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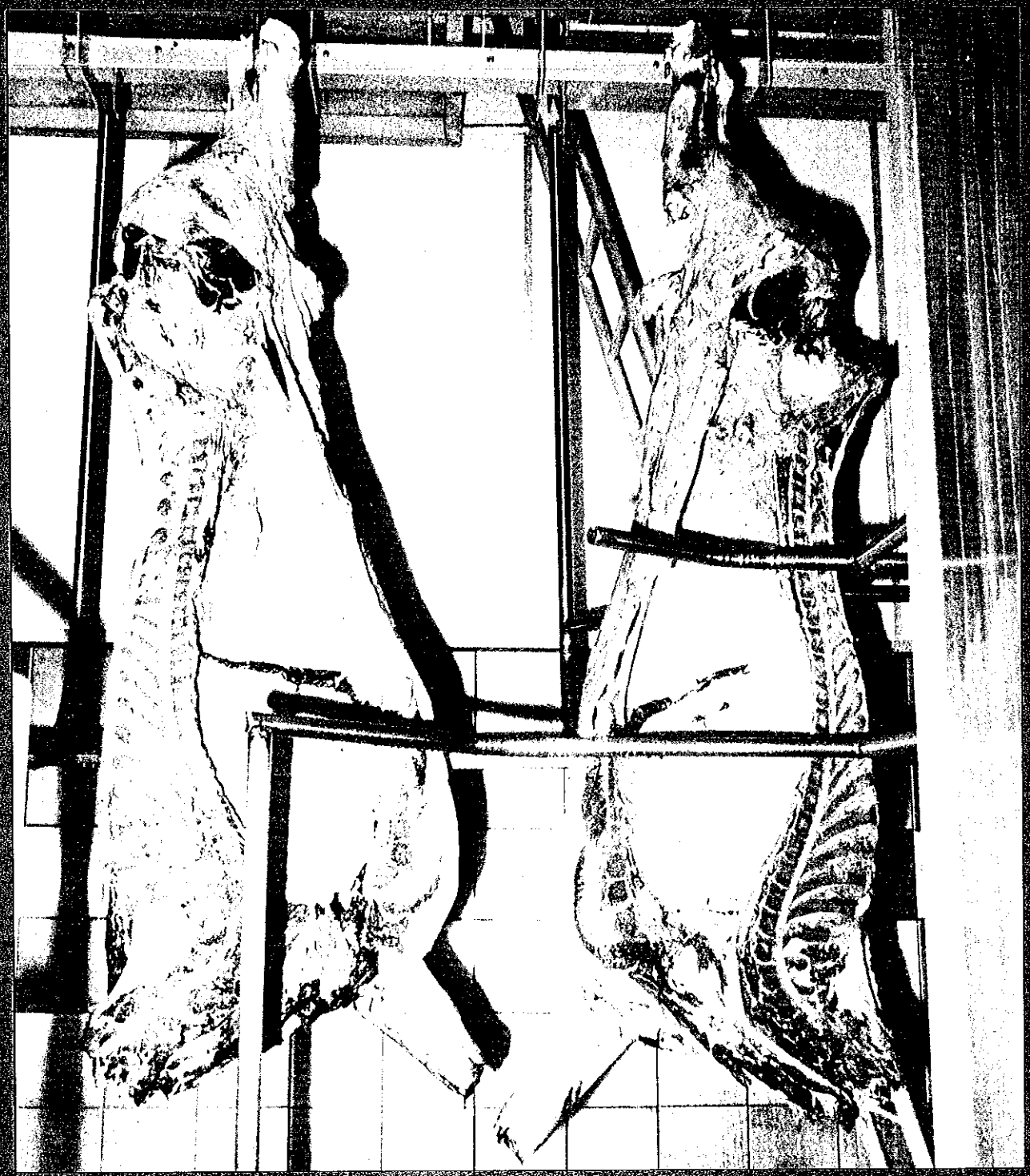

Microwaves in the food industry

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Introduction

The food industry is a graveyard for bright, promising projects using microwave energy. In the late 1960s a spate of microwave-based processes were developed and details published. The general principle appeared to be "if it can be heated let's microwave it". The literature gave the impression that microwaves would become a commonplace and accepted part of modern food processing. In fact the opposite is true.

A weakness in scientific literature is that accounts of failures are rarely published. Few of the microwave processes of the 1960s exist today but, as in the case of ionizing radiation, there has been a recent upsurge of interest in microwave technology by equipment manufacturers and food processors which has led to some developments in Australia.

Why did so many of the promising developments of the 1960s fail? This paper examines the use of microwave energy by the food industry and explains, with the benefit of hindsight, why some processes failed. The lessons to be learned from these failures are important for the future direction of microwave processing and are discussed in relation to recent Australian developments.

Potential of microwave heating

Foods exposed to microwaves are heated as a result of dissipation of energy mainly in the water, and also from ionic conduction of dissolved electrolytes. Microwave energy is especially suitable for drying processes where heat is used to remove moisture. The product surface becomes dry and a poor conductor of heat in the early stages of the process. This slows down conventional dehydration processes. Microwaves are able to penetrate the dry layer (Fig. 1) and heat the food in high moisture regions and thereby increase the rate of drying.

There has been much research into the application of microwave energy to food processing operations (Sale 1976). The Food Science and Technology Abstracts cited 1863 papers on microwave heating between 1969 and 1986. Fig. 2 shows the distribution of these abstracts amongst the various food processing operations. Most interest was in microwave cooking, expected because of the popularity of domestic microwave ovens, followed by thawing, drying, canning, baking, roasting, blanching and tempering. The papers covered the processes mentioned above as well as browning, coagulation, curing, fermenting, freeze-drying, gelatinization, pasteurization, rendering, and even the shucking of oysters and other bivalves.

Despite the extensive range of published research very little microwave power is used by the food industry. Decareau (1985) states that in 1978 about 5.1 MW of microwave power had

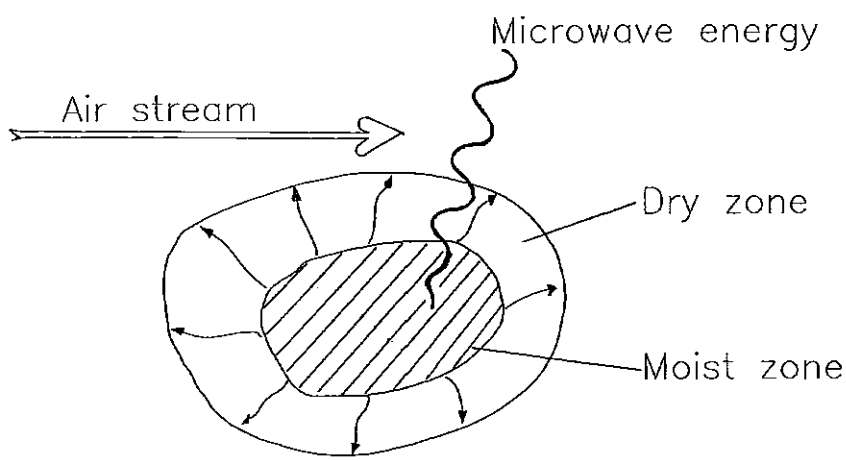

Fig. 1. Drying of a food particle in a microwave field.

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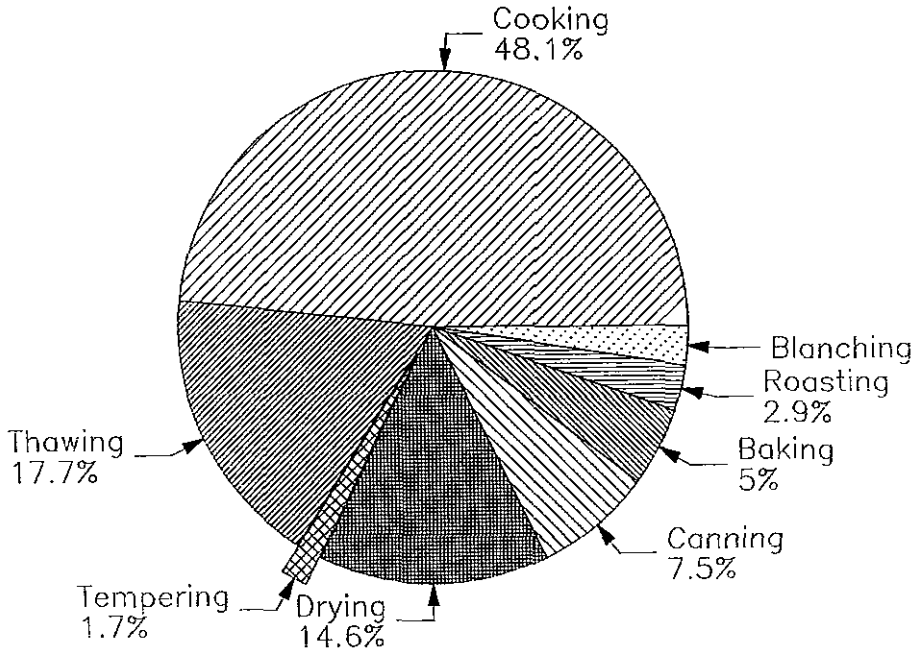

Fig. 2. Distribution of published literature on microwave heating abstracted by the Food Science and Technology Abstracts.

been installed world-wide and by 1984 this had increased to 19 MW, a small fraction of the power needs of the food industry. Microwave tempering, which was discussed in only 1.7% of the published literature on the use of microwaves in the food industry, is the only major success that can be claimed for microwave processing.

Microwave tempering

Tempering is the heating of frozen food, usually cartons of meat in 30 kg blocks, to a temperature just below the freezing point. At that temperature, around −4 °C, food is still firm but can be sliced, diced or minced. The conventional method of tempering is to store food in controlled temperature rooms at about 10 °C or less until the product reaches the desired temperature.

This form of tempering can take several days so scheduling of processes is restricted and manufacturers lack flexibility in processing; with frozen meat there is also a loss of soluble proteins as 'drip'.

In microwave tempering the frozen food quickly heats throughout its mass because microwaves pass through the carton and penetrate deeply into ice. Microwaves, especially at 915 MHz, are sufficiently absorbed to evenly heat foods which have ice uniformly distributed throughout their mass. The energy requirements are small because the amount of heat required to raise the temperature of the food from −18 °C to −4 °C is less than 30 kJ/kg. Several hundred tempering units using microwave energy have been installed around the world and most of these operate at 915 MHz because of the better penetration of microwaves at this frequency. Some microwave tempering units operating at 2450 MHz have also been installed; these units require a cool air blast over the tempered food to prevent surface melting. They also require the cardboard cartons to be removed because of the smaller tunnel.

The advantages claimed for microwave tempering when compared with conventional tempering are:

- rapid heating, of the order of minutes rather than days
- more flexibility for the processor
- minimal loss of solubles
- little or no time for bacterial growth or other spoilage to occur
- unit occupies less space.

In Australia the only microwave frequency designated for industrial, scientific and medical (ISM) use is 2450 MHz so the 915 MHz frequency, preferred for tempering, is not freely available. Processors must seek permission from the Commonwealth Department of Communications before microwave units operating at 915 MHz can be used. Although a microwave tempering unit operating at 915 MHz has been installed in Australia, the use of 915 MHz for ISM is currently under review.

Microwave drying

In the United States, the final stage of potato chip drying was the first industrial use of microwave energy on a large scale and demonstrated the potential of microwave processing. About thirty installations were operating in the mid-1960s. However the process was a failure and while the reasons for this are not simple, the lack of success has hindered further acceptance of microwave energy by the food industry.

Pasta drying, a successful use of microwave energy, was developed by the Microdry Corporation, San Ramon, CA, USA. The process illustrates some of the basic principles and problems in using microwave energy.

It is expensive to remove all the water from a food with microwave energy. Electrical energy costs about two to three times that derived from fuel such as natural gas and most magnetrons can convert only 50 to 60% of this electrical energy into useful microwave energy. A domestic microwave oven, for example, requires 1200 W but only 700 W is available to heat foods inside the oven. The electrical energy not converted to microwaves is dissipated as heat in the magnetron, which has to be cooled. The fan in a microwave oven is used for this purpose. In most microwave applications this heat is wasted but at least one modern microwave dryer attempts to use it. Furthermore not all the available microwave energy is converted to useful heat in the food. When all these losses are taken into account the total cost of microwave heating can be ten times the cost of conventional heating.

Microdry Corporation found that a way around this cost disadvantage was to develop a microwave-assisted, hot-air dryer in which the microwave energy supplies only 10% of the total energy of the process. Heating with microwaves during the initial stages of drying was undesirable not only because of the cost but also because the pasta tended to cook rather than dry. Furthermore if the moisture content was above 20% (wet weight basis) the pasta exploded because of the rapid formation of steam. Microwaves were therefore applied only when the moisture content was reduced to less than 20%. Another feature of the pasta dryer was its continuous operation. Microwave energy is not in general suited to batch drying operations because as the moistsure content decreases, the transfer of energy to the food becomes less efficient.

Advantages claimed for this dryer when compared with a conventional dryer of equivalent capacity are:

- space — the dryer is only 8.3 m long compared to 36 m
- sanitation — because the unit is smaller, it is easier to clean
- speed — the microwave process takes 1.5 h compared to 8 h
- quality — the higher temperature achieved in the microwave-assisted hot-air dryer ($>90\,°C$) compared to about 75 °C in conventional dryers result in pasta with a better colour, texture and with bacterial counts less than 200 colonies per g
- energy — about 25% less total energy is required.

These claims are based on comparisons with the older style pasta dryers. Manufacturers of conventional pasta dryers have countered the microwave threat by producing high temperature dryers that encompass many of the features of the microwave-assisted, hot-air dryer but without the need to resort to microwave energy. In the microwave installations prior to 1981 there was no attempt to use the waste heat generated in the magnetron.

The Hi-Tec microwave dryer: an Australian development

In June 1986 the Ministser for Energy and Technology in the New South Wales Government, The Honourable Peter Cox, launched a microwave dryer at the Killarney peat mine at Bombala, NSW. The dryer was built with the help of State and Commonwealth grants and has a number of features which make it a potentially useful dryer for the food industry.

The dryer consists of 64 magnetrons each rated at 6 kW. The power output is varied according to the amount of energy being reflected back into the magnetrons. This feedback loop prevents overheating of the magnetrons and controls the energy being absorbed by the material. Unlike the design of the pasta dryer described above, the heat lost from the magnetrons is recovered and used to heat the incoming airstream. Trials with foods such as rice, hops and maize have been attempted using the Hi-Tec dryer but, because of its size, it was difficult to properly tune to the thermal requirements of the foods. The University of Wollongong has established a Microwave Applications Research Centre where a smaller unit based on the original design has been built. This may be more appropriate for evaluating microwave drying for the food industry.

Microwave vacuum drying

Vacuum drying is often used for materials that are heat and oxygen sensitive. At reduced pressures the transfer of moisture from the food is not impeded by oxygen or nitrogen molecules and the temperature is limited by the vapour pressure of water. Evaporation decreases product temperature and the rate of drying decreases unless some form of heat can be supplied to the material.

A major problem in vacuum drying is to transfer heat to the product. Conduction of heat is especially slow through the dry surface of the food as gases at low pressures are poor heat transfer agents. Miesel (1978) realized that this was a process in which microwave energy could be applied and built a 'Gigavac' microwave vacuum dryer. This dryer has been used to dry concentrates of orange, lemon, grapefruit, pineapple, strawberry, raspberry, blackcurrant, tea and herbal extracts.

A feature of the Gigavac dryer is its continuous operation. Liquid concentrate of the product to be dried is poured onto a teflon conveyor belt. As the liquid is heated by microwaves at reduced pressure it forms a stable foam which dries at temperatures less than 40 °C. Unlike the pasta dryer the heating requirements were met totally by eight magnetrons each rated at 6 kW, two of which were variable. Infrared sensors were used to monitor and control the temperature of the foam by use of the variable power magnetrons. No attempt to preheat the product using the waste heat from the magnetrons was made. A 49 kg/h plant drying orange juice concentrate from 35% water to 2% in about 40 min using a 48 kW unit has been installed in France.

Although this dryer exclusively uses microwaves, most of the water has already been removed from the original juice to make the concentrate. Therefore the overall process resembles the pasta dryer in that microwave energy is used to remove a small proportion of the original water. An advantage of the process is that, since the product to be dried is a concentrate, retention of volatiles is enhanced. Neither spray-drying nor freeze-drying can use such concentrated liquids and therefore the energy requirements for these processes are greater than for microwave vacuum drying.

Microwave freeze-drying has generated a lot of academic interest in the US. This research has shown that residual gases in the vacuum chamber ionize in the intense electrical fields generated by microwaves. This phenomenon, called glow discharge, can only be avoided when pressures less than 10 Pa are used. High-vacuum pumps are needed to achieve these pressures and this, combined with the batch nature of most freeze-drying processes, has severely limited the commercial development of microwave freeze-drying. The Gigavac dryer in contrast avoids glow discharge by having adjustable waveguides and by operating at pressures near 1 kPa. These pressures are easily achieved using steam ejectors rather than expensive high-vacuum pumps.

Microwave sterilization

Moist foods become stable when spoilage micro-organisms and enzymes are inactivated by heating. Cans are heated with pressurized steam in conventional sterilization. Therefore food is cooked at high temperatures until the coldest part of that food has been heated for a sufficiently long time to achieve commercial sterility. Steam is expensive and, in large cans, food which is near the wall of the can receives an excessive heat treatment.

The ability of microwaves to penetrate into food has spurred many investigations of microwave sterilization. However, there are almost no commercial installations at this time because of technical problems of controlling microwaves for sterilization and the need to develop packaging materials that are transparent to microwaves and yet provide an effective barrier to light, oxygen and moisture. Plastics with these properties are becoming available and will provide an impetus for microwave technology, especially since food contained in these plastics may be warmed in a microwave oven.

What are the problems?

Microwaves do not heat evenly. The turntable in a domestic microwave oven rotates the food in an attempt to overcome uneven heating. Reflections of the microwaves from the walls of the oven cause hot and cold spots to develop and the shape of the food can prevent full and uniform absorption of the microwave energy. This has caused some concern in the United States because of the risk that the parasitic nematode *Trichinella spiralis* may survive in microwave-cooked pork (Zimmerman 1983).

In determining the safety of a heat sterilization process, temperatures during sterilization need to be known at the slowest heating point in a food to within 0.5K. It is difficult to measure temperature in a microwave field because thermocouples are affected by the intense electric field and sensors such as infrared thermometers can only monitor surface temperature. Furthermore, it is difficult to predict the position of the slowest heating point. Despite these problems at least

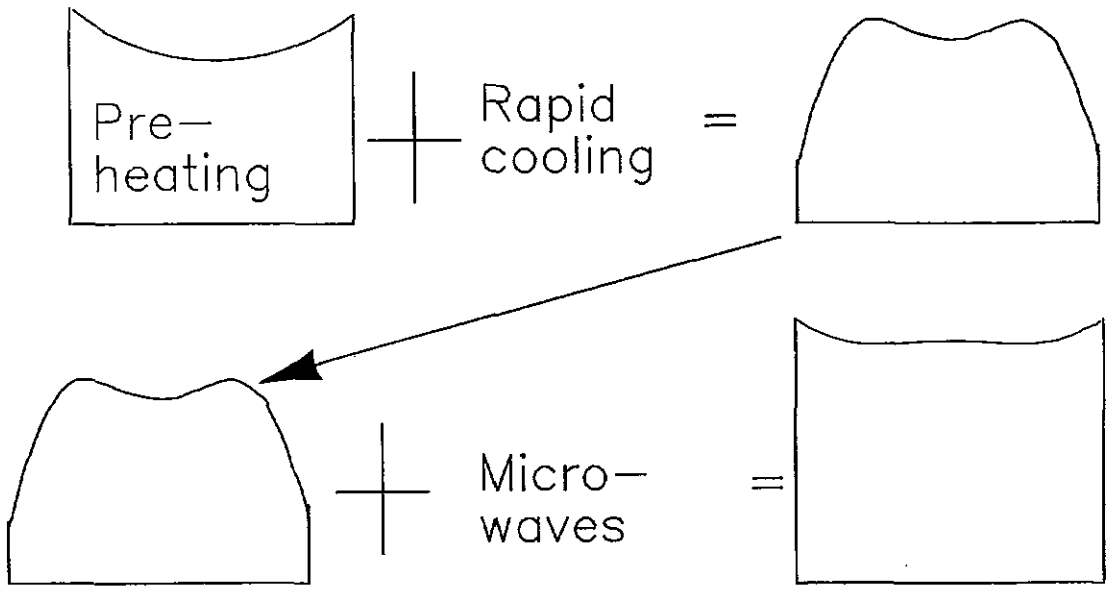

Fig. 3. Temperature profiles of a pouch of food heated by microwave in the Multitherm sterilization process.

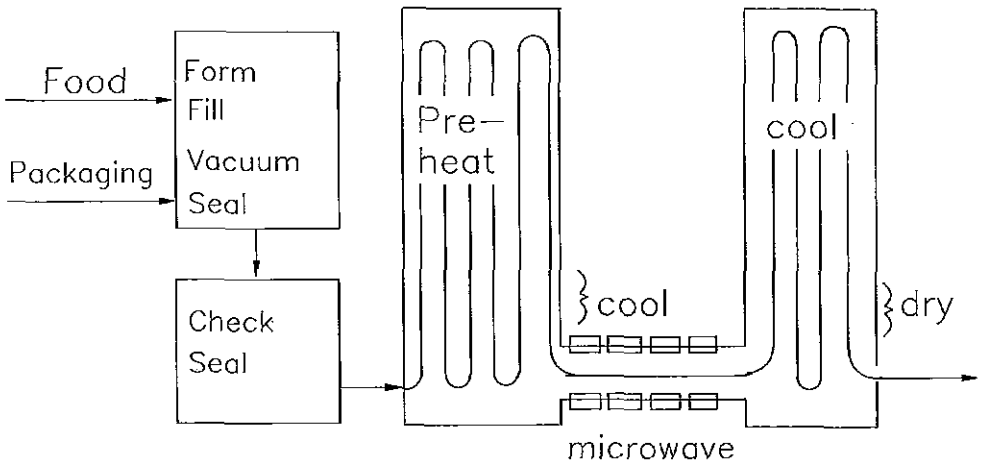

Fig. 4. Flow chart for the Multitherm sterilization process.

one company has developed a microwave sterilization process called the Multitherm process.

Initial studies had shown that temperatures at the corners of microwave heated plastic pouches were much higher than at the centre of the pouch (Stenstrom 1981). This differential was reduced by immersing the pouch in water but not sufficiently reduced to give the high quality wanted in food. Fig. 3 shows temperature profiles for a pouch of food treated to minimize temperature differences throughout the product during microwave sterilization. By heating the pouch and then rapidly cooling just before applying the microwave energy, temperature differences became acceptably small and this process, shown diagramatically in Fig. 4, produced high quality products.

What limits the acceptance of microwave processing?

Acceptance of new technology, including microwave processing, is hindered by the long time before a piece of food processing equipment becomes obsolete. Many dehydrators that were built before World War II are still operational and perhaps as good as they were when they were built. It is difficult for food processors with this kind of equipment to accept modern equipment such as a microwave dryer which will need magnetrons replaced after every 10 000 h. Such a dryer would require major maintenance every year and the cost of magnetrons is a major proportion of the cost of the equipment.

Furthermore if the development period for a new process is too long the problem will be

solved using conventional technology. An example was the finish drying of potato chips using microwaves. This dryer was developed to solve the problem of excessively dark chips, which occurred when using certain types of potato. This problem was solved by manufacturers taking more strict control of the supply and storage of potatoes and by the development of synthetic chip products (O'Meara 1973). Similarly microwave sterilization might be superseded by developments in aseptic processing.

What future for microwave food processing?

Despite the slow acceptance of microwave processing by the food industry there are some trends that would indicate that the future is bright.

The food industry uses more electrical energy than it used to because reliance on steam as the major source of energy is diminishing. Many control systems are now electronic. This means that a change to microwave processing is not as difficult as it used to be and the appropriate skills may exist within the factory to maintain complex electrical equipment.

High interest rates and the consequent need to reduce inventories have led to the 'just-in-time' management philosophy. This strategy requires holding sufficient stock for only immediate needs. It is relevant to the food industry because food is not stable even in frozen storage and it can be costly to store. The features of many of the processes described above is the rapid processing, for example, tempering, which takes only minutes using microwave energy but can take days by other methods.

The popularity of microwave ovens has sparked a consumer demand for foods that can be heated quickly and easily in microwave ovens without being transferred to other containers.

The plastic can is now a reality and may cause processors to consider sterilization techniques such as Multitherm.

The cost of magnetrons is decreasing in real terms and they are more efficient and reliable than they used to be. Some manufacturers are able to use the heat generated in the magnetrons and, with the knowledge gained since the 1960s, efficient use of the energy is easier than before.

Therefore, there may be a future for microwave processing but manufacturers and potential users of microwave equipment should heed the warnings of past failures or they are doomed to repeat them.

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A hot water decontamination system for beef sides

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Introduction

Research work on reduction of microbiological contamination of sheep carcasses (Smith and Graham 1978) led to the development and evaluation of a prototype decontamination cabinet for sheep (Graham *et al.* 1978). This showed that if sheep carcasses were sprayed with hot water sufficient to produce a temperature at the carcass surface of 80 °C for 10 s, significant reductions in bacterial numbers occurred. Graham *et al.* (1978) evaluated a similar system on a commercial sheep slaughter line. In a fully enclosed cabinet with multiple spray nozzles, the required treatment conditions at the surface of the carcasses were achieved and resulted in a reduction of 2.5 $\log_{10}$ units (99.7%) in the bacterial load (measured by total aerobic plate counts and coliform counts) of naturally contaminated lamb carcasses.

On the basis of these results, it was decided to adapt the system used for sheep to a beef slaughter line and:

- ascertain the temperature profile achieved at the surface of beef sides
- evaluate the microbiological effectiveness of the treatment
- determine the operating costs of the system.

Experimental

Equipment

Fig. 1 is a diagrammatic representation of the decontamination system. It was constructed as an extension at the exit of an automatic beef side wash chamber. The wash chamber was located on the chain which transferred the beef sides from the slaughter floor to the chillers. This chain operated at a set speed of 150 mm/s and was independent of the slaughter chain stop/start controls. This provision ensured that a constant treatment time (10.3 s) for all parts of a side was achieved.

The walls and roof of the treatment and exit chambers were of polystyrene sandwich panel construction (75 mm polystyrene with aluminium skin). Stainless steel doors were made up of several sections, each being 1.5 mm thick, approximately 300 mm square and mounted on sprung hinges. The doors were normally closed, and opened only when a side was passing through them. The roof of the unit was above the rail to avoid the necessity to provide an opening for the passage of the hooks.

The spray distribution system consisted of two banks of nozzles ("Nozzles" MR2-4) on each side of the treatment chamber, each bank having eight nozzles located from the top to the bottom of the cabinet. The nozzles were mounted approximately 300 mm back from guide bars which prevented sides from turning in the cabinet, and produced a water spray that provided complete coverage of each side as it passed through the chamber.

Experience with the sheep decontamination unit showed that water quality was not markedly diminished by recirculation if there was a continual make-up of fresh hot water (Graham *et al.* 1978). Approval for recirculation of hot water in the beef system during evaluations was obtained from the Veterinary Authorities within the Australian Meat Inspection Service.

A Grundfos CR30 centripetal pump was used to draw 3.7 L/s of water from a steam heated tank in the bottom of the treatment chamber and supply it to the nozzles at 300 kPa pressure. The spent water was collected in the tank where it mixed with fresh make-up water and was reheated and again used for spraying. An overflow from the tank was maintained to flush fat and floating solids to the drain. The flow of make-up water was adjusted so that there was in excess of 10 complete changes of water in the tank each hour. At the end of the day the tank was drained and the whole recirculation system cleaned.

A wedge-wire screen was fitted into the top of the tank to prevent pieces of fat and bone dust from entering the recirculation system and causing blockages at the nozzle. Some blockages did occur once or twice a week but, due to the design of the nozzle used, were easily cleared.

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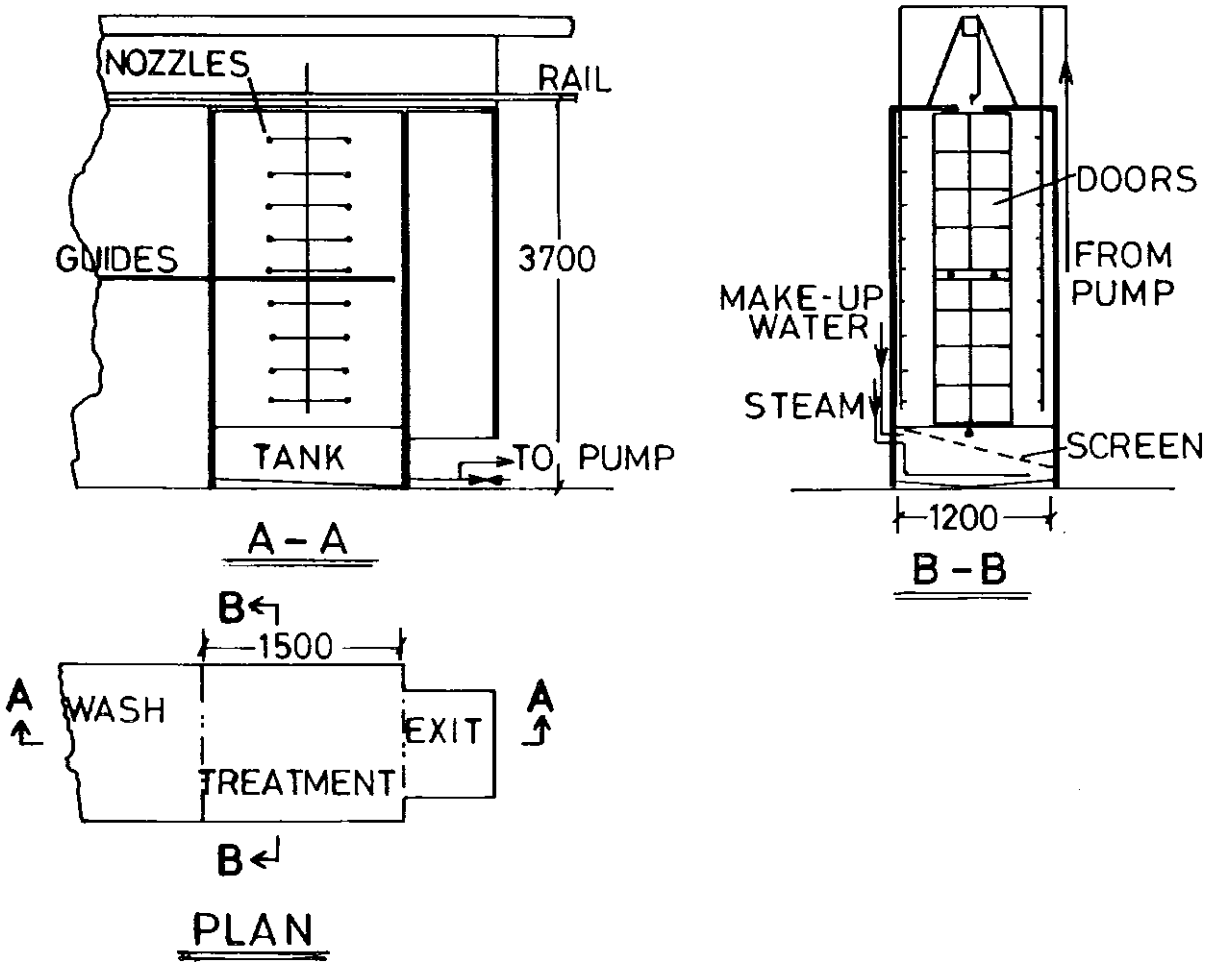

Fig. 1. Diagrammatic sections through the decontamination cabinet with nominal dimensions of the treatment chamber in mm.

Temperature

All temperatures were monitored using flexible copper-constantan thermocouples (type T) connected to a Riken-Denshi potentiometric recorder.

Water temperatures at the surface of beef sides as they passed through the system were measured by inserting thermocouples into a side and raising the sensing tips to a point just above the surface tissue (in the range 1-3 mm above the carcass surface). This procedure was undertaken at the following sites on the beef sides:-

- lateral surface — rear hock, rump, silverside, flank, loin, brisket, shoulder, neck and fore hock
- medial surface — rear hock, topside, inside the flank, anal cavity, diaphragm, sternum, ribs, neck and fore hock.

Temperature monitoring was conducted on an average of one day each week for 6 months.

Water flows

Water flow rates were obtained by timing the flow of water into and out of a container of known volume.

Steam flow

A pitot tube was fixed into the steam line and connected to a differential pressure transmitter. The output of this transmitter was connected to a recorder which provided a continuous record of steam flow.

Water sampling

Samples (150 mL) were taken to ascertain the microbiological and physical quality of both the make-up and recirculated water. The make-up water sample was taken directly from the inlet pipe. The recirculated water was sampled from the pump suction line 0, 5, 10, 15, 30, and 45 mm from the time the first side passed through the cabinet.

An aliquot (0.2 mL) was taken from each sample, spread plated on tryptone-soya peptone-yeast extract-glucose agar, incubated at 25 °C for 3 days and a total aerobic plate count done.

Physical quality was assessed by the determination of the quality of suspended solids in the water which was obtained as described in "Standard Methods" (APHA 1971).

Microbiological sampling

Microbial numbers on 40 sides (from randomly selected carcasses) were ascertained. Samples were taken before and after treatment. Because relatively low numbers of bacteria were expected, a large area of surface tissue was sampled. Five tissue samples, each 20 cm^2, were excised from the surface of the brisket. The brisket was chosen because other work has indicated it to be a "dirty" area relative to the rest of the carcass (Grau 1979; Roberts *et al.* 1984). For the first ten carcasses, the pre-treatment sample was taken from the leading side of the carcass immediately prior to the side entering the wash cabinet and the post-treatment sample was taken from the trailing side immediately after the decontamination treatment. For the next ten carcasses the pre-treatment and post-treatment samples were taken from the trailing and leading sides respectively. Each sample of tissues excised from the brisket was placed in a sterile polyethylene bag.

Ninety-nine mL of 0.1% peptone water was added and the sample was treated for one minute in a Colworth Stomacher 400. Appropriate dilutions were spread-plated on tryptone-soya peptone-yeast extract-glucose agar and incubated at 25 °C for three days to give a total acrobic plate count. Appropriate dilutions were also spread-plated on MacConkey Agar and incubated at 37 °C for 24 h so that a coliform count could be obtained. In addition, for those samples taken following treatment, 0.2 mL aliquots were spread on each of 5 plates of the MacConkey Agar to permit detection of organisms down to levels of 1 per cm^2 of tissue.

Results and discussion

The temperature of the water at the surface of the beef side was approximately 7 °C below that at the pump when the slaughter rate was at the maximum (135 carcasses/h) (see Fig. 2). At slower slaughter rates, the temperature difference was reduced slightly. With the chain stopped, the difference was 1° - 2 °C.

The temperatures recorded at the various

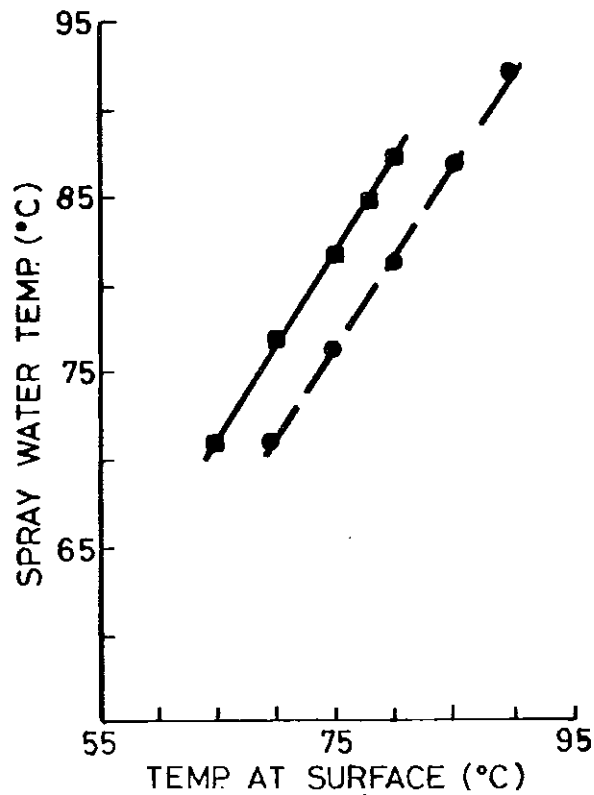

Fig. 2. Temperatures at the carcass surface for various spray water temperatures with a flow rate of 3.7 L/s and slaughter rates of 135 carcasss/h (—◆—◆—) and chain stopped (—•—•—).

sites of a side during treatment varied by less than 1 °C which indicated that the entire surface of the side was subjected to a uniform heat treatment. Each side received a treatment time of 10.3 s.

Several variables affected the temperature of the water in the system and therefore the steam flow required to maintain it. Some of the factors involved were:

- slaughter rate (an increase in slaughter rate caused an increase in the time the doors were open)
- flow rate and temperature of the make-up water
- size of carcasses.

With a fast slaughter rate and with large sides of beef (>120 kg), some of the cabinet doors were open for long periods. This contributed to increased heat losses from the system (135 carcasses/h), as a 'worst-case' situation.

The temperature of the make-up water was 70 °C ± 2 °C. Fig. 3 shows the steam flow required to maintain supply water temperature with a make-up water flow of 0.8 L/s at 70 °C.

From the results shown in Fig. 2, it can be seen that the system must be operated with the

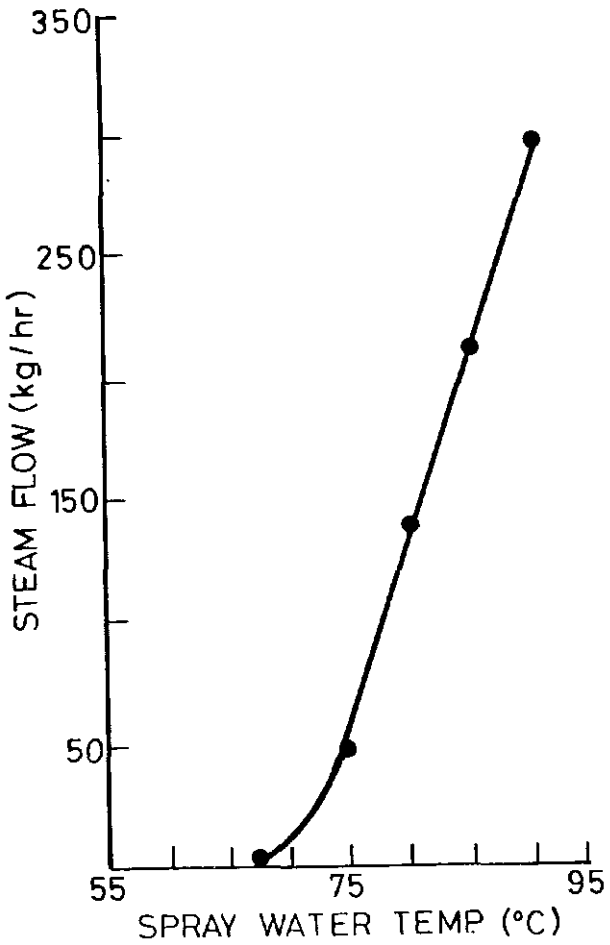

Fig. 3. Steam flow required to maintain spray water temperatures with a make-up water flow of 0.8 L/s at 70 °C and a slaughter rate of 135 carcasses/h.

supply water at a minimum of 87 °C to achieve 80 °C at the carcass surface. The steam flow necessary to achieve this was approximately 250 kg/h. The hot make-up water came from the waste heat recovery system attached to the abattoir's rendering plant. A further 285 kg/h of steam would be necessary if a works was not in a position to heat water using a waste heat recovery system. Therefore, in this case, a total steam flow of 535 kg/h would be required to heat water from ambient to 87 °C, and to maintain this temperature.

Cost of steam varies between works. Steam costs from three plants surveyed in June 1986 were quoted as $8.00, $12.00 and $21.00 per tonne. The two former costs were for coal fired boilers, whilst the latter was for an oil fuelled boiler.

In the case of a works without a heat recovery unit, the steam cost based on these fuel prices for the decontamination system would be $4.30/h, $6.40/h and $11.25/h respectively.

Based upon water costs of $400/ML, the make-up water of 0.8 L/s would cost $1.15/h.

TABLE 1
Total aerobic plate count (TAPC) and suspended solids for recycled water

Source	TAPC number/mL	Suspended solids mg/L
a) fresh make-up water	2.5	—
b) recycled water at time		
0 minutes	2.5	—
5 minutes	<2.5	9.2
10 minutes	5	13.4
15 minutes	A	17.4
30 minutes	5	16.6
45 minutes	2.5	13.8

A Damaged plate
Water flow = 3.7 L/s
Make-up water flow = 0.8 L/s
Tank temperature = 85 °-90 °C
Slaughter rate = 135 carcasses/h

Defining the microbiological acceptability of water as a total aerobic plate count (TAPC) of less than 100/mL, which is the commonly used value for drinking water in Australia (H. Ferguson, private communication), the results from Table 1 indicate that the microbiological quality of the recycled water tested is acceptable.

Most of the solids in the recirculated water were removed by the wedge wire screen. However, there was an accumulation of fine solids over the first fifteen minutes of operation after which time the level remained at approximately 15 mg/L.

The hot water treatment of carcasses resulted in an initial discolouration of the meat surface. This "cooked" appearance disappeared after overnight chilling and the surfaces covered by fat or a membrane recovered their 'bloom'. On exposed muscle surfaces (e.g. where the brisket is split), a slight discolouration was apparent when treated and non-treated sides were compared at 24 h post-mortem. In a chiller containing only decontaminated sides, this slight discolouration was much less obvious as treated to non-treated comparisons could not be made. We consider that this minor discolouration would not be a problem in the carcass trade.

One problem which was not resolved was that of small pockets of water caught in the soft fat which were unable to drain away on some sides. Following overnight chilling most of this water had evaporated, but damp spots were still evident in some areas of the fat surface. Our investigations showed that these pockets of water, which formed as the side of beef passed

TABLE 2
Effect of decontamination treatment[1] on mean total aerobic plate counts (TAPC) on beef sides

TAPC number/cm² before treatment	TAPC number/cm² after treatment	% Reduction
5600	260	95

[1] Average temperature at carcass surface was 75 °C

TABLE 3
Effect of decontamination treatment[1] on coliform presence on beef sides

Number of sides on which coliforms detected before treatment[a]	Number of sides on which coliforms detected after treatment[a]	Number of sides on which coliforms detected after treatment[b]
9	0	2

[1] Average temperature at carcass surface was 75 °C

a) Methodology used limited detection if numbers were present at a level of less than 10/cm²

b) Methodology used limited detection if numbers were present at a level of less than 1/cm²

through the wash, would normally drain in a short time. However, the hot water sprays of the decontamination system apparenty sealed some pockets of water within the fat.

Results of TAPC and coliform counts of brisket samples from 20 randomly selected carcasses sampled before and after decontamination are shown in Tables 2 and 3 respectively. During the period when sampling of the sides was undertaken, water temperature to the pump fluctuated between 80 °C and 85 °C. This meant that temperatures at the beef side surface varied between 73 °C and 78 °C (average 75 °C) and did not achieve the desired 80 °C.

While the effect of the automatic carcass wash alone has not been evaluated in this exercise, Bailey (1971), Patterson (1972), Kotula (1974) and Kelly *et al.* (1982) have reported that the total bacterial numbers at the most highly contaminated sites of carcasses which were spray washed with cold water (approx. 10 °C), remained at approximately $\log_{10}$ 4.0. Thus the contribution of the side wash to the overall reduction in bacterial numbers as a result of our wash/decontamination treatment is negligible.

Because of the very low numbers of naturally occurring coliforms, considerable sampling is required to determine an average count on carcasses. After treatment this problem is exaggerated. Therefore, a more sensitive method was used on the post-treatment samples than on the pre-treatment samples to enable coliform organisms to be detected at levels of not less than 1/cm². Because of the low numbers detected (see Table 3), the reduction of coliforms is difficult to quantify.

Smith and Graham (1978) in their work with naturally contaminated sheep carcasses achieved a reduction of approximately 96% in aerobic organisms on carcasses after a hot water treatment. A reduction of approximately 99% in coliform numbers was also achieved. An indication of the reduction in coliforms by the treatment we used may be inferred from Smith and Graham's results by comparing the aerobic organism reduction achieved by our treatment (95%) with theirs (96%).

Coliforms react to heat decontamination treatment in a similar way to salmonellae (Smith and Graham 1978) and for this reason they can give some indication as to the expected reductions of salmonellae on a heat treated carcass. Salmonellae occur in much lower numbers than coliforms and detection of Salmonellae is more difficult as a result. Detection was not attempted in this study.

Conclusions

During commercial operation, the system produced an average temperature of 75 °C at the surface of the beef sides.

Microbial numbers on beef sides were substantially reduced. Based on total aerobic plate counts, the reduction was 95%. The magnitude of the coliform reductions is difficult to quanitify because the bacteria not only occurred in low numbers, but were not detected on some carcasses at all.

The cost of operation of this decontamination process would vary between works. At a works with a steam cost of $15.00/t and a water cost of $400/ML the operational cost of the unit described would approach $10/h.

Acknowledgements

We wish to thank the management and staff of the Northern Co-operative Meat Co., Casino for their assistance and interest in this project and also I.J. Eustace and B.A. Bill at the CSIRO Meat Research Laboratory for their assistance during the trials.

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Controlled atmosphere storage of kiwifruit using an ultra violet scrubber to remove ethylene

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Introduction

The presence of low concentrations of ethylene in the storage atmosphere are known to reduce the storage life of a number of fruits (Burg and Burg 1965; Knee and Hatfield 1981). Kiwifruit produce small amounts of ethylene and are sensitive to low concentrations of the gas during storage (Harris 1981).

Ventilation of a cool room during air storage may reduce the build up of ethylene, provided that the outside air is not polluted with the gas (Sherman 1985). In controlled atmosphere storage (CA), ventilation with outside air is restricted and ethylene accumulates. In small scale laboratory experiments, ethylene levels can be held at low levels by ventilating the storage atmosphere with premixed gases from cylinders. Harris used this method to examine the effect of 0.03μL/L ethylene on kiwifruit held in an atmosphere of 6% O_2, 15% O_2 and 79% N_2. He found that fruit exposed to ethylene softened faster (Harris 1981).

Scott, Guigni and Bailey (1984) showed that the packaging of kiwifruit in sealed polyethylene bags extended the storage life. The effect is due to a rise in carbon dioxide concentration and a fall in oxygen concentration in the bag. The inclusion of an ethylene absorbent with the fruit further extended the storage life. However, the need to pack fruit in bags soon after harvest may limit the use of this method. A possible alternative method of storage might be to hold the fruit in bulk in a controlled atmosphere room, fitted with an ethylene removal system. This should give better control over storage conditions and avoid the need to pack fruit before storage. Several methods for removing ethylene from a storage room have been studied. Ethylene may be removed by passing the storage atmosphere over a bed of potassium permanganate held on a suitable carrier. However high relative humidity which is desirable in CA stores reduces the effectiveness of the permanganate (Lister *et al.* 1985). Catalytic converters have been suggested for removing ethylene (Sherman 1985) but these are expensive and consume substantial amounts of energy (Shorter and Scott 1985). The Swingtherm method recirculated over a catalytic bed at ~600 °C and cooled before being returned to the storage room.

Gane (1935) reported that ozone could delay the ripening of bananas but produced skin injury. Blanpied *et al.* (1982) stated that ozone can be used to remove ethylene in laboratory experiments, but its corrosive nature and high cost made it unsuitable for commercial use. Blanpied (personal comm) also reported that the production of ozone by the silent electric discharge was greatly reduced when a low oxygen atmosphere, rather than air, was used as the source of oxygen. This is important because many possible applications for low ethylene atmospheres would also involve the use of a low oxygen atmosphere.

Scott and Wills (1973) reported that ultra violet (UV) radiation could be used to remove ethylene. The system requires two different types of UV lamp. One lamp radiates at both 184 nm and 254 nm ([1]Oliphant G36T15H). This lamp decomposes ethylene but also produces ozone, which accumulates (Fig. 1) and can damage fruit. The other lamp ([1]Oliphant G36T15N) radiates at 254 nm only and decomposes ozone. The use of both types of lamps allows the destruction of ethylene without a buildup of ozone (Fig. 2).

Recently this system has been simplified and the cost reduced (Shorter and Scott 1986) by using iron oxide to remove the ozone that is produced by the 184 nm radiation (Fig. 3).

This paper reports the results of a recent investigation on the use of the UV scrubber to provide low ethylene levels during the CA storage of kiwifruit.

[1] Manufacturer Oliphant Pty Ltd, South Australia.

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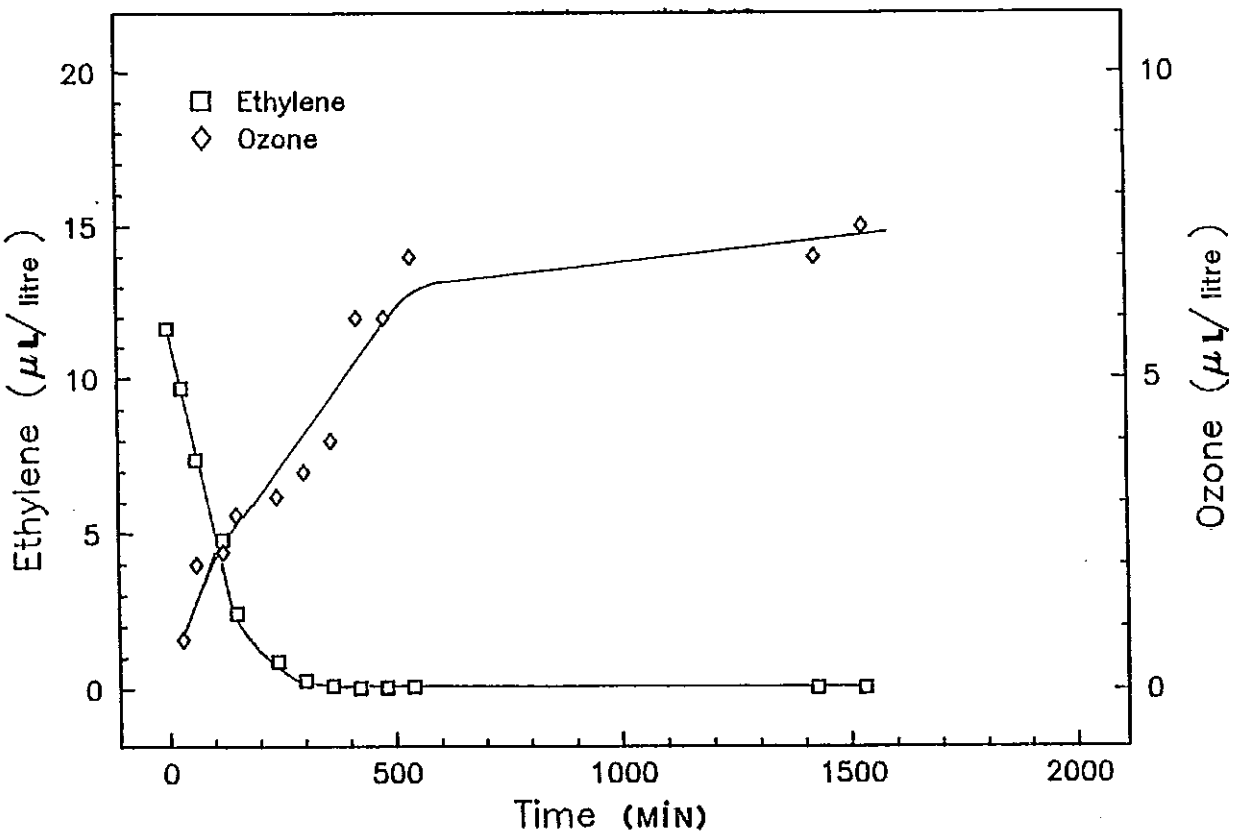

Fig. 1. The decomposition of ethylene in a gas tight space using an UV lamp (Oliphant G36T15H) radiating at 184 and 254 nm. Ozone accumulates with this system. (After Shorter and Scott 1986).

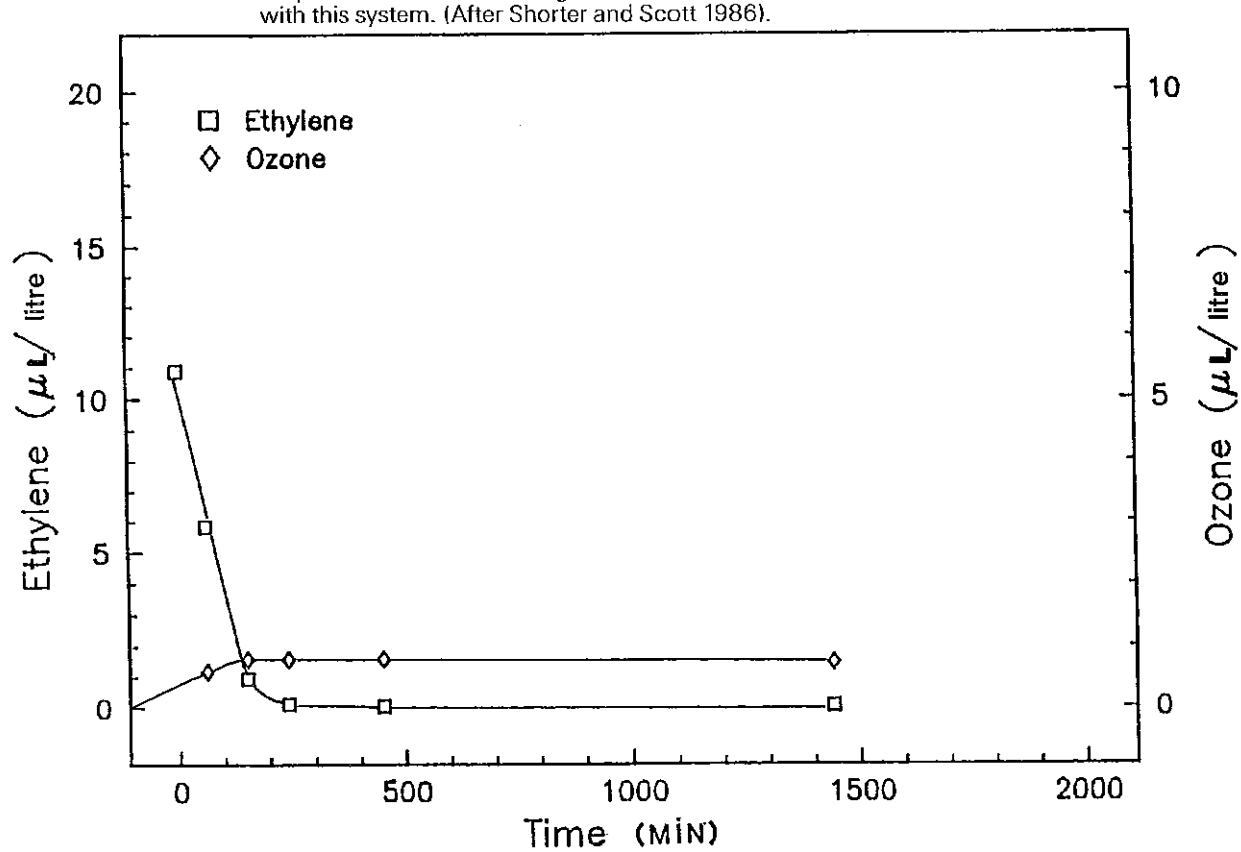

Fig. 2. The decomposition of ethylene in a gas tight space using two different types of UV lamp. The lamp in Fig. 1 was being supplemented by another lamp (Oliphant G36T15N) radiating at 254 nm only. Ethylene is decomposed at a similar rate but ozone concentration remained low. (After Shorter and Scott 1986).

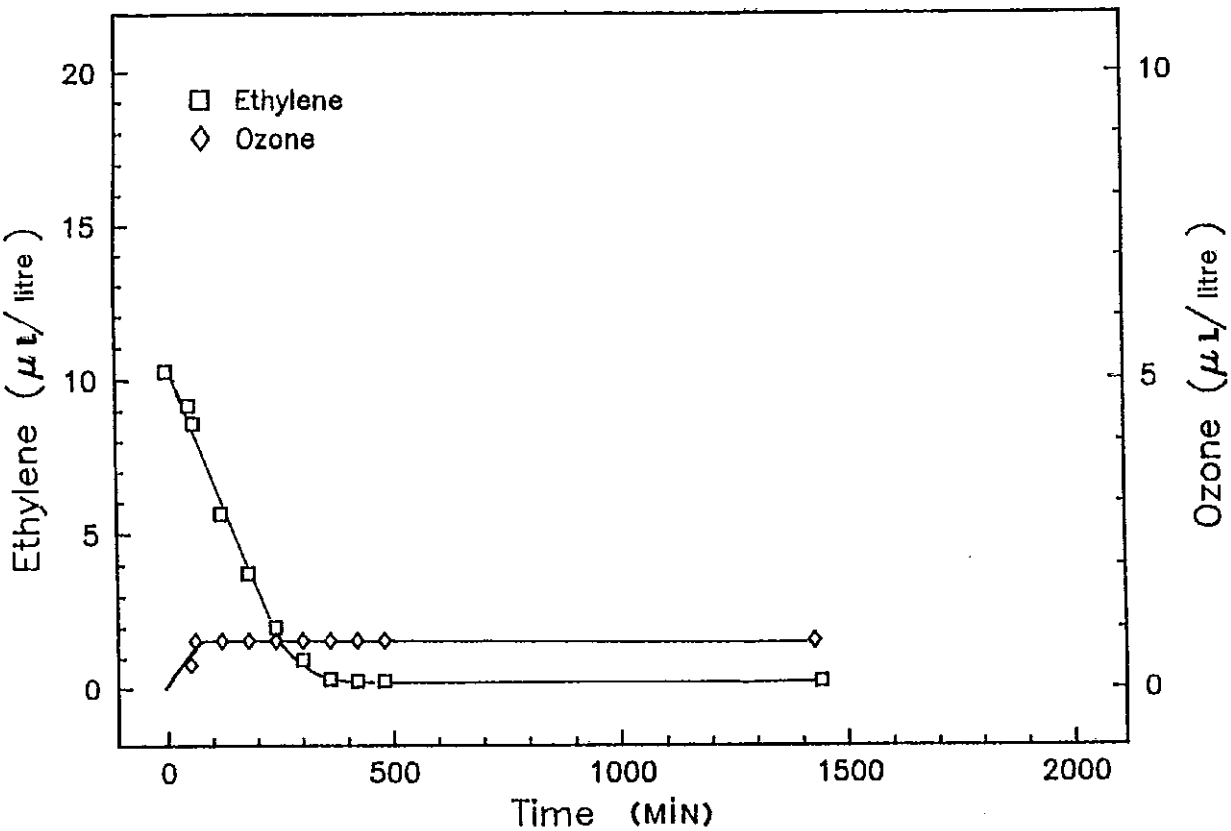

Fig. 3. The decomposition of ethylene in a gas tight space using a UV lamp (Oliphant G36T15H) radiating at 184 and 254 nm and iron oxide. Ozone concentrations remained low. (After Shorter and Scott 1986).

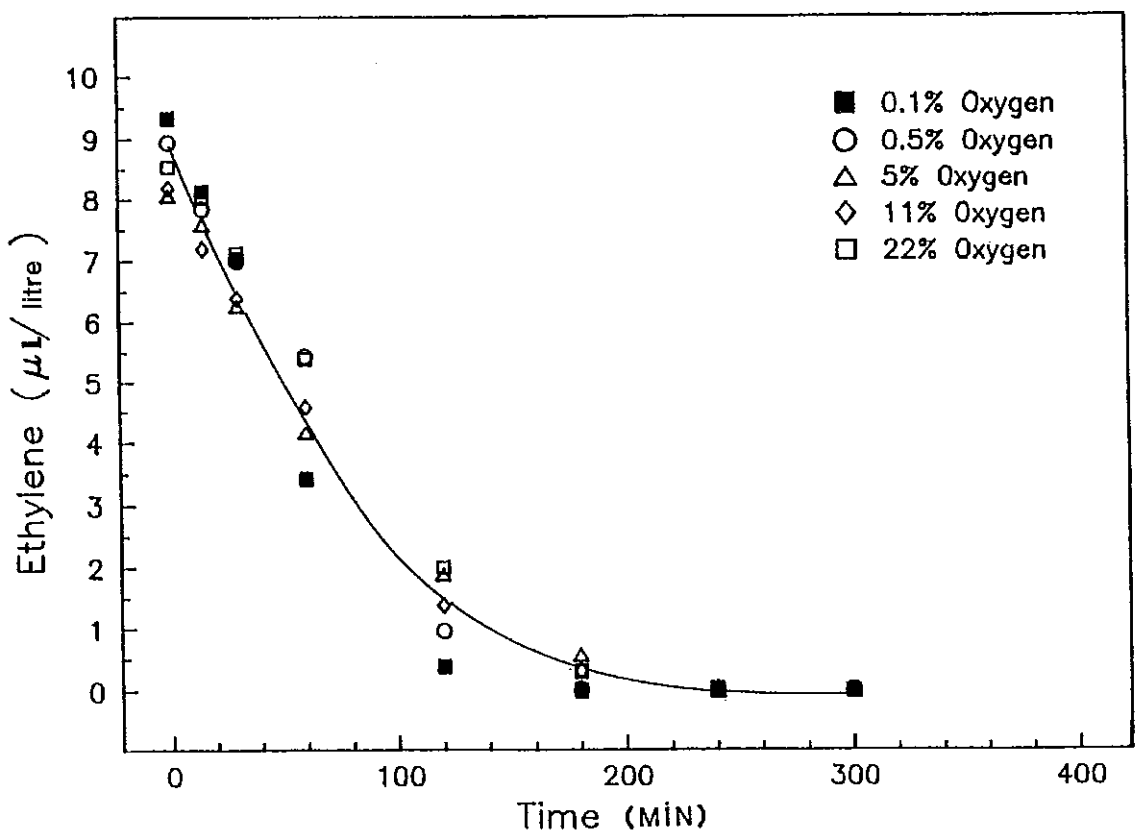

Fig. 4. The decomposition of ethylene under various oxygen concentrations, using UV radiation and iron oxide. (After Shorter and Scott 1986).

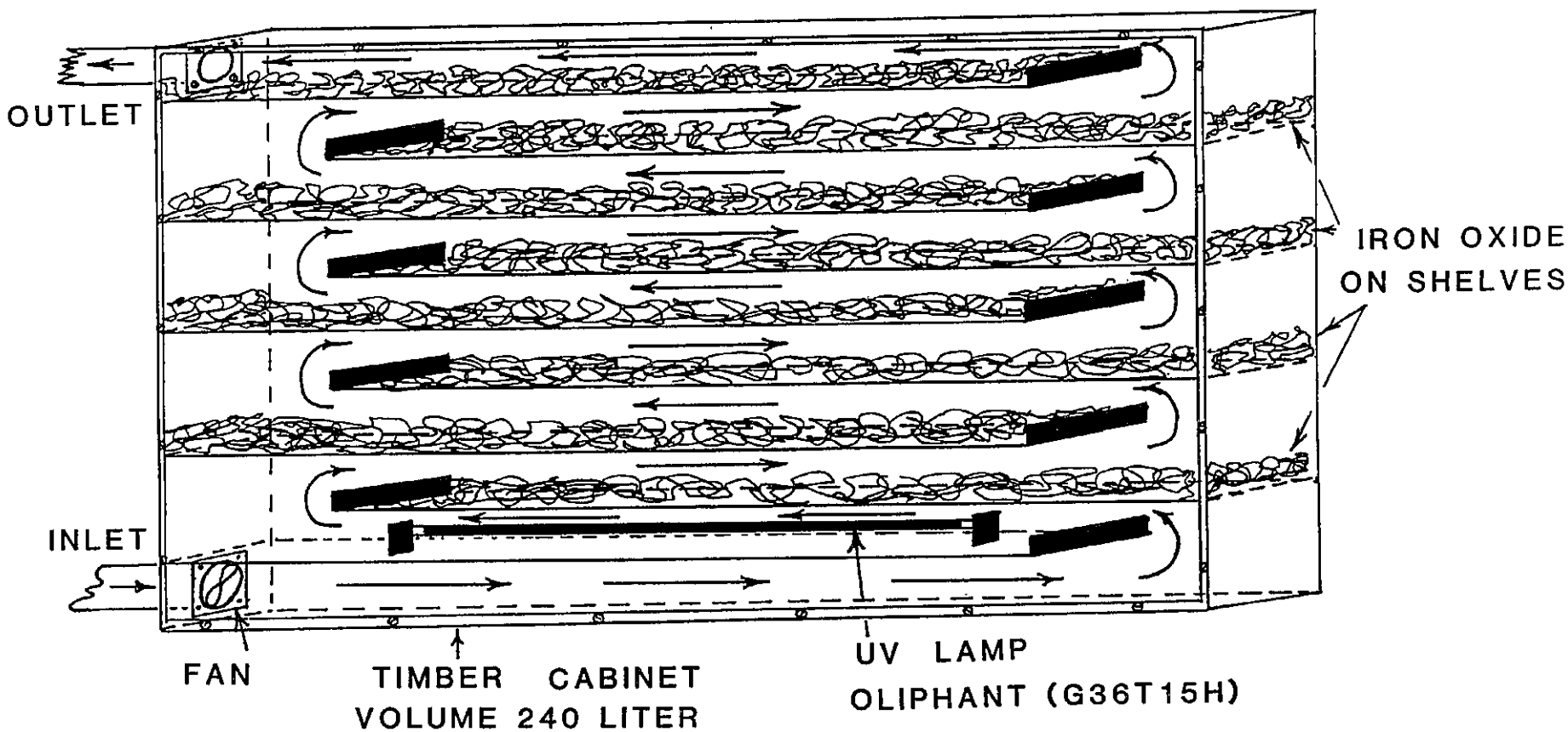

Fig. 5. Diagram of the wooden cabinet containing the UV scrubber (Oliphant G36T15H lamp + iron oxide on shelves) through which the storage atmosphere was passed.

Materials and methods

Two gas tight tents (Shorter and Scott 1987) were erected in a cool room operating at O °C at North Ryde. One tent was fitted with an UV scrubber. This consisted of a gas tight wooden box containing an UV lamp (Oliphant type G36T15H) in one section of the box and iron oxide, supported on shelves, in the other section of the box (Fig. 5). A fan circulated the atmosphere between the tent and the scrubber. A box containing hydrated lime was connected to the tent in order to control carbon dioxide concentrations. Compressed nitrogen was introduced into the tent to lower the oxygen level as required. Control fruit were held in the second tent, which was not sealed but maintained a high humidity and a similar storage temperature to that in the CA tent.

Fruit from northern NSW was stored in the tents during two seasons. Two cultivars, Haywood and Dexter were used in season 1 and one cultivar, Dexter, in season 2. The CA tent was sealed and ventilated with nitrogen to produce an atmosphere of about 3% oxygen. Carbon dioxide was held at ~5% during storage. It was found necessary to occasionally vent the tent with nitrogen to maintain the low oxygen concentration. The concentrations of carbon dioxide, oxygen and ethylene were determined by gas chromatography, soluble solids by refractometer and firmness by compression (scoring — 0 = very soft, 5 = very hard) using replicate samples of 10 fruit. The period (h) of operation of the scrubber was controlled by an automatic timer and the electricity used by the scrubber was determined by a power meter. Storage was terminated when control fruit had obviously softened.

Results and discussion

The concentrations of oxygen, carbon dioxide and ethylene during storage are shown in Fig. 6a, 6b (season 1) and Fig. 7a, 7b (season 2). In both seasons ethylene was held at <0.01 μL/L in the CA storage tent by the UV scrubber. Fruit of both cultivars softened more quickly in air storage than those in the controlled atmosphere (Figs. 8 and 9). In both seasons the soluble solids contents were higher with air storage than with controlled atmosphere storage (Fig. 10). The study demonstrates that the plastic tent and the UV scrubber are suitable for storing kiwifruit under CA with low ethylene concentrations.

During CA storge at O °C the scrubber maintained ethylene at <0.01 μL/L ith 800 kg of fruit in the tent. The power consumption of the scrubber was 110 watts (lamp 30 watts, transformer 70 watts fan 20 watts). This operated for 2 h per day, thus 0.22 kwh was required per day. If it can be assumed that the amount of ethylene removed is directly related to the duration of operation of the scrubber, then the power consumption for continual operation of the scrubber would be 2.6 kwh per day and this should remove the ethylene produced by 9.6 tonnes of fruit.

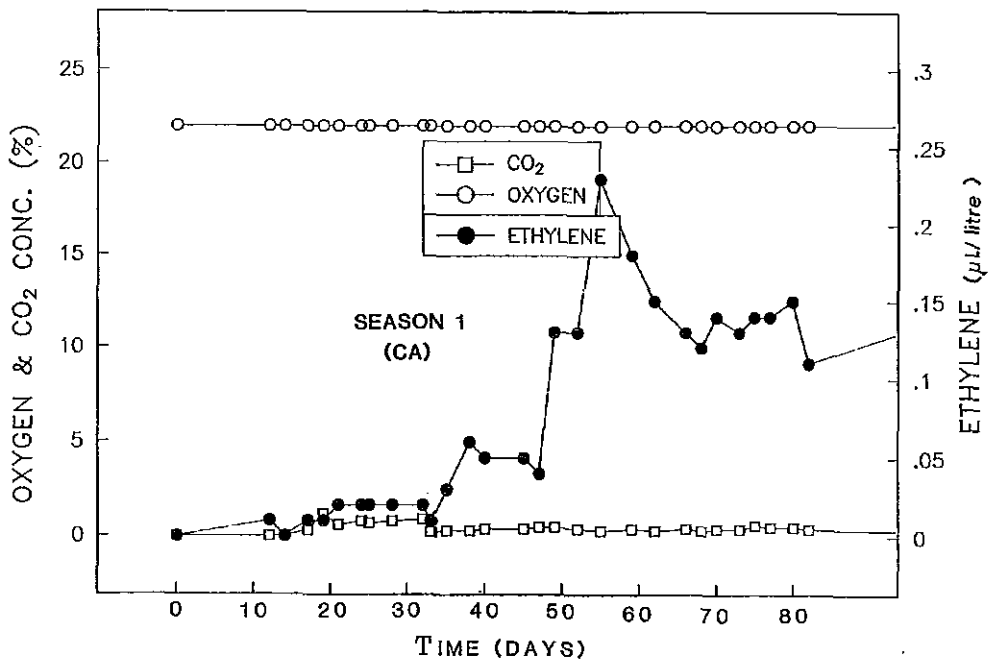

Fig. 6A. Carbon dioxide, oxygen and ethylene concentrations in controlled atmosphere storage (season 1).

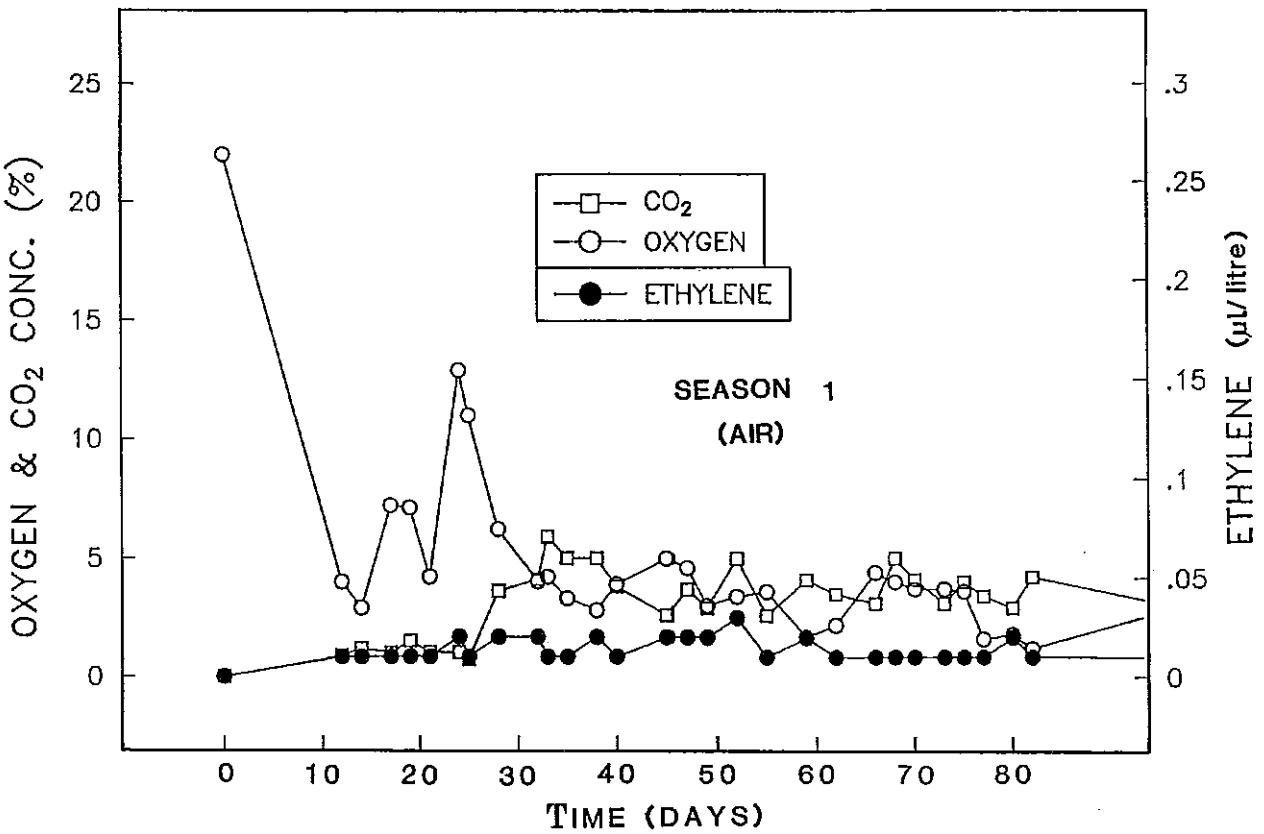

Fig. 6B. Carbon dioxide, oxygen and ethylene concentrations in air storage (season 1).

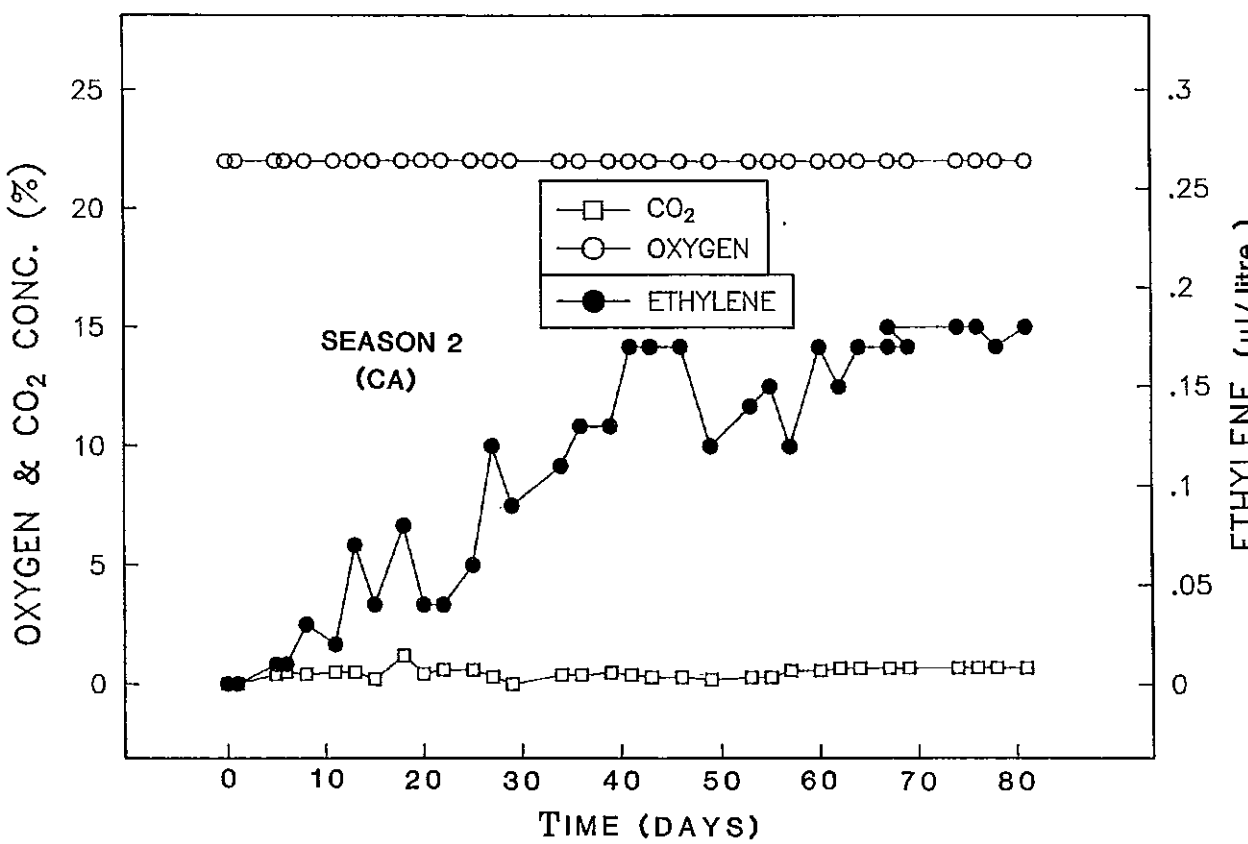

Fig. 7A. Carbon dioxide, oxygen and ethylene concentrations in controlled atmosphere storage (season 2).

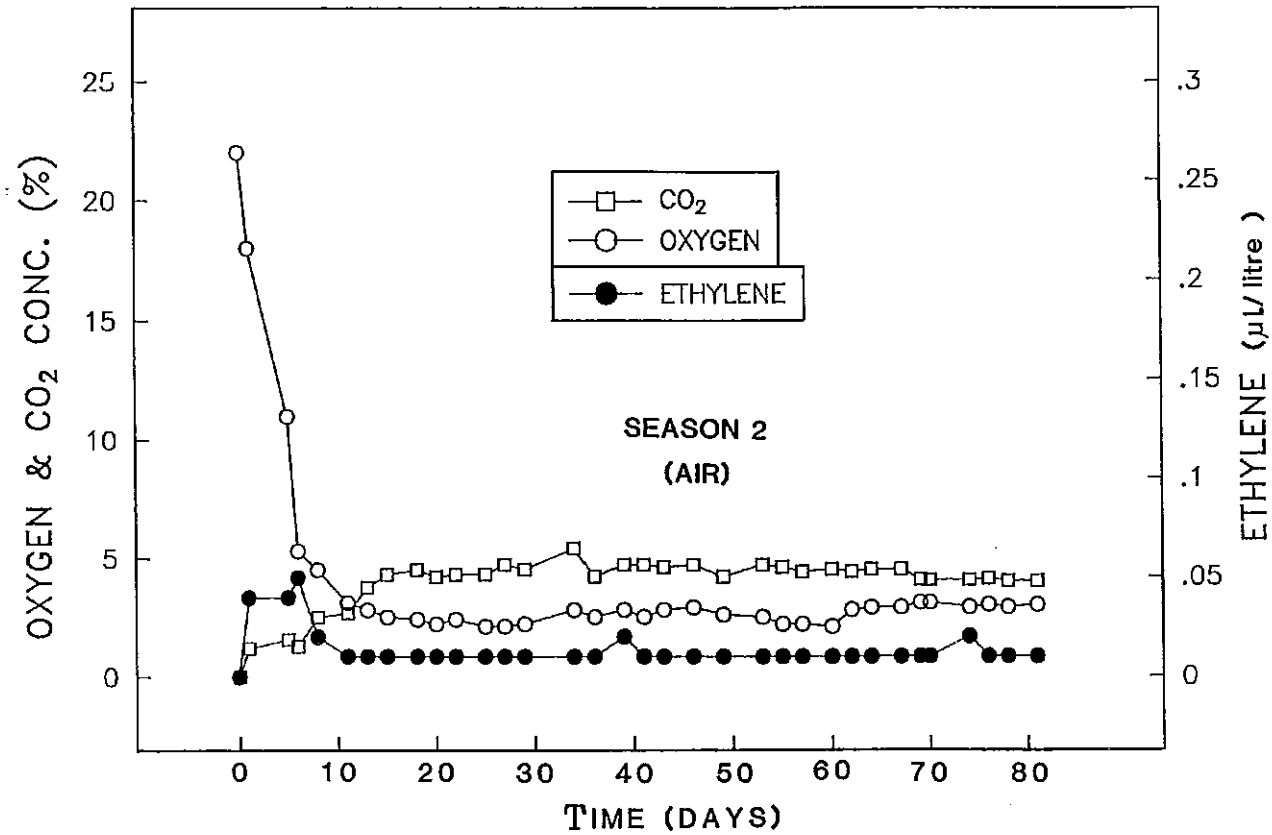

Fig. 7B. Carbon dioxide, oxygen and ethylene concentrations in air storage (season 2).

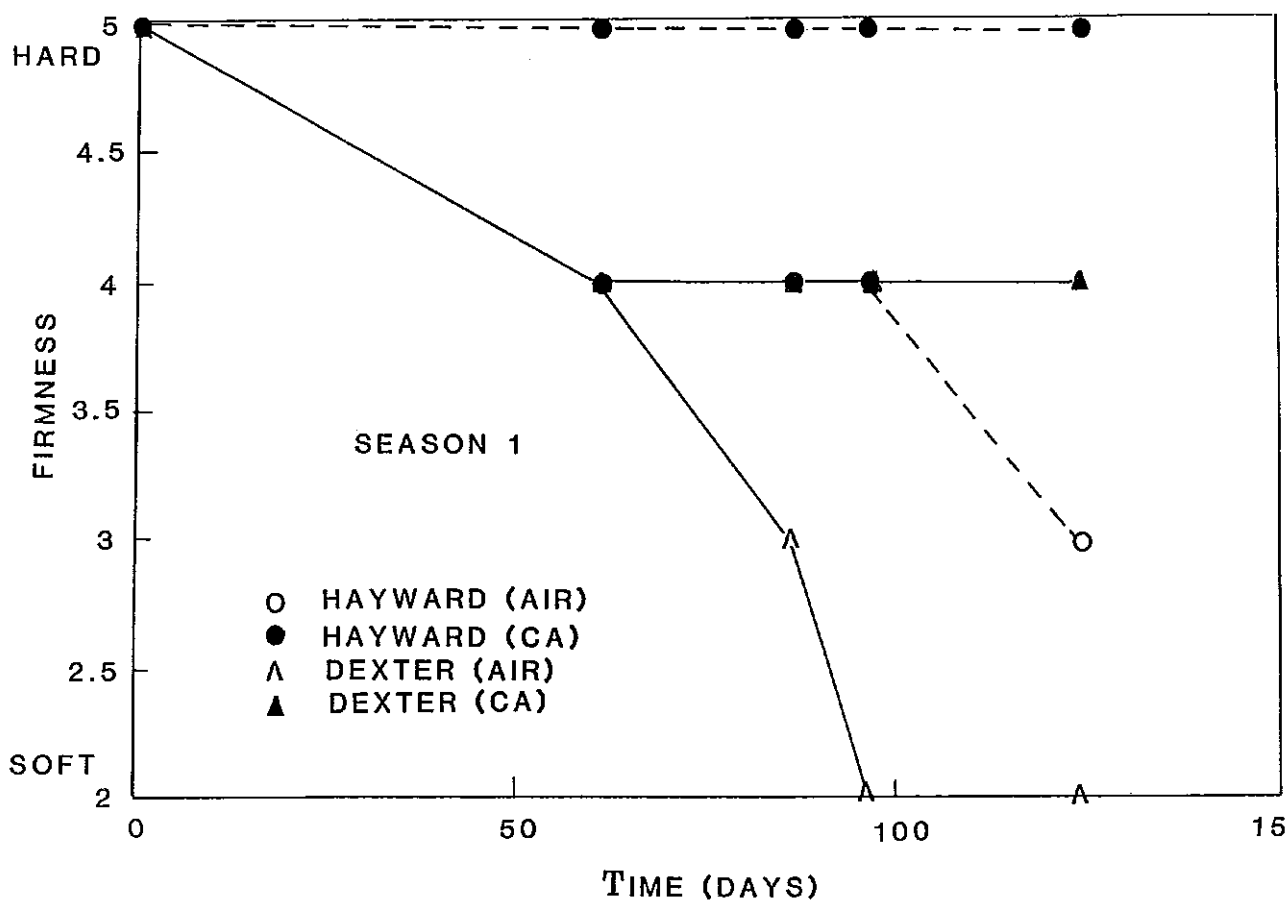

Fig. 8. Firmness of kiwifruit cultivars (Hayward and Dexter) during storage (season 1).

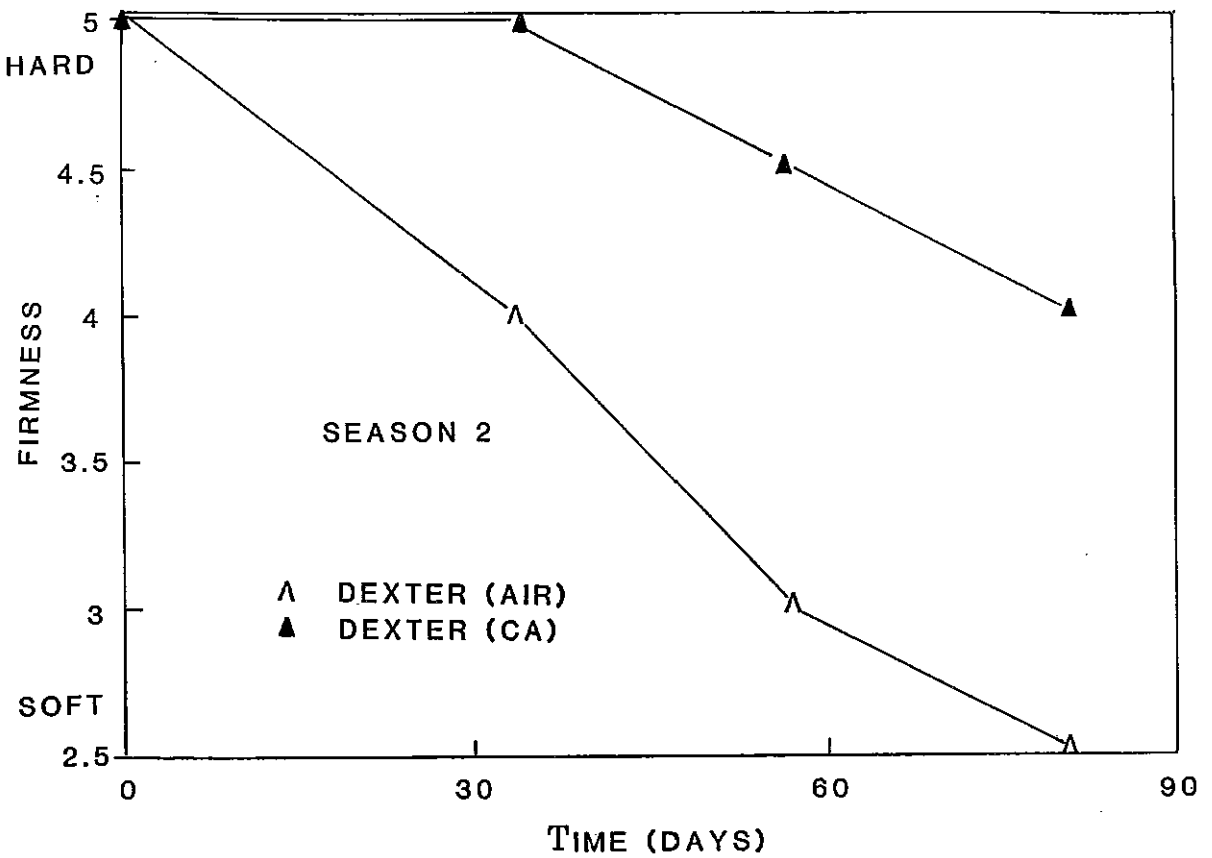

Fig. 9. Firmness of kiwifruit (Dexter) during storage (season 2).

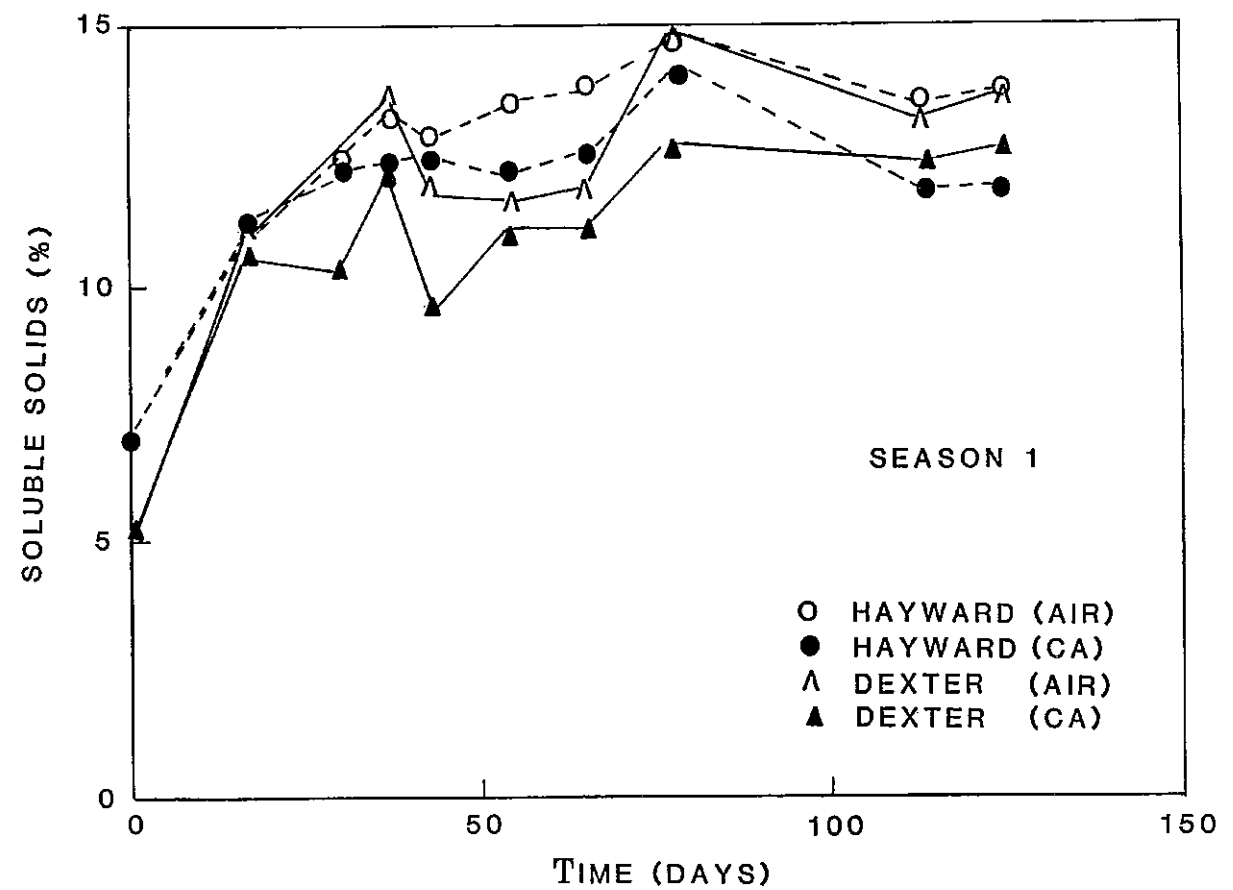

Fig. 10A. Total soluble solids of kiwifruit during storage at 0 °C in air and in a controlled atmosphere (season 1).

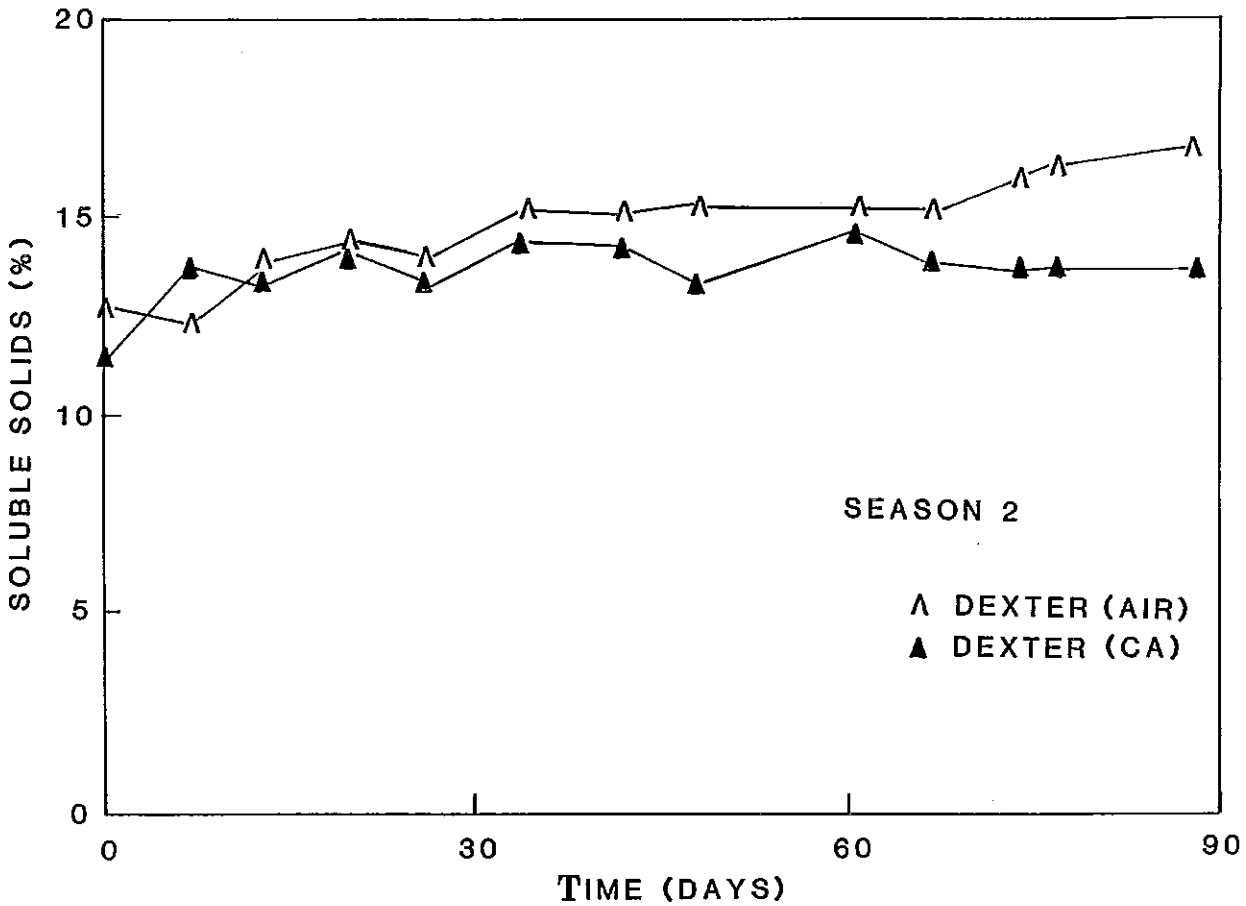

Fig. 10B. Total soluble solids of kiwifruit during storage at 0°C in air and in a controlled atmosphere (season 2).

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News from the Division

Retirements

P.W. Board

Peter Board joined the CSIRO Division of Food Preservation and Transport, as it then was, in February 1950, soon after graduating from the University of Sydney with the degree BSc (Hons) in physical-inorganic chemistry. He was appointed to the Fruit Products and Canning Section to work on "chemical and physical definition of quality in canned foods", and within three months of his appointment Dr J.R. Vickery, Chief of the Division, described him as showing "outstanding initiative and energy". Now at the time of his retirement 37 years later it could be said that Peter's entire subsequent career was foreshadowed in that original assignment and in those attributes of his personality.

His qualities of leadership and drive were recognized when in 1956-57 he was placed temporarily in charge of the branch laboratory which the Division established in the CSIRO Tasmanian Regional Laboratory in Hobart. Then in 1970 he was made Leader of the Food Technology Section of the Food Research Laboratory at North Ryde, and in 1977 Leader of the Applied Food Science Group. He retires from this position with the status of Senior Principal Research Scientist. He is widely respected by his colleagues for his enthusiastic, imaginative, but unselfish approach to the management of research.

Peter Board has published more than 100 scientific and technical papers which represent significant contributions to an astonishing range of areas in food technology, and notably in canning technology. In particular he is the leading Australian authority on the safe heat processing of canned foods and on corrosion in tinplate containers. His standing has been recognized by many committee and consultative appointments within Australia and abroad. He served as Chairman of the Australian Standards Association committees on equipment for thermal processing of canned foods and on double seams for cans, and as a member of the committee on surgical implants as an expert on the electrochemistry of corrosion. At the request of CAFTA he wrote the Code of Practice for Thermal Processing of Low-acid Canned Foods for submission to the MHMRC Food Standards Committee. For many years he has been a member of the Australian Defence Forces Food Specifications Committee. Following a disastrous case of spoilage in Australian canned meat in Britain he was called upon by the Department of Primary Industry to assist in the upgrading of meat canning technology and inspection services. He achieved these objectives by organizing a series of training courses and compiling a manual which has been widely used in Australia and overseas.

On two occasions Peter has been a member of the Australian delegation to meetings of the Codex Alimentarius Commission Committee on Processed Meats in Copenhagen. In 1969 and 1982 he undertook CSIRO study tours to food research centres and food industry establishments in Asia, USA and Europe. He visited India as technical adviser to a World Bank project and was twice invited to visit Uruguay to advise on food processing technology.

In addition to his research and technical commitments Peter Board has thrown himself with vigour into activities concerned with the welfare of his professional colleagues. After serving in several capacities in the CSIRO Officers Association he has recently completed a term as President of the NSW Branch. He was a founding member and is now a Fellow of the Australian Institute of Food Science and Technology; he was Chairman of the NSW Branch in 1974 and Chairman of the AIFST Working Party on Australian Food Inspection Services, and in 1981 he was honoured with the AIFST Award of Merit for meritorious achievement in food science and technology. For six years he was the Chairman of the Editorial Committee of the *CSIRO Food Research Quarterly*.

Peter Board has been eminently successful in establishing cordial relations with technologists and management in the food industry and in related government departments. At some expense to his own research career he has devoted himself to the technical welfare of the industry and has successfully resolved many challenging problems by inspired thinking and application of advanced methods of investigation.

Dr Keith Boardman, Chief Executive, recently described the present role of CSIRO in part in these terms: ". . . it is necessary in the national interest for CSIRO to assist in the development of innovative new products and in solving the more difficult routine problems of production" (*CSIRO Industrial Research News* 1987 (March) 181, 6). Peter Board has been serving the national interest in exactly these ways for more than 30 years.

J.F. Kefford

G.T. Lloyd

Geoff Lloyd graduated Ph.D. from the University of Wales in 1961. He worked as a Development Chemist with the Milk Marketing Board of England and Wales from 1961 to 1965 and as a Dairy Research Officer at the (then) Gilbert Chandler School of Dairy Technology, Werribee, from 1965 to 1968.

Geoff joined the (then) CSIRO Division of Dairy Research in 1968 to work on the development of methods for producing deep-frozen concentrated cheese starter cultures under the direction of Mr E.G. Pont.

Having developed a successful technique for the preparation of concentrated cheese starter culture, Dr Lloyd proceeded to test them in full-scale commercial cheese manufacture. They proved successful and Geoff passed on all relevant information to (then) Mauri Bros and Thomson, who became manufacturers of concentrated starters.

In recent years, Geoff has been involved with a major study in conjunction with Eric Ramshaw, on the flavour compounds in cheese in relation to cheese maturation.

On retirement, Geoff has taken up residence in Queensland.

E.H. Ramshaw

Eric Ramshaw joined CSIRO in 1960 after graduating with a Ph.D. from Cambridge, specializing in organic chemistry.

Eric was first appointed as an Experimental Officer with the (then) Division of Dairy Research. For two years, Eric worked on the gluey flavour defect in casein.

In 1962, Eric Ramshaw was appointed a Research Officer at the Dairy Research Division to work with the Flavour Group. Eric's work centred on the flavour in stored milk protein. He examined the effect of processing parameters on the development of the flavour and characterized the volatile components associated with the off-flavour.

Flavour chemistry methods developed by Eric Ramshaw and the Flavour Chemistry Group were used by the CSIRO Division of Horticultural Research to identify the volatile components of grapes and wine.

Eric was also involved with flavour studies on Feta cheese, flavour compounds in maturing cheese and studies on the off-flavours of chlor-phenolic origin in dairy products. The Flavour Chemistry Group was ably led by Eric.

When not working on flavour studies at the Dairy Research Laboratory, Eric's time is greatly taken up by bridge. Eric is a master player, taking part in many international as well as national competitions. Colleagues wish him well in his retirement.

News from the Division

CSIRO Division of Food Research
Consulting, collaborative research and advisory services

The Division of Food Research through its scientists at Dairy Research Laboratory, Food Research Laboratory and Meat Research Laboratory is available to assist the food and allied industries through the provision of consulting, collaborative research and advisory services. CSIRO policy requires that such services are charged for at commercial rates. Subject to compliance with government guidelines industry could be eligible for taxation concessions up to 150% of expenditure on research and development. Further information on eligibility for tax concessions can be obtained from the Department of Industry, Technology and Commerce, Canberra, ACT.

Class 1. Advisory and Standard Investigatory Services

Advisory work which requires more than 1 hour will be done by the Liaison staff at the Laboratory concerned and charged for at the rate of $70 per hour — the first hour being free. Where routine investigatory work is required similar charges will be made. Travel and related expenses will be charged for at cost.

Class 2. Research Investigatory Services

Research investigations of a non-routine nature which require the diversion of research scientists from strategic research will be charged for at the rate of $85 per hour or $590 per day plus full reimbursement of laboratory consumables, travel and related expenses if any.

Class 3. Contract/Collaborative Research

On a case by case basis the Division is willing to consider proposals for contract and collaborative research and development projects on terms that are negotiable to the mutual satisfaction of the parties concerned.

Class 4. Consultancies

Consultancies will be charged for at $100 per hour or $700 per day plus full reimbursement of all travel and other expenses.

All rates will be reviewed annually.

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