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Using insulation and supplemental cooling to improve the asparagus coolchain

A report prepared for

New Zealand Asparagus Council

D W Brash, F Bollen[1] & B L Bycroft
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[1] Agricultural Engineering Institute, Hamilton

New Zealand Institute for Crop & Food Research Limited
Private Bag 4005, Levin, New Zealand

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1 EXECUTIVE SUMMARY

The effectiveness of a range of insulation materials and supplemental cooling methods was compared on two pallet loads of asparagus. We compared stretchwrap, insect mesh, builder's foil, and Coolguard insulation and used some of these materials in combination with ice (as Thermafreeze ice blanket) or pelleted dry ice (in two polystyrene boxes). Our objective was to find effective means of keeping asparagus cool during airfreight to export markets.

Our main findings were:

a. The major benefit of insulation was as an air exchange barrier.

b. Foil and Coolguard insulation were equally effective and better than stretchwrap.

c. Insect mesh was not a successful insulation treatment.

d. Both supplemental cooling materials had advantages. Dry ice had a larger cooling potential (on a per kilogram basis) but Thermafreeze gave a more uniform temperature distribution within the pallet.

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2 INTRODUCTION

The continued success of the New Zealand asparagus industry depends on delivery of high quality fresh asparagus, particularly to export markets. A major cause of loss of quality is inadequate temperature control during the coolchain from harvest to market. Growers and exporters have little control over storage conditions during airfreight and handling at the export destination. Major problems occur on indirect flights through the tropics when asparagus can be exposed to high temperatures and direct sun for extended periods.

With these concepts in mind, we investigated the potential for using insulating materials with or without supplemental cooling to keep asparagus cool in transit.

Asparagus is a highly perishable crop and, because of its high respiration rate, can generate heat. We aimed towards developing safe, reliable and cost-effective insulation systems for the crop.

In this report we look at the effectiveness of a range of insulating materials and the use of some of them with ice and dry ice cooling. Our objectives were:

> to develop insulation and cooling methods for pallet loads of asparagus which will maintain temperatures in the range 0-10°C (mean less than 5°C) for 24-36 hours after removal from cool storage at 0-2°C and
>
> to investigate the insulating value of insect-proof netting.

3 APPROACH

3.1 Testing equipment and procedure

Tests of the insulation and supplemental cooling treatments were carried out in a coolroom at Levin Research Centre on two pallets of export asparagus (90 x 5 kg boxes with 6 layers of 15 boxes per layer). Temperature probes were placed into asparagus spears in layers 1, 3, 5 and 6 (where 1 = bottom and 6 = top) in the centre, side and corner of each layer. One probe was used to measure air temperature in the coolroom. Boxes were stacked on a layer of Coolguard insulation on a pallet base.

Our testing procedure was to first cool the asparagus to 0-1°C, apply an insulation treatment, then quickly raise the room temperature to 20°C (this took up to 15 minutes). We monitored the temperature in each probe over a 8-9 hour period (except in two long runs of 36 and 41 hours). The insulation treatment was then removed and the asparagus was re-cooled (using forced-air cooling) for the following day's testing.

We were able to carry out 7 runs with each pallet of asparagus. Table 2 shows experimental details. The first pallet was used for Runs A-F and the second for Runs H-N.

3.2 Treatments

Table 1 shows details of insulation and supplemental cooling treatments. The insulated covers were attached to the Coolguard base using 100 mm insulation tape. For the dry ice runs, two polystyrene boxes containing a total of 6.5 - 6.8 kg of dry ice replaced two boxes of asparagus in the top layer of the pallet (one on each side of the centre box). For the ice runs, Thermafreeze (11.6 - 12 kg) was placed on top of the pallet except for the long runs. In Run G strips of Thermafreeze were placed in gaps between boxes in the lower 5 layers (22 kg) and 12 kg on top. In Run M 32 kg of Thermafreeze blanket was placed on top of the pallet.

The quantities of ice and dry ice for the 9 hour runs were calculated to achieve a similar cooling potential (approx. 4 MJ). For the long runs the quantity of ice was calculated to last approximately 36 hours before melting.

3.3 Changes from 1991 approach

Changes were made to the experimental approach in 1992. We placed a horizontal baffle above the pallet and below the fans to reduce air flows over the top of the pallet. In 1992 we did not make a cut in the insulation material when using dry ice. The 1992 experiments were run for a longer period (at least 8 hours), main treatments were replicated and dry ice was held in two uncovered polystyrene containers (not one covered container as in 1991).

Table 1: Insulation and Supplemental Cooling Treatments.

Insulation

1)	Insect mesh	-	obtained from Owens Coolair, Auckland.
2)	Builder's foil	-	a foil/paper/foil combination
3)	Stretch wrap	-	clear plastic, 300 mm wide, wrapped with an overlap to provide a complete pallet cover.
4)	Coolguard Light	-	a foil/plastic foam/polythene combination, approximately 8 mm thick, supplied by Omega Manufacturing and Marketing, Auckland and manufactured by Cargo Technology Corporation, San Diego, U.S.A. (This material is made into all common sizes of pallet covers and container liners that are used on modern aircraft)

Supplementary cooling

1) Pelleted dry ice in two "6-pack" polystyrene boxes without lids. (Latent heat of sublimation of CO_2 is 572 KJ/Kg).
2) Ice in a 'Thermafreeze' ice blanket. Thermafreeze has an outer casing of polyester and contains a water absorbent powder. When fully hydrated the blanket is over 98% water and weighs 8 kg/m^2. The blanket was frozen to 15°C prior to use. (Latent heat of fusion of water is 333 KJ/Kg).

Table 2: Experimental details.

Run	Date	Insulation	Supplemental Cooling
A	1/12/92	Foil	Dry ice
B	2/12/92	Coolguard	Dry ice
C	3/12/92	Coolguard	Ice
D	4/12/92	Foil	Ice
E	6/12/92	Control	None
F	7/12/92	Stretchwrap	Ice
G	8-10/12/92	Coolguard (long run)	Ice
H	14/12/92	Foil	Ice
I	15/12/92	Foil	Dry ice
J	16/12/92	Coolguard	Ice
K	17/12/92	Coolguard	Dry ice
L	18/12/92	Coolguard	None
M	21-23/12/92	Coolguard (long run)	Ice
N	23/12/92	Insect mesh	None

4 RESULTS AND DISCUSSION

4.1 Comparison of mean pallet temperatures

To compare the various treatments, we calculated the mean temperature of each pallet during each run and fitted curves to these data over an 11 hour period.

All treatments maintained a lower mean pallet temperature than the control (no insulation cover and no supplemental cooling) throughout the runs (Figure 1).

By far the least effective treatment was the insect mesh, with only a marginally lower mean pallet temperature than the control. Coolguard without supplemental cooling, stretchwrap plus ice and foil plus dry ice maintained very similar mean pallet temperatures. Coolguard plus dry ice, Coolguard plus ice and foil plus ice were most effective.

Although small differences existed among the performance of the insulation treatments in the controlled environment of our trials, it appeared that the most important effect of the pallet cover was to act as an air exchange barrier between the cool pallet and the warm room. Supplemental cooling lowered mean pallet temperatures compared to Coolguard without cooling.

Differences between replicates were small for all but one treatment. There was some variation between the replicate runs for the Coolguard plus dry ice treatment (approximately 1°C difference after 11 hours). This was possibly due to more effective sealing of the gap between the cover and insulated base for the first run (B) than the second run (K). Differences between replicates in all other treatments were small.

The insect netting provided little resistance to air movement between the pallet and the warm room and was thus unsuitable as an insulation material. It is also likely that the stretchwrapped pallet would be affected by solar radiation more than the Coolguard or foil. We recommend caution in using stretchwrap, particularly in situations where the pallet could be exposed to direct sunlight.

The similar performance of both foil and Coolguard with supplemental cooling suggests that either would be suitable for insulating pallets of asparagus. The choice would most likely be made on economic grounds.

The predicted long run average pallet temperatures for Coolguard treatments are shown in Figure 2. The benefits of a further 20 kg of ice (32 kg total) are shown.

The amount of coolant in the 9 hour runs had the same cooling potential but ice cooled at nearly double the rate of dry ice (97 watts vs 53 watts). After 9 hours about 60% of dry ice remained unused compared to 15% of the ice in Thermafreeze. Dry ice would continue to cool for longer on long runs. We saw no evidence of freezing of asparagus despite the low temperature (-80°C) of dry ice.

4.2 Within pallet variation

Despite the overnight forced-air cooling of the pallets between treatments, we were unable to achieve an initial temperature of between 0°C and 1°C, particularly in the centre of the pallet. This made comparisons of within pallet variation among treatments difficult. However, the trends of the replicates were similar, so some general conclusions could be drawn.

The vertical temperature range (i.e. between layers 1 and 6) within each pallet after 8 hours was less than 5.5°C for all Coolguard or foil plus ice treatments. The dry ice runs varied by as much as 8.2°C after 8 hours. The control and netting runs varied only 4.6°C, but the average pallet temperature for both runs were considerably higher than the other treatments. The central core was the coolest part of the pallet after 8 hours for all treatments.

The main effect of the addition of ice was the cooling of the top layer of the pallet. This can be seen when comparing the mean temperature profiles for layers 5 (Figure 3) and 6 (Figure 4) for runs using Coolguard only, Coolguard plus ice and Coolguard plus dry ice. The mean temperature of the top layer increased quickly without ice. The addition of ice to the top of the pallet reduced the mean temperature of the top layer by as much as 4°C, but had little influence on the fifth layer.

Dry ice lowered mean pallet temperatures (Figure 1) but was not effective in the top layer. Dry ice has a greater cooling capacity for a given weight than ice. This is important to minimise freight costs. Better methods of distributing dry ice in the pallet are required to enable it to be used more effectively.

4.3 Carbon dioxide and oxygen levels in the pallet

Carbon dioxide and oxygen levels were measured after about 6 hours during Runs A, B, D. Where ice was used, the atmosphere composition was close to air (19%, O_2, 1% CO_2). Where dry ice was used the atmosphere contained high carbon dioxide levels (19 and 25% for Runs A and B) and lowered oxygen levels (14 and 12% for Runs A and B). It may be possible to adjust dry ice weights to allow insecticidal atmospheres to develop while avoiding phytotoxic effects.

4.4 Average temperatures over 36 hours

Predictions were made of the mean pallet temperatures over 36 hours for the Coolguard, Coolguard plus 12 kg of ice, Coolguard plus 32 kg of ice, Coolguard plus 6.8 kg of dry ice and the control, based on the results for 1992 (Figure 2). All the treatments showed marked reductions in temperature compared to the control. The addition of 32 kg of ice was the most effective treatment, because it took a longer time to melt than either 12 kg of ice or the dry ice.

We were unable to meet our original objectives of maintaining mean temperatures below 5°C after 24-36 hours (Figure 2). It is likely that under typical airfreight transit conditions temperatures would be much lower than 20°C with only short periods at high temperatures (during tarmac offloads for example). Our objective should be tested under a typical transit temperature regime.

4.5 Comparison with 1991 results

Figure 5 compares some 1991 and 1992 results. The Coolguard plus dry ice treatment is 2°C cooler after 5 hours in 1992. This difference is related to the better sealing in 1992 (no cut in the insulation). Controls warmed faster in 1992. This result is most likely to be related to the changed air flow patterns after the baffle was added in 1992.

5 CONCLUSIONS

5.1 Insulation

a. The major benefit of insulating pallets of asparagus is the prevention of air exchange with a warm exterior environment.

b. Insect mesh is not a successful insulation treatment. A sealed pallet would provide an insect-proof cover for quarantine purposes.

c. Stretchwrap is almost as effective an insulation as foil or Coolguard. However we have concerns about the effect of solar radiation on a pallet covered in clear plastic.

d. The insulation performance of foil and Coolguard is similar under controlled coolroom conditions.

5.2 Supplemental cooling

a. Both ice and dry ice effectively reduce pallet temperatures. For a 24 hour period, 7 kg of dry ice is equivalent to 12 kg of ice. The ice will all melt in the first 10 hours but remove heat at a more rapid rate, depressing the pallet temperature initially. The dry ice will provide constant cooling throughout. Dry ice raises CO_2 levels in the pallet atmosphere. With careful monitoring insecticidal CO_2 levels may be possible while avoiding phytoxicity.

b. The Thermafreeze ice blanket placed on top of the load provides the most uniform temperature distribution in the pallet of all treatments (only 1 - 2.5°C contrast between the mean temperatures of the top and bottom layers).

5.3 Goal of 5°C after 24 hours

a. We were unable to meet this objective with surrounding air temperatures of 20°C. The objective should be tested using a temperature regime typical of airfreight transit conditions and where temperatures are generally much lower than 20°C.

6 REFERENCE

Brash, D.W.; Bollen, F. and Bycroft, B.L. (1992): Using insulation to improve the asparagus coolchain. Report to the New Zealand Asparagus Council. MAF Technology, Levin.

Figure 1. Fitted average pallet temperatures
for all insulation treatments (excluding long runs)

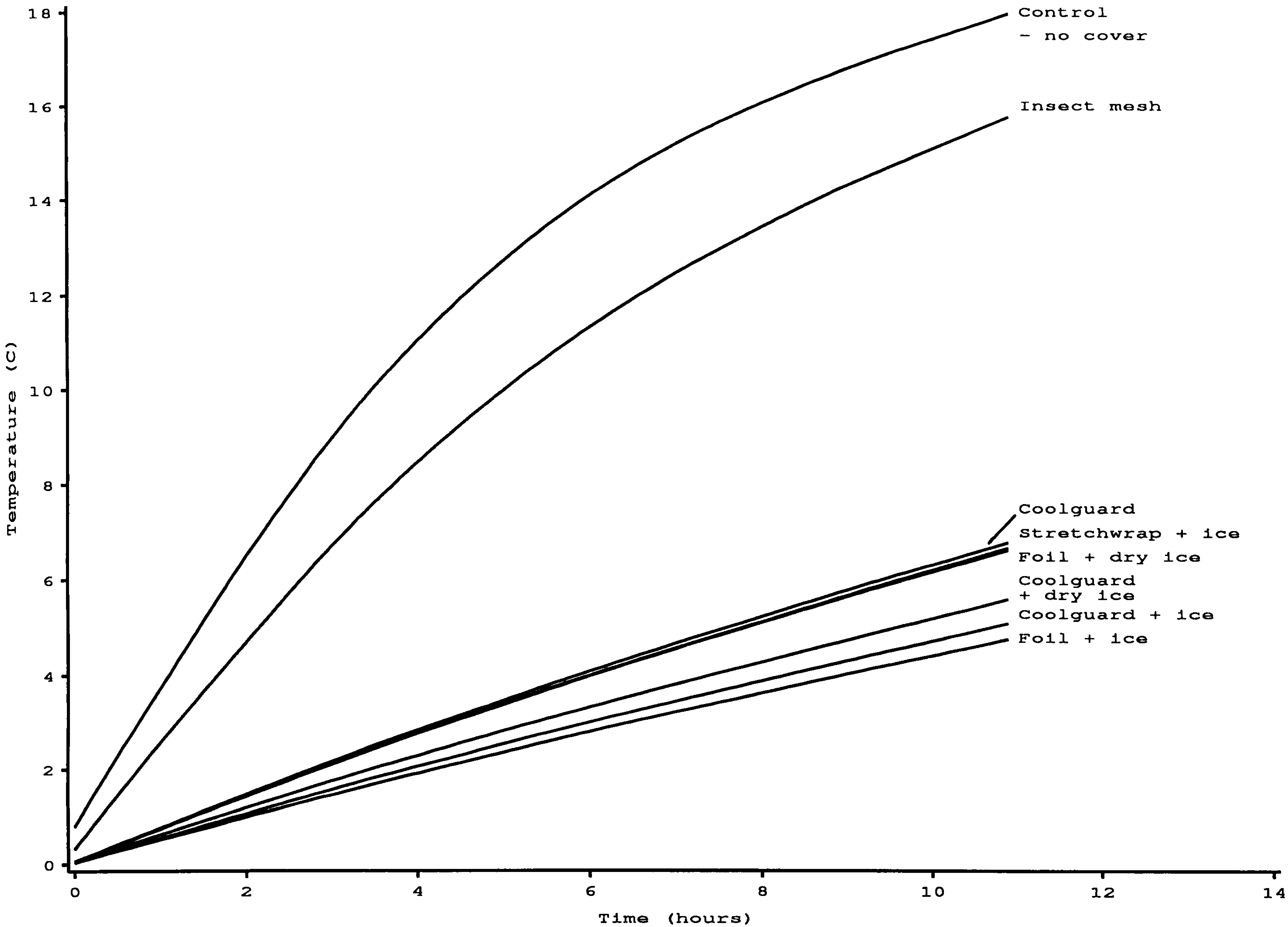

Figure 2. Predicted average pallet temperatures over 36 hours
for Coolguard insulated cover

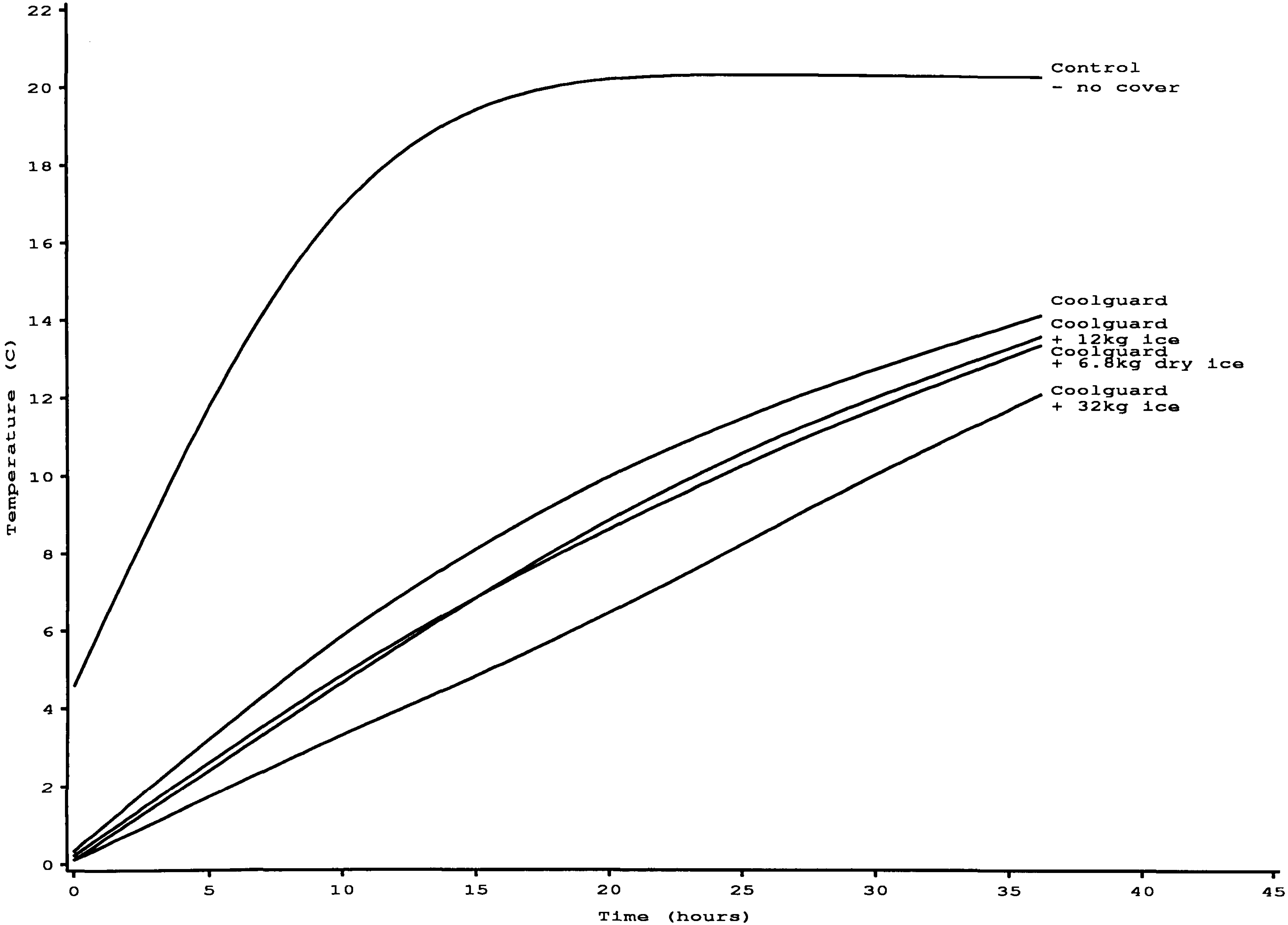

Figure 3. Temperature profiles for coolguard plus cooling
second to top level of pallet

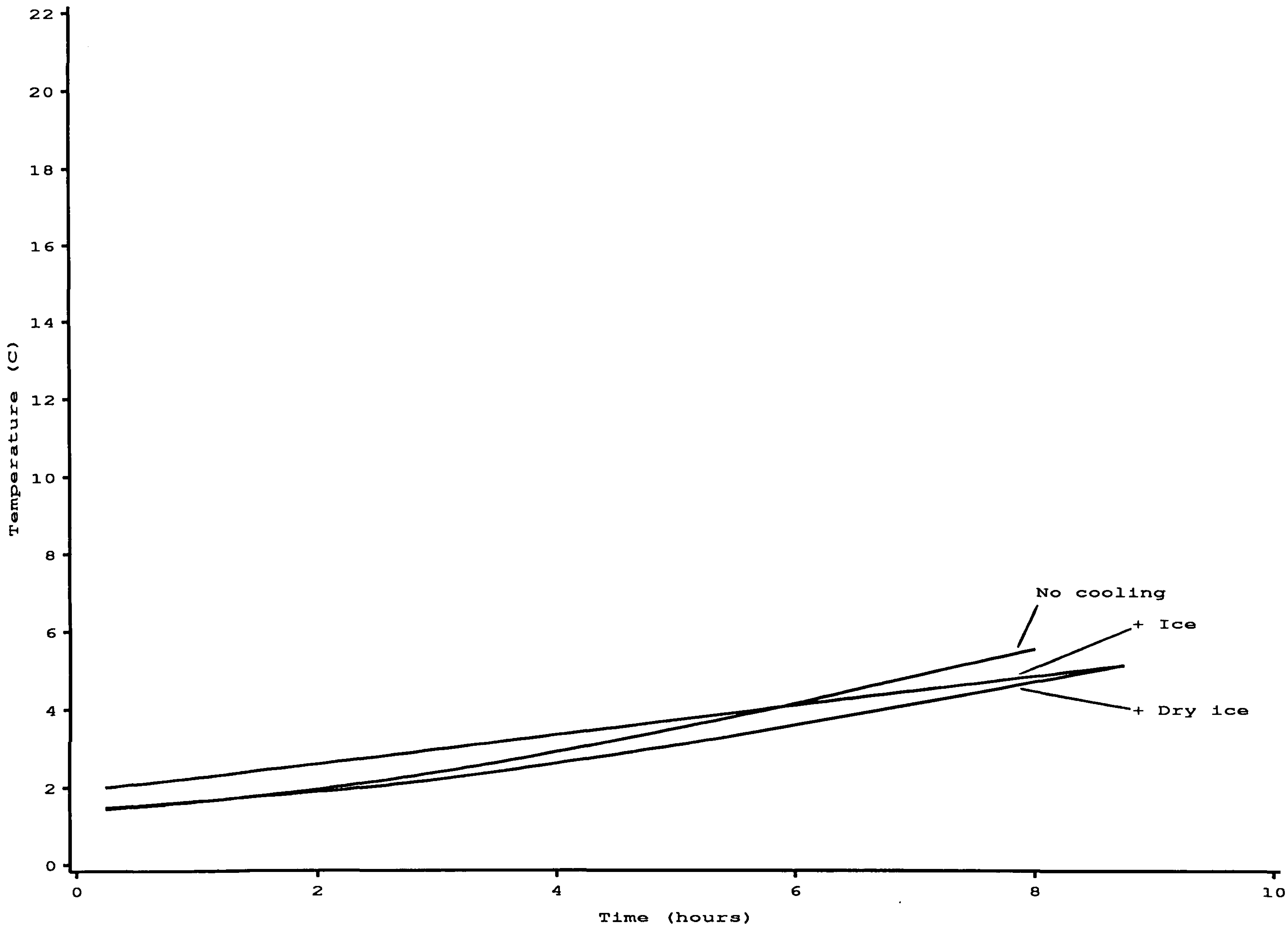

Figure 4. Temperature profiles for coolguard plus cooling

top level of pallet

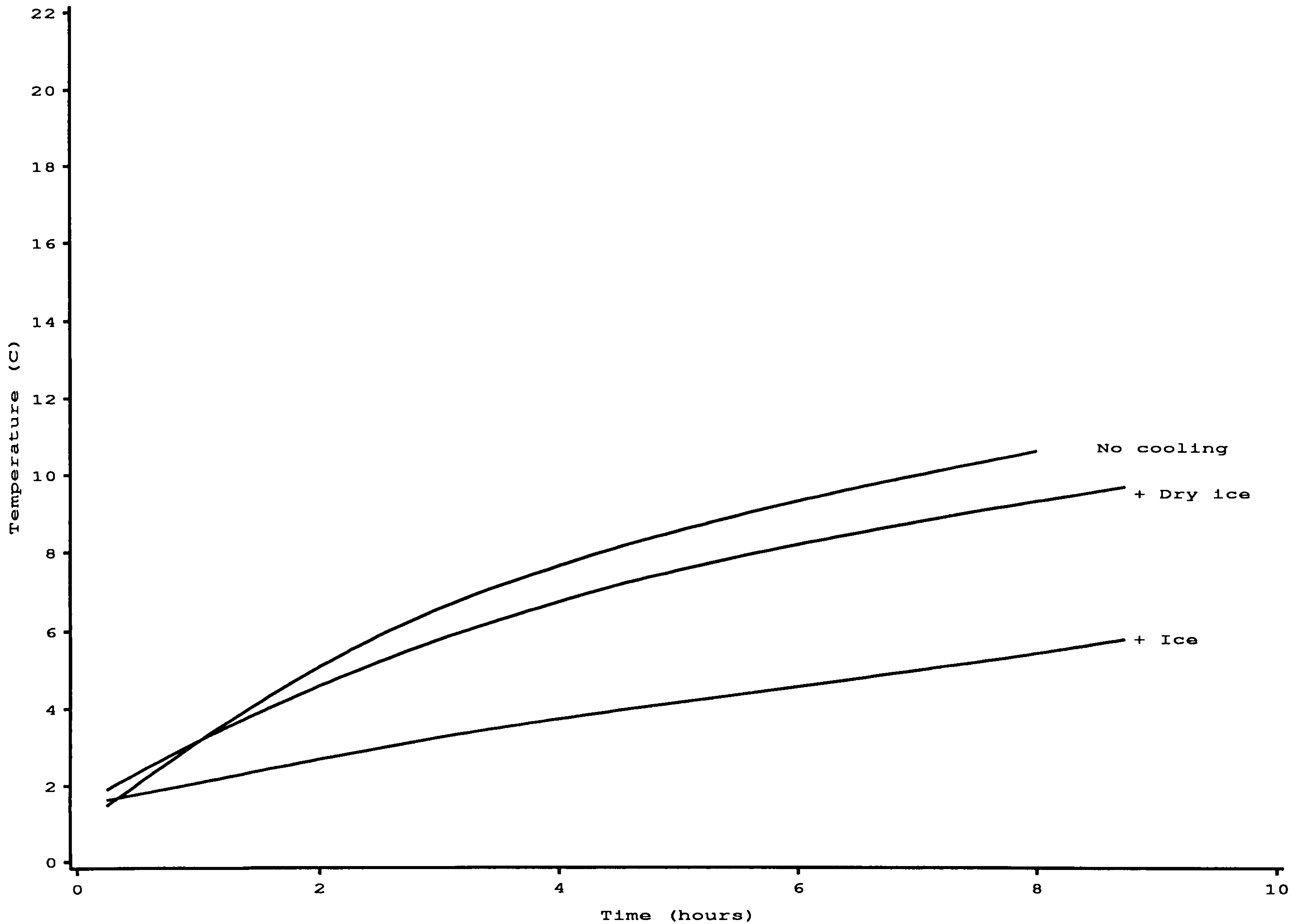

Figure 5. Fitted average pallet temperatures
for treatments used in 1991 and 1992