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Postharvest research on asparagus

A report prepared for
New Zealand Asparagus Council

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CONTENTS

1 EXECUTIVE SUMMARY

This report describes progress on three research projects supported by both the New Zealand Asparagus council and the Public Good Science Fund administered by the Foundation for Research Science and Technology.

Insulated covers proved effective at reducing the warming rate of palletised asparagus, even under hot, sunny conditions. Properly precooled product did not overheat during a normal transit timeframe.

Again a striking extension of shelf-life was obtained by modified atmosphere packaging during simulated airfreight. Problems to be overcome with this technology are identified.

Significant advances have been made in our studies of the metabolism of harvested asparagus. The decline in respiratory quotient observed after harvest appears to be related to metabolism of lipids in the spear tips, resulting in accumulation of malate. Work with asparagus cell cultures has shown that sucrose is an important regulator of the expression of the gene coding for asparagine synthetase. This gene is induced rapidly after harvest. The promoter for this gene will provide a powerful tool for postharvest-induced genetic changes. We are making progress in isolating this promoter.

Postharvest age of asparagus is closely linked to the amount of asparagine in the tips. Attempts to develop a quick-test for asparagine were unsuccessful because of interference from other components of the tissue. The concept is valid and would provide a significant tool for quality assurance, so we believe other approaches should be investigated.

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2 INSULATED COVERS FOR AIRFREIGHTED ASPARAGUS

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2.1 Background

We have been investigating ways of keeping asparagus cool during airfreight. In the 1993 season we tested two insulating covers under conditions that could be expected during an indirect flight through the tropics. We tested small pallets (24 boxes) of packed asparagus in a glasshouse held at 30°C. Earlier experimental work had been carried out on a standard 90-box pallet in a storeroom held at 20°C.

2.2 Approach

Three small pallets of asparagus were cooled to 1-2°C. One was left uncovered, one was covered with builders' foil, and one was covered with a Coolguard cover (foil/foam plastic combination). No coolant was used with the covered asparagus. The pallets were sealed using foil adhesive tape and moved to either a storeroom or a glasshouse, both held at 30°C. The pattern of warming of asparagus spears in representative positions in the three pallets was monitored using temperature sensors connected to a computer. We carried out six runs using the one lot of asparagus - three runs in the glasshouse and three in the storeroom. Five runs were for six hours duration, and the last, in the storeroom, was for 45 hours. This last run was to check on the occurrence of temperature over-run, a problem that could be expected when the respiration of warm asparagus in a covered pallet causes temperatures to rise rapidly beyond ambient temperatures. The high heat generation would quickly make the asparagus un-marketable in a process similar to making compost.

2.3 Results

Foil and Coolguard behaved similarly, slowing the warming rate of asparagus compared to the uncovered pallets. There were differences in the warming pattern when comparing results from the storeroom and glasshouse. After six hours the pallets exposed to the sun had increased in temperature by about 20% more than the ones in the storeroom.

The small pallet, although it had the same shape as the large pallet, has a different surface area to volume ratio. As a consequence the small pallet showed a different warming pattern to the large pallet. We gathered information which will be used to construct a model to help understand heat flows in palletised produce. We measured respiration so that the effect of heat of respiration could be separated from the effect of heat flow through the cover.

The net effect of the heat transfer into the pallet and the respiratory heat produced in the pallet was a relatively constant temperature rise of 0.7°C/hr for the model pallet. No evidence of an accelerated temperature rise was seen.

The covers reduced the warming rate compared to the uncovered controls. It took about 40 hours before the temperature of covered asparagus reached the ambient temperature of 30°C, compared to 24 hours for the uncovered asparagus. The covers markedly reduced heat unit accumulation (by nearly a half over the first 24 hours). Benefits in extension of shelf-life would be predicted.

2.4 Conclusions

Insulating covers will reduce the rate of warming of palletised pre-cooled asparagus, even under the hot, sunny conditions expected in the tropics.

Wrapping of correctly precooled product prior to shipping will not cause overheating under the normal transit timeframe.

2.5 Future work

We need to continue this work to improve an understanding of the heat flow patterns of covered palletised asparagus. We would like to use temperature monitoring to compare the warming of conventionally packed produce with that of covered produce (with appropriate supplementary cooling from ice or dry ice). This monitoring could be carried out either in New Zealand or en route to overseas markets - the latter is more desirable but much more difficult. We would also like to make direct assessment rather than infer quality advantages predicted from heat unit accumulation data.

3 MODIFIED ATMOSPHERE PACKAGING FOR AIR-FREIGHTED ASPARAGUS

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3.1 Background

The use of atmosphere modification for extension of storage life has found commercial application for numerous crops. Studies with asparagus, however, have shown little benefit in extending shelf-life after a period of cool storage. This has ruled out application of the technique for enabling sea-freight of asparagus.

Air freight is, therefore, the freight mode used currently for asparagus exports from New Zealand. This does not provide satisfactory cool chain connections right through to the market, and there are periods when the product is unrefrigerated. This results in significant loss of quality and reduction in shelf-life. We have already investigated the potential for atmosphere modification to protect spear quality during a simulated air shipment under warm conditions and we found that atmospheres can provide a substantial gain in shelf-life.

The most practical approach to obtain a modified atmosphere during air-freight is with sealed plastic film packs. Respiring asparagus produces carbon dioxide and uses up oxygen, thus altering the atmosphere within the package. As the carbon dioxide increases and oxygen decreases inside the package, these gases start permeating through the plastic film along the concentration gradients between the inside and outside. Eventually an equilibrium atmosphere is established when the gas exchange of the asparagus exactly matches the flow through the film.

Package design can be developed if various parameters are known. These parameters include: the respiration rate and weight of asparagus, the temperature, the permeability of the film to carbon dioxide and oxygen, and the area of film.

In this report we outline results of an experiment to develop equilibrium atmospheres in asparagus packs and determine the effects of these atmospheres on residual shelf-life.

3.2 Results

We used information on asparagus respiration rate to design packages using three different films. For each film we made three packs containing different weights of asparagus. These packs were held at 20°C for 4 days to simulate a challenging air-freight shipment. The packs were then opened and the asparagus held in air at 20°C for assessment of residual shelf-life.

The asparagus held in air during the simulated transport had a residual shelf-life of 1.8 days (Figure 1). Asparagus from the modified atmosphere packs had residual shelf-life ranging from 3.3 to 5 days. This represents a substantial extension of shelf-life, and again demonstrates the potential of the technique.

The package atmospheres were modified substantially by the time of the first measurement (18 hours), falling back to a reasonably steady level for the rest of the period. Equilibrium carbon dioxide levels ranged from 2.4 to 5.7% and oxygen levels from 2.5 to 16.2%. There was a strong relationship between oxygen concentration and residual shelf-life (Figure 2), suggesting that reduced oxygen levels are required to achieve shelf-life extension. The relationship with carbon dioxide was weaker.

In two of the modified atmosphere packages significant levels of tiprot developed, reducing shelf-life. Spontaneous spear growth was observed in several the modified atmosphere packages, mostly at a low level. In one pack, though, 12% of spears grew.

3.3 Conclusions

Atmospheres developed within packages of asparagus have the potential to markedly extend residual shelf-life of asparagus. This will lead to improved quality in the market.

3.4 Problems to solve

There are still problems to solve with the technology. The equilibrium atmosphere is dependent on the temperature of the package remaining constant. If the temperature changes, the respiration rate of the asparagus also changes. This leads to a change in the equilibrium atmosphere. This brings a risk of over-modification of the atmosphere, with anaerobic conditions leading to product damage.

The respiration rate of asparagus is very high. This makes it difficult to develop a package based solely on permeation of the gases through the plastic film. Micro-perforated films have been used for applications where high gas flows are needed and may be needed for asparagus packs.

Quarantine inspections present a further problem. Some packs will be opened for the inspection, and, if fumigation is required, all packs will be opened. This is obviously inappropriate treatment for consumer packs. It may be necessary to develop the approach for larger packs which can be readily opened for inspection and fumigation.

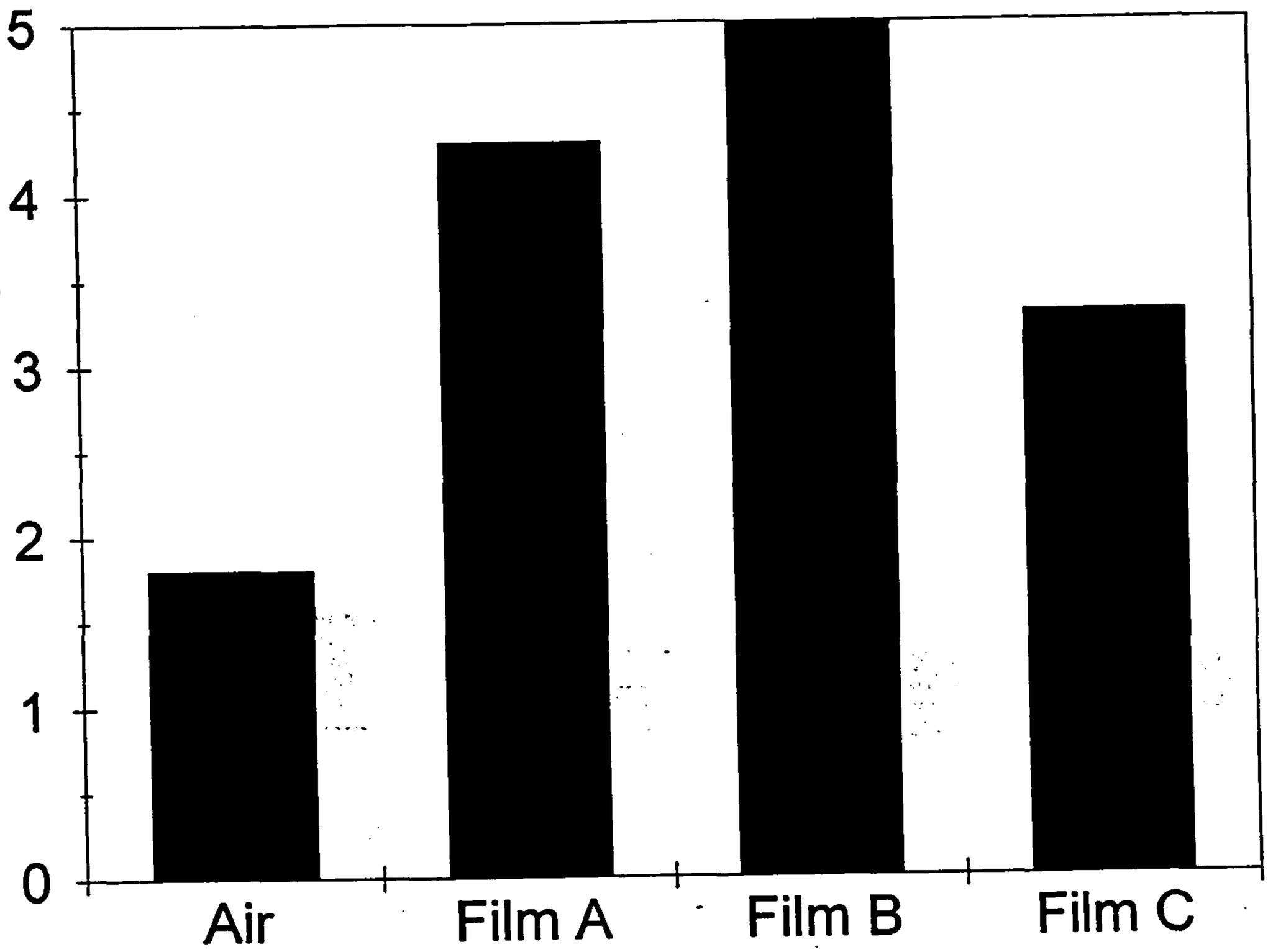

Figure 1: Residual shelf-life of asparagus in modified atmosphere packs.

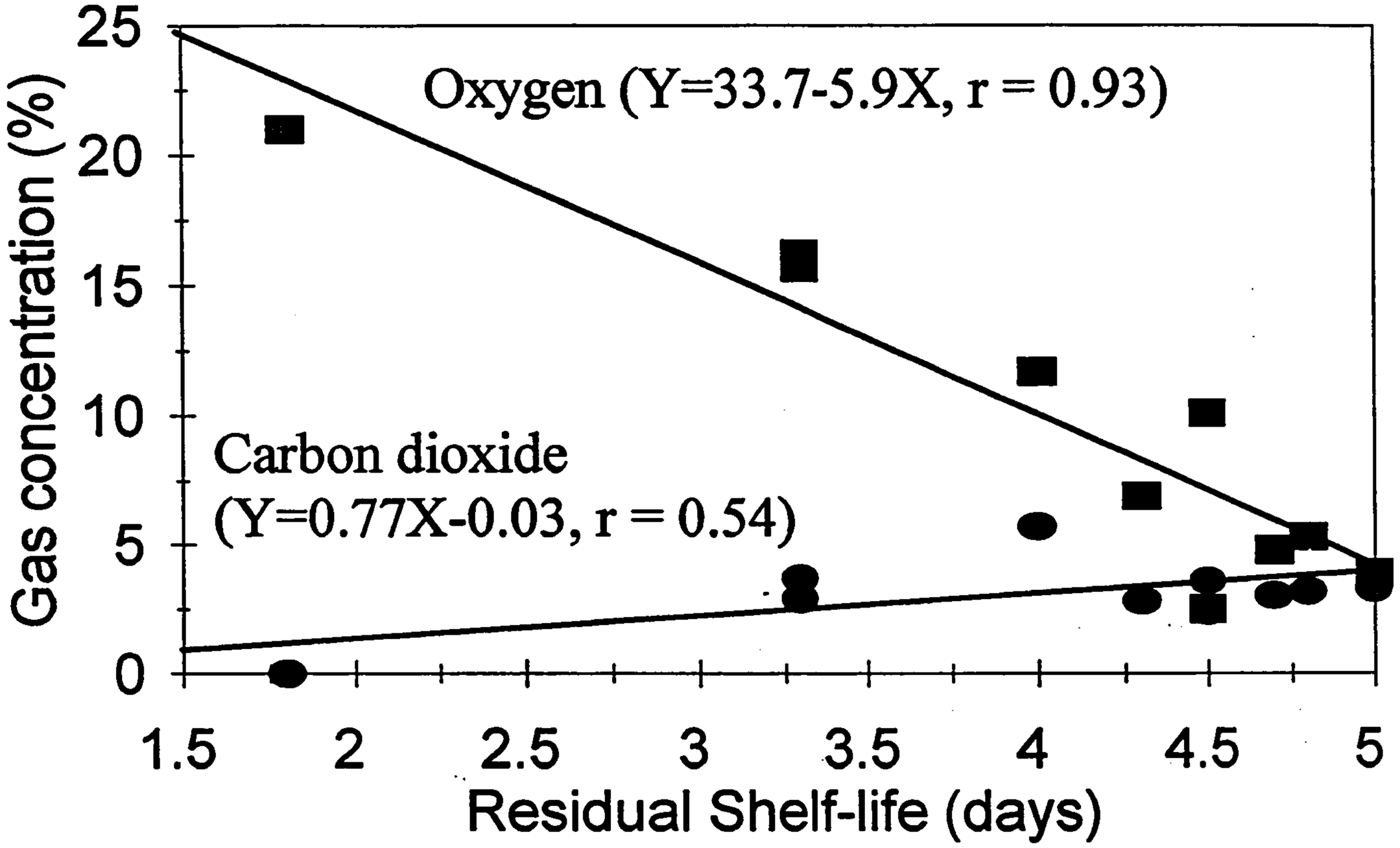

Figure 2: Relationships between carbon dioxide and oxygen concentrations and residual shelf-life.

4 THE BIOCHEMISTRY AND MOLECULAR BIOLOGY OF ASPARAGUS DETERIORATION

Donald Irving, Paul Hurst, Graeme King, Kevin Davies and John Seelye

4.1 Introduction

The aim of this work is to understand the biochemical and molecular changes which accompany the deterioration of asparagus after harvest. Control of processes responsible for these changes will help to maintain shelf-life and enable expansion of asparagus exports.

In our last report, we outlined decline in respiratory quotients, soluble sugar contents of spears of different heights, loss of sucrose from spear tips, and increase in asparagine concentration in asparagus spears. We also reported induction of the enzyme coding for asparagine synthetase in cell cultures following removal of sucrose from the cell culture solution.

Over the subsequent 12 months we have continued our research on asparagus searching to identify the role that sugar loss has in the deterioration process.

4.2 Sugar metabolism

To refine our experimental system, we have examined the postharvest behaviour of tips which have been removed from spears after harvest, and compared the changes in respiration, sugars, and gene expression, with those changes found in normal attached spear tips.

We found nearly identical changes between the two systems and this suggests the factors controlling deterioration reside in the spear tips.

4.3 Lipid metabolism

We have followed up our hypothesis, outlined in the last report, that loss of sugars and decline in the respiratory quotient after harvest indicates a metabolic change resulting in breakdown of lipids. Lipids are vital components of cell membranes and membrane breakdown will lead to tissue breakdown.

The decline in respiratory quotient after harvest was associated with loss of total lipid (Figure 1). At harvest, total lipid comprised about 10% of the dry weight of the tips, but after five days at 20°C, the total lipid content had dropped 6% of dry weight. The subsequent metabolism of the lipid probably results in organic acid (e.g.

malate) synthesis since malate increases within 2 days of harvest along with the enzyme responsible for its synthesis (malate synthase) (Figure 2).

The malate formed could be used as a carbon source for respiration but we think the malate accumulates in the cells so that ion concentrations can be balanced. This ion balance is important particularly when one considers the quantities of ammonia which are being produced during protein breakdown (discussed in earlier reports).

These results were presented at the Research Conference in May, 1994.

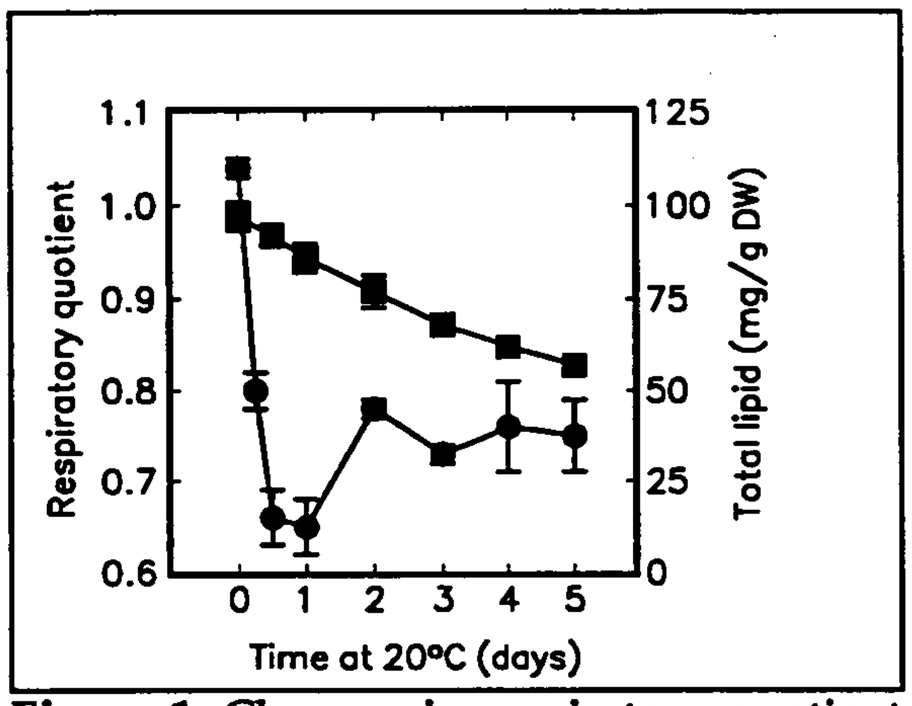

Figure 1. Changes in respiratory quotient (•) and total lipid (■) in asparagus tips.

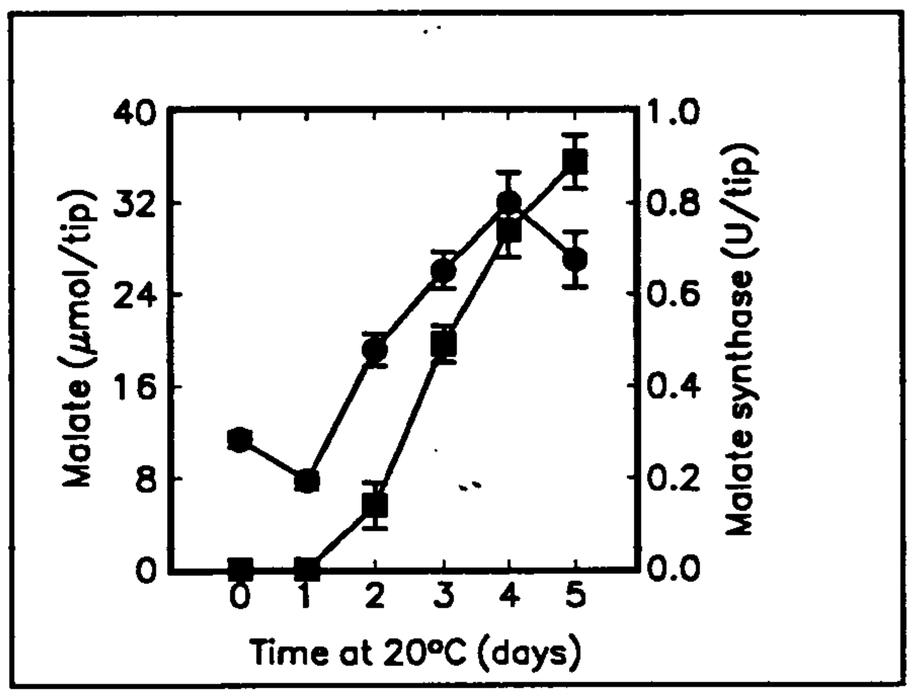

Figure 2. Changes in malate (•) and malate synthase activity (■) in asparagus tips.

4.4 Asparagus cell cultures

We have extended our work on asparagus cell cultures to confirm the importance of sugar loss to induction of genes coding for asparagine synthetase. This enzyme is probably responsible for the increases in asparagine we have reported on in our last report.

We found that upon removal of sucrose and other sugars from the growing medium, cell cultures were induced to produce genetic messages which coded for asparagine synthetase. Soon after the re-introduction of sugars to the growing medium, the gene messages for asparagine synthetase disappeared.

The results are consistent with an important role for sugars as signals to regulate plant development and deterioration.

4.5 Asparagine synthetase gene promoter

Research has continued to isolate the promoter which controls the production of asparagine synthetase message and the enzyme itself. This promoter will allow us to definitively identify the role that sugar loss has in regulating asparagine synthetase production.

To date, we have isolated the asparagine synthetase gene, increased the amount of this gene by cloning it, and the sequence of bases which make up the gene is now being determined. This does not yet mean we have the promoter. This has still to be confirmed by matching the base sequence we have with the published sequence.

5 USING SPEAR TIP COMPOSITION AS AN INDICATOR OF THE POSTHARVEST AGE OF ASPARAGUS SPEARS

Paul Hurst and Ben Sinclair

As a preliminary to this proposal, we evaluated all our data that describes the compositional changes in spear tips during storage of whole spears at 20°C. This was to identify which compound(s) was(were) likely to be useful in determining the postharvest age of asparagus.

We selected asparagine, which steadily accumulates to high levels after harvest, as the most sensitive compound for our purpose. Measurement of asparagine normally requires time-consuming and sophisticated procedures (e.g. high performance liquid chromatography) that are unsuitable for routine use in a project of this nature.

We sought then to evaluate a new procedure, recently published in the scientific literature, that claims to be specific for asparagine. Unfortunately, the procedure proved to be non-specific and other compounds in asparagus severely interfered with the procedure. Thus, we did not proceed with our proposal. However, we still believe that the concept of using tip composition to estimate spear age is valid.