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Effects of high-stress controlled atmosphere disinfestation on asparagus quality

A report prepared for
New Zealand Asparagus Council

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CONTENTS

1 EXECUTIVE SUMMARY

Atmospheres of 60% carbon dioxide at elevated temperature (30-40°C) can effectively disinfest asparagus and allow exporters to sell their premium product in quarantine-sensitive markets. Our priority is now to develop engineering solutions that will allow high-stress controlled atmospheres to be used cost-effectively by the asparagus industry.

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2 APPROACH

The research committee of the New Zealand Asparagus Council asked that we combine two proposed projects: high-stress CA efficacy for insect control, and effects of high-stress CA on asparagus quality. We focused on the effects of high-stress CA on asparagus quality. The detailed results are appended (Appendix 1) in the form of a scientific paper intended for publication in the international journal "International Journal of Food Science and Technology".

We carried out preliminary tests against thrips and aphids. These indicated that ½ hour exposure to a CA containing 60% carbon dioxide at 30 and 40°C gave acceptable control. We propose to carry out more detailed research on the insecticidal efficacy of this treatment if there is appropriate support available.

The research carried out in the 1992/93 season focused on determining the effects of treatment of fresh asparagus with a high-stress CA of 60% carbon dioxide in air at 30° and 40°C. After treatment the asparagus was put through 5 days of simulated handling, including air freight to Japan, before some tests were carried out. The tests consisted of measurements of respiration rate, ammonia accumulation and sensory quality. Recent research has indicated that respiration rate can be an effective gross measure of physiological damage. Ammonia accumulation can indicate the end of shelf-life. Sensory quality (acceptability, "asparagus flavour" and off-flavour development) is the central factor in any disinfestation treatment.

3 CONCLUSIONS

The treatments did not damage the asparagus. Even after 5 days simulated handling and export, the spears treated with 60% carbon dioxide at 30°C were little different to untreated spears. There were slight carbon dioxide effects on off-flavour development. Treatment with 60% carbon dioxide at 40°C produced asparagus which were less acceptable than the controls.

The results may be surprising, as asparagus is generally regarded as delicate. It seems that asparagus will tolerate a severe disinfestation treatment reasonably well. Now we need to develop engineering approaches that would make high-stress disinfestation practicable.

4 APPENDIX

The quality of fresh asparagus following application of a high-stress disinfestation technique.

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Submitted to International Journal of Food Science and Technology.

Please regard this paper as confidential until it is published.

The quality of fresh asparagus following disinfestation with 60% carbon dioxide

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Summary
We sought to determine the effects of a disinfestation procedure on the physiology and sensory quality of fresh asparagus. We treated asparagus with 60% CO_2 in air at 30 or 40°C for 30 min and subjected the crop to a 5-day simulated air freight journey. The control asparagus remained in air at 2°C during disinfestation of the treated asparagus and the simulated journey. During and following the journey, we found no significant treatment effects on shelf-life, respiration rate or ammonia accumulation. Carbon dioxide treatment at 30°C had only a minor effect on overall sensory acceptability of cooked asparagus, largely through production of off-flavours.

Keywords
Asparagus officinalis, carbon dioxide, controlled atmosphere, disinfestation, sensory quality.

Running title: Asparagus quality after disinfestation treatment

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Introduction

Fresh asparagus air freighted from New Zealand to Japan, USA and Australia is frequently subjected to quarantine treatment upon arrival because insects have been detected. The main insect pests of quarantine importance are New Zealand flower thrips and several species of aphid (Watson & Townsend 1981). The combined effects of the chemical used (methyl bromide or hydrogen cyanide) and the warming of the asparagus during quarantine treatment, are highly damaging to the quality and shelf-life of the spears (Beever *et al.* 1985). Furthermore, there is growing consumer resistance to the use of chemicals on food (Maddy 1989).

In response to these problems, researchers have been investigating non-chemical disinfestation procedures involving low temperature, dry heat, vapour heat and controlled atmospheres (Armstrong 1992, Batchelor 1992). We have used controlled atmospheres with very high concentrations of carbon dioxide (60% CO_2 in air) to control New Zealand flower thrips, aphids and other insects, and potentially, to eliminate the need for further quarantine treatments (Potter *et al.* 1993).

Concentrations of carbon dioxide greater than 60% can, however, damage the spears, even at 0°C (Corrrigan & Carpenter 1993). Treatment at 0°C takes several days to kill the insects, but elevated temperature (30-40°C) makes the insects more susceptible to carbon dioxide and they can be killed in a much shorter time (A. Carpenter unpub., Potter *et al.* 1993).

Our research on the senescence of asparagus spear tips (where the first signs of deterioration occur) shows physiological changes such as decline in respiration rate, loss in sucrose, changes in respiratory substrates, accumulation of ammonia, breakdown of protein and changes in gene expression, occurs soon after harvest at ambient temperatures (Hurst *et al.* 1993a, King *et al.* 1990, King *et al.* 1993, Lill *et al.* 1990). These data emphasise the need for low temperature (2°C) soon after harvest to reduce spear metabolic rate and ensure some useful storage- and shelf-life.

For high concentrations of carbon dioxide to disinfest a perishable food crop effectively, high temperatures (30-40°C) are necessary. To avoid the adverse effects of high temperatures on the quality of perishable foods, disinfestation must be for a short period only. The objective of this paper is to show how a carbon dioxide-based disinfestation procedure can be used on a perishable food (fresh asparagus) with small effects on its physiology and eating quality.

Materials and methods

Handling

Fresh export grade asparagus (*Asparagus officinalis* cvs Limbras 18, Limbras 118 and Lucullus) spears were purchased from a commercial packhouse as a mixed lot. Spears were held in a coldroom at 2°C overnight. Next morning, the spears were placed in water at 30 or 40°C for 5 min, to bring them to temperature, and then into 60 l stainless steel containers. Inside each container was a heating coil and small fan, to maintain temperature within ± 1°C. Once the temperature had stabilised at 30 or 40°C (30 min), a flow of 60% CO_2 in air (200 ml min^{-1}) was passed through each container for 30 min. The control asparagus remained at 2°C in air throughout. After the treatments, spears were transferred to a room containing air at 2°C. The temperature in the room was then changed, under computer control, to simulate a 5 day air-freight journey to Japan (Figure 1).

Experimental design and treatments

The experiment was run as a factorial ((2x2)+1), with 2 atmospheres (air, 60% CO_2) and 2 temperatures (30, 40°C) plus control (2°C throughout). The treatments were replicated 3 times, each time using 4 kg of asparagus spears (ca. 150 spears per treatment). Data were analyzed using the means and generalised linear models procedures of the SAS statistical package. Means are expressed ± standard errors of the means where appropriate.

Shelf-life assessment

Shelf-life (days to become unsaleable) of spears (3 replicates of 5 spears per treatment) at 20°C was assessed twice: immediately after treatment and after the simulated journey, according the method described by King *et al.* (1986).

Respiration measurement

Spears (3 replicates of 5 spears per treatment) were taken after the treatments and left at 20°C for 1 hour. Spears were then cut to 150 mm long, enclosed in 2 l glass jars, and ventilated with a flowing airstream (0.7 l min^{-1}) at 20°C. The air emerging from the jars was analyzed for carbon dioxide concentration using an ADC infra-red gas analyser. After the 5 day simulated journey, another group of spears was subjected to the same respiratory measurements.

Ammonia determination

Ammonia accumulation in 30 mm tip sections of freeze-dried spears (3 replicates of 5 spear tips per treatment) was measured 3 times; before the treatments and after 2 days and 5 days of the simulated journey. Ammonia was measured using phenolhypochlorite (King *et al.* 1990).

Sensory evaluation

Spears were taken after the simulated journey (3 replicates of 16 spears per treatment), tied in bunches and steamed for 12 minutes standing upright in beakers containing 100 ml water, which were in turn, in a covered pot of rapidly boiling water. Spears were steamed to give the best indication of their flavour and the presence of any off-flavours. We thought that boiling the asparagus in salted water might mask or leach some of the flavour components.

The cooked spears were trimmed to 100 mm length and served warm to sixteen experienced panellists. Each panellist assessed one spear from each treatment per sitting for flavour, off-flavours and acceptability. Spears were rated by marking a point on a 160 mm unstructured linear scale, anchored by a vertical mark 5 mm from each end of the line. Scores were assigned by measuring the distance of the panellists' mark from the left hand anchor point of the scale. Panel assessments were replicated three times - mid morning, late morning and mid afternoon, and new treatment code numbers were used at each session. Spears were coded with three digit random numbers and presentation order was randomised. The level of probability deemed significant in these sensory studies was 10%.

Results and discussion

Shelf-life

There was no difference in shelf-life amongst spears from the treatments. The mean shelf-life after the treatments was 3.4 ± 0.06 days, and after the 5-day simulated journey, 1.8 ± 0.05 days. The loss of about 1.5 days of shelf-life during the 5 days of the simulated journey is in keeping with the loss of about 1 day per week at 1°C (King *et al.* 1986).

Respiration rate

There were no differences in spear respiration rate amongst the treatments. Following the treatments, the mean respiration rate for all the asparagus was 9.7 ± 0.2 μmol CO_2 g^{-1} fresh weight h^{-1}. After the 5 day simulated journey, respiration rate of the spears was 7.0 ± 0.3 μmol CO_2 g^{-1} fresh weight h^{-1}. Respiration rate would be expected to increase if the treatments had induced heat or carbon dioxide injury (Irving 1992; Irving *et al.* 1991). Beever *et al.* (1985) reported an increase in the respiration rate of asparagus spears following fumigation treatments that damaged the spears and accelerated the appearance of tip rot, butt rot and lesions.

Ammonia accumulation

All asparagus spears accumulated ammonia to the same extent. Before the treatments, the ammonia concentration was 30 ± 1 µmol g^{-1} dry weight. After 2 and 5 days of the simulated journey, mean ammonia concentrations were 32 ± 1 and 40 ± 3 µmol g^{-1} dry weight, respectively. We thought accumulation of ammonia might occur part-way through the simulated journey following the treatments and the fluctuations in temperature, and this is why we sampled spears 2 days into the journey. However, the ammonia concentrations measured were far below those characteristic of asparagus spears at the end of their shelf-life (80 - 160 µmol g^{-1} dry weight, Hurst *et al.* 1993b).

Sensory evaluation

Results of the sensory analysis are given in Table 1. Control spears had more flavour ($P<0.07$) and were more acceptable ($P<0.0002$) than were treated spears, but there were no differences in off-flavour ratings between the treatments. Air- and carbon dioxide- treated spears had similar flavour and acceptability, but carbon dioxide treated spears had more off-flavours ($P<0.003$) than did air treated spears. However, mean off-flavour ratings for carbon dioxide treated and air treated spears were similar to that of the controls. There were no significant differences in mean ratings for any attribute between the two different temperature levels and the controls, although the 40°C treated spears had the lowest flavour and acceptability ratings. There were no significant atmosphere by temperature interactions.

Our previous study (Corrigan and Carpenter 1993) showed the sensory quality of cooked spears was similar when spears had been stored in air or 60% CO_2 (in air) at 0°C. Our data here suggest that 60% carbon dioxide at high temperature (30 - 40°C) for a short period (up to 1 hour) can begin to induce off-flavours in the cooked product, emphasising the need to keep the duration of high temperature treatment short.

We did not cook our asparagus with salt. If our asparagus had been cooked with salt, the off-flavours may not have been so easily detected. Conventional methyl bromide fumigation had a detrimental effect upon the flavour of asparagus that had been cooked with salt (Beever *et al.* 1985).

Fumigation with methyl bromide and 60% carbon dioxide, at elevated temperature (30-40°C), clearly leads to loss of flavour and acceptability of cooked asparagus. However, our results here suggest minor changes in sensory quality following treatment with 60% carbon dioxide at 30°C.

Conclusions

A disinfestation technique involving high concentrations of carbon dioxide at 30°C did not significantly affect the physiology of fresh asparagus and had small effects on the eating quality of the cooked product. Since the disinfestation technique described, did not unduly affect fresh asparagus, a highly perishable vegetable, the technique might be effective on a range of food products.

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Table 1: Panel sensory assessments of asparagus spear portions (top 100 mm) after disinfestation treatment and 5 days simulated transport.

Treatment	Panellist Sensory Ratings		
	Flavour[1]	Off-Flavours[2]	Acceptability[3]
40°C, 60% CO_2	73.9	57.4	66.9
40°C, air	74.8	37.8	74.6
30°C, 60% CO_2	78.3	56.1	74.9
30°C, air	82.3	46.4	80.1
Control	85.7	46.0	92.7
F Test Probabilities			
Control vs Treatments	0.07	0.53	0.0002
Control vs Atmosphere	0.56	0.003	0.14
Control vs Temperature	0.15	0.46	0.12
Control vs Atmosphere x Temperature	0.71	0.32	0.78

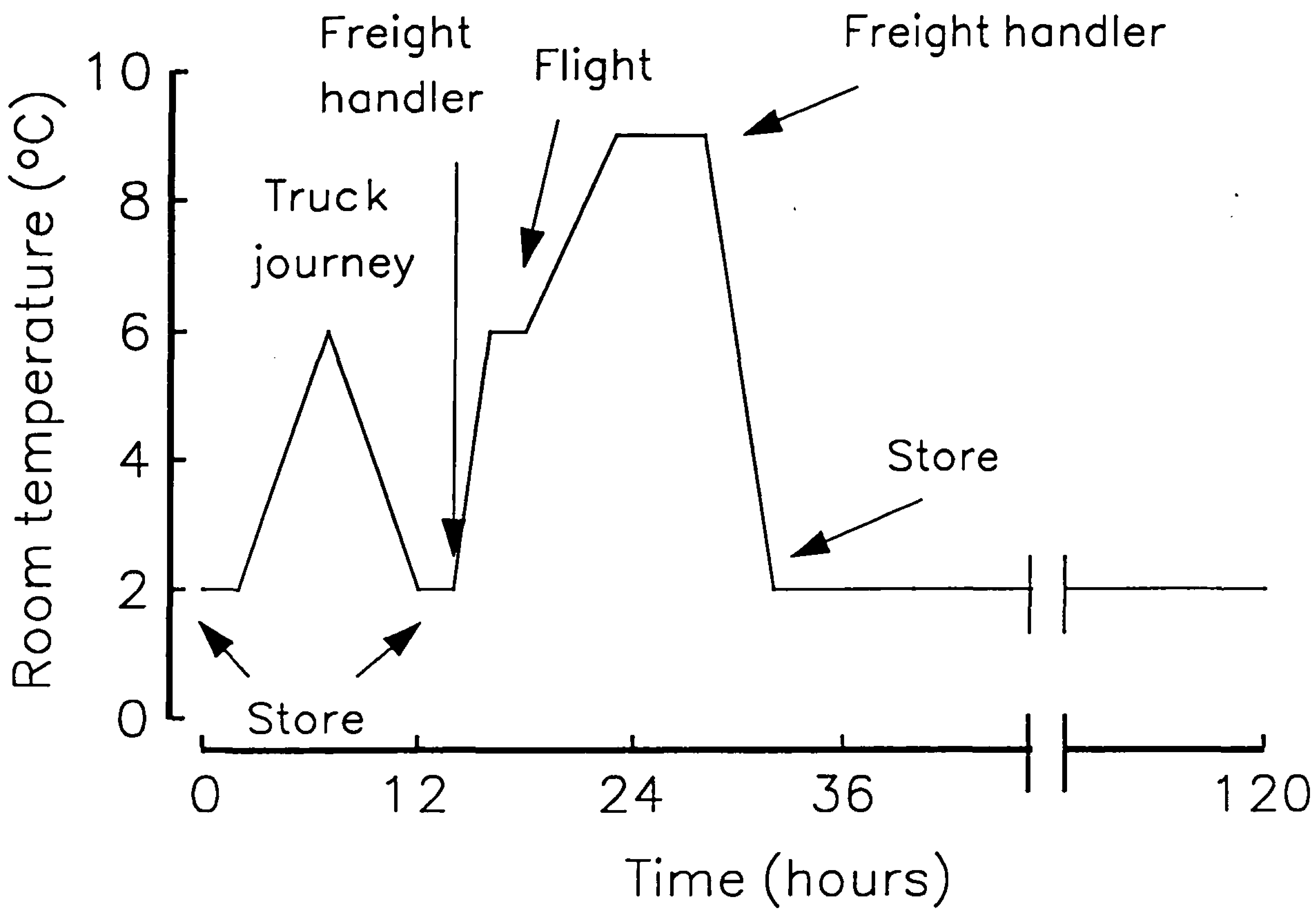
[1] 0=no characteristic asparagus flavour 150=strong characteristic asparagus flavour

[2] 0=no off flavours 150=strong off flavours

[3] 0=totally unacceptable 150=totally acceptable

Figure Legend

Figure 1: Air temperature profile of a storage room containing asparagus during a simulated journey from New Zealand to Japan. The simulation (after disinfestation treatment) involved: cool storage, a truck journey to the international airport, cool storage, forwarding to a freight handler, the flight, off-loading by freight handlers in Japan, and cool storage of the asparagus until it was marketed. This simulation is based on actual temperature records from an asparagus crop on a commercial flight from New Zealand to Japan (D.W. Brash, unpub).



Freight handler
Flight
Freight handler
Truck journey
Store
Store
Room temperature (°C)
0
2
4
6
8
10
0
12
24
36
120
Time (hours)