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Improving The Asparagus Coolchain

Report to the New Zealand Asparagus Council

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Summary

Variation in handling practices at the start of the coolchain, (i.e. at the grower and packhouse end) had a marked effect on retail shelf-life of asparagus.

A set of coolchain guidelines for the asparagus industry have been developed. The target within New Zealand is to accumulate less than 250 degree-hours and the maximum is 500 degree-hours. These correspond to the loss of 1 and 2 days shelf-life before the asparagus leaves New Zealand.

A perforated insulation material is most appropriate for non-refrigerated export consignments. To maintain low temperatures to an export destination insulation and cooling are required.

Important Conclusions

Coolchain Monitoring

A set of coolchain guidelines for the asparagus industry have been developed after two years of monitoring heat unit accumulation along the coolchain from field to export market. Table 1 summarises the guidelines set out as targets and maximums. The aim is to meet the target and never to exceed the maximum.

Table 1. Handling Guidelines For Export Asparagus

TARGET Coolchain Link	**Requirement**	**Heat Units (approx)**
Grower	Up to 2 hours between harvest and delivery to packhouse (2 hrs at 20°C)	40
Packhouse	Pack and cool to 3°C and truck same day (2 hrs at 20°C, 5 hours to cool, maintain at 3°C. Apply TTM* at packing	110
Truck	Maintain at 3-5°C in transit (10 hrs at 5°C)	50
Freight-Forwarder	Maintain at 2-3°C for up to 1 day (24 hours at 2°C)	50
	Acceptable TTM Score = 1 or 2	**Total 250**
MAXIMUM Coolchain Link	**Requirement**	**Heat Units (approx)**
Grower	Up to 4 hrs between harvest and delivery to packhouse (4 hrs at 20°C)	80
Packhouse	Cool to 3°C within 10 hours of arrival, pack first or second day, maintain at 3°C until trucking on second day. Apply TTM* at packing	220
Truck	Maintain 3-5°C in transit	50
Freight-Forwarder	Maintain at 2-3°C for up to 2 days (48 hours at 3°C)	150
	Acceptable TTM Score = 3 or 4	**Total 500**

* Time-temperature monitor

A quality checklist gathers information on a consignment from the packhouse to the freight-forwarder. Time temperature monitors are used to confirm adherence to the guidelines. The checklist will allow an exporter and his supplier to make decisions on the most appropriate flight, destination or end use.

Insulation

Using insulation for export consignment during airfreight will not keep asparagus cool during transit for the 2-3 days required. A well-insulated sealed pallet load of asparagus is warm at the top of the load after 8 hours and over the whole pallet after 24-30 hours.

A perforated foil is most appropriate when there is no supplementary cooling. It slows warming, prevents moisture loss and protects asparagus from heating in the sun, without the danger of over-heating which could occur in heavily insulated asparagus once it reaches ambient temperatures. To maintain low temperatures to an export destination insulation and cooling are required.

Introduction

The long-term aim of this project is to devise handling guidelines which set heat unit (or degree-hour) limits to asparagus for each step in the coolchain. The New Zealand asparagus industry could use this information to ensure only asparagus with adequate residual shelf-life is sent overseas.

The 1990 work reported here builds on information collected in 1989 and had four aims.

1. To gather more information on temperature changes from field to packhouse and from packhouse to freight forwarder.

2. To confirm, in a simulated experiment, that variation in heat unit accumulation at the start of the coolchain (grower and packhouse) affected retail shelf-life of asparagus.

3. To find simple methods of monitoring heat unit accumulation along the coolchain within New Zealand.

4. To test methods of reducing heat unit accumulation during air transit using insulating materials.

1. Coolchain Monitoring

Materials and Methods

Electronic temperature loggers were used to monitor asparagus temperatures from five fields to packhouse on five farms during November 1990. One of the loggers was faulty so information was available from only four growers. After two weeks the loggers and were used to log temperatures from the packhouse to freight forwarders. Information on timing, spear temperatures (measured using a probe thermometer) and weather conditions was also collected. Time-temperature monitors (3M brand, 5I model) were attached to asparagus pallets at the packhouse and read periodically from packhouse to freight forwarder.

Results and Discussion

a. Grower to Packhouse

Growers took between 0.5 and 5.5 hours to harvest, transport and deliver asparagus to the packhouse. The number of heat units varied from 7 to 108 degree-hours. Table 2 summarises asparagus harvest formation from grower to packhouse with detail in Appendix 1. One grower (Grower One) packed his own asparagus and the others supplied a cooperative packhouse. The heat unit accumulation was not large (mean of 48 degree-hours) compared with expected overall harvest to market accumulations of 730 to 1700 degree-hours from last year's work (Brash 1990). The within-New Zealand component from last year's work was 350-870 degree-hours.

Asparagus temperatures were in a narrow range of 13 to 23°C. Most of the variation in heat unit accumulation was caused by the wide range in time between harvest and arrival at the packhouse.

Table 2. Asparagus heat unit accumulation from field to packhouse.

Grower	Runs Monitored	Start Time	Hours to Packhouse	Max. Field Temp[a]	Temp. on Arrival[b]	Heat Units (deg-hrs)	Est'd Heat Units[c] (deg-hrs)
1	9	0800	2.5	16	16	35	35
2	6	1115	3.1	21	17	62	55
3	6	0930	2.7	20	18	53	50
4	4	0930	2.2	19	17	41	38
Mean	25	0945	2.6	19	17	48	44

[a] Temperature from logger
[b] Using portable probe at packhouse
[c] Estimated from "temperature on arrival" multiplied by "hours to packhouse"

Table 2 shows early morning harvests reduced heat unit accumulation. Grower One started harvesting three hours earlier than Grower Two. Grower Two took just over half an hour longer to deliver asparagus to the packhouse but had nearly twice the mean heat unit accumulation.

Packhouse operators have asked about the value of measuring spear temperature on arrival at the packhouse. Spear temperature will be useful to estimate the cost of cooling to storage temperature and the results in Table 2 also show spear temperature could be useful for estimating field heat accumulation. When temperature on arrival is multiplied by hours from picking the result (given in the last column of Table 2) is a fair approximation of actual heat unit accumulation (as measured by the logger).

Over 70% of the asparagus was packed on arrival at the packhouse (18 out of 25 harvests). The remainder were packed either next day (3/25) or after two days (4/25). Presumably the holding over of asparagus before packing indicates a period of high daily yield. Temperature records indicate the packhouse coolstore was overloaded at this time. Asparagus took a long time to cool from field temperatures to less than 5°C.

In the three samples packed next day the asparagus was still cooling and 6-7°C at the time of packing, 16-22 hours after entry to the coolstore. The mean heat unit accumulation was 250 degree-hours (range 180-300).

In the four examples packed after two days in the coolstore the mean heat unit accumulation was 370 degree-hours (range 240-520). Asparagus at the low end of this range cooled to 5°C in 8 hours showing that rapid cooling will minimise heat unit accumulation when asparagus is held before packing.

This study was not aimed at measuring the heat-unit accumulation at the packhouse. The results show however that slow cooling capacity and slow throughput lead to high heat unit accumulation at the packhouse. I have insufficient information to suggest a desirable heat unit accumulation at the packhouse for cooling and packing. Last year's work reported a mean packhouse total of 140 degree-hours (range 50-180 degree-hours).

b. Packhouse to Freight Forwarder

Six pallets were monitored in 4 consignments but only one consignment yielded a complete set of data. One consignment had a faulty temperature logger and on another the recording sheet was not filled in. Two pallets on another consignment went to the wrong freight-forwarder, were loaded onto an aircraft then off-loaded and kept at the Air New Zealand cargo facility. I hope this does not happen often. It also highlights the difficulty of gathering useful information along the coolchain. Results for four pallets are summarised in Table 3.

Table 3. Coolchain monitoring from Packhouse to Freight Forwarder

Consignment	25/11/90 (Mis-directed)		27/11/90	
Pallet	**1**	**2**	**3**	**4**
<u>Temperature (°C)</u>				
Packhouse, at loading	3	5	8	8
Highest temp. on truck	7	7	11	11
Freight-forwarder	2-3	2-3	4-5	3-5
<u>Heat units (deg-hrs)</u>				
In truck	60	60	104	113
Freight-forwarder	620	550	91	108
<u>Moisture loss *(%)</u>	2.1	1.8	2.4	1.4

* Packhouse to freight forwarder

The results show that improvements could be made to temperatures of asparagus at loading and on the truck.

The Time-Temperature Monitors (TTMs) were not adequately tested. The 5I model has a five point scale with a blue dye advancing along the scale when temperatures are over 5°C. After 48 hours above 5°C the dye reaches 5 on the scale. All TTMs recovered at the freight forwarders gave a reading of 5. The temperatures from the logger with pallets 3 and 4 indicated the TTMs should have been on point 3 (about 20 hours over 5°C). Pallets 1 and 2 had a reading of 5 as expected.

The TTMs used were old stock. Further tests with fresh stock will be required for a full evaluation of TTMs. (Only a small number of monitors were required for this experiment and it was hoped the old stock would be adequate. New stock must be ordered in 500-item lots).

Commercial use of TTMs would need cooperation from packhouse operators and exporters in particular to set up and read the tags. Exporters would need to have guidelines on TTMs and know how to act on the score. Ideally TTMs should be set up after packing and read on leaving the packhouse, on arrival at the freight forwarder and just prior to aircraft loading. The weak links in the coolchain could then be identified. Based on limited experience to date getting this comprehensive information will be difficult. The most important reading will be the one made by the exporter just prior to loading.

TTMs do not measure heat units. The scale is not linear. The dye moves along the scale when temperatures are over 5°C but if the temperature doubles the dye will not move at twice the speed. When the dye covers Score 1 we know the TTM has experienced at least 6 hours over 5°C, Score 2 at least 12 hours, Score 3 at least 21 hours, Score 4 at least 33 hours and Score 5 at least 48 hours. In other words at Score 5 the TTM has experienced at least 240 degree-hours.

TTMs cost about $3.00 each. Temperature loggers are too expensive for logging every consignment. A disposable (one-trip) logger costs $50 while electronic loggers can be hired for $75/month.

2. Insulation

Materials and Methods

Four half-pallet loads of packed second-grade asparagus were used for four experiments over a nine day period in December 1990. Experiments were set up in a coolstore at 5-6°C and brought out into the open (in one experiment) or into a covered shed (in three experiments). Various insulation options were tested. Experiments were carried out for various times from 8 to 54 hours. After each experiment the asparagus was uncovered and cooled overnight. Temperatures were measured using probes inserted into a spear.

(a) <u>Experiment 1</u>

This experiment measured asparagus temperatures and moisture loss from one uncovered and two insulated half pallets of asparagus over a 29 hour period after removal from the coolstore. Pallets were placed outside into windy, partly cloudy conditions. Results are summarised in Table 4.

Table 4. Temperatures and Moisture Loss of Asparagus, Insulation Experiment 1.

	n[a]	Temperature (°C)				Moisture Loss (%)
Time		10 am	Noon	6 pm	2 am	3 pm next day
Hours		0	2	8	16	29
Outside Air Temp	1	17	16	14	12	
Insulation						
Uncovered	4	6	14	14	12	4.9
Building foil	2	5	8	11	13	0.1
Coolguard[b]	4	4	8	11	13	0.1

[a] Number of measurements

[b] A foil/polybubble/foil combination manufactured by Cargo Technology Corporation, San Diego.

Variation in the initial temperatures was thought to be related to coolstore variation rather than any insulating effects established while the experiment was being set up.

In windy, cloudy conditions the insulating effects of both materials were lost at a similar rate with most of the effect lost after eight hours. (The insulation did not cover the pallet floor). The results show a marked reduction in moisture loss caused by covering. A moisture loss of 5% is close to the limit before wilting symptoms are expected.

(b) Experiment 2

This experiment measured asparagus temperatures from uncovered and three covered half-pallets over a seven hour period after removal from a coolstore. Pallets were placed in a shed with shade and shelter from the wind.

Table 5. Temperatures of Asparagus, Insulation Experiment 2 (n = 1).

	Position[a]	Temperature (°C)			Temp. Change (°C)
Time		9.30 am	11.30 am	4.30 pm	9.30 to 4.30
Hours		0	2	7	7
Outside Air Temp.		17.2	19.0	19.5	
Insulation					
Uncovered	Top	5.2	16.7	18.9	13.7
	Bottom	4.4	7.6	12.8	8.4
Coolguard with floor	Top	7.1	13.4	16.9	9.8
	Bottom	4.5	5.3	5.9	1.4
Omega, no floor	Top	5.4	11.4	16.9	11.5
	Bottom	6.1	6.5	7.2	1.1
Omega, with floor	Top	6.3	10.0	13.5	7.2
	Bottom	5.1	4.8	5.5	0.4

[a] Pallets were stacked 3 layers high, with measurements made in the top and bottom layers, probes were placed into asparagus in the middle box in each 3 x 5 box layer

[b] Foil/polybubble/foil combination. A pre-commercial product supplied by Omega Manufacturing and Marketing Ltd, Auckland, N.Z.

Table 5 shows that a temperature gradients quickly set up with asparagus at the top of the pallet warming up more quickly than at the bottom. The results Gradients of 9-10°C developed between top and bottom. Insulation slowed warming but even the best insulation treatment could not maintain low temperatures at the top of the pallet for seven hours. A floor between asparagus and the pallet slowed warming. There was a small gap (about 10 mm wide) between the insulated cover and the floor (made of the same material).

(c) Experiment 3

This experiment was carried out at the same location as Experiment 2 over eight hours and was similar in layout to Experiment 2.

Table 6. Temperatures of Asparagus, Insulation Experiment 3 (n = 1)

	Position	Temperature (°C)			Temp Change (°C)
Time		9.15 am	11.15	5.15	9.15 to 5.15
Hours		0	2	8	8
Outside Air Temp		19.0	24.0	19.8	
Insulation					
Uncovered	Top	7.9	12.6	17.1	9.2
	Bottom	6.5	13.2	16.8	10.3
Coolguard, with floor	Top	4.5	7.8	12.7	8.2
	Bottom	7.0	7.1	7.5	0.5
Bldg foil, with floor	Top	5.9	12.6	16.2	10.3
	Bottom	5.4	4.9	6.7	1.3
Perf. bldg foil with *floor	Top	4.7	10.0	14.9	10.2
	Bottom	4.8	5.6	7.6	2.8

* The perforated cover had 20 holes of 15 mm diameter, eight in the top, three on each side, and none in the floor.

Table 6 shows a similar response to insulation as in Experiment 2. Coolguard was only slightly more effective than building foil in this experiment. Building foil is used currently by exporters for insulation. There was little difference between the non-perforated and perforated foils. The perforated foil offers an opportunity for combining insulating properties with prevention of heat buildup inside a cover once asparagus has warmed to ambient temperatures.

(d) Experiment 4

This experiment was carried out at the same location as Experiment 2 over 54 hours and was similar in layout to Experiment 2. The aim of this experiment was to find out how long a sealed insulated cover could retain low temperatures and then to see whether warmed asparagus would generate its own high temperatures and high CO_2/low O_2 atmosphere inside the pallet cover.

Table 7. Temperatures and Moisture Loss of Asparagus, Insulation Experiment 4 (n = 2 except for uncovered where n = 1)

	Position	Temperature (°C)						Moisture Loss (%)
Time		10 am	Noon	6 pm	10 pm	6 pm	4 pm	4 pm
Hours		0	2	8	24	32	54	54
Outside Air Temp		16.8	20.4	17.1	18.0	19.4	21.7	
Insulation								
Uncovered	Top	6.5	14.0	16.0	17.0	19.0	20.6	3.0
	Bottom	3.4	6.6	13.0	15.8	18.4	20.6	2.6
Coolguard, sealed[a] with floor	Top	4.7	9.7	14.5	15.9	19.3	22.5	0.3
	Bottom	3.5	3.8	5.8	11.2	14.1	19.5	0.0
Omega, not sealed, with floor	Top	3.8	7.9	13.4	16.0	19.7	30.7	0.5
	Bottom	3.5	3.6	8.4	12.1	15.2	23.3	0.5
Omega, sealed, with floor	Top	4.0	6.9	11.0	13.8	17.3	25.8	0.4
	Bottom	3.6	4.4	5.9	10.8	14.0	22.3	0.1

[a] Airtight seal between cover and floor using masking tape

The results show that a well-insulated, sealed pallet load of asparagus is warm at the top of pallet after 8 hours and over the whole pallet after 24-30 hours. This period would be insufficient for an export consignment which takes 2-3 days to reach its destination following packing at a freight-forwarder in New Zealand. Supplementary cooling would be required to maintain low temperatures to the export destination. This is done currently using dry ice.

Temperatures were beginning to rise above ambient after 32 hours. A high of 31°C was reached after 54 hours on one pallet. This pallet had the freshest asparagus and therefore the highest respiratory potential (it was 4 days younger as it was not included in Experiment 1).

Moisture loss was lower than in Experiment 1 because the asparagus was held under sheltered conditions. Gas concentrations after 54 hours were 12.3% CO_2/7.7% O_2 for the sealed Coolguard treatment, 3.5% CO_2/17.2% O_2 for the sealed Omega treatment and 0.7% CO_2/19.7% O_2 for the unsealed Omega treatment. Despite the high temperatures in the unsealed Omega treatment the atmospheres were close to the composition of air. Small amounts of ventilation will prevent development of damaging atmospheres. The sealed treatments by contrast showed a potential for damaging atmospheres to develop.

3. Accumulated Heat Units after harvest and Shelf-life

Materials and Methods

A simulation experiment was set up using Levin HRC temperature control rooms. The temperature regimes used were aimed at investigating the link between variation in degree-hour accumulation just after harvest (i.e. grower/packhouse variation) and shelf-life in an export market such as Japan. The knowledge gained in earlier work was used to set up realistic temperature profiles.

The eight temperature regimes were a combination of four simulated field-to-packhouse regimes combined with a rapid or slow packhouse to market regime (see Table 8).

Table 8. Temperature Regimes in the Shelf-life experiment.

Treatment	Degree-hours	Description
A. Field to Packhouse		
1. Rapid	50	Straight to packing
2. Same day	150	5 hrs at 20°C then packed
3. Next day	250	8 hrs at 20°C, cooled rapidly, packed next day
4. Slow	350	8 hrs at 20°C, cooled slowly, packed next day
B. Transport		
1. Cool, to Japan	800	Maintained at 3°C within NZ, not over 15°C during flight
2. Warm, to Japan	1200	Maintained at 5°C within NZ, except during trucking (10°C); warm temperatures during flight, up to 25°C

Asparagus was harvested locally on 15/1/91.

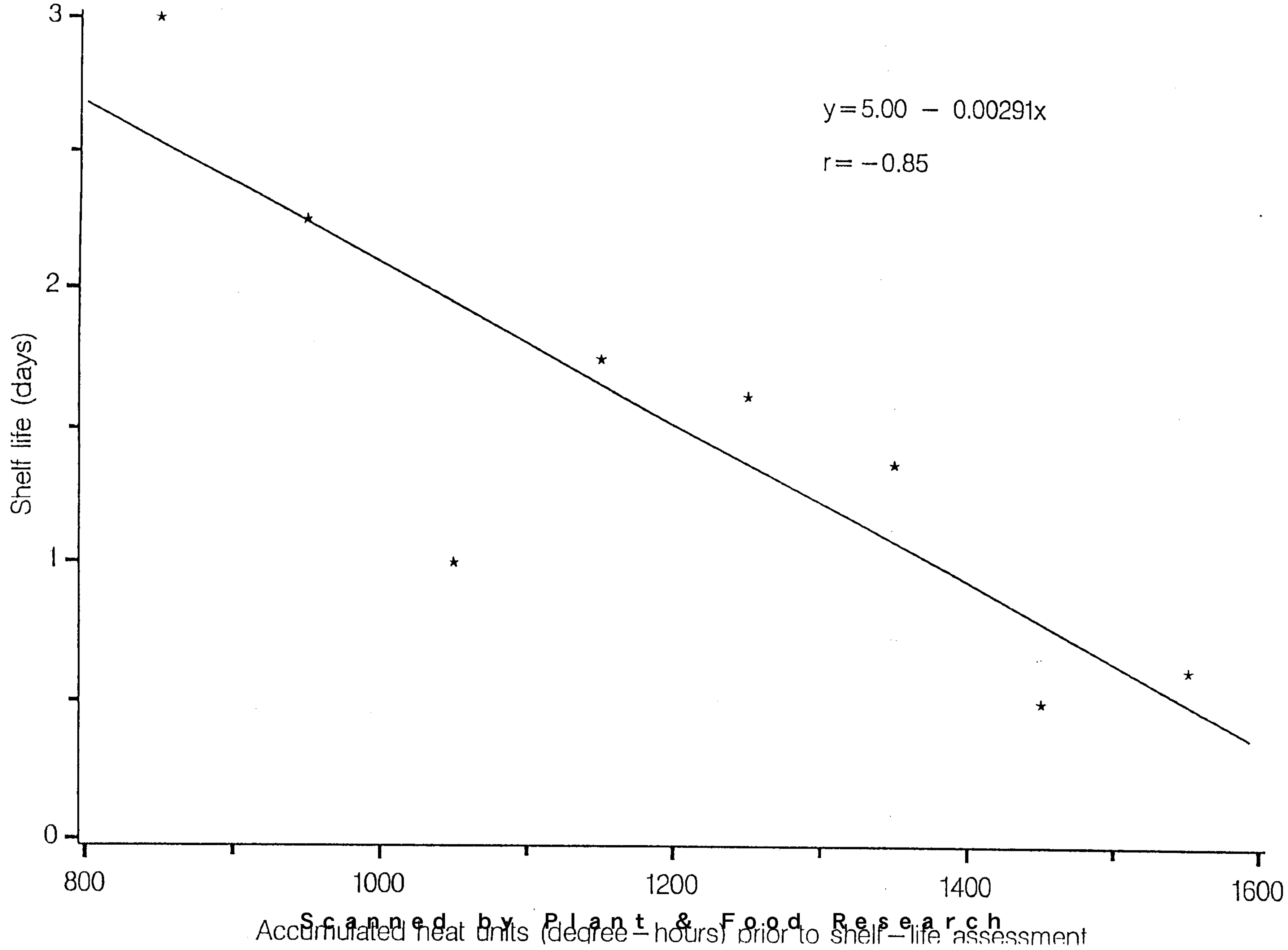
Each plot contained seven spears. There were four replications of each treatment. Two replicates used Lucullus variety and two used Limbras 118.

After simulated transport, spears were placed at 20°C to assess shelf-life. Ratings were made using a Visual Quality Scale:

1	=	as fresh;
3	=	slight wilt, very slight wrinkle on stem;
5	=	browning of stem bracts, more pronounced wilting;
7	=	soft rots starting to develop, some browning of spears, wilting and feathering of spears;
9	=	more extensive rotting and stem collapse, bud wilting, browning of spears.

Even numbered ratings were given when quality was intermediate between two ratings.

Figure 1 Relationship between accumulated heat units and shelf life (r was significant at $P < 0.01$)



A rating of 6 was regarded as unacceptable for sale, and marked the end of shelf-life.

Results and Discussion

Asparagus not kept cool after harvest has a shorter shelf-life (Fig 1). Variation in heat units during the grower/packhouse phase of the coolchain affected residual shelf-life.

The relationship shown in Figure 1 is similar to that obtained by King *et al* (1988) but the shelf-life in our experiment was generally lower. While this difference may be related to differences in production factors (site, cultivar) and experimental techniques (such as interpretation of the rating scale or humidity during simulated transport) it is likely that harvest date was an important factor. Our spears were harvested at the end of the harvest season when shelf-life potential is lower. Hurst *et al.* (1991) have shown that shelf-life of spears decreases as the harvest season progresses. King *et al.* (1988) used asparagus harvested in mid-season. Their results are likely to be more typical of asparagus used for export.

4. Coolchain Guidelines for the New Zealand Asparagus Industry

As a result of the studies carried out in 1989 and 1990-91 a set of coolchain guidelines for the asparagus industry have been developed. The guidelines can be set out as "Targets" and "Maximums" with the aim being to meet the Target and never to exceed the Maximum.

Target within New Zealand is to accumulate less than 250 degree-hours and the Maximum is 500 degree-hours. These correspond to the loss of 1 and 2 days shelf-life before the asparagus leaves New Zealand.

Table 9 uses the relationship between heat units and residual shelf-life developed by King *et al.* (1988) to show the effect of the guidelines on expected retail shelf-life of asparagus sent to Japan.

If the Target degree-hour accumulation is met, and the asparagus is sent on a direct flight to Japan, it will have nearly five days shelf-life (option 1). Meeting the Maximum limit within New Zealand followed by a direct flight gives nearly four days shelf-life in Japan (option 4). If delays occur in transit then meeting the Target would ensure the asparagus still had over two days shelf-life (option 3).

Table 9. Effect of Target and Maximum heat unit accumulation on shelf-life of asparagus in Japan.

Heat Unit Accumulation (Degree-hours)				Shelf Life
In New Zealand	**Flight[a]**	**In Japan[a]**	**Total**	**(days)**
1. Target (250)	Lowest (80)	Lowest (360)	690	4.9
2. Target (250)	Mean (240)	Mean (450)	940	3.9
3. Target (250)	Highest (430)	Highest (660)	1340	2.3
4. Max. (500)	Lowest (80)	Lowest (360)	940	3.9
5. Max. (500)	Mean (240)	Mean (450)	1190	2.9
6. Max. (500)	Highest (430)	Highest (660)	1590	1.3

[a] based on Table 3 Brash (1990).

Handling guidelines within New Zealand are shown in Table 1. Each link in the coolchain must be committed to meeting their requirement set out in the table. A Time-temperature monitor (TTM) score of 1 or 2 would be acceptable (i.e. up to 12 hours over 5°C) in meeting the Target heat unit accumulation. As long as the TTM score had not completed a score of 5 then the consignment would be within the Maximum limit (i.e. less than 48 hours over 5°C from packing).

Table 10 suggests a quality checklist to accompany asparagus consignments from the packhouse to the freight-forwarder. The checklist would also allow an exporter and the supplier to make decisions on the most appropriate flight, destination or end use. Information would be sent back to the packhouse for the supplier.

Table 10. Quality Checklist for Export Asparagus.

Packhouse		
	On arrival	Supplier's name:
		Time, date:
		Hours from harvest:
		Spear temperature:
	On departure	Time, date:
		Spear temperature:
		TTM score:
Freight Forwarder/Exporter		
	On arrival	TTM score:
	On departure	TTM score:
		Time, date:
		Flight/destination:
		AWB number:

References

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Hurst, P.L., King G.A. and Irving, D.E. (1991). The Physiology of Postharvest Deterioration of Asparagus. Report to the New Zealand Asparagus Council.

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Appendix 1. Asparagus heat unit accumulation from field to packhouse.

Run	Grower	Start Time	Hours to Packhouse	Max Field Temp[a]	Temp on Arrival[b]	Heat Units (deg-hours)	Est'd Heat Units[c] (deg-hours)
1	One	0800	1.5	15	14	22	21
2		0900	0.5	15	15	7	7
3		0740	2	17	17	32	34
4		0800	2.5	17	17	39	42
5		0845	3	17	17	36	51
6		0800	4	18	16	72	64
7		0600	3	13	14	36	42
8		0600	5	17	n.m.	56	--
9		0830	1	16	16	16	16
Mean		0800	2.5	16	16	35	35
10	Two	1100	5.5	20	18	109	99
11		1200	2	22	19	43	38
12		1100	3	23	16	65	48
13		1000	0.5	20	16	10	8
14		1130	3.5	17	15	56	52
15		1200	3.5	23	21	88	84
			4				
Mean		1115	3.1	21	17	62	55