COOLING RATES OF GRAPE BOXES
as influenced by box depth and use of integral air-flow channels

In a previous article (Leuvennink & Moelich, 2004), we reported on the variation in forced-air cooling rates in grape boxes depending on position in the pallet stack, location of pallets in the cooling tunnel, the use of perforated bags, and how this information can be used in the selection of monitoring positions to avoid low temperature injury during cooling. The relatively long forced-air cooling times of the 9 kg grape box and the resultant bottlenecks created at commercial cold stores was also highlighted.

This communication reports on: (1) forced-air cooling times in 9 kg grape boxes with different internal depth, but otherwise identical design, and (2) the incorporation of an integral air-flow channel into 9 kg and 4.5 kg grape boxes to increase the rate of cooling in commercial pallet stacks.

Effect of box depth on cooling rates of 9 kg grape boxes
Cooling profiles were determined on Waltham Cross grapes packed in non-perforated outer bags in shallow 600 x 400 x 118 mm and deeper 600 x 400 x 127 mm “interstack” 9 kg grape boxes (Fig. 1A). The forced-air cooling was done in an experimental cooling tunnel, using 20 boxes stacked in four layers, simulating four layers of a commercial pallet stack. Thermocouples were inserted in the standard commercial thermocouple position, and across all other positions in a layer to determine average temperature. Grape berry pulp and air temperature data were recorded in the two middle layers with Squirrel loggers at 1-hour intervals to enable the calculation of 90% cooling times.

Cooling profiles were also determined on Flame Seedless grapes packed in 54 x 2 mm perforated bags in shallow 600 x 400 x 118 mm and deeper 600 x 400 x 127 mm “interstack” 9 kg grape boxes (Fig. 1B). The trial was conducted in a commercial cooling tunnel in the Northern Cape. Placement of thermocouples was in the 9th layer of the pallet, in the standard position, and across positions in this layer to establish average temperature.

In the Waltham Cross non-perforated bag trial, the 90% cooling time in 127 mm deep boxes was 30.4% quicker in the commercial thermocouple position than in the 118 mm boxes (Fig. 2A). The average across all stacking positions was 28.3% quicker in the 127 mm box. Similar results occurred for 9 kg boxes of Flame Seedless in perforated bags in the commercial cooling tunnel (Fig. 2B). Here the 90% cooling time of grapes packed in deeper boxes was 32.4% quicker in the thermocouple position, while the average across positions was 26.7% faster (Fig. 2B). It is well known that the plastic outer bags used for packing grapes slows the cooling process by restricting ventilation. Therefore, the faster cooling rates achieved with a deeper box, can be ascribed to the extra free space enabling improved air flow, and hence, faster heat exchange. However this extra free space increases the transport and shipping costs, due to reduction in pallet payload.

Effect of integral air-flow channels on cooling rates of 9 kg and 4.5 kg grape boxes
The integral air-flow channel, now referred to as the V-Channel, comprises a dovetail cutout in the bottom of standard 4.5 kg and 9 kg double-walled, corrugated grape boxes (Fig. 3). The V-Channel is incorporated into the box by a push-out action using a jig. The resulting V-Channel enables additional ventilation for heat exchange during forced-air cooling.

During the 2005 fruit season, commercial cooling trials were conducted using boxes which featured the V-Channel, but were otherwise identical to the standard C90D (600 x 400 x 118 mm) and B041 (400 x 300 x 118 mm) boxes. The cooling rates of the packaging combinations shown below, were established in commercial cooling tunnels, using approximately 20 000 V-Channel boxes, in total.

Fig 1: The 9 kg “interstack” boxes with ventilation holes centred in the side-walls, (1A) and with ventilation holes in top and bottom corners (1B)

* Patent pending
1) 9 kg standard C9D box with 48 x 2 mm perforated bags, tested at the International Grape Company, Auskenneh, Namibia.
2) 4.5 kg standard B041 box with non-perforated bags, tested at the Cape Orchard Co, Auskenneh, Namibia.
3) 9 kg standard C9D box with 48 x 2 mm perforated bags, tested at Kanoneiland, Northern Cape.
4) 4.5 kg standard B041 with 54 x 2 mm perforated bag, tested at Kanoneiland, Northern Cape.

All boxes were manufactured using double-walled corrugated paperboard, using designs already available in the South African grape industry.

Across all packaging formats and cooling facilities, the 90% cooling time was reduced by between 30.0% and 44.4% in the commercial thermocouple position (Fig. 4). The average 90% cooling time was reduced by between 21.0% and 35.1%. The air-flow channel was therefore effective in dramatically improving the cooling rate and especially effective in improving the cooling in the inner columns commonly referred to as “dead” columns.

To illustrate how the reduction in cooling time can benefit cools room throughput, the full cooling cycles of two of the commercial trials are shown in Figure 5 & 6. In the first example (Fig. 5A), the 9 kg boxes with air-flow channels were loaded out for road transport shortly after reaching 1°C, after a cooling cycle of approximately 36h. Extrapolation of the log-transformed data indicated that this cooling cycle was reduced by 2.99h to 34h, therefore by more than 75% (Fig. 5B). Since many cold stores operate cooling tunnels in multiples of 12h cycles, this reduction is significant in a commercial environment since it enables more rapid throughput. Similarly, in a high capacity cooling facility, the cooling time to reach 0.5°C in 4.5 kg boxes packed with non-perforated bags was reduced from 36h to 12h (see log temperature of -0.3 in Fig. 4B), when the air-flow channel was incorporated (Fig. 6A and B). Again, this reduction is significant, since the grapes could be loaded out, within 24 hours. In this case, the reduction in cooling time made it possible to start cooling the grapes coming in from a new day’s harvest, shortly after harvest. For the grapes packed into the boxes without V-Channels, the cooling period had to continue for another 12 hours.

The faster cooling rates achieved by the air-flow channel, inevitably raises the question regarding how this may impact on low temperature injury in grapes. It is known that the cooling rate in palletised grape boxes is not uniform throughout the pallet. In the fastest cooling positions, sub-zero temperatures can be reached on the delivery air side of the pallet within hours after the onset of cooling (Leuvennink & Moelich, 2004). The temperature profiles of the grape berries positioned next to the ventilation hole of the peripheral boxes without the V-Channel, and the temperature profile of berries next to the corresponding ventilation hole where the air-flow channel was incorporated, is shown in Figures 5A and 6A. These locations represent the positions on the pallet stack, which cool fastest during forced-air cooling and therefore have the highest risk for low temperature injury. The cooling rate of grapes packed in these positions, was similar for the 9.0 kg boxes with and without the V-Channel (Fig. 5A). In the 4.5 kg boxes (Fig. 6A), in simi-
lar positions, the temperatures reached sub-zero levels approximately 7h after the onset of cooling with the V-Channel, compared to 11h in the standard box. This means that in the 4.5 kg boxes, the grapes in the fastest cooling positions were exposed to sub-zero temperatures for 17 of the 24h cooling cycle in the boxes with the air-flow channel, compared to sub-zero exposure for 21h in the longer 32h cycle where no air-flow channel was incorporated. This suggests that the air-flow channel may even reduce the risk of low-temperature damage. However, as always, proper monitoring in these positions to avoid injury remains important for effective quality management, regardless of whether an air-flow channel is incorporated in the box, or not.

Conclusions
This research showed that for grapes packed in perforated and non-perforated bags, the cooling cycles of 9 kg grape boxes can be reduced by approximately 30% by increasing the internal box depth from 118 to 127 mm. Trials comprising approximately ten thousand boxes of each of the 4.5 kg and 9 kg double walled box concepts indicated that the incorporation of integral air-flow channels can reduce cooling cycles by between 30 and 44%. The actual reduction obtained, may vary according to the cooling capacity, layout and operational procedures employed at specific cooling facilities.

Table grape producers and cooling facilities with the requirement for more rapid cooling of pallets can employ either of the above-mentioned methods. However, some role-players have indicated that the monetary value associated with the loss of one layer from the pallet payload and the expected rise in packaging costs when the depth of the box is increased, is unacceptable. The V-Channel therefore provides a cost effective alternative.

The air-flow channel may also be used to enable use of higher delivery-air temperatures, with the view to reduce the risk of chilling related disorders, but without increasing the length of the cooling cycle beyond that of existing standard boxes. It can also be used to obtain acceptable cooling times for grapes packed in non-perforated bags, which enable more versatile fruit quality management. Effective monitoring in the fastest cooling positions on the pallet stack, remains important to prevent low temperature injury.

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REFERENCE
Fig 5: Cooling profiles with and without air-flow channels for 9 kg 600 x 400 mm grape boxes packed with 48 x 2 mm bags, (A) and (B), in a commercial cooling tunnel.

Fig 6: Cooling profiles with and without air-flow channels for 4.5 kg 300 x 400 mm grape boxes with non-perforated bags, (A) and (B), in a commercial cooling tunnel.

www.delecta.co.za  info@delecta.co.za
tel +27 (0)21 930 1181  fax +27 (0)21 930 1183  
P.O. Box 420, Parow, 7499, Cape Town, South Africa