414	0.6732 (13) 0.0117	0.5181 (13) 0.0697	0.0624 (13) 0.8395	–0.3197 (13) 0.2870	0.6610 (13) 0.0139
Black-arr	0.3387 (13) 0.2576	0.5713 (13) 0.0414	1.0000 (13) 0.0000	0.1047 (13) 0.7335	–0.1062 (13) 0.7298	1.0000 (13) 0.0000	0.5027 (13) 0.0800	0.3382 (13) 0.2583	0.4975 (13) 0.0836	0.0396 (13) 0.8979	0.2641 (13) 0.3833
Lent-arr	0.2439 (13) 0.4219	–0.2160 (13) 0.4785	0.1047 (13) 0.7335	1.0000 (13) 0.0000	0.5875 (13) 0.0348	0.1047 (13) 0.7335	0.1682 (13) 0.5828	–0.3268 (13) 0.2757	0.2042 (13) 0.5033	0.2735 (13) 0.3660	–0.2983 (13) 0.3222
Dusk-arr	0.0000 (13) 1.0000	–0.0309 (13) 0.9203	–0.1062 (13) 0.7298	0.5875 (13) 0.0348	1.0000 (13) 0.0000	–0.1062 (13) 0.7298	0.2330 (13) 0.4436	0.2178 (13) 0.4747	0.1788 (13) 0.5589	0.1169 (13) 0.7037	0.1924 (13) 0.5289
Black	0.3387 (13) 0.2576	0.5713 (13) 0.0414	1.0000 (13) 0.0000	0.1047 (13) 0.7335	–0.1062 (13) 0.7298	1.0000 (13) 0.0000	0.5027 (13) 0.0800	0.3382 (13) 0.2583	0.4975 (13) 0.0836	0.0396 (13) 0.8979	0.2641 (13) 0.3833
Grey	–0.1045 (13) 0.7340	0.6732 (13) 0.0117	0.5027 (13) 0.0800	0.1682 (13) 0.5828	0.2330 (13) 0.4436	0.5027 (13) 0.0800	1.0000 (13) 0.0000	0.2111 (13) 0.4887	0.2300 (13) 0.4497	0.0214 (13) 0.9447	0.2984 (13) 0.3221
LTemp	–0.2398 (13) 0.4301	0.5181 (13) 0.0697	0.3382 (13) 0.2583	–0.3268 (13) 0.2757	0.2178 (13) 0.4747	0.3382 (13) 0.2583	0.2111 (13) 0.4887	1.0000 (13) 0.0000	0.0135 (13) 0.9651	–0.1048 (13) 0.7333	0.9356 (13) 0.0000
Moist	0.7187 (13) 0.0056	0.0624 (13) 0.8395	0.4975 (13) 0.0836	0.2042 (13) 0.5033	0.1788 (13) 0.5589	0.4975 (13) 0.0836	0.2300 (13) 0.4497	0.0135 (13) 0.9651	1.0000 (13) 0.0000	0.5133 (13) 0.0728	–0.1925 (13) 0.5287
PFirmo	0.4815 (13) 0.0958	–0.3197 (13) 0.2870	0.0396 (13) 0.8979	0.2735 (13) 0.3660	0.1169 (13) 0.7037	0.0396 (13) 0.8979	0.0214 (13) 0.9447	–0.1048 (13) 0.7333	0.5133 (13) 0.0728	1.0000 (13) 0.0000	–0.3303 (13) 0.2704
Diffph	–0.5007 (13) 0.0813	0.6610 (13) 0.0139	0.2641 (13) 0.3833	–0.2983 (13) 0.3222	0.1924 (13) 0.5289	0.2641 (13) 0.3833	0.2984 (13) 0.3221	0.9356 (13) 0.0000	–0.1925 (13) 0.5287	–0.3303 (13) 0.2704	1.0000 (13) 0.0000

Ryan data correlation

A Ryan temperature recorder was placed in an empty avocado carton in the packhouse. The carton containing the Ryan recorder was placed in the top layer of the last pallet to be loaded at the door end of the container. At the Westfalia packhouse the objective is to place at least one Ryan recorder in every second container.

More than 3 000 Ryan temperature recordings on Transvaal fruit for the past 4 years were available for analyses. During 1992 and 1994 however 16 and 4 Ryan recorders respectively were directly monitored by a Grant Squirrel thermocouple taped to the Ryan recorder. It was decided to analyse only the 1994 data to determine the correlations between Ryan air temperature and actual air and pulp temperatures in various positions in the container. The same procedure as for Transvaal fruit was also applied on fruit shipped from Durban. Twenty seven of these Ryan recorders were analysed to investigate if temperature increases occur during transport from the production area to the port of Durban.

Voyage temperature surveys

Material and methods

Only Class 1 fruit approved for export was used for temperature monitoring and condition assessment. The fruit was packed into corrugated cardboard boxes, column stacked and palletised before cooling. The pre-cooled fruit was transported from the packhouse to Cape Town in refrigerated road trucks (RMT's). The delivery air temperature setting of the trucks at the beginning of the season was 7,5°C and was lowered to 6,5°C and 5,5°C later in the season.

Containers and vessels

Delivery and air return temperatures (DAT and RAT) as well as pulp temperatures in the warmest and coldest positions were monitored.

It must be noted that containers, vessels and stowage positions were chosen at random to reflect the commercial situation.

Temperature sensor position

In most cases air and pulp temperatures in the warmest and coldest positions were monitored. This procedure was followed because results of previous surveys indicate that these are the most relevant temperatures when evaluating the commercial situation.

Pulp temperatures were measured in two pallets of fruit in a container. One pallet was loaded in the front and the second pallet was loaded at the door end in the container. The temperature of the warmest fruit was measured in the top layers of the pallets at the door end of the container. The temperature of the coldest fruit was measured in the bottom layers of the pallet.

Temperature logging

All thermocouples (TC's) installed in a container were connected to a calibrated Grant Squirrel electronic temperature logger. These data loggers were programmed to record all TC temperatures at 6 hour intervals from the time of loading into the container until it was disconnected on the Rungis market in Paris.

Statistical Analysis

The data was statistically analysed by using the Statgraphics computer programme. Analysis of variance, multiple regression and simple correlation techniques were used.

RESULTS AND DISCUSSION

The three most important post-harvest factors affecting market quality of avocados are fruit age between picking and marketing, picking maturity and product temperature during handling and transport.

Pre-shipment conditions — Transvaal Fuerte avocados

Fruit age has a significant effect on fruit firmness on the market. The 1994 data confirms the significant relationship between fruit age and fruit firmness found during previous seasons. The older the fruit, the softer it becomes.

Although the actual empirical firmness values vary from season to season (probably due to climatical conditions), it was again concluded that South African sea freight avocados must not be older than 28 days on arrival at the market. Optimising all handling and transport conditions can extend the total storage life beyond 28 days but can drastically reduce post-harvest quality losses. However, it must always be kept in mind that the temperature management system was not designed and never intended to extend the total storage life beyond 4 weeks. This system was designed to ensure acceptable fruit quality after 4 weeks from picking and still enabling the retail market to distribute and sell a quality product. It must also be kept in mind that shipments from South Africa should arrive every 8 days and that extended distribution and selling periods may result in retailers carrying old stock while fresh fruit is already available.

Fruit firmness at packing is positively correlated with fruit firmness on arrival at the market. It confirms that fruit firmness can be used as an indicator of firmness on arrival at the overseas market. If the results of the previous seasons are also considered, it can be stated that fruit firmness at picking must not exceed 26 FIRMO units based on Westfalia results, but this must still be verified for the total industry.

Moisture content at the time of picking of Fuerte avocados is correlated with fruit firmness. Correct picking maturity is therefore a prerequisite for good market condition.

Fruit firmness of Transvaal Fuerte avocados on arrival at Rungis is negatively correlated with lenticel cold injury. Softer fruit (higher firmo readings) developed less lenticel damage. Lenticel damage was not a commercially significant quality disorder during the past three seasons.

No statistical significant correlation exists between dusky external discolouration and internal pulp defects like grey pulp and pulp spot and optimum transport temperature conditions. However softer fruit developed significantly more dusky coloured chilling injury as well as significantly more grey pulp and pulp spot.

Pre-shipment conditions — KwaZulu/Natal Fuerte avocados

- Fruit age based on all KwaZulu/Natal samples, is also significantly but negatively correlated with fruit firmness on arrival at the market. Everdon samples however showed no significant relationship between fruit age and fruit firmness at the market. Reasons for this may be:

Too few samples analysed — only 13.

Relatively short variation in the data between picking and arrival at Rungis.

- Temperatures increased in Durban harbour. A total of 27 Ryan recorders were analysed to establish the extent of temperature rise at the time of loading the container onto the vessel. Of these Ryan recorders 37 % recorded a rise in temperature of less than 1°C. However the same percentage recorded a rise in temperature of 3° to 5°C. The period of temperature rise and therefore absence of refrigeration was 1 hour or less for 44 % of the containers, and 2 hours or more for 56 % of the containers. Two Ryan's recorded an absence of refrigeration for 6 hours. It is important to limit the time without refrigeration. An investigation into methods to curtail this rise and periods without refrigeration is of utmost importance to ensure good quality fruit shipped through Durban harbour.
- Fruit firmness on arrival at Rungis of KwaZulu/Natal avocados is positively correlated with quality and appearance. Softer fruit developed more black cold and grey pulp.
- A correlation exists between containerisation temperature for KwaZulu/Natal Fuerte avocados and fruit firmness at Rungis. The results confirm the findings of the 1993 season on Transvaal produced Fuerte avocados, i.e. the bigger the difference between the actual pulp temperature and the optimum DAT of packhouse cold store (the warmer the fruit), the softer the fruit arrives in the market. In the case of KwaZulu/Natal Fuerte 43 % of the softening could be directly related to fruit being containerised warmer than the estimated optimum temperature.

Table 3
Pulp Temperature distribution on arrival in Cape Town for 1993 and 1994 seasons.

		TEMPERATURE INTERVALS °C								
Year	*Regime*	*4.5 a*	*5–6*	*6–7*	*7–8*	*8–9*	*9–10*	*10–11*	*11–12*	*12+*
1994	7.5	0	0	0	33.33	66.67	0	0	0	0
	7	0	4.95	22.77	37.62	20.79	10.89	0	0	2.97
	6.5	1.98	7.51	28.85	38.34	15.02	5.14	1.58	0.4	1.19
	6	0.89	9.82	73.21	13.39	0.89	0.89	0.89	0	0
	5.5	6.67	21.05	53.86	13.68	3.51	0.88	0.18	0	0.18
	5	12.2	39.02	36.59	12.2	0	0	0	0	0
1993	7.5	1.64	1.64	4.92	22.95	42.62	18.03	6.56	0	1.64
	7	2.25	1.12	8.99	38.2	32.58	10.11	2.25	1.12	3.37
	6.5	0	0.8	26.4	44	26.4	2.4	0	0	0
	6	0	5.83	74.76	16.5	2.91	0	0	0	0
	5.5	1.08	12.66	37.43	38.34	8.68	1.08	0.54	0.18	0
	5	0	12.66	45.57	36.71	3.8	1.27	0	0	0

a) Bigger than 4°C, but smaller or equal to 5°C

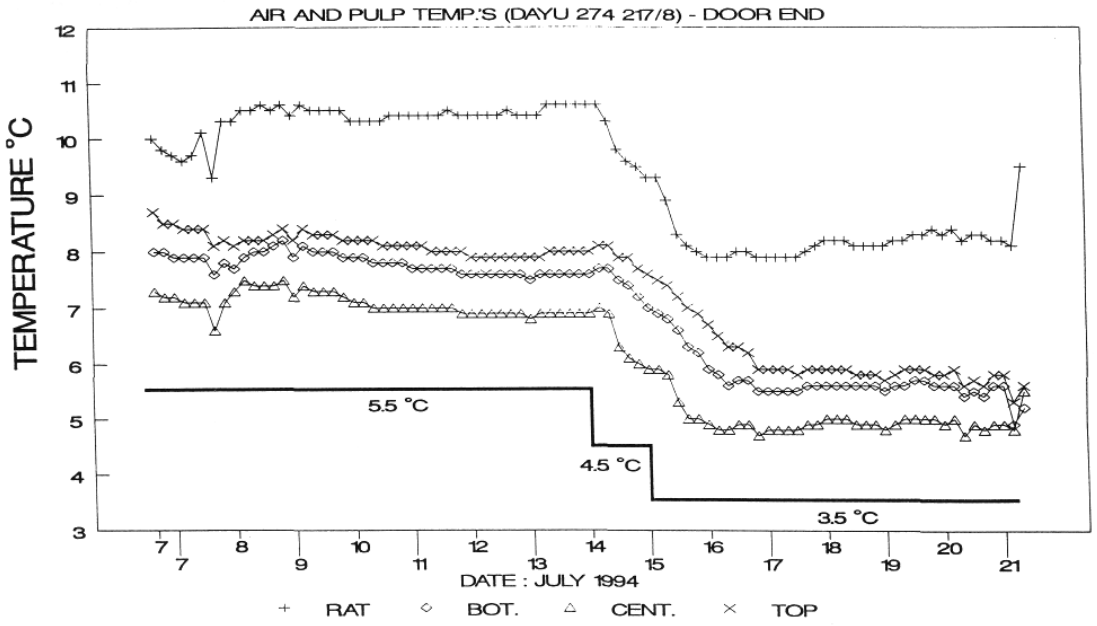

Figure 1
Air and pulp temperature for the Transvaal 907 as measured by the Grant Squirrel compared to the instruction.

By substituting the linear regression coefficients into the linear model equation it can be stated that the pulp temperatures at containerisation of KwaZulu/Natal produced Fuerte must not be warmer than 1,5°C above the optimum specified DAT of the cold store. This value is based on 13 samples for one season and therefore needs further verification. Containerisation at colder pulp temperatures however significantly increased the incidence of Black cold injury on arrival. More data is however required to formulate an industry recommendation. Temperature management procedures for KwaZulu/Natal produced avocados need further and more detailed investigation.

Table 4
Pulp temperature at arrival in Cape Town and at containerisation.

Season	*Pulp Temperature (°C)*		
	Arrival	*Containerisation*	*Difference*
1989	8,90	6,76	-2,14
1990	7,53	6,47	-1,06
1991	7,24	7,34	+0,10
1992	7,52	8,98	+1,46
1993	7,30	8,40	+1,10
1994	6,80	7,00	+0,20

Container loading temperatures

Temperature maintenance during handling in the port was within the optimum specification during the 1994 season. Port handling did not negatively effect market condition. Dusky coloured cold injury however increased but this may be more related to late chilling injury than to port handling temperatures. Care must however be taken during handling in the port not to "overcool" the avocados because dusky chilling injury may be induced.

The total industry difference between pulp temperature on arrival in Cape Town and at containerisation is summarised in Table 4. This data clearly indicates an improvement in 1994 where there was an 0,2°C warming during containerisation compared to more than 1°C to the previous two seasons.

The vast improvement in arrival pulp temperatures (Table 3), temperature maintenance during containerisation and voyage temperature management resulted in much improved market quality during the 1994 season. Fruit firmness improved from 38 Firmo units in 1993 to 33 units in 1994. Less variation in firmness during the 1994 season was found compared to the previous season.

Chilling injury was significantly reduced from 0,5 % in 1993 to 0,17% in 1994. The temperature management system as applied during 1994, therefore resulted in firmer fruit with less chilling injury compared to previous season.

Ryan data correlations

The 1994 Ryan air temperature and actual pulp temperatures as recorded by Grant Squirrel data loggers were correlated.

It was found that the Ryan air temperature data correlates highly significantly (99 %, n = 55) with the following:

- Actual temperature instruction to the Master i.e. specified carrying temperature instruction *(*r = 0,79).
- DAT as recorded by the ship's temperature data logger (r = 0,89). DAT as recorded by the Grant Squirrel (r = 0,90).
- RAT as recorded by the ship's temperature data logger (r = 0,90). The biggest deviation was found between the Ryan and Grant Squirrel RAT recordings (r = 0,59). The reason for this is due to the different sensing positions. The Ryans were installed at the door end while the Grant Squirrel sensor was installed in the centre of the container in the delivery air plenum. The Grant Squirrel therefore recorded the coldest RAT in the container.

The highly significant correlations found during 1994 made further statistical analyses unnecessary. It therefore proved that Ryan air temperature recorders can be used to assess temperature trends during handling and transport of avocados.

These trends can give a good indication of potential fruit quality. The industry must however ensure that the Ryan recorders are placed in a carton, this gives a true reflection of the air temperature so that it can be related to product quality.

Despite some limitations in Ryan temperature data, mainly due to the fact that it records air temperature which may vary according to position, this data can immediately reflect temperature trends during storage and transport. It is therefore a very valuable tool for an experienced person to judge the potential quality of a container of avocados on arrival in the market. The evaluation accuracy is however, dependant on the reliability and relationship between Ryan air temperature data and actual fruit pulp temperature. The latter is the most accurate indication of potential fruit quality.

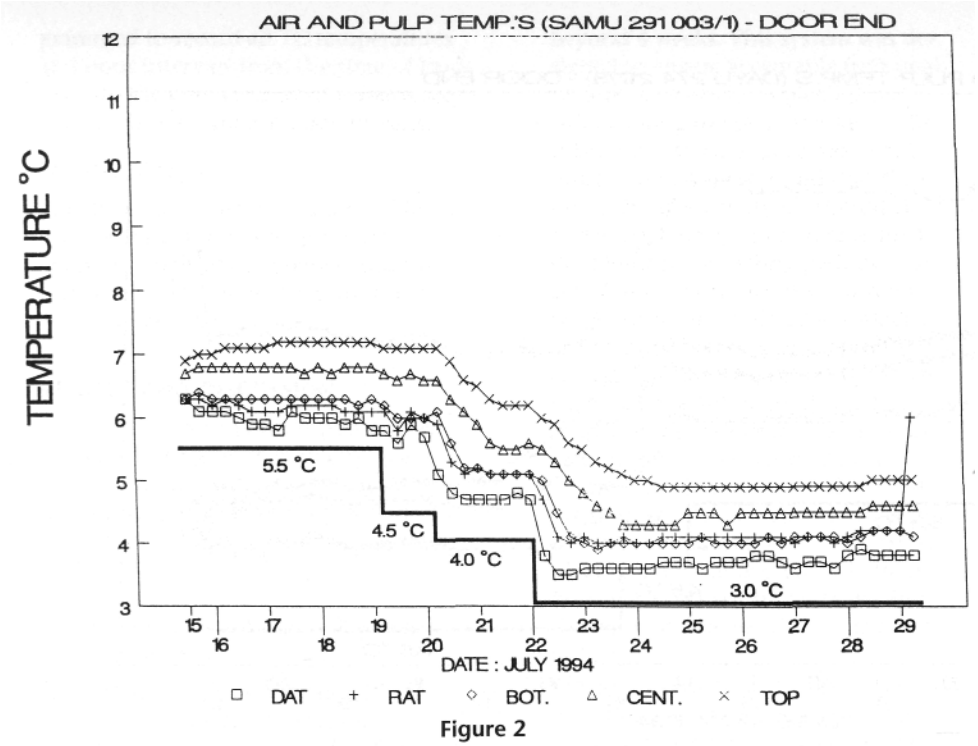

Figure 2

Air and pulp temperature for the City of Durban 908 as measured by the Grant Squirrel compared to the instruction.

Voyage temperature conditions

Warmer than specified air temperatures during the voyage result in an excessive softening during subsequent handling. Too low temperatures must also be avoided to minimise chilling injury. These concepts resulted in a temperature management formula being applied during the past two seasons. Basically it calls for a gradual step down of the DAT and manipulating the DAT in order to keep the RAT within 1,5 °C from the specified DAT.

This procedure was followed during 1994 and two examples are illustrated in Figures 1 and 2.

The results with the Grant Squirrels are summarised as follows:

- Voyage temperature can be accurately controlled if RAT is kept within 1,5°C of the DAT of the ship.

- If DAT is not stabilised within 3 days of departure, RAT and pulp temperature tend to increase.
- Short periods (maximum 12 hours) of lower DAT (cold blasting) can be applied to effectively reduce the RAT.
- The vessel can control the pulp temperature within 1°C from the DAT when the fruit is adequately precooled.
- Poor DAT control results in elavated RAT and pulp temperatures and poor market quality (Transvaal 907). Discrepancies between Ryan and Grant Squirrel temperatures data on the one hand and ship's temperatures on the other hand indicate need for vessel calibration.

General discussion

The data for 1994 confirm to a large extend the findings for 1991 to 1993 (Bezuidenhout & Eksteen, 1994). The more important results can be summarised as follows:

- Fuerte avocados older than 28 days between picking and marketing developed more chilling injury (longer low temperature exposure) and were softer than younger fruit irrespective of optimum temperature management procedures.
- Freshly picked avocados can be transported and shipped warmer than older fruit and will arrive in a good condition provided optimum voyage temperatures are maintained.
- In 1993 pulp temperatures of the fruit on arrival in the port had a significant effect on final condition. On containerisation however older fruit has to be at the optimum shipping temperature. Freshly picked fruit can be containerised at a maximum of 4°C above the initial specified delivery air temperature. No such correlation could be found for the 1994 season. This may indicate that the pulp temperatures on arrival in Cape Town were within the optimum for 1994, and can therefore be used to define optimum arrival pulp temperatures. Extrapolation was necessary during 1993.

The following maximum pulptemperatures for Transvaal avocados to be containerised is recommended:

-"Fresh" avocados (up to 3 days old on ETA of the vessel) must not be warmer than 4°C above holding store intake temperature.

-"Medium" avocados (between 4 and 6 days old on ETA of vessel) must not be warmer than 3°C above holding store intake temperature.

-"Old" avocados (7 days and older on ETA of vessel) must not be warmer than 2°C above holding store intake temperature. If practical and possible, one degree above DAT must be the goal.

- Voyage temperature management can only be successful if all air and pulp temperatures can be controlled within the optimum specification as from departure. Warm RAT's during the first phase of the voyage requires drastic DAT

manipulation which can induce chilling injury and soft fruit.

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