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Long-distance transport of avocados

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SYNOPSIS
Problems experienced with the cooling of avocados point to a lack of contact between fruit and air. This is due to packaging design, the method of stacking and because the size of the ISO pallets used is not compatible with the loading bay of the refrigerated road vehicle and container. Tests were carried out with a new design of carton, providing better ventilation and a non-standard size of pallet to fit the available modes of transport. Indications are that these changes contribute much towards maintaining fruit temperatures throughout the journey. Further investigations are aimed at improving the temperature gradient throughout a pallet by means of forced air cooling, and at maintaining an uninterrupted cooling chain. The possibility of containerisation at the producer is being investigated.

INTRODUCTION

Consistent high quality is of vital importance if South Africa is to maintain and possibly further expand its share of the European avocado market.

While good quality fruit at harvest is a first requirement, proper post-harvest handling procedures, such as packaging, cooling, refrigerated transport and containerisation, are just as essential if this quality is to be maintained. Because of the long distances to be covered, these procedures will often determine the difference between a good or a poor turnout.

Although much progress has been made during the past years in the field of refrigerated transport and containerisation, fruit temperatures and the temperature distribution throughout the load at the port of arrival still leave much to be desired. Yet there are indications that this problem is not due to any lack of capacity or deficiency in the control of the refrigeration systems used. The most likely cause appears to be inadequate heat transfer between fruit and air, ie the available air does not reach into and move through the load. This in turn, happens because of the design of the telescopic carton commonly used, the method of stacking and the standard 1,200 mm x 1,000 mm ISO pallet which does not fit properly into a refrigerated transport vehicle or into a standard 20 ft container. Interruptions of the cold chain between the packhouse and the container ship are considered to be a contributory factor.

Experiments to improve heat transfer were carried out by Westfalia, using dunnage to close the gaps between the pallets and/or employing the so-called 'chimney-stack' which leaves a space in the centre of each pallet, thus exposing more cartons to the airstream. Although the latter method was reasonably successful, it resulted in a loss of about 17 percent of usable container space, which was unacceptable.

It was then decided to radically change both the size of the pallet and the design and size of the cartons to a new (non-standard) package in which the above-mentioned shortcomings were eliminated as far as possible. Furthermore, extensive tests were conducted on prototype packages involving a typical refrigerated shipping cycle comprising cooling, refrigerated road transport and refrigerated containerisation on board ship.

DESIGN OF PALLET AND CARTON

To ensure maximum contact between cold air and fruit, air should not be allowed to by-pass the pallets, but should be forced through them. The pallets should therefore completely fill the road transport vehicle and more important, the container, as it is in this container that fruit is stored for over half the storage period.

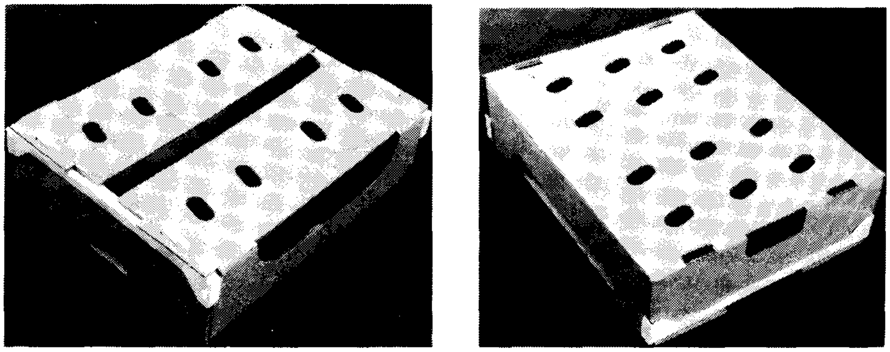
It was found that a pallet size of 1,145 x 1,110 mm would meet these requirements. Ten of these pallets would fill a container with inside dimensions of 5,770 x 2,300 mm, allowing a total clearance of 80 mm in the width and 45 mm in the length of the container. These were provisional dimensions which could be changed to suit the practical situation. The clearances should be small enough to ensure a tight fit, but large enough to allow manoeuvring by forklift trucks. The proposed size of the carton to suit this pallet was 370 x 286 x 90 mm, which could be arranged in 12 (4 x 3) cartons per tier.

The design of the carton would be a compromise between three basic requirements, namely:

- maximum number of ventilation openings to ensure minimum air resistance
- adequate mechanical strength
- low cost in relation to the contents.

During the cooling and transport cycles, cartons are subjected to three different basic air flow patterns: horizontal flow (in the cold room), downflow (in the road transport vehicle) and upflow (in the container). This had to be taken into account when designing the ventilation openings. Another important consideration was that the openings should register exactly when the cartons were stacked, so as not to impede the air flow.

Discussion between Westfalia Estate and a carton manufacturer resulted in the development of the prototype interlocking carton which was used for field tests (Figure 1).



Top Bottom

Fig 1 Prototype interlocking carton

TESTING PROCEDURE

The testing programme was divided into two phases. During phase one, the comparative cooling rate of fruit was determined in the telescopic and interlocking cartons. Phase two involved the measurement of fruit temperatures during a typical shipping cycle, using the interlocking carton.

Phase 1: Comparative cooling rate

Two tests were conducted on Fuerte variety, one using count 12, the other with count 16 fruit, Contrary to the normal practice of palletising inside a cold room, for the purpose of testing, the fruit was palletised in the Westfalia Estates packhouse under ambient conditions to ensure an even, initial temperature throughout the pack. The pallets were then simultaneously transferred to the cold room and cooled until equilibrium between fruit and air temperatures was reached. The temperatures of fruit pulp and skin were measured by means of custom-made stainless steel thermocouple probes, which were inserted into the fruit in cartons designated for testing at the third tier from the bottom, the centre and top of the pallets. Additional probes were placed in strategic positions around the pallets to measure air temperature. The air velocity around the pallets was measured using a hot wire anemometer. The probes were connected to a Kaye data logger which was programmed to deliver a printout of the temperatures at predetermined intervals. Thus a complete record of temperatures over the testing period was obtained.

Phase 2: Shipping cycle

A typical refrigerated shipping cycle from producer to port of destination comprises cooling, refrigerated road transport to the Cape Town docks, as well as refrigerated containerisation at the Container Terminal Holding Store (CTHS) and on board ship.

Monitoring fruit temperatures on board ship proved difficult if the same recording equipment was to be used. It was therefore decided to use two batches of fruit, each comprising ten pallets, *ie* sufficient to fill two standard containers. Both batches were to be cooled simultaneously and transported in the same vehicle. However, after containerisation, one container was to be shipped overseas, while the other was to be kept at the CTHS. The temperature in this container was to be monitored over the same period it would take the ship to reach Southampton. The temperature of the supply air was to be kept at the same value throughout the tests. In this way, the sea voyage was to be simulated while the container was closely monitored.

The two batches were prepared in the Westfalia packhouse using interlocking cartons, pillar-stacked. As the production cost of a batch of 370 x 286 mm cartons for testing purposes only, was prohibitive, the nearest available standard size of 365 x 295 mm was used. However, this necessitated the use of two different sizes of pallets. Each batch of ten pallets therefore consisted of eight pallets of 12 (4x3) cartons per tier and two pallets of nine (3 x 3) cartons per tier. Each pallet was designated by an identification number.

Temperature measurements were carried out in the same way as in the previous test, with the temperature probes installed in corresponding locations in ten of the 20 pallets. Fruit was then cooled at a nominal air temperature of 8°C until equilibrium was reached.

After cooling, the pallets were transferred to a refrigerated vehicle of the South African Transport Services (SATS), which was especially prepared for the test. The test pallets were evenly distributed throughout the loading bay to show up possible hot spots. Additional 'redundant' pallets were added to fill the vehicle completely. Prior to loading, the vehicle was pre-cooled. In consultation with Westfalia, the temperature control of the supply air was set at 6,5°C. During the journey, fruit temperatures, as well as the temperatures of the supply and return air, were monitored using an inverter to power the data logger from the vehicle's battery.

On arrival in Cape Town, the fruit was trans-shipped into separate containers. This was done under temperature-controlled conditions at a refrigerated warehouse. Care was taken to keep the position of the test pallets in both containers identical. At this stage, additional probes were installed to measure air temperature distribution in the container which remained in Cape Town. Both containers were taken to the CTHS and hooked up to the same refrigeration system. The temperature of the supply air was set at 4,5°C, in accordance with the standard practice. Two days later, one container was loaded on board ship and connected to the ship's refrigeration system.

To ensure that both batches of fruit would undergo identical treatment, the container remaining in the CTHS was disconnected from the refrigeration system during the time the other one was being transferred to the ship. The temperature setting of the supply air on board ship was 4,8°C.

The data logger provided hourly printouts of fruit and air temperatures inside the container in the CTHS, until the test was terminated on arrival of the ship in Southampton. The fruit in the test cartons was then visually inspected and removed to the Fruit and Fruit Technology Research Institute (FFTRI) at Stellenbosch.

RESULTS

Phase 1: Comparative cooling rate

There was a marked improvement in the rate of cooling in the interlocking carton, compared with the telescopic carton. The reduction in cooling time to bring down the initial temperature difference between fruit and air by 90 per cent (0,9 cooling time), varied from 12 per cent at the bottom of the pallet, to 22 per cent in the centre and 30 per cent at the top. The difference in cooling rate appeared to increase with air velocity, which also increased from bottom to top. The influence of a carton on the one downstream, was also greater in the case of a telescopic carton than in the case of an interlocking carton.

Phase 2: Shipping cycle

Of the fruit used for testing, some were packed warm, while the remainder had been kept overnight in the packhouse. The initial fruit temperatures therefore varied between pallets, but were the same throughout each individual pallet.

Figure 2 shows the variation of pulp and skin temperatures with time of warm and 'pre-cooled' fruit. Only during the initial stages of cooling was there any significant difference between skin and pulp temperatures, the highest recorded being just over 1,0°C. For this reason, only the pulp temperatures were considered during the remainder of the test.

The time required to reduce the temperature difference between fruit and air by 90 per cent was as high as 24 hours in the case of warm fruit, and 17 hours in the case of 'pre-cooled' fruit. Generally, the slowest cooling rate was in the top cartons. The cooling rate in the various pallets differed as they were exposed to different air velocities. These velocities could, however, not be accurately determined because of the constantly changing pattern of the other pallets in the cold room which, in turn, influenced air flow around the pallets being tested.

A rise in temperature occurred during transfer into the SATS vehicle while the fruit was exposed to ambient conditions, as can be seen in Figure 3. Temperatures however, dropped soon after the vehicle doors were closed.

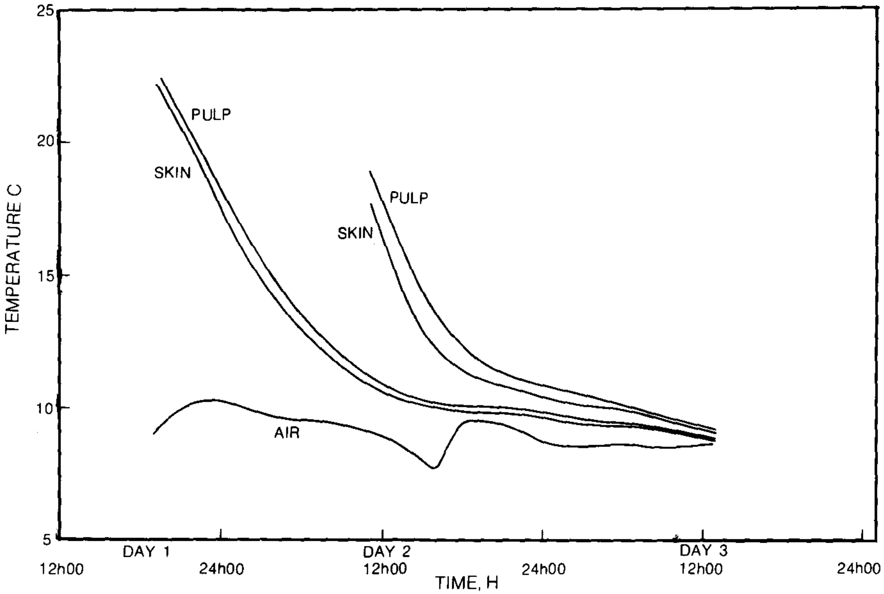


Fig 2 Variation of fruit pulp and skin temperatures of avocados (count 12) as a function of time during passive cooling

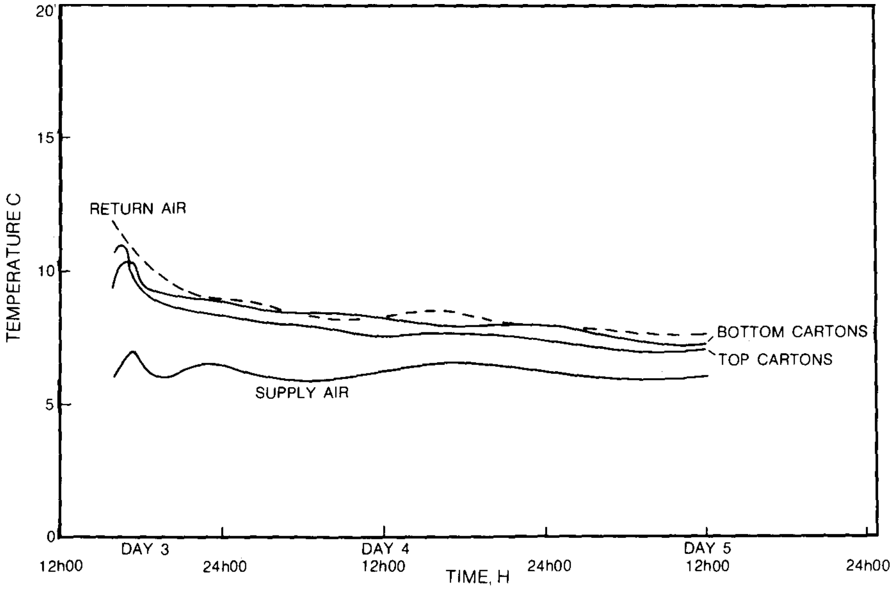


Fig 3 Variation of fruit pulp temperatures of avocados (count 12) as a function of time during refrigerated road transport

The refrigeration unit is capable of maintaining the loading bay of the vehicle at -30°C and therefore has capacity to spare when operating at 6,5°C. The control system of the refrigeration unit was modified so as to maintain the maximum air flow rate. A decrease in the fruit temperature could therefore be expected. Unfortunately, space had to be left at the rear between the pallets and the door to accommodate cartons required for inspection in Cape Town. The resulting opening caused the air to bypass, in particular, the front pallets, which was evident from the difference in fruit temperature between the front and rear pallets. The resultant overall temperature reduction of the load during the journey was between 1,0°C and 2,0°C.

On arrival in Cape Town, the fruit temperature varied between 6,5°C and 9,5°C, while the average temperature of the supply air was maintained at just above 6,0°C.

The advantage of transferring the fruit from a vehicle to containers under temperature-controlled conditions, is shown by the fact that the temperature rise during this procedure was minimal (Figure 4).

On instruction from the Perishable Products Export Control Board, the supply air temperature at the CTHS was maintained at 4,5°C until the temperature of the return air had dropped to 5,5°C. Thereafter, the temperature of the supply air was raised to maintain the return air temperature at 5,5°C. This control was maintained throughout most of the storage period. The temperature history of the fruit during this period is shown in Figure 4.

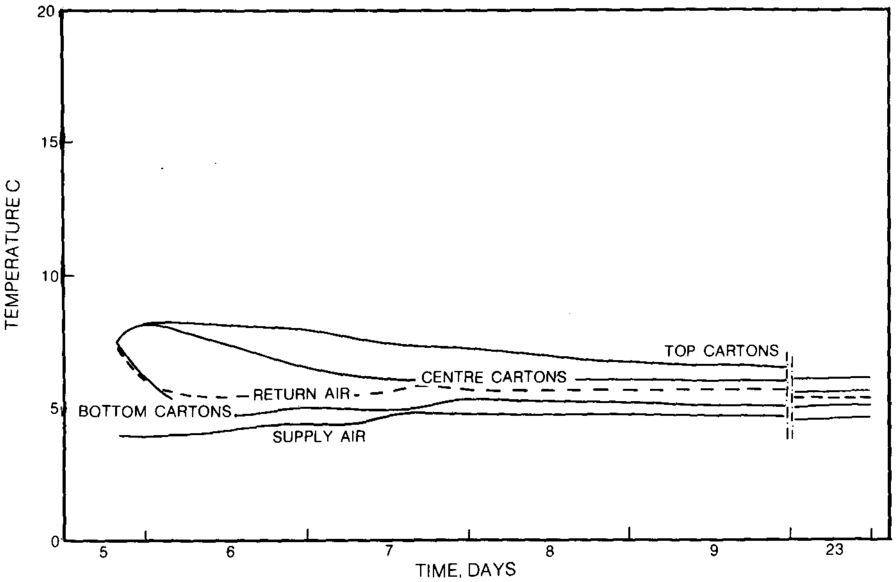


Fig 4 Variation of fruit pulp temperatures of avocados (count 12) as a function of time during refrigerated containerisation.

Because the cold air was supplied via the T-bar floor, a large proportion tended to flow unobstructed to the rear of the container. From there it rose through the rearmost pallets and returned via the void above the load, thus bypassing the centre and upper parts of the front pallets. This can be seen from the distribution of the air temperature shown in Figure 5.

Nevertheless, after three days of containerisation (Day 9), even the temperature of the fruit in the top carton of the pallets closest to the portholes was reduced to 6,8°C. The maximum and minimum temperatures at the end of the test (Day 23) were measured at 6,2°C and 4,7°C respectively.

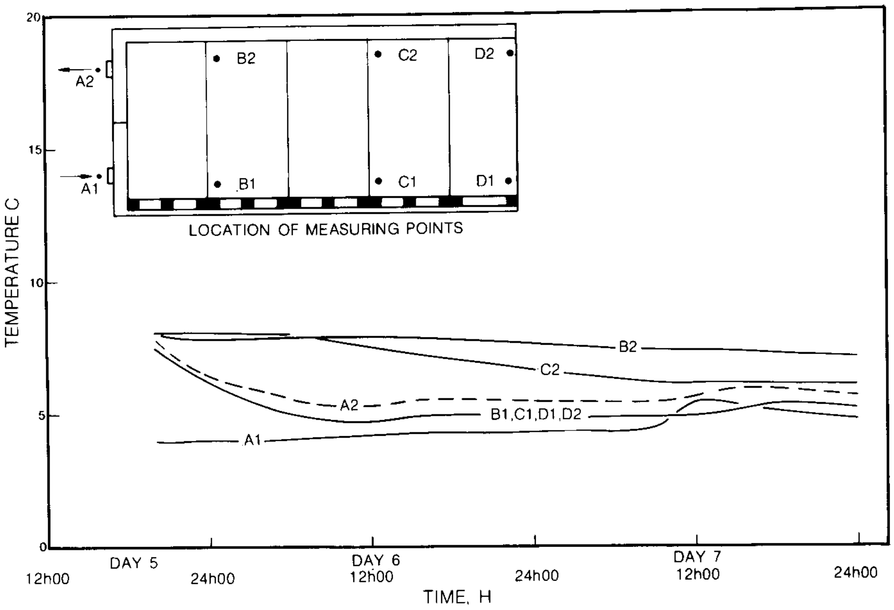


Fig 5 Variation of air temperatures as a function of time during refrigerated containerisation.

CONCLUSIONS AND RECOMMENDATIONS

The results of the experiments carried out have shown that avocados can be cooled down and maintained at the required shipping temperature successfully, provided that:

- a carton which allows optimum air circulation is used,
- a registered stacking pattern is used,
- the vehicle container is completely filled, and
- the refrigeration chain is not interrupted.

Investigations by Haas & Felsenstein (1) on the cooling rate of avocados packed in cartons in a wind-tunnel, indicate that there is no significant gain in increasing the free flow area (total area of openings as a percentage of carton area), perpendicular to the direction of air flow beyond a certain value. Figure 6 shows the half-cooling time of a stack of four cartons of Hass variety, count 22. While the fastest cooling rate remains virtually the same, the slowest cooling rate hardly improves above 9 per cent free flow area.

The carton used during the tests had a percentage of free flow area of 7,85 per cent in the direction of vertical air flow, and therefore appears to approach the optimum value. In the direction of horizontal air flow, this percentage was in excess of 15 per cent.

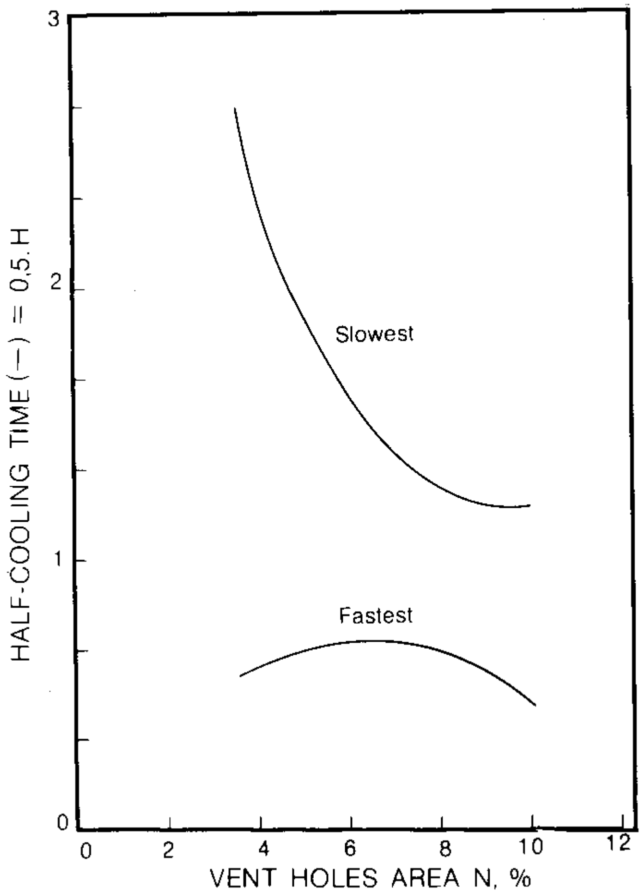


Fig 6 Half-cooling time as a function of vent holes area. Air velocity 0,1 m/s. Curves indicate slowest and fastest cooling rate (Haas & Felsenstein).

The test at Westfalia Estates during passive cooling with a predominantly horizontal air flow, revealed that the cooling rate improved significantly if a clearance of at least 5 mm was left between the fruit and the lid. This would mean that different carton heights would be required to cover the range of export fruit between counts 10 and 22. The increased height of the carton would result in a reduction of the number of tiers per pallet and the number of cartons per container.

It may well be that equal or better cooling rates will be achieved by doing away with the 5 mm clearance and employing one of the methods of forced cooling, described in the Avocado Exporters Packing Guide (2). This would also improve the temperature gradient throughout the pack, which was found to be a shortcoming of the passive cooling method, and ensure faster cooling.

Experiments with forced cooling have been conducted in the past, but were abandoned because the method resulted in a high incidence of cold injury. The results of the work carried out recently by Toerien (3), and Vorster, Toerien & Bezuidenhout (4), on the influence of temperature on the fruit during the pre- and post-climacteric phases, warrant further investigation on the forced-cooling method. The faster the load can be cooled, the quicker it can be despatched. This may reduce the time between the first and last pallet being loaded. Little can be done with regard to improving the cooling rate in the existing vehicles and containers, except ensuring that they are completely filled. From the time this investigation was carried out, a new carton of 370 x 285 mm has been introduced which can accommodate the relevant code groups under the mass grading system. The size of this carton closely approaches the one originally proposed, and will ensure even better utilisation of the available space. Unfortunately, the relatively small volumes of avocados being shipped do not warrant the designing of special containers for avocados only.

Ideally the refrigeration chain should not be interrupted before the fruit reaches the overseas market. Therefore, steps have already been taken to investigate the possibility of containerisation at the producer during the coming season.

Previous and future investigations are ultimately expected to lead to the establishment of certain standards which will ensure that fruit quality will be maintained throughout the cooling chain.

REFERENCES

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