Improved Airfreight Coolchain Operation

Report to NZ Asparagus Council

Part I Dry Ice as a Supplemental Coolant - Experimental Study
Part II Technical Specification for Improved Airfreight Coolchain Operation.

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Contents

Part I - Dry Ice as a Supplemental Coolant - Experimental Study

1. Introduction

This research has been carried out collaboratively by Don Brash, Crop&Food Research, and Frank Bollen, Lincoln Technology. It represents the culmination of several years work in this area by both groups with Asparagus Council and FRST support.

The initial proposal to the Council was to complete the current research, assemble this information into a technology package and investigate methods for commercialising the technology. We had proposed licensing users, or branding the technology. The level of funding available has meant that we have worked primarily on the research and summation of the technology status to date.

Previous work on supplemental cooling has identified that the major concern with the use of dry ice is the poor temperature uniformity in pallets (Brash *et al.*, 1993). This is due to the 'point source' nature of a polystyrene box in the stack. This work has also identified the need for good sealing of the pallet to optimise the retention of cool air, which raises some concerns about excessive atmosphere modification in the pallet when dry ice is used.

The primary research objectives were:

- To develop an improved delivery system for dry ice to overcome poor temperature uniformity within a wrapped pallet of asparagus.
- To determine the degree of atmosphere modification for wrapped pallets of asparagus with and without dry ice.

2. Experimental Procedure and Results

2.1 Setup

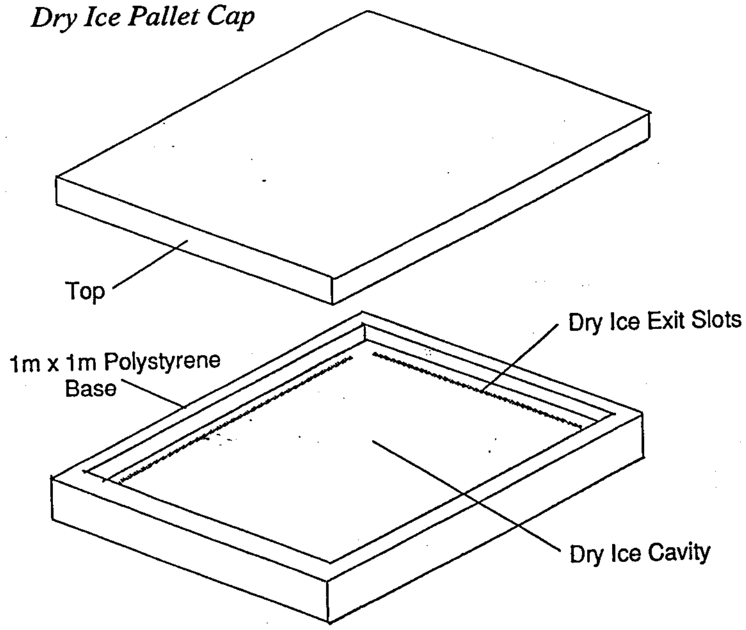
Due to the unavailability of asparagus, broccoli was used during the experiments, as it has similar respiration rate to asparagus. Two hundred and seventy kilograms of broccoli was packed into 90 asparagus boxes and held in one of the controlled temperature rooms at Levin Research Centre. Five runs were completed as detailed below:

Run	Treatment	Length of run (hr)	Weight of Dry Ice (kg)
1	Polythene wrap	7	8.1
2	Polythene wrap	6	0
3	Polythene wrap	16	12.1
4	Plastifoil (foil/plastic laminate)	7	0
5	Plastifoil	6	12.0

The pallet was instrumented with 20 thermocouples to map produce temperatures. In addition, thermocouples were used to measure the temperatures around the dry ice cap, and four external air temperatures. Prior to each run the room was cooled and air drawn through the product to reduce the temperature to a target of 1.0°C ± 1.0°C. Once the temperature was uniform the pallet was wrapped and the dry ice added (where appropriate). The room temperature was then set to 20 °C and the produce temperatures and CO_2 levels were recorded as the pallet warmed.

The 1 m x 1 m distribution cap is shown in Figure 1. It consisted of two sheets of 20 mm thick polystyrene taped together on either side of a 20 mm deep well. The centre of the cap was filled with dry ice and the cold CO_2 was able to enter the pallet through narrow slots cut in the base close to the walls. No CO_2 was delivered to the centre of the pallet.

Figure 1: Dry Ice Pallet Cap



2.2 Dry ice distribution technique

Figure 2 below shows a typical range of temperatures for the treatments with the experimental dry ice distribution cap and Figure 3, a wrapped pallet with no supplemental cooling. These figures show average temperatures for each layer of the pallet. The addition of the dry ice to the pallet reduced overall temperatures in the pallet and in particular suppressed the temperatures in the top layers.

Figure 2: *Average layer temperatures for warming pallet with dry ice (Polythene wrap)*

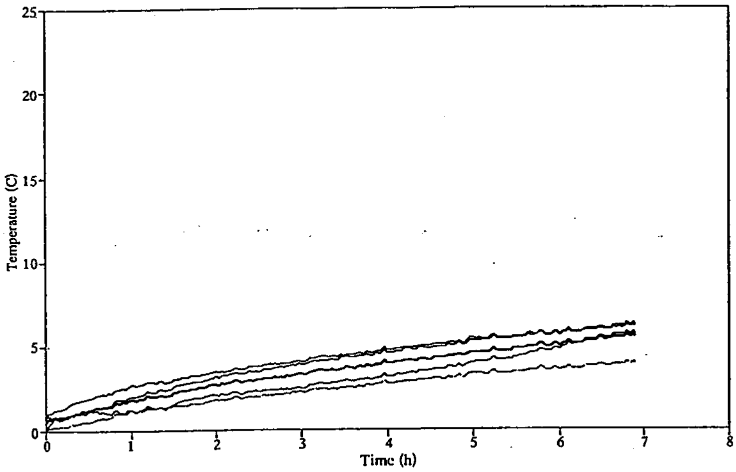


Figure 3: *Average layer temperatures for warming pallet with no supplemental cooling (Polythene wrap).*

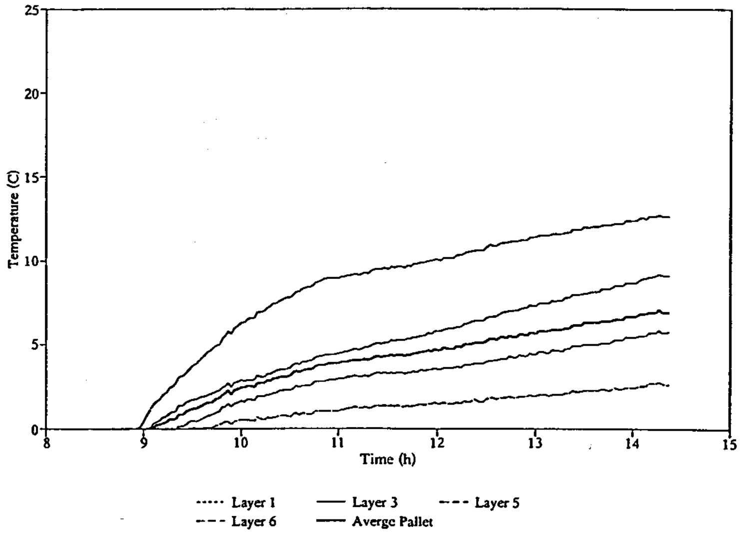
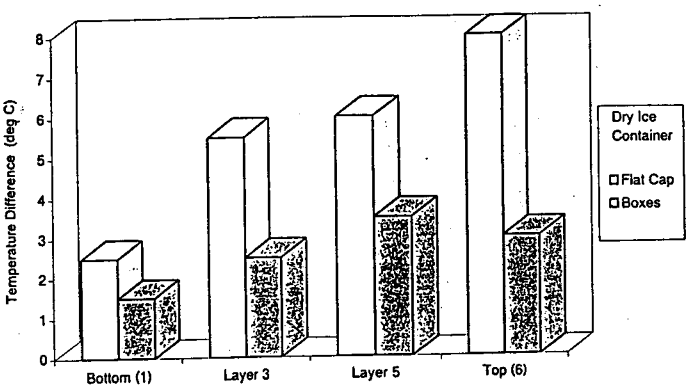


Figure 4: *Typical temperature profiles in layers - with dry ice and polythene wrap*



The traditional method of adding dry ice coolant to a pallet is to place two polystyrene boxes in place of asparagus boxes in the top of the pallet. This results in a cold core to the pallet as the dry ice falls through the middle (Brash *et al* 1994.). The concept of the dry ice cap was to distribute this cold air to the outside of the pallet. This was successfully achieved and the temperatures on the faces of the pallet were markedly reduced. Temperatures at the centre of the pallet were also improved. The corner boxes were not effectively cooled however, and temperatures rose more rapidly. The within layer variation was therefore higher than for the dry ice boxes (Fig 4) The base of the cap proved to be too thin to adequately insulate the product underneath and some freezing was recorded in the centre of the pallet. The net effect of this temperature depression, in the middle of the pallet was to create temperature variation within the layer similar to previous trials with asparagus (Brash, *et al.* 1994). The solution here would be to increase the thickness of the polystyrene cap, however limited head space in the airplane will mean that this is not a practical option.

The conclusion from this work is that the proposed dry ice cap provides little improvement in CO_2 distribution over the boxed option and neither method of delivering dry ice to the pallet is as effective as the ice blanket system.

2.3 Atmosphere modification

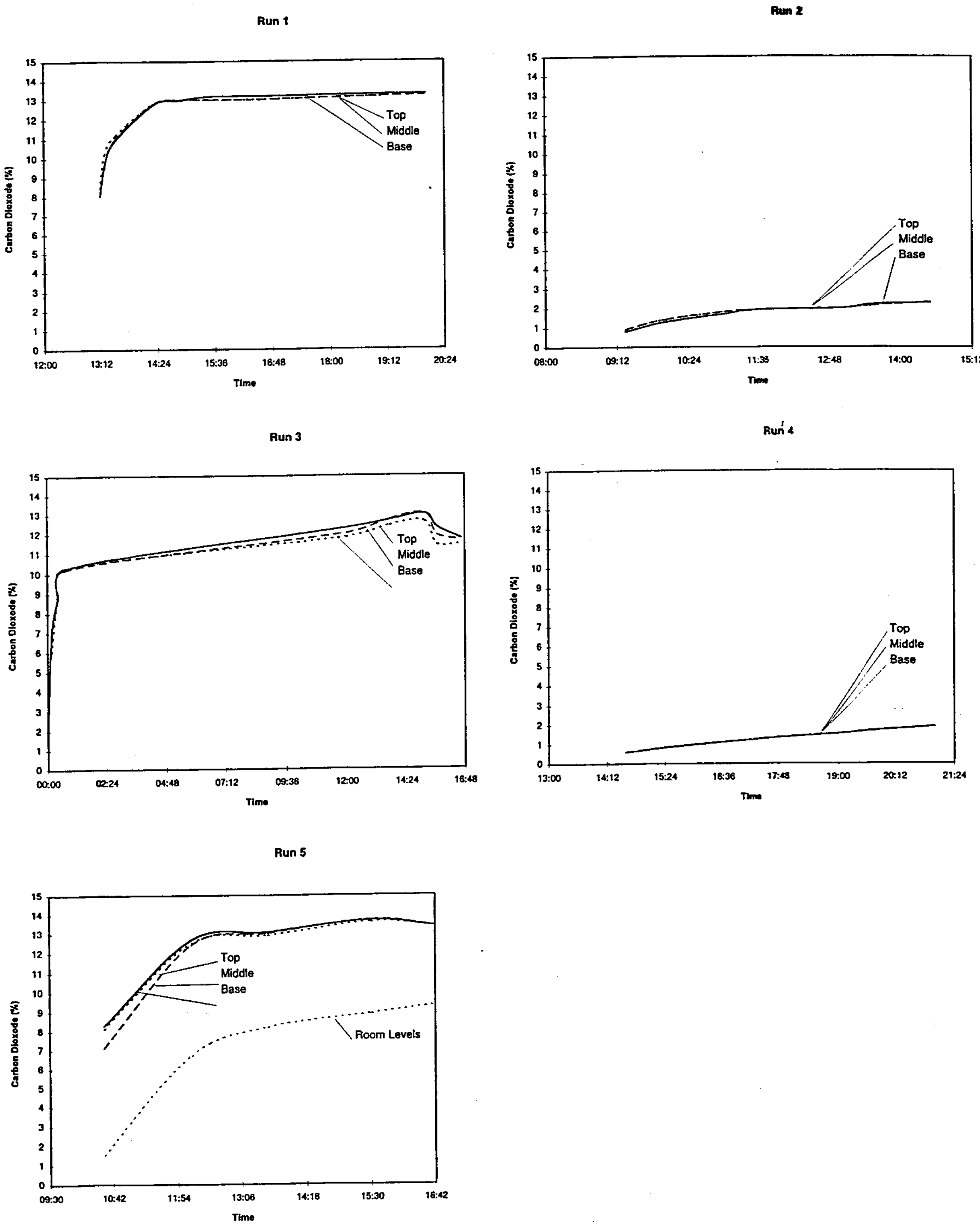
One of the major concerns for these insulation trials has been the degree of atmosphere modification which could potentially occur during transit, and to what extent this might impact on the asparagus quality. Good insulation effectiveness is helped if the pallet is well sealed, but this works against the need to allow air exchange to maintain O_2 and CO_2 levels that are not phytotoxic.

The levels of CO_2 recorded in the pallets are shown in Figure 5. Where dry ice cooling is used the internal atmosphere tends to equilibrate quite rapidly (within 1 hour) at approximately 13% CO_2. In the sealed pallets without dry ice, levels had reached 2-5% in 6 hours. These levels are not likely to affect asparagus quality over a 48 hour period.

The final concentration of CO_2 in the pallet will be highly dependent on the degree of sealing which can be achieved. In these experiments great care was taken to seal the wrap as effectively as possible using tape. It is suspected that in industry poorer seals will be the norm and CO_2 levels will be correspondingly lower.

The CO_2 levels in wrapped pallets of asparagus will not reach phytotoxic levels in general applications.

Figure 5: *CO_2 levels in pallets of asparagus with and without dry ice coolant*



Research conclusions

- If dry ice is used as a supplementary coolant it will be very difficult to obtain temperature uniformity within the pallet.

- Atmosphere modification within the pallet, with or without the use of dry ice, will not result in atmospheres with CO_2 levels which can damage asparagus.

Part II - Technical Specification for Improved Airfreight* Coolchain Operation

The following discussion represents the summation of several studies carried out over a number of years to determine methods of improving the asparagus coolchain.

The objective of every operator throughout the coolchain should be to maintain asparagus quality by moving product quickly and keeping the temperature as close to 2 °C as is practicable. The major points where there is poor temperature control are in the paddock/packhouse, on the truck and during air freight. In the air freight sector temperature is very difficult to control. If live animals are being transported these take temperature precedence, and on non-direct flights unloading at tropical destinations always occurs.

At all these points in the system it is important to adequately cool the asparagus before, shield produce during, and re-cool the asparagus after the operation.

1. Cooling

- At every opportunity reduce the temperature rapidly back to 2 °C.

2. Insulation

- The most cost effective method of maintaining a precooled temperature is to wrap the produce.
- The primary function of the wrap is to retain the cold air so a base is needed and it must be sealed to the sides.
- The insulation combines with the gaps in the sides of the asparagus boxes to create a very effective insulation layer and additional foam insulation is not necessary.
- A foil laminated wrap is preferable as it functions best in solar exposure conditions.
- The wrap should be robust and not easily punctured or ripped.

* This discussion on cost effective methodologies for improving coolchain operations applies primarily to air freight, but is equally applicable to other sectors.

- The best way to air-freight is on a "P1G" or "airline pallet" (holds 6 asparagus pallets). There is less handling, the insulation is easy to apply and effective.

  The airlines generally prefer P1G's as they are easier to handle and the freight rate is lower. Their use will only increase, however, if exporters collaborate to fill them in preference to each one filling the smaller LD-3's.

- Insulation of airfreight containers (LD-6, LD-3, etc) using foil wraps is not effective at present because:
  - the wraps are not sealed (particularly around the base),
  - the foil which is often used is in contact with the aluminum skin and this reduces its effectiveness to practically zero. To improve this situation the foil wrap needs to be separated from the container skin, by an air gap.

3. Supplemental cooling

- The second most effective option for improving the temperature maintenance in uncontrolled environments is to use supplemental cooling.

- The two options are dry ice pellets and ice-gel blankets.

- For a shipment to Japan use 275 g Ice per box of asparagus
  160 g Dry Ice per box of asparagus.

- The advantages of the dry ice option are:
  - it is readily available
  - easy to use
  - sublimes in flight - no disposal problems
  - has a higher cooling capacity than an equivalent weight of ice.

- The advantages of the ice-gel blanket are
  - much more effective and uniform cooling than dry ice
  - no loss of product space (generally).

  Some disposal problems may arise in the future, and the user requires a large freezer to store the blanket prior to use.

4. Package Design

- Some modification to box size and design is suggested to optimise the use of space in the cargo hold. The full allowable cargo height is 1.625 m for 767 and 747 planes. A pallet base with runners attached on their sides requires a minimum of 50-60 mm. With the current box height at 260 mm, this leaves only 15 mm for the ice-gel blanket. Reducing the box size to 254 mm would leave sufficient room to stack two layers of ice on top of the product. It is not clear if this would be sufficient to impact on the specified spear length.

Appendix 1

1995 Asparagus Conference Poster

Improved Air-freight Coolchain Operation

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The Trial:

Research has been targeted at developing a cost effective system for the asparagus air-freight coolchain. An air-freight trial was completed to evaluate the recommended system in comparison to existing freight methods.

The work was a continuation of FoRST and NZAC funded research which has investigated the use of different types of insulation materials (including film wraps, foil wraps and foil/foam wraps such as Coolguard), different cooling regimes in both simulated and actual handling systems to improve the out-turn shelf life of asparagus on arrival at the export market.

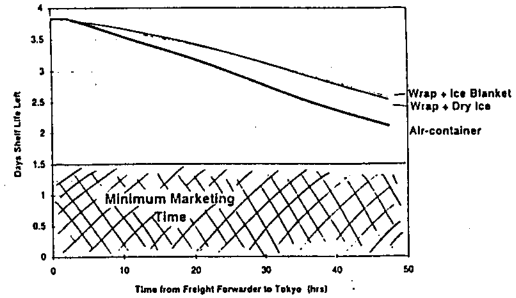
Three systems were evaluated in a commercial trial:

1. A conventional system - boxes stacked in an air-freight container (LD-8).
2. Wrapped pallet with Dry Ice in a polystyrene box.
3. Wrapped pallet with an Ice Blanket.

Temperatures were monitored on a direct flight to Japan and the effect of the temperature exposure on shelf life calculated:

Conclusion:
Wrapping produce will provide a benefit of 12 hours marketing time (@ 20°C) on a direct flight to Japan.

Effect of Air-freight Insulation on Asparagus Shelf-life



Recommendations:

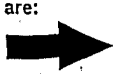
COOLING
- Properly precool asparagus

INSULATION
- Seal the pallet to keep the cold air in, especially the base
- The foil and the foil/foam are very similar in performance
- A wrap is more effective than an air-freight container
- Foil lining within a container is not effective unless there is an air gap

SUPPLEMENTAL COOLANT
- Use at least *275g *Ice*/box of asparagus
  *160g *Dry Ice*/box
- Ice blanket on top of the asparagus provides more uniform temperature distribution than the dry ice in a polystyrene box

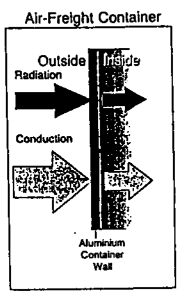
How Insulation Works:

Major heat sources warming asparagus are:

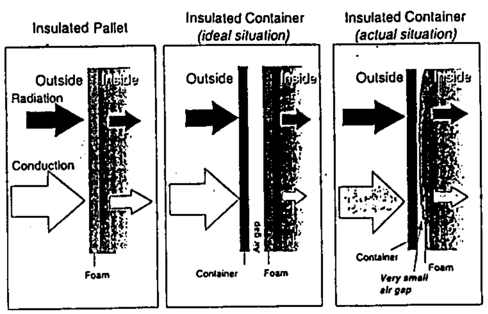


and

No Insulation



Foam Insulation



Foil Insulation