IDENTIFYING AND RECTIFYING COMPLACENCY IN THE SOUTH AFRICAN AVOCADO COLD CHAIN

M.C. Dodd[1], R.M. Nelson[2], G. Nortje[2] and E. Louw[1]

[1] Perishable Products Export Control Board, P.O. Box 509, Paarden Eiland, 7420 Cape Town, South Africa
[2]South African Avocado Growers' Association, P.O. Box 866, Tzaneen 0850, South Africa.

The South African Avocado industry is facing ever increasing competition in its current markets. Increasing quality expectations along with flat prices and volatile currency exchange rates drive the profitability equation downwards. In order to try and reduce costs without compromising quality, an in depth analysis was conducted on the cold chain to see where there were challenges. This commenced at the pack-house and extended through the pre-cooling operation, consolidation, road transport loading and unloading, to the point of loading into the shipping containers. No analysis was conducted into the links of the cold chain en route to market (during the sea voyage and beyond). The analysis showed that in many links of the cold chain the fruit is subject to temperature abuse. This takes the form of the fruit on occasion being pre-cooled to pulp temperatures lower than the stipulated set point. This can only occur when the delivery air temperature in the pre-cooling store is set excessively low in an attempt to cool the fruit quickly in order to free up the space for further intakes. In many other cases the fruit pulp temperature is several degrees above set point due to insufficient time spent in the pre-cooler or poor pre-cooling protocols.
Then the loading of the fruit into refrigerated road trailers at temperatures above and below set point is made. The road trailers are unable to maintain the fruit at set point and there is invariably an up to 2°C increase in fruit pulp temperature during the 40 hour road trip to the port. These conditions result in the need to pre-cool the fruit in the port before loading into containers. All the above lead to the industry resorting to expensive technology such as controlled atmosphere to maintain fruit firmness during the sea voyage. The analysis shows that there is opportunity to tighten up the cold chain with concomitant benefits to quality and reduction in input costs.

Keywords: avocado, cold chain, South Africa

IDENTIFICACIÓN Y RECTIFICACIÓN DE ESTÁNDARES SATISFACTORIOS EN LA CADENA DE FRÍO DEL AGUACATE DE SUDÁFRICA

M.C. Dodd[1], R.M. Nelson[2], G. Nortje[2] y E. Louw[1]

[1] Perishable Products Export Control Board, P.O. Box 509, Paarden Eiland, 7420 Cape Town, South Africa
[2]South African Avocado Growers' Association, P.O. Box 866, Tzaneen 0850, South Africa.

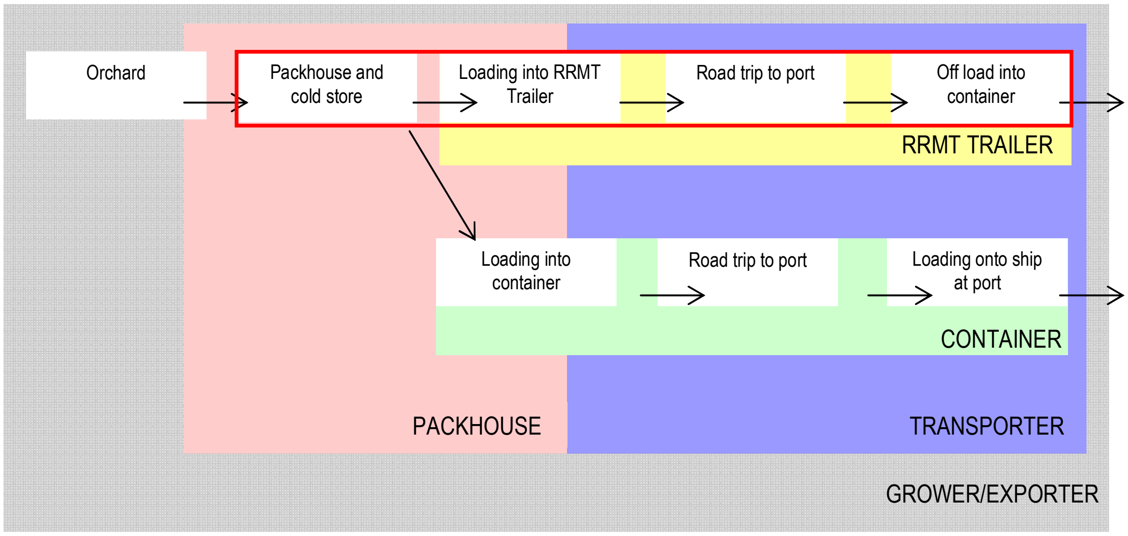
La industria del aguacate de Sudáfrica está enfrentada a una competencia cada vez mayor en el mercado actual. Las crecientes expectativas de calidad junto con los precios fijos y volátiles cambios de divisa están hundiendo la ecuación de rentabilidad. Para intentar reducir los costos sin comprometer la calidad, se realizó un análisis en profundidad de la cadena de frío para detectar cuáles eran los desafíos. Comenzó en el área de embalaje y se amplió a todo el proceso de prerrefrigeración, consolidación, carga y descarga del transporte terrestre hasta el punto de carga en los contenedores de envío. No se realizaron análisis de la cadena de frío en la ruta hasta el mercado (durante el transporte marítimo y posteriormente). Los análisis demostraron que en muchos eslabones de la cadena de frío, la fruta se veía sometida a golpes de temperatura. Esto puede ocasionar que la pulpa se prerrefrigere a temperaturas inferiores al valor de control estipulado. Esto sólo puede ocurrir si la temperatura del aire circulante en prerrefrigeración es demasiado baja al intentar refrigerar la fruta más rápidamente para liberar espacio de entradas posteriores. En otros casos, la temperatura de la pulpa es varios grados superior al valor de control, por no pasar el tiempo suficiente en prerrefrigeración o por protocolos de prerrefrigeración inadecuados. Posteriormente viene la carga de la fruta en acoplados refrigerados a temperaturas superiores o inferiores a los valores de control. Los acoplados de transporte no pueden mantener la fruta en el valor de control, y existen cambios de hasta 2º C en la temperatura de la pulpa durante el viaje por carretera de 40 horas hasta el puerto. Estas condiciones obligan a prerrefrigerar la fruta en el puerto antes de cargarla en los contenedores. Todo esto conduce a la industria a recurrir a costosas tecnologías como la atmósfera controlada para mantener la firmeza de la fruta durante el transporte marítimo. Los análisis demuestran que existe la oportunidad de intensificar la cadena de frío con beneficios tanto para la calidad como para los costos de inversión.

Introduction

The South African regulations for the export of perishable products are very strictly applied and require that such products meet predefined standards in order to be passed as fit for export. In the case of avocados, these standards stipulate that fruit pulp temperatures must not differ by more than 2℃ from the temperature specified on the export manifest documents. Since the South African authorities often find that consignments of avocados destined for export have fruit pulp temperatures outside of this 2℃ tolerance, the exporter is obliged by these authorities to take steps to bring the pulp temperatures of his export cargo to within the temperature norms, before the authorities will accept such fruits for export. The more common situation is that the fruits are found to be too warm and in consequence the exporter is obliged to re-cool his fruit – which is an expensive and time-consuming process.

The South African avocado export cold chain comprises many role players as the fruit progress from orchard to consumer. The defining principle of long distance shipment of avocados is to pre-cool the fruit quickly and maintain the fruit pulp temperature as close as possible to the desired set point (Ryall and Pentzer, 1982; Zauberman, Schiffman-Nadel and Yanko, 1977). This principle is an absolute requirement for quality maintenance of all fruit kinds (Kader, 2002; Thompson *et al,* 1998). With frequent "change of hand" of produce along the cold chain there is a potential for this afore mentioned principle to be ignored or mismanaged at the expense of avocado quality. It was therefore deemed necessary to analyze the South African avocado cold chain and identify the weak links and suggest ways of improvement.

In South Africa the Perishable Products Export Control Board (PPECB) is responsible for, and empowered by the National Department of Agriculture to check the quality of all fruit for export, as well as to manage the cold chain for these products. The data analysis was aimed at investigating the efficiency of the packhouse, and the road transporter with regards to temperature management from the packhouse to the port during the 2006 season. Actual temperature readings as recorded by PPECB assessors were analyzed and compared against optimum set points along the chain. The diagram below illustrates the interaction between different role players in transporting avocados from the orchard to the port. The red block indicates the scope of this report.



1. <u>Methodology</u>

Throughout the 2006 avocado season the PPECB assessors measured the pulp temperature of the avocado fruit designated for export at different stages of the cold chain between the packhouse and the port. The measurement is done by inserting a calibrated temperature probe into the flesh of the fruit and recording the temperature on the data sheets provided. This information is entered into a database and can be retrieved and linked to specific packhouses, transporters and even refrigerated trailers. The 2006 data were analysed and compared with the recommended set points using the following temperature measurements along the cold chain:

1. **Loading temperature**: Pulp temperature of the fruit as it leaves the packhouse and is loaded into a refrigerated road motor trailer (RRMT).
2. **Off-loading temperature**: Pulp temperature of the fruit as it is off-loaded at the Table Bay port in Cape Town harbor.

These two temperature measurements were analysed and compared to evaluate the efficiency of the packhouses and the transporters when handling the fruit. Loading temperature outside of the recommended set-point (warmer or colder) would imply that the packhouse is delivering fruit that is already out of specification before the journey to the port has even started and might imply incorrect cold storage of fruit post-packing. Off-loading temperatures that differ (by more than 2ºC) from the loading temperatures would imply that the RRMT is not capable of maintaining the loading temperature during the journey to the port. It should be noted that the recommended set-point of the fruit differs throughout the season and is related to the avocado cultivar and physiological maturity at the time of harvest.

2. Results

3.1 Packhouse and cold store analysis (Loading temperature analysis)

The cold store and packing facility is the first link in the cold chain after harvest. Fruit is brought to the packhouse, pre-cooled, packed and stored in the cold store whilst awaiting transport to the port. The fruit is then loaded into a RRMT and transported to the port for export. The set pulp temperature for avocado storage and transport is between 5 and 8 ºC depending on the physiological maturity and cultivar of fruit. Forty-two avocado packhouses were studied during the 2006 season (1586 RRMT loads):

- 60% of RRMT loads were found to have loading temperatures 2℃ or higher than the set point.
- 33% of packhouses had off-loading temperatures which were 2℃ warmer than the loading temperature.

TABLE 1: Examples of Packhouses with pulp temperatures of 2℃ and warmer than set point at time of loading RRMT

Pack house Code	Total loads	Warm loads	% Warm loads	Avg. ºC warmer than set point	Standard deviation from avg.	Max ºC warmer than set point
A	231	97	42	2.1	1.4	12.4
B	55	36	65	2.3	1.2	7.0
C	35	14	40	2.1	1.1	6.5
D	49	35	71	2.9	1.7	10.0
E	26	9	35	1.9	0.7	3.4
F	112	67	60	2.4	1.1	7.4
G	28	10	36	1.7	0.8	3.6
H	88	34	39	2.1	1.3	7.1
I	172	161	94	3.3	1.2	9.7
J	150	48	32	1.7	1.0	7.8
K	32	29	91	3.2	1.1	7.0

Table 1 shows the results of selected packhouses having loading temperatures 2℃ or more above of the set point prior to the departure of the load by road transport to the port. Forty percent of packhouses were found to have >70% of their loads delivered warm, and some of these were found to have more than 90% of their fruit loads delivered warm.

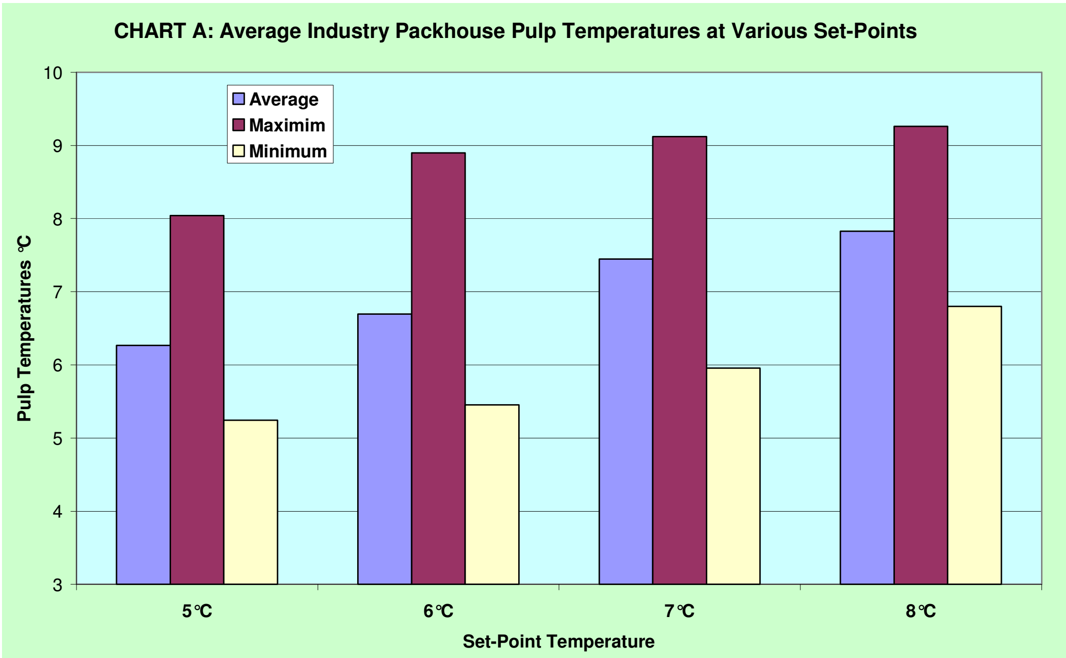
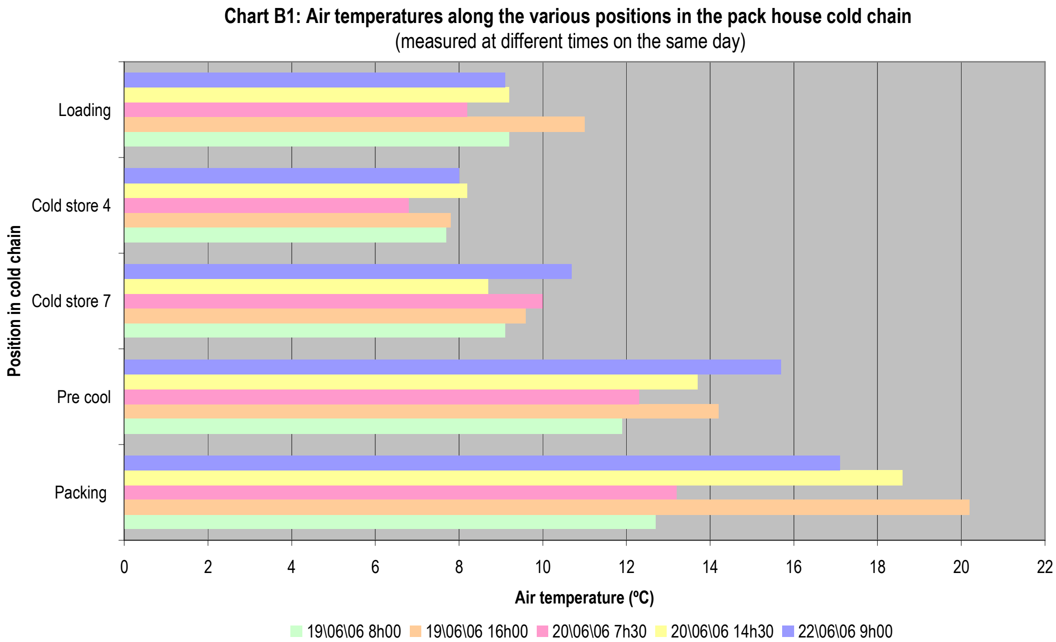


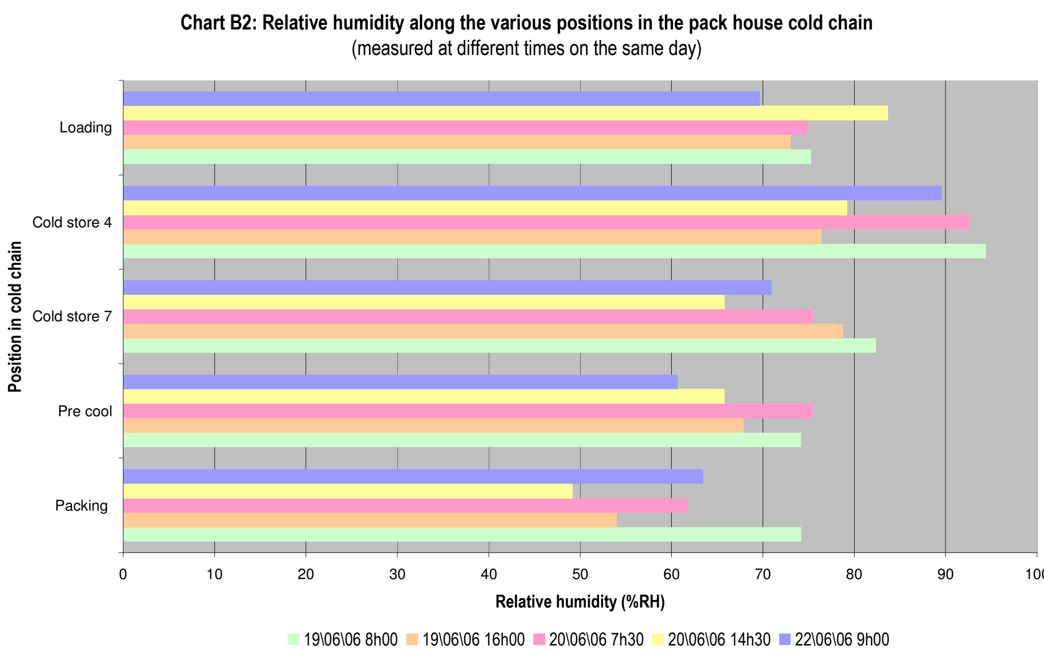
Chart A shows the degree to which minimum and maximum loading temperatures vary from the designated set point. It was observed that some packhouses delivered fruit loads at temperatures more than double the recommended set-point. It is also clear that some packhouses deliver fruit that is below the recommended set-point.

Discussion:

Packhouses are often loading fruit with a pulp temperature much warmer than the recommended set point. Storing avocados at a warm temperature will trigger an increase in the respiration rate resulting in the softening of the fruit (Biale, 1941). When this occurs at the start of the cold chain it can trigger ripening, with the fruit arriving at the export destination having a compromised shelf life as a result of early senescence and decay. Loading fruit at temperatures colder than the optimum was also quite common during the 2006 season. Avocados are sensitive to low temperatures, and storage at below set point temperatures can lead to external chilling injury (Bezuidenhout *et al*, 1992). Fruit showing signs of > 1% chilling injury is not commercially accepted and can lead to rejections at the final destination. Packhouses that load at non-optimal temperatures usually do so for all set points and this poor start to the cold chain can potentially compromise the shelf life and quality of export avocados.

In an attempt to investigate this further and to possibly explain the reason for the deviations, the PPECB recorded the temperature and relative humidity in the different areas of selected packing/storage facilities at different times of the day. The results as follows (Charts B1 and B2):





This illustrates that the packing and cold room areas of this packhouse are not maintained at the optimum temperature (5.5 – 7.5ºC) for avocado cold storage and can possibly be the cause for the non-optimum pulp temperatures experienced during the loading of RRMT's. Although the temperatures are much lower in the cold room areas, this is not maintained at loading. The time of day also seems to influence the temperature and relative humidity of the different areas in the packhouse and cold store, illustrating the inability of air conditioning units to maintain a constant temperature. Possible rectifications include the installation of insulated and refrigerated air locks when entering the different areas to ensure that an even (in-spec) temperature is maintained in each area. Relative humidity is also not maintained at optimum (95%) and can lead to unnecessary moisture loss from the fruit. To address this, the size of the evaporator coils in the cold stores needs to be reviewed relative to the volume of fruit and the size of the room.

Temperature fluctuations and abuse, even if the duration is short, associated with cooling delays and cold-chain breakage have been identified as factors compromising the quality and shelf life of strawberries (Nunes *et al* 2003) and tomatoes (de Castro *et al* 2005) and may result in the rejection of an entire load. It is suggested that exposing avocados to temperature fluctuations this early in the cold chain can lead to quality issues later in the chain and possible losses once exported.

3.2 Road transporter analysis (Off-loading temperatures)

Road transport companies are used to transport the fruit from the cold store to the port. The monitoring of RRMT's is currently not part of the legislative procedures within the PPECB Act although regular temperature measurements are made. Several transporting companies were used during the 2006 season of which 1321 RRMT's were analysed:

- 62% of Loadings were found to have loading temperatures >2°C above set point.
- 13% of Loadings had off-loading temperatures that were 2°C warmer than loading temp.

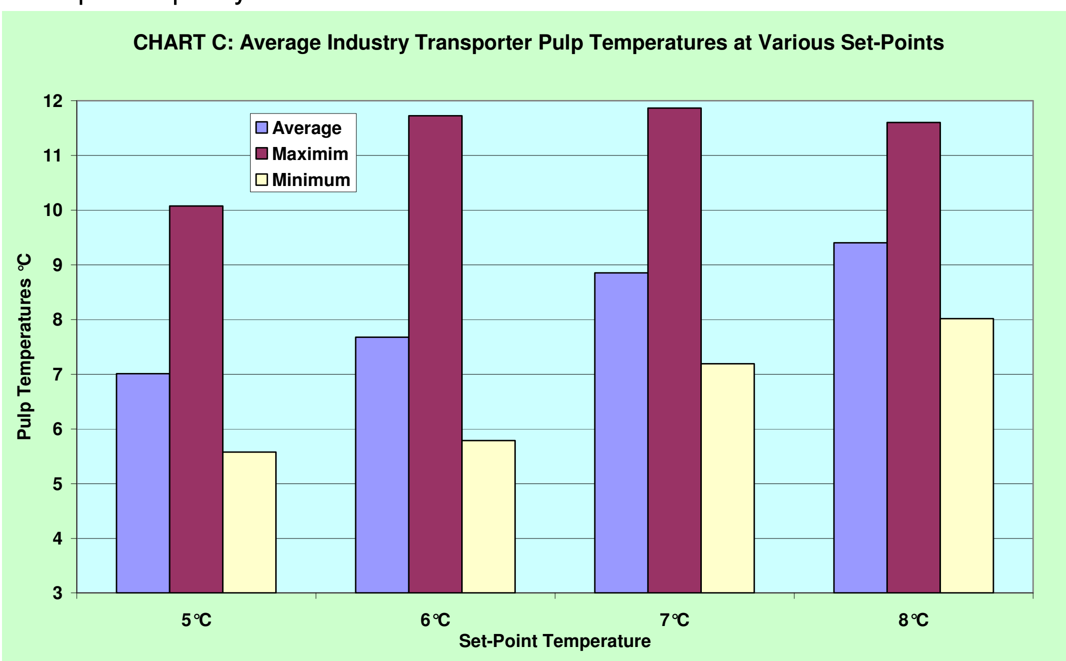
It is recommended that avocados be transported at set-points of between 5 and 8°C depending on the physiological maturity and cultivar of the fruit. Table 2 shows examples of Transport companies with pulp temperatures 2°C or more higher than the set point:

Table 2: Examples of Transporters with off-loading temperatures of 2°C or warmer than set point

Transporter	Total loads	Warm loads	% Warm loads	Avg. ºC warmer than set point	Standard deviation of avg.	Max ºC warmer than set point
1	137	60	44	2.1	1.1	8.0
2	6	1	17	1.8	0.7	2.8
3	2	2	100	2.6	0.7	3.1
4	4	2	50	2.2	0.5	2.8

Transporter	Total loads	Warm loads	% Warm loads	Avg. ºC warmer than set point	Standard deviation of avg.	Max ºC warmer than set point
5	292	129	44	2.0	1.1	7.1

We analysed the ability of the transporting vehicles to maintain the loading temperature of the fruit throughout the journey by expressing the difference between the loading and off-loading temperatures. The results showed that not all transport companies operate with the same success with regards to keeping produce within 2℃ of set-point. Reasons for this might include different insulation, refrigeration equipment and general handling of the cargo. Growers are advised to make use of transporters that can maintain the temperature requirements of avocados throughout the journey to the port as this will not just ensure better fruit quality but also minimize the expenses of re-cooling once the load reaches the port. Thus, if fruit is loaded with the correct pulp temperature and the RRMT keeps the temperature constant throughout the journey there should be no need for re-cooling of fruit at the port, continuity in the cold chain will improve quality and save both time and cost.



Analysing this further for each of the set-points (Chart C) , the trends were similar to that seen for the packhouse analysis. Again avocados were sometimes subjected to temperatures significantly higher or lower than the designated set-points. This can accelerate the ripening processes of the fruit and result in the early onset of senescence and decay that shortens shelf life.

Discussion:

Some of the major role players responsible for the transport of avocados to the port fail to deliver fruit with a pulp temperature at the recommended set point. Upon inspection at the port, such fruit is rejected for loading into a shipping container and is rerouted to the cold stores for re-cooling. These consignments are only loaded once their pulp temperatures have reached the stipulated set point. This not only causes a delay in the logistics of the export process, but also generates extra costs for the grower. Transport companies with poor cold chain management performance need to be challenged in terms of the efficacy of their equipment.

3. <u>Conclusions and Recommendations</u>

Avocados are sensitive to both high and low storage temperatures. Storage temperatures that are too high will result in soft fruit while temperatures that are too low will result in fruit with external chilling injury (Vorster *et al,* 1991). Both these conditions make fruit less acceptable to the customer once it arrives at the export destination and more likely to be rejected. Both packhouses and transporters have been identified as weak links in the cold chain. The former sometimes fail to commence the chain with fruit cooled to optimum temperatures, whilst the latter sometimes fail to maintain the temperature whilst en route to the port. This study has shown that there is considerable temperature abuse occurring in the cold chain, which leads to increased costs such as re-cooling fruit in the port as well as the need to use expensive technologies such as 1-MCP and Controlled Atmosphere to slow down the ripening and decay of the fruit.

In pursuit to rectify this it is suggested that the focus be shifted to the air flow dynamics in the cold chain. Packaging and palletisation play a very important role in enabling the cooled air to move freely around the fruit The packaging design needs to be optimized so that it allows for even airflow in a horizontal direction on all four faces for pre-cooling and land based cold storage. Additionally the base of the cartons must allow for adequate vertical air flow though the pallets as occurs during the container transport. Consideration should be given to this when designing and choosing outer packaging materials and pallets for export. Should inner packaging be used, the same principles apply when selecting such materials. Improved packaging can possibly alleviate some of the difficulty experienced in cooling and maintaining fruit pulp temperature.

Another solution to this unsatisfactory start to the cold chain is to containerise the fruit inland as an alternative to the use of refrigerated trailers. It has been shown that inland containerised fruit versus fruit containerised at the harbor (RRMT transported) showed a lower incidence of soft arrivals (Nelson *et al,* 2001). Earlier containerisation means less handling and a reduced opportunity for temperature mismanagement during the journey between the packhouse and the port.

Our analysis of the avocado cold chain is that if basic principles (rigorous temperature management and choice of packaging/transport medium) are applied and strictly adhered to, this will result in improved fruit quality and cost savings to the growers (most notably the cost of re-cooling fruit). We also suggest that with improved cold chain management, it might be possible, for certain cultivars and at specific physiological maturities, to avoid having to resort to the high additional palliative costs of Controlled Atmosphere or 1-MCP. The efficacy of the cold chain is only as good as its weakest link.

4. References

BEZUIDENHOUT, J.J., VORSTER. L.L., TOERIEN, J. C. 1992. Temperature management – The basis for successful export of South African 'Fuerte' avocados. Proceedings of the Second Word Avocado Congress. pp 427-433.

BIALE, J.B. 1941. The climacteric rise in respiration rate of the Fuerte avocado fruit. Proceedings of the American Society for Horticultural Sciences. Vol 39 pp 137-142.

DE CASTRO, L.R., VIGNEAULT, C., CHARLES, M.T., CORTEZ, L. A. B. 2005. Effect of cooling delays and cold-chain breakage on 'Santa Clara' tomato. Journal of Agriculture and Environment. Vol 3(1) pp 499-54

KADAR, A. A. 2002. In: Post harvest technology of horticultural crops. Third edition. Publication no 3311, University of California. DANR.

NELSON, R.M., BEZUIDENHOUT, J.J., DONKIN, D.J. 2001. An overview of the export market situation and fruit quality during the 2000 avocado season. South African Avocado Growers Association Yearbook. Vol 24 pp 5-12.

NUNES, M.C.N., EMOND, J.P., BRECHT, J.K. 2003. Quality of strawberries as affected by temperature abuse during ground, in-flight and retail handling operations. Acta Horticulture Vol 604 pp 239-246.

RYALL, A.L., HARVEY, J.M. 2002. Handling, transportation and storage of fruits and vegetables. Vol 2. Fruits and tree nuts 2nd. Ed. AVI Pub. Co. Westport CT. USA.

THOMPSON J.F., MITCHELL F.G., CRISOSTO, C.H., KASMIRE R.F. 2002. In: Commercial cooling of fruit, vegetables and flowers. Publication no 21567, University of California. DANR. pp 1- 7.

VORSTER, L.L., BEZUIDENHOUT, J.J., TOERIEN, J.C. 1991. The principles of temperature management – Commercial results. South African Avocado Growers Association Yearbook. Vol 14 pp 44-46.

ZAUBERMAN, G., SCHIFFMAN-NADEL, M., YANKO, U. 1977. The response of avocado fruits to different storage temperatures. Hortscience Vol 12 pp 353-354.