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Export Cauliflower Quality Improvement

1996-1998

V McVeigh, R Lancaster, D Phillips & SC Tan

Agriculture WA

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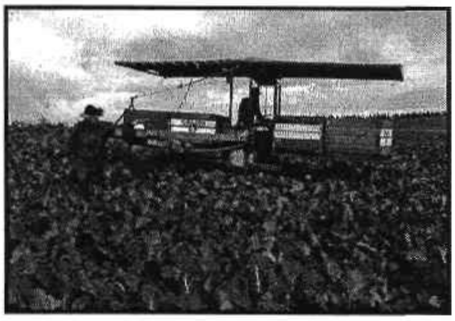


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Final report for the project VG 94043
January 1996 to December 1998

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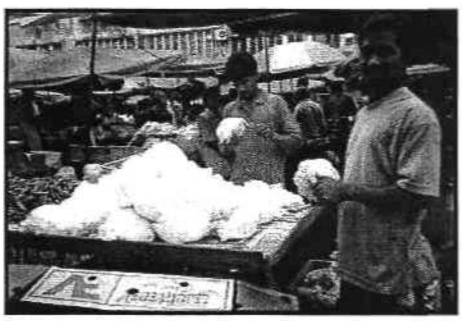


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Dennis Phillips
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Project VG 94043

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1. Summaries

1.1. Industry summary

This three year study is the first conducted in Australia which has evaluated and assessed the postharvest chain for export cauliflowers. From harvesting to transportation to the wharf, the project has identified a range of improved practices to ensure optimum quality of cauliflower at the destination market. The project has also examined cauliflower agronomy issues such as the effect of seed weight, seedling weight and phosphorus nutrition and placement on yield and harvest period, as well as variation in potting mix composition within a seedling cell tray.

Producing and exporting about 15 000 tonnes per year of fresh cauliflower to the Singaporean and Malaysian markets, the Western Australian export cauliflower industry recognised the need to maintain market share for the Australian product by supplying the market with consistently superior quality than competing suppliers. The industry realised that Australia cannot compete on price alone in export markets, hence the "Export Cauliflower Quality Improvement" project was initiated to identify and consolidate "best production and handling practices".

The project has identified several management practices to improve the quality of cauliflower at outturn that will benefit the Western Australian export industry and ultimately Australia's competitive position within this market sector.

Bruising
Bruising during field handling and transport was identified as the major contributor to poor outturn of cauliflower after storage. It was directly related to curd blackening (black spot) development in curds exposed to short periods of high temperature and humidity after cool storage. The project confirmed that overmature cauliflowers are more susceptible to bruising. Therefore harvesting cauliflower at their peak maturity or even slightly immature, is critical to ensure quality at outturn is optimised. Practices that maximise uniformity of maturity and thus minimise the number of harvests required to completely harvest the crop, need to be adopted by growers. More uniform maturity should minimise the opportunity for curds to go overmature between harvests.

Precooling
Improved precooling practices such as shortening the length of time cauliflowers are stored and regular checks on core temperature and relative humidity of the coolroom, will improve cauliflower shelf life at the destination. The precooling coolroom is designed to remove field heat from cauliflowers and cool them to a core temperature of 0-1°C. Achieving optimum core temperature should take about one day. However, cauliflower in bulk bins can be stored for up to five days in the coolroom in periods of peak supply. Cauliflowers precooled for a shorter period will have lower levels of curd weight loss resulting in higher returns to growers who are paid on a packed weight basis. The project identified that three out four packing houses could have improved the operation of their precooling coolrooms at the time they were tested.

Field and nursery production
Cauliflower seed weights had no influence on germination rate, yield or maturity. However, it was discovered that those seeds that had germinated late (after four days) produced poor quality seedlings or failed to produce a seedling. It was also found that heavier seedlings, for both the normal and SuperFrax® seed grades, went on to produce a significantly higher yield than light seedlings.

The composition of potting mix in a 200 cell tray is not the same across the entire tray suggesting another reason why there is non-uniformity among seedlings from the nursery. The agronomy trials also determined that the current industry practice of applying phosphorus (twin offset bands at planting) is a satisfactory method during summer transplanting providing the rate is at least 160kg/ha (P). During the winter, the application of extra phosphorus in the potting mix at the nursery may increase yields. Phosphorus nutrition does not influence the spread of harvest at any time of the year.

Transport
Results showed that road transport is not a weak link in the cool chain process. Both Pantech® and Tautliner® refrigerated trucks used by the industry have excellent cooling capacity with only a 0.5°C increase in core temperature of packed cauliflowers recorded during the 300 km trip from Manjimup to Fremantle. However, the initial core temperature of the product before dispatch is often above the recommended temperature for transport. The project confirmed that a reduction in quality is not necessarily due to high transit temperature, but may be due to the way the product was handled prior to dispatch. Length of time in the precooling coolroom and the core temperature of curds at the time of packing prior to dispatch may contribute to a reduction in quality.

Hydrocooling and chlorination
Hydrocooling is a quicker method of precooling than room cooling. Cauliflower curds were hydrocooled to a core temperature of 3°C after a one hour dipping in cold water (less than 2°C). Room cooling cauliflowers resulted in a core temperature of 6°C after 20 hours and forced air cooled cauliflowers were 1.8°C after 20 hours. Chlorination of hydrocooling water significantly decreased the amount and severity of postharvest rots and curd blackening after 3 weeks at 2°C and 6 days warm store at 24°C. The process offers great potential for improving outturn quality of the product and needs to be investigated further.

Field management practices
Overmature and pink or yellow curds account for about 13% of crop loss in the field (Shellabear, 1995). The current sequence of field harvest events is one curd cover operation, followed later by two cover and harvest operations, and finally two harvest only operations without leaf covering. A cost/benefit study confirmed that one extra harvest and cover operation addition to the current practice would recover 30% of the losses currently attributable to pink or yellow and 50% of the overmature losses. The cost of recovering 50% overmature and 30% yellow/pink curds is approximately \$750/ha for a return of \$892/ha, earning the industry an extra \$500 000 based on current production levels.

1.2. Technical summary

This three year study is the first conducted in Australia that has evaluated and assessed the postharvest chain for export cauliflowers. From harvesting to transportation to the wharf, the project has identified a range of improved practices to ensure optimum quality of cauliflower at the destination market. The project has also examined cauliflower agronomy issues such as the effect of seed weight, seedling weight and phosphorus nutrition and placement on yield and harvest period, as well as variation in potting mix composition within a seedling cell tray.

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The major findings of the project were:

- Bruising of cauliflower curds is directly related to curd blackening after a period of cool storage and subsequent exposure to ambient temperature and high humidity.
- Overmature cauliflowers, ie. those with separated shoulder florets, are more susceptible to bruising than immature cauliflowers.
- April/May is the worst time of the year for curd blackening at outturn. The disorder is thought to be caused by dehydration and subsequent oxidation. Secondary infections with bacterial and fungal rots are often associated.
- Precooling methods of some Manjimup packing houses needed improvement at the time of testing. Slow precooling times were a common problem as were inappropriate loading temperatures.
- Precooling cauliflowers for 24 hours resulting in a final core temperature of 5-8°C could not be shown to result in poorer quality at outturn than more rapid cooling.
- Plastic bubble wrap bin liners reduced air flow through field bins resulting in approximately 50% longer precooling times than loose filled bins.
- Plastic bubble wrap sheets between each layer of cauliflower within the bulk bin, slightly reduced bruising and allowed cool air to pass through the cauliflowers resulting in faster precooling rates than where bin liners were used.
- Cauliflower bins can be left in the field awaiting transport to the packing house for up to 8 hours without adversely affecting quality of cauliflower curds, providing ambient temperature does not exceed 31°C.
- Cauliflower seed weight had no influence on the rate of germination, final yield or spread of harvest.
- Those seeds that are late in germinating (four days to germinate) produce poor quality seedlings.

- Heavier seedlings produce higher yields than lighter seedlings (for both normal and SuperFrax® seedlings).
- A seedling cell tray of 200 cells may not have uniform potting mix composition across the whole tray suggesting a source of seedling non-uniformity.
- During summer, the application of phosphorus at 160kg/ha in twin offset bands at planting achieved higher yields than other phosphorus treatments.
- During winter, an application of extra phosphorus in the potting mix at the nursery may also achieve higher yields than current practice.
- Phosphorus nutrition has no affect on the spread of harvest at any time of the year.
- Road transport by Tautliner® or Pantech® was not a source of significant product deterioration because these trucks have the cooling capacity to maintain core temperature of cauliflower.
- Some packaging materials such as certain carton liners and individual bags, are not suitable for cauliflower storage and marketing.
- Paper wrapped cauliflowers lose more weight than modified atmosphere packaging but differences in quality between paper wraps and modified atmosphere packaging are small after 3 weeks at 1°C and 2 days at 20°C.
- Hydrocooling as a precooling process, reduce core temperature of the cauliflower curds much faster than conventional or forced-air cooling with minimal or no weight loss.
- Hydrocooling cauliflowers with 100 ppm of chlorine significantly reduced rots and curd blackening after 3 weeks at 2°C and 2 days at 24°C.
- Market specifications and consumer requirements for the Malaysian market were confirmed by a consumer survey in Kuala Lumpur.
- Two additional curd covering operations to the current common industry practice of one curd covering, two covering and harvest operations, and two harvest only operations, recovers about 50% of pink/yellow curds that are currently rejected at harvest with the normal grower practice. To recover 30% of pink/yellow losses and 50% of overmature losses, an extra harvest and cover operation should be done.

2. Recommendations

2.1. Harvest maturity

Bruising is associated with accelerated curd blackening in storage (black spot). Bruising was measured by the severity of black spot, rots and blemishes. Findings indicate that grossly overmature cauliflowers are more susceptible to bruising and development of rots/blemishes during autumn (April/May).

To minimise poor outturns in South East Asian markets, cauliflower curds should be harvested before any loose floret development and avoid practices resulting in bruising injury such as dropping the cauliflower, applying too much pressure when cutting the curd and general rough handling. This may be important for industry that a shift to harvesting less mature or immature cauliflower should improve outturn quality. A change in production systems needs to be investigated to assess viability of such a finding.

Further work should be undertaken to determine the reason why curds are more susceptible to black spot and rots/blemishes during autumn. Research into initial populations of resident bacterial pathogens on the surface of the curd should be done to determine whether bacterial colonisation of aerial plant parts may be more prolific during autumn after damage has occurred.

2.2. Precooling

2.2.1. Testing commercial coolrooms

Results have found that storing cauliflower curds for 24 hours resulting in a core temperature of 5-8°C does not result in poor quality of cauliflowers at outturn. However, complacency with precooling should be avoided as three out of the five packing houses monitored could have greatly improved the performance of their precooling rooms.

In consultation with industry, the following have been identified for close examination at each packing house:

- Regular core temperature checks of cauliflower before packing and relative humidity of the coolroom monitored.
- Keep door closed at all times (particularly during summer).
- Check door seals from inside the room (with lights off, light from outside shows through the gaps).
- Obtain a higher relative humidity by wetting the floor of the coolroom or attach water misters from the roof and use intermittently. With free water in the coolroom, hygiene must be practiced by scrubbing the floors and walls with chlorine to avoid mould growth.
- All refrigeration machinery such as the evaporator should be kept clean. Dust and fluff can gather on the air entry side of the evaporator, reducing air flow which can increase temperature in the room (Story 1989).

These are all "critical control points" that need to be considered in future quality assurance programmes for the industry.

To isolate the effects of inadequate precooling on the quality of cauliflowers, this study should be repeated but have a precooling period more representative of industry practice, that is, 2-4 days of precooling not 24 hours.

2.2.2. The effects of bin liners on precooling

Results showed that using bin liners around the bulk bin reduces air flow thus resulting in longer precooling times to remove field heat. This in turn causes greater weight loss and reduces quality. Bubble wrap sheeting between the layers slightly improves quality of curds as bruising is reduced. The size of the bubble wrap sheet should be the same as the internal dimensions of the bin. If the sheet is too large the overlap tends to run up the side of the bin creating a similar effect as a bin liner. The recommended bin treatment is to use the bubble wrap sheeting between each layer of cauliflower curds in the bin. The grower must make sure that oversize sheets are folded down away from the side of the bin so that the gaps in the sides of the bin are not blocked.

2.3. Field handling studies

This work confirmed that curds in bulk bins left in the field for up to 8 hours suffer small reductions in curd quality, weight loss and financial return at outturn. Beyond 8 hours in the field before precooling, quality deteriorates. Although this work did not show that time in the field (up to 6 hours) adversely affected quality, it is still recommended to deliver cauliflowers to the packing house as soon as possible.

2.4. Seed, seedling and nutritional factors affecting yield and harvest period

2.4.1. Seed weight

Seed weight cannot be used as an indicator of final yield. However, late germinating seeds (not related to seed weight) produce poor quality seedlings and ultimately low yields and quality. If a pre-germination and seeding method was devised which enabled identification and elimination of late germinating seeds then this would increase field recovery rates, improve quality and increase profit per hectare.

2.4.2. Seedling weight

A simple cost effective technique needs to be developed in the nursery to identify heavy seedlings. Heavy seedlings produce higher yields than lighter seedlings. It is likely that the extra cost of not planting light seedlings in the field would be outweighed by increased returns from the higher yields that heavier seedlings would produce.

2.4.3. Nursery practice

Further mixing of potting mix by nurseries is suggested to ensure that the potting mix composition within each cell of a seed tray is more uniform. This may reduce the variation in seedlings making more uniform plants for transplanting into the field. Other strategies such as supplying all nutrients more uniformly through irrigation water need investigation compared to current practice. Application of extra phosphorus in the potting mix at the nursery during winter may also increase yields.

2.4.4. Phosphorus nutrition and placement

Phosphorus nutrition does not influence the spread of harvest during any time of the year. Application of phosphorus in a twin offset band at planting with a rate of at least 160kg/ha

(P) during summer transplanting, had the highest yield compared to other phosphorus treatments.

2.5. Road transport evaluation

Both the Pantech® and Tautliner® refrigerated semi-trailers maintained core temperature of the packed cauliflower plus or minus 0.5°C for a 5-6 hour period. Problems existed with time delays in precooling, incorrect loading disrupting air circulation within the refrigerated van and the inability of coolrooms to bring curd core temperature down to optimal levels prior to dispatch.

To overcome these problems the following is recommended:

i) Precooling of cauliflowers should be no longer than four days to reduce excessive weight loss (cauliflowers can be precooled for 3-5 hours to achieve 1-2°C, however cauliflower curds are sometimes left in the precooling room for up to 5 days because of pack house supply management problems).
ii) Ensure air flow is not disrupted by having a free air path down the sides and rear of the van, have pallets on the floor and a solid return air bulkhead with bottom air entry.
iii) Precool cauliflower to a core temperature of at least 1°C (see recommendation on precooling). This will allow the Pantech® or Tautliner® to maintain the 1°C core temperature ±0.5°C.

Packers should be consulting with cooling engineers to assess the suitability of their cooling units for what they are trying to achieve. Implementation of a quality assurance process to ensure that packers are achieving the desired result is recommended.

2.6. Packaging

Some wrapping materials assessed were not beneficial in extending shelf life. Most individual bags and carton liners did not create suitable oxygen and carbon dioxide levels to achieve the desired effects of modified atmosphere storage. For example, the high density polyethylene bag created an atmosphere too low in oxygen and induced anaerobic respiration. For those wrapping materials that were able to extend shelf life of cauliflower, the beneficial effects were not great. Further investigations should be carried out to find the ideal wrapping material for cauliflower.

2.7. Hydrocooling and chlorination

Chlorine reduces postharvest rots and curd blackening when cauliflowers are hydrocooled. Hydrocooling is a much quicker method of precooling than forced air cooling and percent weight loss per curd is also halved with hydrocooling. It is recommended that a cost benefit analysis is done to determine the cost effectiveness of hydrocooling cauliflower compared to forced air cooling.

2.8. Better leaf covering

Curds that are overmature and yellow account for 11.1% of total crop loss and costs the industry about $1.1m (assuming total yield is 25t/ha and farm gate price is 85c/kg) (Shellabear, 1995). The industry standard is to perform one leaf covering prior to harvest, two harvest and cover operations then two harvests. From the cost benefit analysis, it is recommended to perform two additional curd cover operations to recover approximately 50% of pink/yellow losses or perform one extra harvest and cover operation to recover 30% of pink/yellow losses and 50% of overmature losses. The nett benefits of the two options are \$320/ha and \$142/ha respectively.

2.9. Export markets

After the 1996 study tour of Kuala Lumpur and Singapore, the strong message that came across was the presence of competitors such as the United States. Importers indicated that they prefer WA cauliflowers because of their high quality. However, some importers complained about freezing of cauliflowers in sea containers and inconsistency of supply from Australia.

2.10. Future work

The overall conclusion reached from the postharvest work is that bruising has a greater effect on curd quality after transport and outturn than cool chain practices in the field, packing house or in transit. Cool storage practices used by the Western Australian industry could however be greatly improved and currently result in dollar losses through excessive dehydration of the product.

Future emphasis should be placed on practices which minimise bruising and curd injury while minimising curd weight loss after harvest. A cooling method which requires further research is hydrocooling in bins lined with heavy duty bubble wrap liners using chlorinated cold water. The commercial feasibility of this needs to be tested because it offers the multiple benefit of reduced bruising, rapid precooling and zero weight loss (possibly even re-hydration).

Field recovery rates can be improved by using more uniform seedlings from early germinating seeds. The commercial practicality of using only the best plants as planting stock needs to be investigated and a cost benefit study conducted to demonstrate the economic benefit to the whole industry.

Figure 1: Harvesting cauliflowers, Manjimup Western Australia.

3. Acknowledgments

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Vynka McVeigh
Agriculture Western Australia
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4. Background

Over the last five years, the value of Western Australia's cauliflower exports has remained steady, despite a 5% fall in 1997/98 to $20 million. In 1995/96, the industry exported 17 438 tonnes of fresh cauliflower which was worth about $22.3 million. In 1997/98, the WA industry exported 15 043 tonnes valued at $19.7 million (ABS 1997/98). Western Australia predominantly exports cauliflower to four Asian markets, Malaysia, Singapore, Hong Kong and Brunei, which imported 57%, 37%, 2% and 1% respectively, of the total. In 1997/98, Singapore was the only market into which Western Australia increased its cauliflower exports. With the recent falling trend in production and value of cauliflower exports and only an increase in one of the industry's markets, the information presented in this report is very timely.

Competitors are a constant threat to the Australian industry. To maintain market share, the industry must be market aware and know what the competitors are doing and what the buyer needs (both importer and end-consumer). To remain competitive, the following issues needed to be addressed:

- Our position in South East Asian markets is due to the high quality of cauliflowers supplied. Australian cauliflowers are bought by importers because they are of good quality not because they are the cheapest. The export industry could not compete on price alone as the cost of domestic labour is too high.
- As sea freight is used, the time it takes to arrive at destination markets (7-10 days) allows the quality to deteriorate, therefore only the best quality cauliflower should be packed in the carton.
- Poor outturns damage the industry's market position therefore it is most important to reduce curd blackening particularly during April/May and, to a lesser extent, September/October. Exporters commonly lose 1-2 shipments due to breakdown in transit during this season.
- The reasons for poor outturns are not well documented but thought to be mainly curd blackening after bruising and dehydration in the packing and cooling process. Unpublished research has provided evidence that temperature is the most important factor affecting increased browning of cauliflower florets (Suslow and Cantwell 1997). It was also discovered that much discolouration occurred in mechanically damaged areas of the florets.
- There is a lack of knowledge about consumer requirements in South East Asian markets.

This HRDC project, Export Cauliflower Quality Improvement 1996-98 (VG 94043), attempts to address these industry problems. The objectives of this project are to:

⇒ minimise bruising and black spot of cauliflower curds
⇒ investigate precooling methods and weight loss
⇒ determine the effects of field handling
⇒ monitor road transport methods
⇒ improve packaging
⇒ reduce yield losses in the field
⇒ identify and meet consumer demands in south east Asian markets

4.1 Literature review

4.1.1. Bruising reduction

Limited information is available on specific postharvest problems of cauliflowers such as bruising, black spot and rots. Story (1989) covers factors affecting mechanical damage such as over-packing or under-packing of a carton.

4.1.2. Precooling and weight loss

Most commodities show signs of shrivelling or wilting after losing three to five percent of the initial weight (Mitchell 1992). According to Story (1989) the first stages of storage, whilst the product is cooling, is when most moisture is lost. Therefore, fast cooling of the product reduces overall weight loss. Using an efficient forced air coolroom, precooling cauliflowers thoroughly should take about 3 - 5 hours (Story 1989). Some commercial coolrooms do not perform as efficiently.

4.1.3. Cool chain handling

To reduce the 36.4% industry average yield loss from reject curds (Shellabear 1995), improving postharvest practices was the main focus of this project. From literature searches, it was found that very little work had been done on postharvest research of cauliflowers.

Existing information relates to general postharvest practices of certain commodities with emphasis on storage conditions. Cauliflower should be precooled and stored at 0-2°C with 90-95% relative humidity (Tan, Haynes, Phillips 1994). Joyce and Yuen (1988) have reported that cauliflower is an ethylene sensitive commodity and should not be stored with ethylene producers such as apple, banana and avocado.

4.1.4. Road transport

Story (1996) and the Australian United Fresh Transport Advisory Council has produced a code of practice for the transport of fresh produce by road. It recommends that cauliflower should be transported at 0°C with 95-98% relative humidity. The acceptable receiving pulp temperature should be 0-3°C.

4.1.5. Packaging

Emond, Boily and Mercier (1995) looked at water vapour resistance properties of various perforated plastic films. Tan *et al* (1993) discovered that the sealed high density polyethylene bag retarded yellowing in broccoli and basically improved market quality. Zong (1990) concluded that to gain the beneficial effects of individual film wrapping of cauliflowers, high humidity is the crucial factor. Boehm (1990) outlined that cauliflower would have a good potential for the application of modified atmosphere packing providing the transit temperature is 0-5°C and the packaging created an atmosphere of no more than 5% carbon dioxide and oxygen.

4.1.6. Crop loss

Shellabear (1995) confirmed crop losses account for 36.4% from transplanting to export shipment. These losses were mainly caused by crop protection and harvest maturity factors such as overmaturity, and pink/yellow curds. The latter causes accounts for 13.9% of total crop loss, much of which is thought to be a consequence of uneven maturity. If all cauliflowers matured within 3-4 days allowing one or two harvests then there would be less scope for curds to become overmature because they were not picked at the correct time. The current Export Cauliflower Quality Improvement project (1996-98) investigated the relationship of seed size/vigour and seedling variability on uniformity of harvest. A cost/benefit analysis was done to reduce curd yellowing and overmaturity through better management practices such as more frequent leaf covering and harvest operations.

4.1.7. Seed, seedling size and phosphorus placement on yield

Finch-Savage (1986) found that slow germinating cauliflower seeds produce fewer healthy normal seedling than faster germinating seeds. Finch-Savage and McKee (1990) confirmed that seedling non-uniformity due to seed quality had little impact on agronomic significance on growth after transplanting.

Phillips *et al* (1994) found that phosphorus applied at 124 kg/ha before planting would give 99.9% of maximum yield of cauliflower grown in the Manjimup area. Research was done to examine the effect of phosphorus placement on crop establishment.

4.1.8. Market and consumer requirements

To maintain a competitive edge in export markets, suppliers must be in tune with customer demands. Historically, there has been very little detailed feedback from consumers about their preferences due to the marketing structure and trading methods in South East Asia (Hatton 1996).

In light of known information presented in the literature review, the project aimed to address each objective in the following way:

⇒ Minimise bruising of cauliflower curds
Due to poor outturns, particularly during April/May, bruising of cauliflower curds was investigated using a standardised bruising technique and measurement of black spot development.

⇒ Precooling methods and weight loss
With optimum temperature and humidity conditions known, monitoring of packing house coolrooms was done to identify improvements which could be made to commercial coolroom operation and practices, thus reducing dehydration and improving shelf life of cauliflower.

⇒ Effects of field handling
Weight loss was monitored during the postharvest chain. The effects of leaving cauliflowers in ambient conditions for a number of hours was investigated by monitoring weight loss and quality of cauliflowers after storage in such conditions.

⇒ Road transport
In light of recommended code of practice of refrigerated transport, monitoring temperature, humidity and the effects on quality of cauliflower for both Pantech® and Tautliner® refrigerated trailers was investigated.

⇒ Improve packaging

Although 20kg cauliflower cartons are not entirely satisfactory for optimum outturn, it is what the industry and importers accept. Therefore, studies were done into various forms of packaging such as paper wraps and carton liners to determine the best product for maintaining optimum quality at outturn.

⇒ Crop losses

Recommendations stated in the Shellabear report (1995) were taken into account to reduce the 36.4% loss from seedlings which for various reasons, did not go on to produce exportable curds. The project addressed the recommendations by determining bruising susceptibility, the cost and percentage recovered by extra covering and harvests, and investigating the effects of rate of phosphorus, seed size and seedling size on crop uniformity and ultimately yields.

⇒ Meet consumer demands of the export market

In order to become more market aware and ultimately maintain the competitive edge, consumer demands must be met by providing the market with what they want. A market study tour was conducted to determine market requirements from the point of view of the importer and supermarket manager. Later, a consumer survey funded by Agriculture Western Australia was conducted in July/August 1997, to determine market requirements from the view point of the Malaysian consumer.

Figure 2: Project Officer, Vynka McVeigh, and Manjimup cauliflower grower, Ian Ryan, peg out research plot on his family property.

5. Harvest maturity and bruising susceptibility

5.1. Harvest maturity effects on quality of cauliflower

5.1.1. Introduction

Cauliflowers for export are harvested as 'naked curds' without any wrapping of leaves to protect them from subsequent handling injury. This is done to maximise the weight of marketable product in the carton. It is important to harvest cauliflower for export at the correct maturity and size suitable for a particular market, while minimising the potential for bruising and handling injury.

Exporters and growers have identified the need to reduce curd blackening at outturn in South East Asian markets, particularly during April/May. The aim of this study is to determine if cauliflower curd quality is influenced by curd maturity at harvest and identify maturity stages which minimise the risk of curd deterioration and poor outturn. This study was undertaken to satisfy the project objectives: i) minimise bruising and black spot; ii) determine the effects of field handling and, iii) meet consumer demands.

5.1.2. Materials and method

These experiments were conducted on commercial cauliflower properties in the Manjimup area of Western Australia. Cauliflower curds were harvested every second or third day over four harvests. Two methods of assessing the effects of bruising, maturity and day of harvest on subsequent quality of florets were used at various times.

Method 1
In this method, cauliflowers from each date of harvest represented a different maturity stage.
Maturity stage 1: At this date, curds harvested were immature, tight and small.
Maturity stage 2: This harvest, three or four days after stage 1, was considered to be the industry standard maturity (control)
Maturity stage 3: The third harvest stage, two or three days later, showed slight separation of base florets of the curd (slightly overmature).
Maturity stage 4: These were overmature curds with separated florets (Table 1).

Table 1: Curd description of cauliflowers harvested at various maturity stages.

Maturity Stage	Curd Description
1	curd compact and tight, immature, 15cm or less in diameter
2	curd slightly loose, 15-20 cm in diameter
3	shoulder florets moderately separated
4	florets separated, long floret stalks, overmature, 20 cm in diameter

Before harvest, eight cauliflower plants, for each of the five replications, at relatively the same visual maturity were chosen and a peg was put next to each. Two curds from each replication were harvested at each date and ten florets were removed from each cauliflower curd. The first five base florets were removed from each cauliflower and subjected to bruising. The next five florets from the same cauliflower were removed and were not bruised.

One hundred florets were collected at each harvest or maturity stage and this was done for each of the four maturity stages, making a total of 400 florets for the trial. Two hundred florets were bruised using a standardised bruising technique and 200 were not bruised (control). The variety used was *Plana*.

The standardised bruising technique consisted of an FT 327 fruit penetrometer with a modified flat metal base, mounted in a drill press (Figure 3). The floret was placed under the penetrometer and the metal base attached to the penetrometer was pressed onto the top of the floret until the gauge of the penetrometer reached 8 kg. One bruise per floret was made. Due to maturity differences, maturity stage 1 florets were smaller in size compared to the over-mature florets from maturity stage 4.

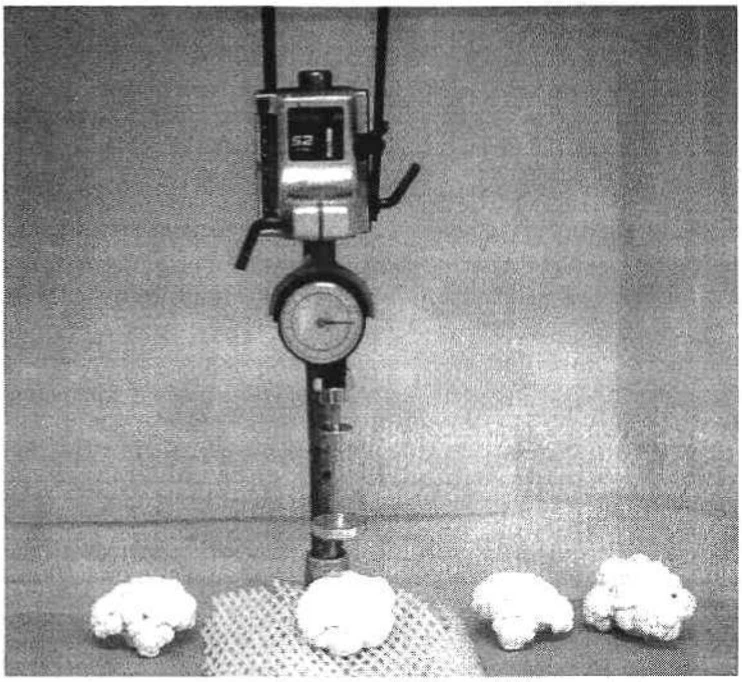


Figure 3: Bruising technique used on cauliflower florets.

The treated and control florets were then placed in separate cardboard cartons. Each floret was placed side by side in a single layer on a sheet of foam webbing on the bottom of the carton. The cartons were stored in warm store conditions of about 21-25°C with 80% relative humidity. The warm store was a small 2 x 3 metre coolroom in which a small thermostat heater was used to achieve the required temperature and wet hessian bags placed on the floor increased the humidity. These conditions were used to simulate conditions of an open air wet market such as those found in Malaysia and Singapore, the main markets for cauliflower. Quality assessments of the florets were recorded after four days in warm store and then put back for a further two days to assess quality after six days in warm store (Table 2). Curd discolouration included rots/blemishes and black spot. Turgor ratings were based on visual assessment and the rubbery characteristics of the floret.

Table 2: Quality assessment scoring system

Score	Turgor	Severity rots/blemishes	Severity black spot	% Surface area affected by curd discolouration
1	very turgid	none	none	0 %
2	turgid	slight	slight	1-5 %
3	slight soft	moderate	moderate	6-10 %
4	soft	severe	severe	11-15%
5	very soft	very severe	very severe	16-20 % & over

Method 2
To test if bruising susceptibility between maturity stages was affected by weather on the day of harvest, the cauliflower curds were collected using a second method. Curds that visually represented maturity stages one, two, three and four were collected on the same day from plants deemed to be at different stages of development. One curd from each maturity stage was harvested from three replications, that is, 12 curds harvested on each harvest day. This was repeated at four consecutive dates from the same crop when weather was different. In total, another 48 curds were harvested for this second method from which 480 florets were tested. The curds were treated in the same way as the previous method.

To obtain a nutritional benchmark of the crop, a leaf analysis was done. Thirty leaves from thirty plants at the buttoning stage were randomly collected. The fourth youngest fully expanded leaf from each plant was chosen for analysis. The leaves were dissected to separate the leaf blade from the midrib. A separate analysis was done on both leaf parts.

Data was analysed using GENSTAT statistical package, version 5.0 (Lawes Agricultural Trust, Rothamsted Experimental Station). All analyses used analysis of variance with differences between means compared by least significant difference (l.s.d.). The level of significance used was $P \leq 0.05$.

5.1.3. Results and discussion

5.1.3.1. Spring harvest

Method 1
Sequential harvest - different days for each maturity stage
(Effect of maturity stage)
The spring trial was done from 7 - 14 October 1996. The susceptibility of bruising on the florets was indicated by the severity of rots/blemishes and black spot (Figure 4 and 5). Much of the discolouration occurred in the mechanically damaged area on the top of the floret. It is highly likely that blackened tissue (black spot) is largely a consequence of the bruising damage applied to the floret by the treatment. Rots appear to be a secondary infection and may include bacterial soft rot pathogen *Erwinia carotovora* and *Pseudomonas* spp. (Suslow and Cantwell 1997, unpublished).

After four days warm store, maturity stage 4 (overmature) significantly ($p \leq 0.05$) showed the highest severity of rots/blemishes and percentage surface area affected by curd discolouration, with scores of 3.04 and 2.60 respectively (Table 3). The bruised florets from maturity stages 3 and 4 had the worst black spot severity after four days warm store. The bruising technique may have contributed to the high incidence of black spot on the overmature florets. Overmature florets were very loose and could not take the pressure applied by the penetrometer therefore more mechanical damage was sustained on a loose floret than a hard, tight floret.

Table 3: Quality assessment scores of florets after **four days** warm store (spring harvest).

Treatment	Maturity stage	Turgor	Severity rots/ blemishes	Severity black spot	% Surface area discoloured	% Weight loss/ floret
Bruised	**1**	3.30	1.00	1.60	1.60	9.47
	2	2.36	1.62	2.36	2.12	13.12
	3	3.04	1.20	2.48	2.12	8.00
	4	3.18	3.04	2.64	2.60	5.35
Not bruised	**1**	3.36	1.00	1.36	1.36	10.20
	2	2.12	1.14	1.56	1.52	14.00
	3	2.42	1.00	1.52	1.52	8.44
	4	2.70	1.06	1.46	1.44	6.09
	LSD ($p \leq 0.05$)	**0.26**	**0.20**	**0.25**	**0.21**	**ns**

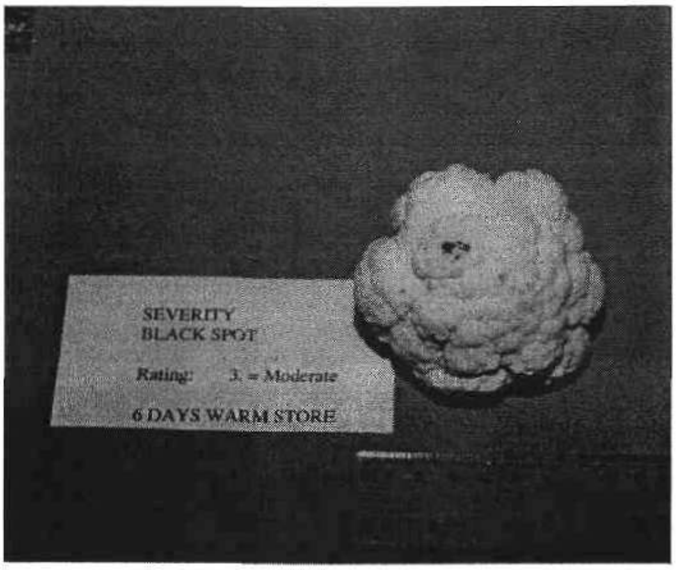


Figure 4: Floret after bruising with a moderate severity of black spot after six days warm store.

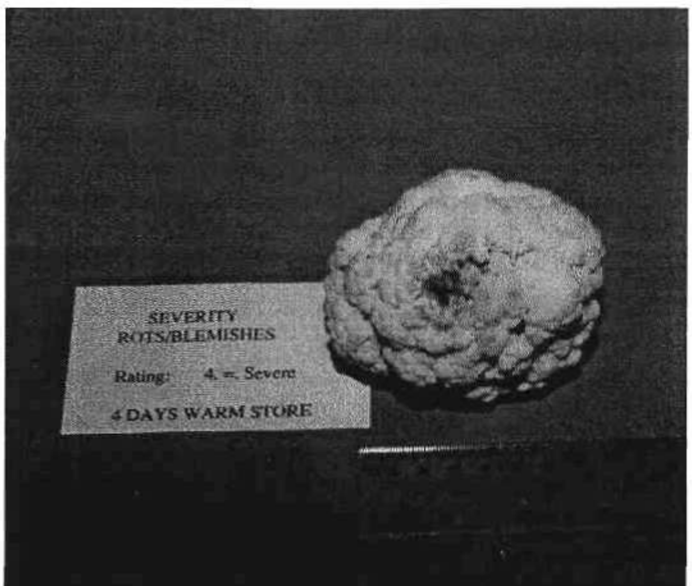


Figure 5: Floret after bruising with a severe rating of rots and blemishes after four days warm store.

Table 4: Quality assessment scores of florets after **six days** warm store (spring harvest).

Treatment	Maturity stage	Turgor	Severity rots/ blemishes	Severity black spot	% Surface area discoloured	% Weight loss/ floret
Bruised	**1**	3.42	1.20	2.26	2.06	17.51
	2	2.52	2.14	2.96	2.48	15.41
	3	3.18	2.00	3.32	2.74	13.43
	4	3.46	3.70	3.46	3.18	9.48
Not bruised	**1**	3.42	1.00	1.78	1.66	19.20
	2	2.32	1.00	1.76	1.72	15.93
	3	2.74	1.04	2.02	1.92	14.34
	4	2.90	1.14	1.96	1.94	9.98
	LSD ($p \leq 0.05$)	**0.27**	**0.45**	**0.29**	**0.23**	**ns**

Maturity stage 4 (bruised florets) also significantly showed the highest severity of rots/blemishes and percentage surface area discoloured after six days warm store (Table 4). Florets that were not bruised also showed signs of rots and black spot because of normal deterioration in warm, humid conditions. However, Figure 6 clearly shows higher severity scores for bruised florets compared to unbruised florets. Immature small cauliflowers (stage 1) were significantly less susceptible to bruising related deterioration than more mature florets.

From the spring harvest, it was found that bruised florets from maturity stage 4 had significantly higher severity of rots/blemishes after four and six days warm store. The results show that overmature curds tend to be more susceptible to bruising while immature florets were least susceptible. Bruised florets at all maturity stages showed more black spot than unbruised and bruising is associated with accelerated black spot development.

From the leaf analysis, the percentage dry basis of nitrogen contained in the leaf blades were considered high according to Weir and Cresswell (1993). Both potassium and phosphorus content were normal (Appendix 13.1).

Method 2

Same maturity stages harvested on different days (Effect of harvest day)

The second method whereby cauliflowers from all maturity stages (1-4) were collected on 4 consective dates showed there were significant differences between florets harvested on different days, for the same maturity stage. Factors such as ambient temperature, humidity and other unknown factors affected bruising susceptibility but by how much could not be determined. Because the second method showed that weather and other factors experienced on the day of harvest affected the results, the first method, whereby a maturity stage was collected on the one day only, must be interpreted with caution. Bruising susceptibility was affected by maturity stage but weather effects experienced on the day of harvest affected the results as well. However, the underlying result from both methods was that the severity of rots/blemishes and black spot was highest among the florets that were bruised.

Table 5: Quality assessment scores of florets from all maturity stages (mean of stages 1- 4) harvested on different days, followed by **six days** warm store (spring harvest).

Treatment	Day of harvest	Turgor	Severity rots/ blemishes	Severity black spot	% Surface area discoloured	% Weight loss/ floret
Bruised	**1**	3.63	1.39	2.20	2.05	19.08
	2	2.98	1.77	3.23	2.72	16.47
	3	3.43	2.02	3.17	2.82	13.29
	4	2.90	1.52	2.83	2.47	11.41
Not bruised	**1**	3.37	1.02	2.00	1.93	20.58
	2	2.68	1.00	1.83	1.78	16.53
	3	2.85	1.03	2.32	2.18	14.31
	4	2.43	1.02	1.72	1.63	12.55
	LSD ($p \leq 0.05$)	**n.s**	**0.23**	**0.26**	**0.22**	**ns**

Statistical analysis of the data showed that there was no significant interaction between maturity, bruising (bruised and not bruised) and the day the florets were picked (ie. m x b x d). However, a significant interaction occurred between bruising by day (b x d). In other words, there was a significant difference for all quality attributes except for turgor and percentage weight loss between day 1 and day 4 for both the bruised and unbruised treatments (Table 5). This means that the day the florets were picked has had an effect on how severely bruising subsequently affected the quality ratings of the florets after 6 days warm store. For example, Table 5 shows that day 3 had a relatively greater effect on rots/blemishes for bruised florets than for unbruised florets compared to other days.

Another significant interaction occurred between maturity and day. Table 6 shows that maturity stages 3 and 4 recorded the highest severity of all the quality attributes except the percentage surface area discoloured. This means that overmature cauliflower are more susceptible to rots and black spot regardless of whether they were bruised or not. The trend was not always consistent however, with for example, maturity stage 1 florets giving disproportionately poorer quality scores from the day 3 harvest than the other harvests and stage 3 relatively better on this day. It is unknown whether this is a real difference or an artefact of experimental technique.

Table 6: Quality assessment scores of florets at different maturity stages (combined bruised and unbruised) harvested on same day, followed by **six days** warm store (spring harvest).

Day of harvest	Maturity stage	Turgor	Severity rots/ blemishes	Severity black spot	% Surface area discoloured	% Weight loss/floret
DAY 1	**1**	2.90	1.07	2.00	1.83	20.20
	2	3.22	1.12	2.08	1.88	18.24
	3	4.23	1.38	2.03	2.05	19.98
	4	3.63	1.25	2.28	2.20	20.90
DAY 2	**1**	2.47	1.17	2.13	1.97	16.63
	2	2.43	1.20	2.40	2.13	15.86
	3	3.30	1.60	2.80	2.47	17.72
	4	3.13	1.57	2.80	2.43	15.79
DAY 3	**1**	3.00	1.50	2.83	2.40	14.70
	2	3.03	1.27	2.57	2.33	13.00
	3	3.10	1.33	2.53	2.40	13.00
	4	3.43	2.00	3.03	2.87	14.51
DAY 4	**1**	2.57	1.10	2.27	2.07	12.91
	2	2.43	1.20	2.07	1.93	11.57
	3	2.50	1.27	2.30	2.03	11.88
	4	3.17	1.50	2.47	2.17	11.57
LSD ($p \leq 0.05$)		**0.38**	**0.31**	**0.36**	**ns**	**1.24**

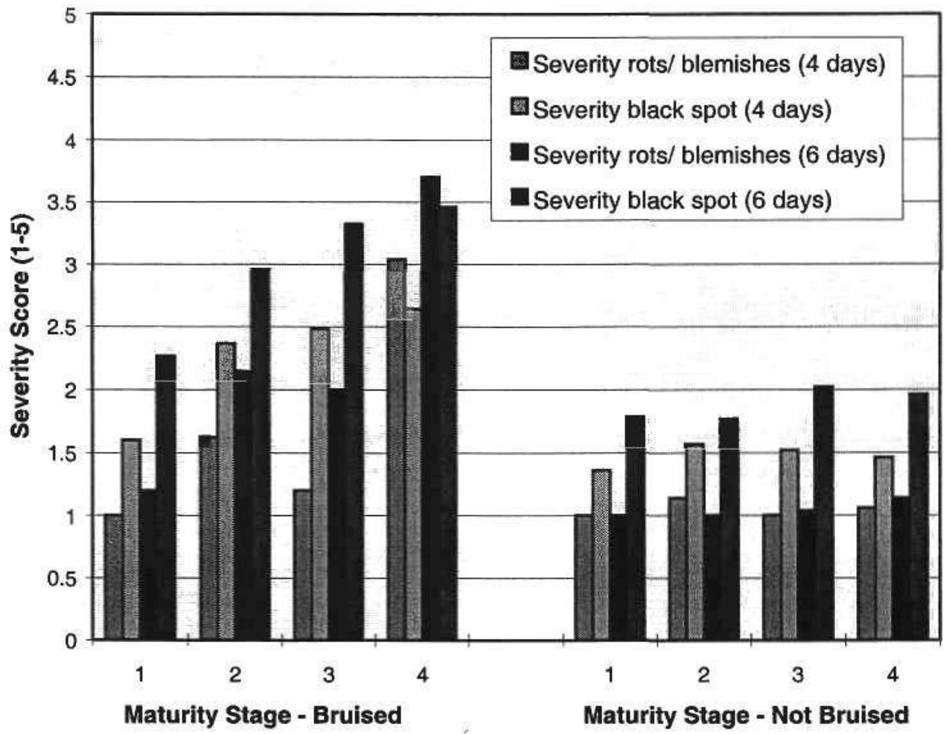


Figure 6: Effect of bruising on florets from different maturity stages after four and six days warm store (spring harvest) for the sequential harvest method (different days for each maturity stage).

5.1.3.2. Summer harvest

Method 1
Sequential harvest - different days for each maturity stage
(Effect of maturity stage)

The summer trial was done from 9 - 17 January 1997. This trial showed similar results to the spring trial. After four days warm store, maturity stage 4 showed significantly ($p \leq 0.05$) higher severity of rots/blemishes and percentage surface area affected by rots and black spot, than all other stages with scores of 3.38 and 2.76 respectively (Table 7). Small immature florets from stage 1 again gave the lowest scores for rots and blemishes. There was no significant interaction between bruise and maturity for the severity of black spot, however the main effects were significant. This means the severity of black spot was more severe at maturity stage 4 whether bruising occurred or not.

After six days warm store, bruised florets from maturity stage 4 showed the highest scores for turgor, severity of rots/blemishes and percentage surface area discoloured. The severity score for rots/blemishes for maturity stage 4 was a high at 4.06 (Table 8) (Figure 7). Again, stage 1 florets had significantly less rots and blemishes and percentage surface area discoloured. Table 8 also shows that there was no significant interaction between maturity and bruise for the severity of black spot, however the main effects were highly significant.

A comparison analysis was done between the spring trial and the summer trial. It showed that there was a significant difference in severity of black spot between the spring and summer trials after 4 and 6 days warm store. After 4 days warm store there was a significantly ($p \leq 0.05$) greater severity of black spot among the later maturities from the spring trial than the comparable stages from the summer trial. After 6 days warm store, the spring harvested florets from bruised treatments at maturity stages 3 and 4 showed the greatest severity of black spot of all maturity stages and times of harvest.

In summary, both the spring and summer trials have confirmed that overmature cauliflowers are more susceptible to bruising than immature cauliflowers, taking into account that the weather experienced on the day of harvest may sometimes have affected the result. This is important for the cauliflower industry in that a shift to harvesting less mature cauliflower curds should improve outturn quality. A change in production systems needs to be investigated to assess the economic viability of this finding.

Table 7: Quality assessment scores of florets after **four days** warm store (summer harvest).

Treatment	Maturity stage	Turgor	Severity rots/ blemishes	Severity black spot	% Surface area discoloured	% Weight loss/ floret
Bruised	**1**	2.54	1.42	2.20	2.06	7.77
	2	2.20	2.24	2.18	2.28	7.69
	3	2.18	2.44	2.08	2.08	5.33
	4	2.36	3.38	2.52	2.76	5.78
Not bruised	**1**	2.24	1.00	1.72	1.62	8.90
	2	1.86	1.08	1.74	1.62	8.40
	3	1.70	1.16	1.96	1.82	6.53
	4	1.62	1.40	1.98	1.98	6.63
	LSD ($p \leq 0.05$)	**0.22**	**0.55**	**ns**	**0.26**	**ns**

Table 8: Quality assessment scores of florets after **six days** warm store (summer harvest).

Treatment	Maturity stage	Turgor	Severity rots/ blemishes	Severity black spot	% Surface area discoloured	% Weight loss/ floret
Bruised	**1**	2.58	1.82	2.68	2.38	9.85
	2	2.64	2.64	2.92	2.94	11.42
	3	2.26	2.92	2.54	2.34	7.96
	4	3.30	4.06	3.26	3.74	9.05
Not bruised	**1**	2.30	1.02	2.04	1.86	11.27
	2	1.92	1.12	2.38	2.20	11.38
	3	2.04	1.18	2.30	2.08	9.38
	4	2.42	1.62	2.72	2.70	9.04
	LSD (p≤0.05)	**0.30**	**0.51**	**ns**	**0.33**	**ns**

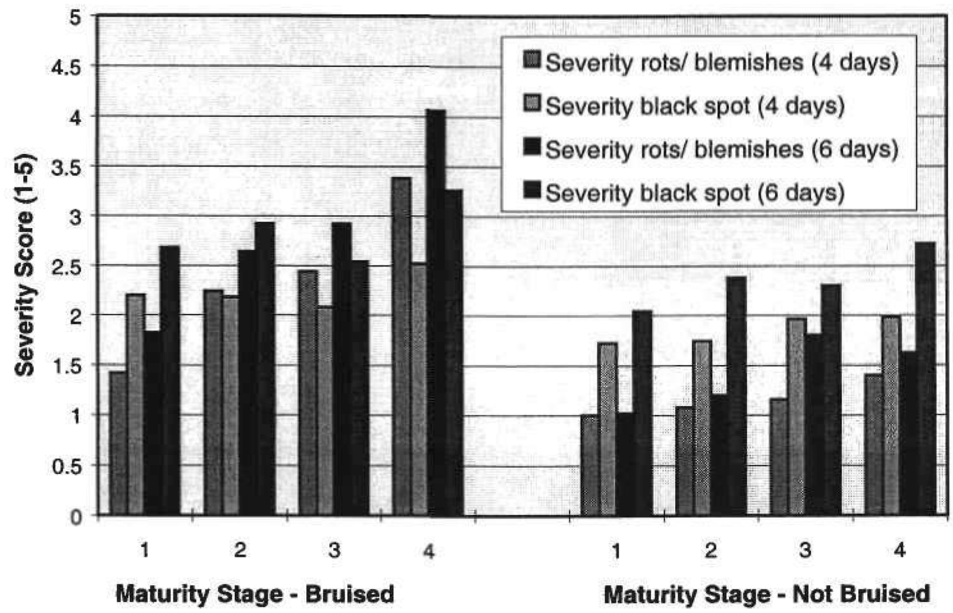


Figure 7: Effect of bruising on florets from different maturity stages after four and six days warm store (summer harvest).

The second method (Method 2) where by florets from different maturity stages were harvested on the same day was not done for the summer harvest.

5.2. Seasonal effects on bruising of cauliflower

The aim of this work was to determine the effects of bruising during the course of one year, that is, the susceptibility of bruising on cauliflower harvested at different seasons.

5.2.1. Materials and method

The methods used were almost the same as the harvest maturity trial, with both Method 1 and Method 2 being followed at each harvest date. The differences were that a humidifier was used instead of wet hessian bags to maintain a more accurate relative humidity in the warm store and phosphonic acid (Fossic 200®) was used at the rate of 8ml of product per litre of water to minimise downy mildew developing on the florets. In previous tests downy mildew symptoms on florets contributed to curd discolouration at times. The florets were dipped in phosphonic acid solution and allowed to dry before being placed in warm store.

5.2.2. Results

5.2.2.1. Spring harvest (4 - 10 November 1996)

Method 1

After four days warm, store bruised florets at maturity stage 4 significantly ($p \leq 0.05$) had the highest turgidity score of 2.04 (Table 9). Bruised florets at maturity stage 3 showed significantly the greatest severity of rots and blemishes. Maturity stage 3 with bruising also showed significantly the greatest percentage of surface area affected by rots and black spot. After six days warm store, maturity stage 4 with bruising showed significantly ($p \leq 0.05$) the greatest severity of rots and blemishes (Table 10). The results also showed that bruised florets from maturity stage 3 and 4 had the greatest surface area affected by rots and black spot.

The severity of black spot did not have a significant interaction with bruise and maturity after 4 and 6 days warm store, however, the main effects of bruise and maturity were significant. In other words, maturity stage 4 florets significantly had a higher severity of black spot regardless of whether bruising occurred or not, and bruised florets always had a higher severity of black spot than not bruised.

Table 9: Quality assessment scores of florets after **four days** warm store (spring harvest).

Treatment	Maturity stage	Turgor	Severity rots/ blemishes	Severity black spot	% Surface area discoloured	% Weight loss/ floret
Bruised	**1**	1.44	1.18	2.00	1.94	8.07
	2	1.52	2.00	2.46	2.20	7.01
	3	1.82	2.72	2.70	2.42	5.77
	4	2.04	2.04	2.48	2.28	6.90
Not bruised	**1**	1.28	1.06	1.68	1.58	9.84
	2	1.20	1.18	1.94	1.76	8.19
	3	1.14	1.18	1.96	1.84	6.21
	4	1.52	1.26	1.88	1.76	7.62
	LSD ($p \leq 0.05$)	**0.19**	**0.35**	**ns**	**ns**	**ns**

Table 10: Quality assessment scores of florets after **six days** warm store (spring harvest).

Treatment	Maturity stage	Turgor	Severity rots/ blemishes	Severity black spot	% Surface area discoloured	% Weight loss/ floret
Bruised	**1**	1.70	1.44	2.50	2.20	11.59
	2	1.84	2.22	2.90	2.54	12.04
	3	2.32	3.30	3.18	3.12	8.33
	4	2.78	3.84	3.30	3.42	10.27
Not bruised	**1**	1.46	1.04	2.14	2.02	13.41
	2	1.62	1.22	2.24	1.98	13.82
	3	1.98	1.44	2.36	2.30	8.84
	4	2.24	1.82	2.60	2.48	11.21
	LSD ($p \leq 0.05$)	**ns**	**0.39**	**ns**	**0.30**	**ns**

Method 2

During the spring harvest, the only significant interaction was between maturity and day (Table 11). Maturity stages 3 and 4 overall recorded the highest severity for all the quality attributes meaning that overmature cauliflower are more susceptible to rots and black spot regardless of whether they were bruised or not. The degree to which the less mature floret stages were affected by the treatments varied with the day of harvest in some cases. For example, floret maturity stage had less effect on the severity of black spot for florets harvested on day 2 than the other days of harvest. Prevailing conditions on the day of harvest therefore had some effect on subsequent quality of outturn of cauliflowers but the overriding trend was for less mature florets to outturn better than overmature florets.

Table 11: Quality assessment scores of florets at various maturity stages harvested on different days followed by **six days** warm store (spring harvest).

Day of harvest	Maturity stage	Turgor	Severity rots/ blemishes	Severity black spot	% Surface area discoloured	% Weight loss/floret
DAY 1	**1**	1.50	1.13	2.17	1.97	11.99
	2	1.67	1.37	2.37	2.33	11.24
	3	1.80	1.67	2.97	2.63	12.45
	4	2.43	1.77	2.57	2.53	15.31
DAY 2	**1**	1.37	1.13	2.23	1.93	10.59
	2	1.43	1.33	2.27	2.07	11.78
	3	1.53	1.70	2.47	2.27	11.64
	4	1.93	1.87	2.47	2.30	12.65
DAY 3	**1**	1.07	1.37	2.40	2.03	7.96
	2	1.50	1.47	2.30	2.03	9.02
	3	2.20	1.70	2.53	2.40	9.43
	4	2.67	2.30	2.47	2.50	9.70
DAY 4	**1**	1.83	1.17	2.37	1.97	10.30
	2	2.30	1.83	2.43	2.37	11.29
	3	2.50	1.80	2.50	2.37	11.96
	4	2.60	2.80	2.97	3.03	11.58
LSD ($p \leq 0.05$)		**0.35**	**0.49**	**0.34**	**0.33**	**1.49**

5.2.2.2. Summer harvest (10 - 24 February 1997)

Method 1

After four days warm store, bruised florets at maturity stage 4 showed significantly ($p \leq 0.05$) the greatest severity of rots and blemishes with a score of 2.50 (slight to moderate) (Table 12). Bruised florets at maturity stage 4 also recorded the highest severity of black spot with a score of 2.68.

After six days warm store, the bruised florets at maturity stage 4 showed significantly ($p \leq 0.05$) the greatest severity of rots and blemishes (moderate to severe). Both maturity stages 3 and 4 with bruising showed the highest severity of black spot (Table 13) (Figure 8).

Table 12: Quality assessment scores of florets after **four days** warm store (summer harvest).

Treatment	Maturity stage	Turgor	Severity rots/ blemishes	Severity black spot	% Surface area discoloured	% Weight loss/ floret
Bruised	**1**	2.28	1.90	2.18	2.12	8.37
	2	1.88	1.40	2.22	2.04	6.77
	3	2.24	1.82	2.26	2.14	6.47
	4	1.94	2.50	2.68	2.30	3.97
Not bruised	**1**	2.10	1.00	1.98	1.90	9.70
	2	1.80	1.06	1.88	1.78	7.45
	3	1.78	1.00	1.64	1.60	7.17
	4	1.34	1.08	1.42	1.38	4.31
	LSD ($p \leq 0.05$)	**0.19**	**0.44**	**0.29**	**0.20**	**ns**

Table 13: Quality assessment scores of florets after **six days** warm store (summer harvest).

Treatment	Maturity stage	Turgor	Severity rots/ blemishes	Severity black spot	% Surface area discoloured	% Weight loss/ floret
Bruised	**1**	2.62	2.08	2.70	2.34	11.86
	2	2.14	1.76	2.90	2.48	7.35
	3	2.32	2.36	3.24	2.68	9.82
	4	2.18	3.16	3.12	2.70	7.16
Not bruised	**1**	2.58	1.02	2.34	2.14	13.51
	2	2.00	1.12	2.36	2.16	7.55
	3	1.90	1.14	2.52	2.16	10.66
	4	2.10	1.22	1.84	1.84	7.53
	LSD ($p \leq 0.05$)	**0.22**	**0.45**	**0.31**	**0.26**	**ns**

Method 2

For the summer harvest, the significant interaction was bruising and the day of harvest (Table 14), showing that the day the florets were harvested again had an effect on the quality ratings after six days warm store.

Table 14: Quality assessment scores of florets from all maturity stages (mean of stages 1 - 4) harvested on different days, followed by **six days** warm store (summer harvest).

Treatment	Day of harvest	Turgor	Severity rots/ blemishes	Severity black spot	% Surface area discoloured	% Weight loss/ floret
Bruised	**1**	2.25	1.28	2.50	2.22	10.87
	2	2.25	1.78	2.78	2.40	9.90
	3	2.20	2.02	2.97	2.53	10.18
	4	2.45	3.10	3.40	3.12	8.96
Not bruised	**1**	2.13	1.00	2.30	2.07	11.76
	2	2.05	1.12	2.45	2.13	10.40
	3	2.02	1.15	2.40	2.15	10.74
	4	2.15	1.32	2.55	2.25	8.89
	LSD (p≤0.05)	**ns**	**0.31**	**0.23**	**0.21**	**ns**

Maturity and day also showed a significant interaction for all quality assessments except for the severity of rots/blemishes (Table 15). Maturity stages three and four recorded the highest severity for most the quality attributes.

Table 15: Quality assessment scores of florets from different maturity stages harvested on the same day followed by **six days** warm store (summer harvest).

Day of harvest	Maturity stage	Turgor	Severity rots/ blemishes	Severity black spot	% Surface area discoloured	% Weight loss/floret
DAY 1	**1**	2.33	1.07	2.27	2.10	12.04
	2	2.03	1.00	2.33	2.10	10.51
	3	2.03	1.30	2.37	2.13	10.22
	4	2.37	1.20	2.63	2.23	12.49
DAY 2	**1**	2.17	1.40	2.23	2.00	8.99
	2	1.93	1.43	2.43	2.03	8.95
	3	2.40	1.40	3.03	2.63	11.06
	4	2.10	1.57	2.77	2.40	11.61
DAY 3	**1**	2.40	1.40	3.03	2.63	11.06
	2	2.10	1.57	2.77	2.40	11.61
	3	1.97	1.60	2.40	2.13	9.45
	4	1.97	1.77	2.53	2.20	9.74
DAY 4	**1**	2.53	2.23	3.03	2.67	10.54
	2	2.17	2.10	3.2	2.80	8.49
	3	2.13	1.87	2.70	2.43	8.32
	4	2.37	2.63	2.97	2.83	8.36
LSD (p≤0.05)		**0.25**	**ns**	**0.33**	**0.29**	**1.35**

5.2.2.3. Autumn harvest (23 April - 7 May 1997)

Method 1

After four days warm store, bruised florets at maturity stage 4 show significantly ($p \leq 0.05$) the greatest score for turgidity, 3.30 (slightly soft) and the greatest severity of black spot, 3.80 (moderate to severe) (Table 16). Unbruised florets at maturity stage 1 showed significantly the greatest percentage weight loss per floret, 9.36% after four days warm store. This finding was consistent with trends in spring and summer for less mature florets to lose more weight than mature and overmature florets. Weaker cell walls in immature tissues may have contributed to this effect. Although, the severity of rots/blemishes did not have a significant interaction after 4 days warm store, the main effects, bruise and maturity, were significant. Once again, maturity stage 4 florets had a much higher severity of rots/blemishes whether the florets were bruised or not. Similarly, with the severity of black spot after 6 days warm store (Table 17), there was no significant interaction between bruise and maturity but the main effects were significant. This means that bruised florets had a higher severity of rots/blemishes than those florets that were not bruised and florets from maturity stage 4 had a higher severity of rots/blemishes than any other maturity stage regardless of bruising.

Quality assessment scores of florets after six days warm store showed maturity stage 4 florets with bruising recorded significantly the highest scores for turgor, severity of rots/blemishes and the greatest percentage of curd discolouration (Table 17).

Table 16: Quality assessment scores of florets after **four days** warm store (autumn harvest)

Treatment	Maturity stage	Turgor	Severity rots/ blemishes	Severity black spot	% Surface area discoloured	% Weight loss/ floret
Bruised	**1**	1.98	2.66	3.06	2.78	7.41
	2	2.26	2.78	2.92	2.64	5.27
	3	2.46	3.70	3.08	2.84	5.11
	4	3.30	4.90	3.80	3.78	3.74
Not bruised	**1**	1.84	1.08	2.88	2.36	9.27
	2	1.94	1.38	2.52	2.12	6.02
	3	2.12	1.76	2.34	2.16	5.15
	4	2.38	3.24	3.48	2.98	3.73
	LSD ($p \leq 0.05$)	**0.21**	**ns**	**0.26**	**ns**	**0.51**

Table 17: Quality assessment scores of florets after **six days** warm store (autumn harvest)

Treatment	Maturity stage	Turgor	Severity rots/ blemishes	Severity black spot	% Surface area discoloured	% Weight loss/ floret
Bruised	**1**	2.48	2.90	3.22	2.84	8.97
	2	2.46	3.42	3.70	3.08	7.56
	3	3.04	4.38	3.78	3.76	9.00
	4	4.36	4.86	4.66	4.62	6.15
Not bruised	**1**	2.18	1.16	2.90	2.50	10.71
	2	2.06	1.86	3.24	2.60	8.66
	3	2.46	2.32	3.30	2.68	11.43
	4	3.52	4.18	4.32	4.02	7.05
	LSD ($p \leq 0.05$)	**0.27**	**0.46**	**ns**	**0.32**	**ns**

Method 2

For the autumn harvest, the interaction between bruising and day was again significant (Table 18) meaning the day the florets were harvested may have had an effect on the subsequent outturn quality of the florets. The overriding trend was consistently for unbruised florets to produce better quality scores than bruised florets at most dates of harvest.

Table 18: Quality assessment scores of florets from various maturity stages harvested on different days followed by **six days** warm store (autumn harvest).

Treatment	Day of harvest	Turgor	Severity rots/ blemishes	Severity black spot	% Surface area discoloured	% Weight loss/ floret
Bruised	1	2.38	2.48	3.20	2.70	8.83
	2	2.93	4.18	3.75	3.53	7.61
	3	3.08	4.18	3.93	3.60	10.35
	4	3.55	4.72	4.35	4.20	7.87
Not bruised	1	2.17	1.07	2.60	2.13	10.85
	2	2.20	1.67	3.05	2.45	8.53
	3	2.60	2.00	3.30	2.82	11.99
	4	3.02	3.82	3.93	3.63	8.79
	LSD ($p \leq 0.05$)	**0.26**	**0.38**	**ns**	**0.27**	**ns**

A significant interaction was again found between day of harvest and floret maturity for all quality assessments (Table 19). Maturity stages 3 and 4 recorded the highest severity for most of the quality attributes meaning that overmature cauliflower are more susceptible to rots and black spot regardless of whether they were bruised or not.

Table 19: Quality assessment scores of florets from various maturity stages harvested on different days followed by **six days** warm store (autumn harvest).

Day of harvest	Maturity stage	Turgor	Severity rots/ blemishes	Severity black spot	% Surface area discoloured	% Weight loss/floret
DAY 1	1	2.20	1.40	2.73	2.30	11.17
	2	2.13	1.47	2.80	2.23	10.41
	3	2.33	1.87	2.80	2.37	8.93
	4	2.43	2.37	3.27	2.77	8.84
DAY 2	1	2.30	2.60	3.30	2.67	8.05
	2	2.30	2.63	3.20	2.73	7.95
	3	2.87	3.53	3.70	3.37	8.62
	4	2.80	2.93	3.40	3.20	7.67
DAY 3	1	2.23	2.57	3.23	2.60	1.15
	2	2.30	2.47	3.63	3.07	11.27
	3	3.63	3.83	3.97	3.70	12.42
	4	3.20	3.50	3.63	3.47	10.84
DAY 4	1	3.27	4.17	4.20	3.77	8.71
	2	2.57	4.27	4.27	4.13	9.07
	3	3.17	4.30	4.27	4.03	8.25
	4	3.13	4.33	3.83	3.73	7.30
LSD ($p \leq 0.05$)		**0.37**	**0.53**	**0.36**	**0.38**	**0.80**

5.2.2.4. Winter harvest (5 - 12 August 1997)

Method 1

After four days warm store, bruised florets at maturity stage 2 showed significantly ($p \leq 0.05$) the greatest score of turgidity (3.66)(slight soft - soft). Maturity stage 3 significantly had the greatest severity of rots/blemishes (3.72)(moderate to severe) and the greatest percentage of surface area discoloured (1-5%) (Table 20). Quality assessment scores of florets after 6 days warm store showed bruised florets at maturity stage 3 significantly had the greatest severity of rots/blemishes (Table 21). Maturity stage 3 also had the highest surface area discoloured (6-10%).

Table 20: Quality assessment scores of florets after **four days** warm store (winter harvest).

Treatment	Maturity stage	Turgor	Severity rots/ blemishes	Severity black spot	% Surface area discoloured	% Weight loss/ floret
Bruised	**1**	2.86	1.98	2.04	2.16	5.26
	2	3.66	2.46	2.64	2.22	7.65
	3	3.06	3.72	2.70	2.64	4.32
	4	3.04	1.96	2.66	2.34	8.71
Not bruised	**1**	2.62	1.00	1.98	1.78	5.67
	2	2.96	1.06	2.40	2.02	8.16
	3	2.06	1.22	1.88	1.88	4.72
	4	2.36	1.02	2.02	1.88	8.78
	LSD ($p \leq 0.05$)	**0.26**	**0.35**	**0.24**	**0.20**	**ns**

Table 21: Quality assessment scores of florets after **six days** warm store (winter harvest).

Treatment	Maturity Stage	Turgor	Severity rots/ blemishes	Severity black spot	% Surface area discoloured	% Weight loss/ floret
Bruised	**1**	3.08	2.54	2.86	2.56	10.72
	2	3.62	2.98	2.86	2.42	11.03
	3	3.30	4.14	3.38	3.00	8.11
	4	3.22	2.68	3.20	2.64	11.75
Not bruised	**1**	2.56	1.14	2.48	2.12	11.51
	2	2.96	1.24	2.50	2.08	11.55
	3	2.34	1.34	2.34	2.10	8.33
	4	2.34	1.30	2.40	2.04	12.02
	LSD ($p \leq 0.05$)	**ns**	**0.35**	**0.26**	**0.22**	**ns**

Method 2

The significant interaction from the winter harvest was between bruising and day of harvest. However, significance was only shown with turgidity and the severity of rots/blemishes. Again, this shows that the day the florets were harvested may have affected the ratings for turgidity and severity of rots/blemishes after six days warm store (Table 22). Bruising continued to be the main factor contributing to poor quality after storage.

Table 22: Quality assessment scores of florets from various maturity stages harvested on different days followed by **six days** warm store (winter harvest).

Treatment	Days of harvest	Turgor	Severity rots/ blemishes	Severity black spot	% Surface area discoloured	% Weight loss/ floret
Bruised	**1**	2.77	2.55	2.97	2.52	9.31
	2	3.27	3.47	3.03	2.77	8.96
	3	2.52	3.05	2.92	2.53	8.25
	4	2.42	2.50	3.02	2.58	9.17
Not bruised	**1**	2.45	1.13	2.58	2.17	10.15
	2	2.73	1.25	2.58	2.20	10.04
	3	2.22	1.35	2.18	2.00	9.08
	4	2.28	1.13	2.35	2.02	9.93
	LSD ($p \leq 0.05$)	**0.21**	**0.31**	**ns**	**ns**	**ns**

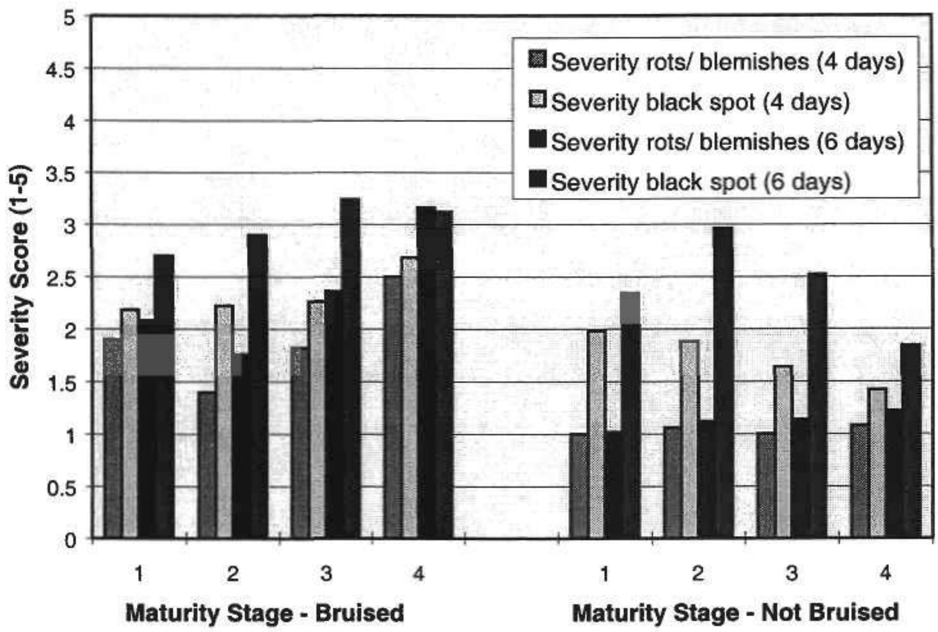


Figure 8: Effect of bruising on florets from different maturity stages after four and six days warm store (summer harvest).

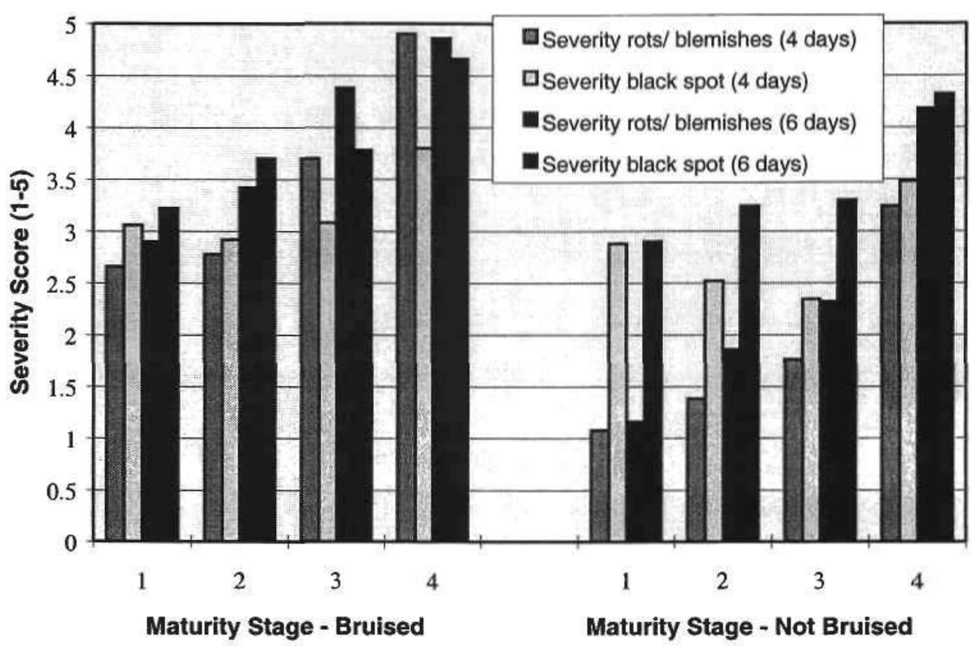


Figure 9: Effect of bruising on florets from different maturity stages after four and six days warm store (autumn harvest).

5.2.3. Discussion and conclusions

The findings from this study indicate that maturity stage 4 florets (grossly over-mature) are more susceptible to bruising and development of rots/blemishes during autumn harvest (April/May) than any other time of the year. This can be seen when comparing summer and autumn trials. Overall autumn had a greater severity of rots/blemishes (Figure 9) compared to the summer (Figure 8).

The reason why curds are more susceptible to bruising during autumn is unclear. Whatever the reason, higher bruising susceptibility during autumn must be caused by other factors other than harvest maturity. This is because even the unbruised florets still recorded higher ratings of black spot and rots/blemishes in April/May compared to any other time of the year. Although quality of fresh vegetables generally depends on the quality achieved at time of harvest, other preharvest factors such as climatic conditions, cultural practices and genetics, also influence quality as well (Weston and Barth 1997). Suslow and Cantwell (1997 unpublished) found that florets vary widely in the initial populations of resident bacterial pathogens on the surface of the curd, prior to harvest and process wounding. This may suggest that bacterial colonisation of aerial plant parts may be more prolific during autumn after damage to the curd has occurred.

The finding that maturity stage 4 florets (grossly over-mature) are more susceptible to bruising and development of rots/blemishes was clearly shown from the first method of harvesting (method 1), in which only immature florets (stage 1) were harvested on day 1 and subsequent harvests were more advanced stages of maturity. However, the second method of harvesting (method 2), in which florets from maturity stages 1 - 4 were harvested all four harvest dates, showed that the day of harvest had an effect on floret quality after storage at all maturity levels. In other words, weather effects (ie. ambient temperature and humidity) may have affected the quality ratings recorded after six days warm store. Therefore, the results from the first method must be interpreted with caution.

The underlying result that came from both methods was that the severity of rots/blemishes and black spot is highest among florets that have been bruised and the trend for higher severity was with those florets from maturity stage 3 and 4 (overmaturity).

Loss of turgidity of florets in spring and summer, was highest for maturity stage 1 florets (bruised and not bruised) after 4 days warm store. This may have been a consequence of maturity stage 1 florets being smaller in size than the florets from other maturity stages. Immature florets have weaker cell walls with higher water permeability. This may also have contributed to this effect. A counter balancing effect in favour of harvesting immature florets was their relative tolerance to deterioration effects related to bruising.

Results for maturity stage 4 need to be treated with caution because in some cases, excessively mature florets were crushed by the penetrometer at 8 kg pressure and other times they were not . This may have resulted in variable bruising severity among florets in this treatment. This maturity stage was included for completeness of the study and would not normally be accepted as marketable for export.

From these results, it is recommended to growers that cauliflowers should be harvested before they show signs of overmaturity. Handling the cauliflowers more carefully in the field and the packing house to reduce pressure bruising, particularly during autumn, is also recommended. The results confirm the relationship between bruising and damage and curd blackening in conditions simulating the outdoor markets in South East Asia, ie. more bruising results in more blackening. To minimise poor outturn from this cause, curds should be harvested before any loose floret development and bruising injury should be minimised.

5.2.4. Future research

Future research into why quality problems occur during the autumn harvest should be done. Experiments to determine if bacterial and/or fungal causing rots are present on the cauliflower at greater microbial loads during some times of the year should be conducted as well as investigations into the role these bacterial/fungal pathogens play in black spot development.

Studies need to be conducted to confirm that immature whole curds are as tolerant to bruising and its related quality effects at outturn, as individual florets. If so, a cost/benefit study on the effects of harvesting smaller immature curds needs to be undertaken to determine cultural and management changes required to make this an economically viable option.

6. Precooling and shelf life

"*Cooling of fresh produce is the simplest and most powerful way of reducing physiological deterioration*" (Story 9:1989). Various fresh products have different rates of respiration, therefore some products give off more heat than others resulting in a higher rate of deterioration. Cauliflower has a respiration rate of 51 watts/tonne at 0-3°C (Story 1989). This rate is not as high as other products. For example, broccoli has one of the highest respiration rates of 211 watts/tonne at 0-3°C. Regardless of respiration rate, fresh produce responds well to low temperatures by slowing deterioration and prolonging shelf life.

6.1. Testing commercial coolrooms

6.1.1. Introduction

Precooling is the first stage in the cool chain and is when produce is cooled immediately after harvest to remove field heat and bring core product temperature down to the optimum for storage. Industry practice is for precooling to commence approximately 4 - 6 hours after harvesting. Precooling is normally done in wooden bulk bins and the aim is to cool the cauliflowers to a core temperature of between 0-2°C before packing into cartons. The product loses weight through water loss during cooling and this has been estimated as much as 115 400 kg per year across the whole industry.

The Western Australian cauliflower industry use two types of cooling, forced-air and conventional. In forced-air cooling an air extractor fan is used to create an air pressure difference between opposite faces of bulk bins or cartons in two stacks with a central open channel between them (Figure 10). The pressure difference allows cool air to pass through the produce in the bulk bins which removes field heat rapidly (Watkins and Ledger 1990). Conventional cooling is when cool air passes on the outside of the bulk bins but is not drawn through the bins as in the forced air method. Conventional cooling is unsuitable for precooling highly perishable products like broccoli.

According to Story (1989), an efficient forced air coolroom should thoroughly cool produce in 3-5 hours. Fast cooling reduces the total amount of moisture lost. With forced air cooling, the amount of air flowing over the product actually increases moisture loss for an initial period. This initial fast air flow is cut back after a short period of time allowing produce to be quickly cooled with minimal water loss. With conventional cooling, produce will lose more moisture because it takes longer to cool, and the product core temperature is higher for longer.

In this study, four coolrooms used by export packing houses were monitored to compare their effectiveness in cooling cauliflowers to the required temperature with minimal weight loss. The aim of the study is to identify any inadequacies in coolroom operation to allow improvements to be made. Monitoring was done in the winter and summer to give a comparison during different times of the year.

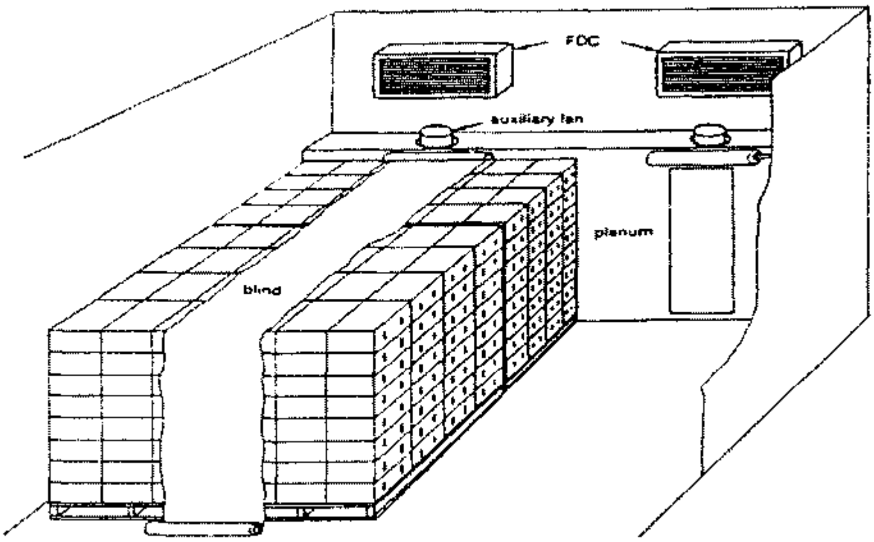


Figure 10: Cartons of produce being forced-air cooled. (Source: Watkins and Ledger, 1990:6)

6.1.2. Treatments

Each coolroom monitored is a separate treatment. The treatments of this trial were the coolrooms of the following packing houses located in Manjimup, Western Australia:

a) Manjimup Vegetable Export Growers (M-Veg)
b) Manjimup Apple Export Syndicate (M.A.E.S)
c) Manjimup Packers Pty. Ltd.
d) Wescorp International
e) Thermfresh® coolroom (Manjimup Horticultural Research Centre)

6.1.3. Materials and method

Three of the four commercial coolrooms monitored used conventional cooling, one was forced-air and the control was a Thermfresh® high humidity room at Agriculture Western Australia's Manjimup Horticultural Research Centre.

The Thermfresh® coolroom was considered a highly efficient coolroom which maintains high humidity and rapidly achieves a product core temperature of 0-4°C. Although the Thermfresh® can operate as a forced-air coolroom, it was not used this way in this study because insufficient produce was available to operate it efficiently. Despite this fact, the Thermfresh® still had excellent air flow qualities.

Five half tonne bulk bins of cauliflowers (variety *Plana*) were harvested from a commercial cauliflower property over a period of two hours. The bins were labelled 1-5 in order of harvest. One bin was delivered to each of the packing houses and one to the Manjimup Horticultural Research Centre (MHRC). For each bin, the two layers of cauliflowers from the top of the bin were removed without damage. This allowed access to the third layer of cauliflowers located at the middle of the bin (each bin is 6 layers deep). From the third layer, twenty cauliflower curds were measured and labelled 1-20 with small pieces of paper held at the butt of the curd with a drawing pin. The curds were taken from the middle of the bin because that is where the curds would take the longest to cool.

Measurements that were recorded before placement of these bins in the coolroom were:

i) temperature and humidity of the coolroom
ii) fresh weight of each curd
iii) core temperature of each curd using hand held temperature probe
iv) market quality score (Table 23)
v) density score (Table 24)
vi) time at which the cauliflowers were put in the coolroom.

Table 23: Market quality scoring system

Quality score	Market standard
1	reject (severe)
2	reject (moderate)
3	poor marketability
4	good marketability
5	export standard
6	export standard
7	excellent export standard

Source: Shellabear, 1994.

Table 24: Density scoring system

Score	Curd characteristics
1	loose, open, long floret stalks, flat base
2	moderately compact
3	compact, short floret stalks, curled based

Source: Shellabear, 1994.

Before the bin was placed into the coolroom, a Tinytag® temperature probe data logger was pressed into the base of one cauliflower located at the third layer and a Tinytag® relative humidity data logger was hung on the outside of the bin. The data loggers took readings every 5 minutes during the 20 hours of precooling. The two top layers of cauliflowers taken out of the bin were carefully replaced on top of the cauliflowers that were measured. The bin was placed in a stack, at least two bins high and in the middle of the coolroom to avoid any hot spots. All bins were left overnight in the five coolrooms. At the time, it was considered industry practice to harvest one day, precool overnight and pack the curds in export cartons the following day. However, in periods of peak supply the bins can often be in the coolroom for up to five days awaiting to be packed.

The above procedure was done for all the five bins, one in each coolroom. There were three replications. Each replication represented a day of harvest and there were three separate harvest dates. Harvesting occurred every third or fourth day.

After about 20 hours of precooling, the twenty numbered cauliflowers were removed from the bin. Weight and core temperature were measured again. Quality ratings were not done at this time because visual quality would not have changed dramatically in 20 hours of precooling. The twenty cauliflowers were then wrapped in industry standard paper and packed into export cartons. Each carton held ten wrapped curds. The data loggers were down loaded after precooling.

The cartons (ten cartons per time of harvest) were subjected to six days warm store at 21°C and 85-95% relative humidity. After four days in warm store, each curd was weighed, market quality score (Table 23) and quality assessment score recorded (Table 25). The cartons were then placed back in the warm store for another two days. After which the same measurements were recorded again.

The warm store conditions were used to simulate conditions in an open air wet market in humid countries such as Malaysia and Singapore. Quality ratings and weight loss of the cauliflowers were measured to determine whether the precooling method of the different coolrooms affected overall quality at outturn.

Data was analysed using GENSTAT statistical package, version 5.0 (Lawes Agricultural Trust, Rothamsted Experimental Station). All analyses used analysis of variance with differences between means compared by least significant difference (l.s.d.). The level of significance used was $P \leq 0.05$.

Table 25: Quality assessment scoring system

Score	Turgor	Severity rots/blemishes	Severity black spot	% Surface area affected by curd discolouration
1	very turgid	None	none	0 %
2	turgid	slight	slight	1-5 %
3	slight soft	moderate	moderate	6-10 %
4	soft	severe	severe	11-15%
5	very soft	very severe	very severe	16-20 % & over

6.1.4. Results and discussion

6.1.4.1. Winter harvest (5 -18 June 1997)

The commercial coolrooms were labelled A - D for confidentiality reasons.

The mean core temperatures of the cauliflower curds before precooling were between 9°C and 14°C depending on the weather conditions at time of harvest. After 20 hours precooling, core temperatures varied between the coolrooms from 1.1°C and 5.4°C (Table 26, Figure 11). Cauliflowers precooled in the various coolrooms showed different rates of cooling (Table 27). Coolroom C performed the worst with cauliflowers not reaching a core temperature of 2°C after 20 hours, at any of the three times tested. This coolroom had a low relative humidity of 74.8% and cauliflowers at the end of the period had a mean core temperature of 8.2°C (Table 28). The other rooms took a reasonable amount of time to reach a core temperature of 5°C but an unacceptable number of hours to reach 2°C. For example, coolroom B took 21.5 hours to achieve a core temperature of 2°C.

It was expected that the high number of hours would have resulted in excessive weight loss of curds. However, this was not the case. Regardless of whether the curds took 21 or 3 hours to achieve a core temperature of 2°C, weight loss was not significantly different for each coolroom (Table 29). An explanation to this result may be the time of the year. In the winter months, a mean core temperature ranging between 3.0 - 8.2°C during 20 hours of precooling does not result in a high weight loss (Table 28).
Mean core temperatures were calculated from the sum of core temperatures at half hour intervals (during the 20 hours) divided by the number of core temperature recordings. To

obtain the final average core temperature figure in Tables 28 and 36, the three core temperature figures from each replication or harvest were averaged.

Table 30 shows calculations of vapour pressure deficit (VPD) of each of the coolrooms. VPD is a measure of the potential for the cauliflowers to dehydrate while cooling based on temperature and humidity of the coolroom. The lower the VPD reading the better the coolroom is, that is, less moisture is lost from the produce. When comparing coolroom D with the Thermfresh®, coolroom D would dry out the product 2.3 times more than Thermfresh®. Coolroom C had the highest VPD of 2.3 millibars (mb).

After four days warm store the cauliflowers precooled in the various coolrooms did not show any significant difference in quality except for percentage curd discolouration (Table 31). It was only after six days warm store that any significant difference was shown. Cauliflowers precooled in Coolroom B significantly had the worst overall quality after six days warm store (Table 32). Cauliflowers from coolroom B were considered rejects, had the highest severity of rots/blemish and a high percentage of curd discolouration. Cauliflowers stored in the Thermfresh® only had slightly better quality than the other coolrooms.

Table 26: Mean core temperature (20 curds) of cauliflower before and after 20 hours precooling using hand held temperature probe (winter harvest).

	Harvest 1 Date: 6/6/97		**Harvest 2 Date: 10/6/97**		**Harvest 3 Date: 13/6/97**	
	Before precooling	**After precooling**	**Before precooling**	**After precooling**	**Before precooling**	**After precooling**
Thermfresh ®	n/a	n/a	9.6°C	2.7°C	12.1°C	2.7°C
Coolroom A	11.2°C	3.2°C	12.4°C	2.6°C	13.5°C	3.0°C
Coolroom B	12.5°C	5.4°C	10.9°C	1.9°C	13.1°C	1.1°C
Coolroom C	14.5°C	4.0°C	12.6°C	3.7°C	14.1°C	4.7°C
Coolroom D	13.7°C	1.4°C	11.5°C	1.2°C	14.1°C	1.1°C

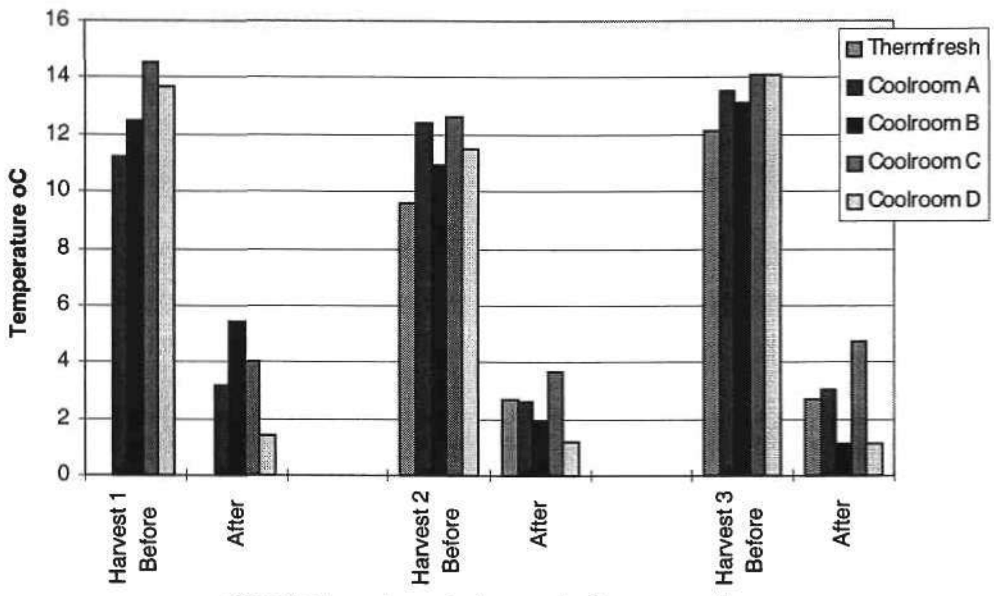


Figure 11: Mean core temperatures (°C) of cauliflowers (harvested on three separate days) before and after 20 hours of precooling stored in various coolrooms (winter harvest)

Table 27: Number of hours for core temperature of cauliflowers to reach 5°C and 2°C (winter harvest).

	HARVEST 1 6/6/97		**HARVEST 2 10/6/97**		**HARVEST 3 13/6/97**	
	5°C	**2°C**	**5°C**	**2°C**	**5°C**	**2°C**
Coolroom A	4 hrs	9.5 hrs	5 hrs	12 hrs	7 hrs	19 hrs
Coolroom B	9 hrs	14 hrs	8.5 hrs	21.5 hrs	2 hrs	3.5 hrs
Coolroom C	13 hrs	*	13.5 hrs	*	20 hrs	*
Coolroom D	3.5 hrs	6 hrs	2 hrs	8 hrs	4 hrs	8 hrs

** Core temperature did not reach 2°C*

Table 28: Mean core temperature of cauliflower from three harvests and humidity of coolrooms during precooling stage (20 hours) using data loggers (winter harvest).

	Average core temperature (°C)	**Average relative humidity (%)**
Thermfresh® (MHRC)	3.1(est.)	84.4%
Coolroom A	4.3	78.4%
Coolroom B	4.4	81.4%
Coolroom C	8.2	74.8%
Coolroom D	3.0	75.5%
LSD ($p \leq 0.05$)	**2.2**	**ns**

Table 29: Mean percentage weight loss of cauliflowers after each storage stage (winter harvest).

	After precooling	**After 4 days warm store**	**After 6 days warm store**
Thermfresh® (MHRC)	0.86%	2.6%	4.4%
Coolroom A	0.85%	2.7%	4.6%
Coolroom B	0.95%	2.8%	4.7%
Coolroom C	0.95%	2.8%	4.4%
Coolroom D	1.05%	2.9%	4.7%
LSD ($p \leq 0.05$)	**ns**	**ns**	**ns**

Table 30: Vapour pressure deficit calculations (winter harvest).

	Average temperature (°C)	**Average humidity (%)**	**Vapour pressure (mb)**	**VPD (mb)**
Thermfresh® (MHRC)	3.1	84.4%	6.9	0.3
Coolroom A	4.33	78.4%	6.8	0.2
Coolroom B	4.44	81.4%	7.1	0.5
Coolroom C	8.23	74.8%	8.9	2.3
Coolroom D	2.95	75.5%	5.9	0.7

Table 31: Quality ratings after four days warm store (winter harvest)

	Overall quality	Turgor	Severity rots/ blemishes	Severity black spot	% Curd discolouration
Thermfresh® (MHRC)	2.7	2.6	3.2	3.6	2.9
Coolroom A	2.5	2.7	3.7	3.6	3.0
Coolroom B	2.7	2.7	3.4	3.6	2.7
Coolroom C	2.9	2.6	3.1	3.3	2.6
Coolroom D	2.7	2.7	3.6	3.5	2.7
LSD ($p \leq 0.05$)	**ns**	**ns**	**ns**	**ns**	**0.26**

Table 32: Quality ratings after six days warm store (winter harvest)

	Overall quality	Turgor	Severity rots/ blemishes	Severity black spot	% Curd discolouration
Thermfresh® (MHRC)	2.1	2.6	4.0	3.8	3.3
Coolroom A	2.1	2.9	4.3	4.0	3.4
Coolroom B	1.8	2.6	4.4	3.9	3.6
Coolroom C	2.1	2.7	4.1	3.8	3.3
Coolroom D	2.3	2.5	3.8	3.7	3.1
LSD ($p \leq 0.05$)	**0.25**	**0.22**	**0.34**	**ns**	**0.28**

6.1.4.2. Summer harvest (9-22 February 1998)

Coolrooms B and C had operational problems during the monitoring period. Hence the high core temperatures after precooling in coolrooms B and C after the second harvest, 12.8°C and 8.6°C respectively (Table 33, Figure 12).

Coolroom D was the best coolroom for precooling when compared with the Thermfresh®, particularly at harvest date 1 (Table 34). Coolroom D took nearly the same time (13 hours) as the Thermfresh® for cauliflowers to reach a core temperature of 2°C. Disregarding Coolrooms B and C at the second harvest due to mechanical problems, Coolrooms A and D either did not reach a core temperature of 2°C or took over 19 hours for cauliflowers to obtain a core temperature of 2°C.

The number of hours taken to draw down the cauliflowers to the required core temperature affected the percentage weight loss during the summer months. Coolroom A and B significantly ($p \leq 0.05$) had the highest percentage weight loss, 1.43% and 1.25% respectively, during the precooling stage (Table 35). This was to be expected as Coolroom A took over 19 hours to reach a temperature of 2°C if at all. Coolroom B, as mentioned previously, had an operational breakdown, and as a consequence cauliflower precooled in this room had increased moisture loss.

The highest mean core temperature during the precooling was Coolroom A at 9.9°C (Table 36). The figures in Table 36 are the means of the final readings from the data loggers over the three dates.

With the vapour pressure deficit (VPD) calculations (Table 37), Coolroom A recorded the highest VPD of 2.9 millibars. Coolroom A is 3.2 times more likely to dry out the cauliflower during precooling than the Thermfresh®.

Coolroom B has been omitted from Tables 36 and 37 because a breakdown occurred during two replications. Coolroom C had only a minor operational problem during the second replication.

Table 33: Mean core temperature (20 curds) of cauliflower before and after 20 hours precooling using hand held temperature probe (summer harvest).

	Harvest 1 Date: 9/2/98		**Harvest 2** Date: 12/2/98		**Harvest 3** Date: 16/2/98	
	Before precooling	**After precooling**	**Before precooling**	**After precooling**	**Before precooling**	**After precooling**
Thermfresh ®	14.8°C	2.0°C	16.2°C	1.9°C	13.5°C	1.6°C
Coolroom A	17.9°C	8.5°C	18.0°C	3.1°C	15.4°C	3.7°C
Coolroom B	16.2°C	6.5°C	17.2°C	12.8°C	14.5°C	6.0°C
Coolroom C	16.1°C	3.5°C	14.1°C	8.6°C	15.5°C	2.8°C
Coolroom D	16.7°C	1.3°C	17.8°C	1.9°C	15.3°C	1.3°C

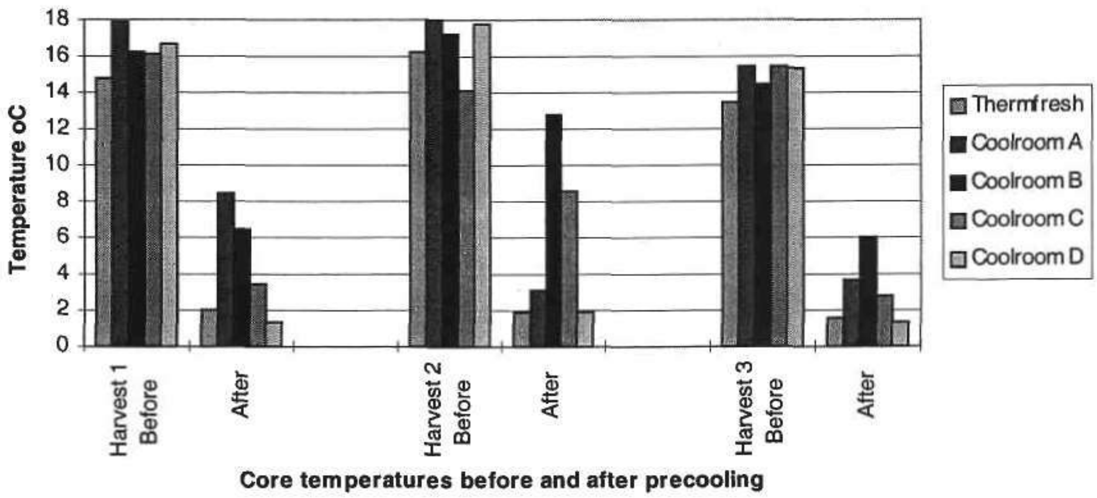


Figure 12: Mean core temperatures (°C) of cauliflowers (harvested on three separate days) before and after 20 hours of precooling stored in various coolrooms (summer harvest).

Table 34: Number of hours for core temperature of cauliflowers to reach 5°C and 2°C (summer harvest).

	HARVEST 1 Harvest date: 9/2/98		**HARVEST 2** Harvest date: 12/2/98		**HARVEST 3** Harvest date: 16/2/98	
	5°C	**2°C**	**5°C**	**2°C**	**5°C**	**2°C**
Thermfresh ®	7 hrs	12 hrs	6 hrs	11 hrs	2 hrs	4.5 hrs
Coolroom A	*	*	13.5 hrs	19.5 hrs	17 hrs	22 hrs
Coolroom B	~	~	~	~	~	~
Coolroom C	12.5 hrs	*	~	~	6 hrs	12.5 hrs
Coolroom D	8 hrs	13 hrs	12 hrs	17.5 hrs	8.5 hrs	12.5 hrs

* *Core temperature did not reach 5°C or 2°C*

~ *Coolroom did not function properly*

Table 35: Mean percentage weight loss of cauliflowers after each storage stage (summer harvest).

	After precooling	After 4 days warm store	After 6 days warm store
Thermfresh® (MHRC)	0.87%	3.0%	3.7%
Coolroom A	1.43%	2.5%	3.1%
Coolroom B	1.25%	3.1%	3.1%
Coolroom C	0.93%	3.0%	3.1%
Coolroom D	1.07%	3.0%	3.3%
LSD ($p \leq 0.05$)	**0.09**	**0.26**	**0.32**

Table 36: Mean core temperature of cauliflower from three harvests and humidity of coolrooms during precooling stage (20 hours) using data loggers (summer harvest).

	Average core temperature (°C)	Average relative humidity (%)
Thermfresh® (MHRC)	3.2	85% (estimation)
Coolroom A	9.9	74.4%
Coolroom C	6.8	79.1%
Coolroom D	5.1	84.3%
LSD ($p \leq 0.05$)	**4.25**	**13.22**

Table 37: Vapour pressure deficit calculations (summer harvest).

	Average temperature	Average relative humidity (%)	Vapour pressure (mb)	VPD (mb)
Thermfresh® (MHRC)	3.2	85.0%	7.5	0.9
Coolroom A	9.9	74.4%	9.5	2.9
Coolroom C	6.8	79.1%	8.5	1.9
Coolroom D	5.1	84.3%	7.6	1.0

There were small differences in overall quality between Coolrooms A, B and C (considered the worst precooling conditions) and Coolroom D and the Thermfresh® (considered the ideal precooling conditions) after six days warm store (Table 39). Cauliflowers stored in the worst precooling conditions had an overall quality score closer to being a reject cauliflower. Cauliflower precooled in the best precooling conditions had overall better quality scores. Other quality attributes recorded showed a similar pattern. Coolroom B, C and Thermfresh® had the highest severity of rots/blemishes. The reason why cauliflowers precooled in Thermfresh® had a high severity of rots/blemishes is because of the maturity of the cauliflowers in the bin as grower determined maturity can vary within a bin.

Table 38: Quality ratings after four days warm store (summer harvest).

	Overall quality	Turgor	Severity rots/ blemishes	Severity black spot	% Curd discolouration
Thermfresh® (MHRC)	3.2	2.3	2.2	2.9	2.4
Coolroom A	3.7	2.1	1.5	2.6	2.2
Coolroom B	3.3	2.2	1.9	2.7	2.2
Coolroom C	3.5	2.0	1.6	2.7	2.3
Coolroom D	3.4	2.1	1.5	2.7	2.3
LSD ($p \leq 0.05$)	**0.26**	**0.16**	**0.36**	**ns**	**ns**

Table 39: Quality ratings after six days warm store (summer harvest).

	Overall quality	Turgor	Severity rots/ blemishes	Severity black spot	% Curd discolouration
Thermfresh® (MHRC)	2.2	3.0	3.0	4.0	3.5
Coolroom A	2.8	2.4	2.0	3.8	3.1
Coolroom B	2.4	3.0	3.0	3.8	3.5
Coolroom C	2.6	2.4	2.5	3.8	3.5
Coolroom D	2.7	2.6	2.2	3.8	3.4
LSD ($p \leq 0.05$)	**0.30**	**0.32**	**0.50**	**ns**	**0.28**

Even though operational breakdown occurred in some of the coolrooms causing higher than usual core temperatures, it showed very little difference in quality between the cauliflowers precooled in the different coolrooms. This suggests that other factors such as harvest maturity may be affecting the quality of cauliflowers as well as the precooling conditions of the coolroom.

6.1.5. Conclusion

During the winter months, precooling cauliflowers for a 20 hour period to achieve final core temperatures of between 3°C and 8.2°C, did not greatly affect weight loss. The results showed that cauliflowers precooled in a coolroom with high temperature and low humidity were of slightly poorer quality.

During the summer months, cauliflowers lose significant amounts of moisture during precooling, however weight loss did not result in highly significant differences in quality of cauliflowers precooled in the different coolrooms. The results of this work suggest that time taken to precool cauliflowers (up to 20 hours) only had a small effect on quality of curds at outturn. Other factors such as bruising are probably more important determinates of final quality

During certain times of the summer months, which can be the busiest time, coolrooms are stacked with the maximum number of bins of cauliflower. With maximum capacity, it takes longer to pack large amounts of cauliflower, therefore the cauliflowers can be in the precooling coolroom for up to five days. Quality of cauliflowers would most likely be poorer if precooling conditions of the coolroom were 5-6°C at 75-80% relative humidity for five days. The effects of longer term cooling on outturn quality need to be tested further.

This study identified opportunities for improved performance of three coolrooms. When implemented this should improve curd quality at outturn. The regular checking of core temperature is an important factor. The collaborative approach with industry to examine the cool chain has highlighted key issues for future improvement.

Consultation with industry has identified the following points for close examination at each packing house:

- Regular core temperature checks of cauliflower before packing and relative humidity checks of coolroom.
- Keep door closed at all times (particularly during summer). In general, for every 1°C rise in temperature, relative humidity falls by 7%.
- Check door seals by going inside the coolroom, close the door and turn off the lights. Any gaps will be seen as light from outside shows through.
- If necessary wet the floor of the coolroom to obtain a higher humidity. Practice hygiene within the coolroom by scrubbing the floor with chlorine to avoid mould growth.
- All refrigeration machinery such as the evaporator should be kept clean. Dust and fluff can gather on the air entry side of the evaporator, reducing air flow which can increase temperature in the room (Story 1989).

6.2. Effects of bulk bin treatments on precooling

In order to reduce bruising of cauliflower, some commercial packing houses in Manjimup have been supplying bulk bins to growers with bin liners or plastic bubble wrap sheets. Different packing houses use various methods to minimise bruising during road transport from the growers property to the packing house. One packing house used plastic bubble sheets which the growers are provided with to separate each layer of cauliflower within the bin. This is claimed to reduce cauliflowers rubbing together during transport to packing house. Another pack house, at the time of testing, used plastic bubble wrap bin liners which surround the inside of the bin to reduce bruising through vibration with the side of the wooden bin. Other houses use no material to reduce bruising, only cauliflower leaves on the bottom of the bin.

Whether these bin treatments actually reduce bruising and by what degree has been investigated. There has also been suggestions that bin liners interrupt air flow through the bin when precooling. Therefore, the aim of this work is to determine whether various bin treatments affect precooling draw down rates and the quality of cauliflowers. Trials were conducted in the summer and winter to give a comparison during different times of the year.

6.2.1. Treatments

There were four bin treatments used in the experiment, replicated three times. Each harvest represented a replication. Four bins were harvested on each harvest day. There were three harvests over a period of two weeks. The bin treatments were as follows:

i) **BIN 1** - Loose bin, cauliflower leaves on the bottom and top of the bin (control)
ii) **BIN 2** - Plastic bubble wrap between the layers of cauliflower
iii) **BIN 3** - Plastic bubble wrap bin liner
iv) **BIN 4** - Plastic bubble wrap between layers and bubble wrap bin liner

6.2.2. Materials and method

The materials and method used is basically similar to the previous precooling investigation. The only difference being that the bins were precooled in the one coolroom, the Thermfresh® coolroom at the Manjimup Horticultural Research Centre (MHRC). This trial focussed on the effects of bin treatments on precooling and bruising, not the different precooling techniques of various coolrooms, hence the precooling was done in the one coolroom.

Four bins of cauliflowers were harvested each with the different bin treatments. The variety for the summer harvest was *Plana* and for the winter harvest, *Granite*. The bins were labelled 1 - 4. The four bins were then transported to MHRC for measurement before being placed in the Thermfresh® coolroom. Thirty cauliflowers were taken from the middle of each bin, labelled 1-30 and the following measurements were taken:

- i) temperature and humidity of the coolroom
- ii) weight of each curd
- iii) core temperature of each curd using hand held temperature probe
- iv) market quality score (Table 23) and reason for reject
- v) density score (Table 24)
- vi) time at which the cauliflowers were put in the coolroom.

After measuring, the thirty cauliflowers were replaced in the bin and the bin was put in the Thermfresh® for precooling. This was done for all four bins. The four bins were placed in the coolroom as shown in Figure 13. During the summer trial, the Thermfresh® was running at a temperature of between 0.2°C to 4°C with a 94% relative humidity. During the winter trial, the temperatures ranged from 0.2°C to 6°C with 98% relative humidity. During precooling, core temperature of one cauliflower from each bin and relative humidity was measured using data loggers. The four bins were left overnight in the coolroom for about 22 hours during the summer trial and 19 hours during the winter trial.

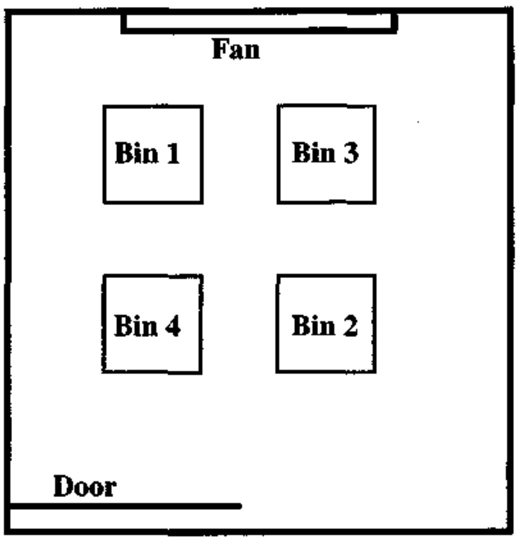


Figure 13: Configuration of bins in Thermfresh® coolroom

After precooling the thirty cauliflowers were removed from the bin. Weight and core temperature were measured again. The cauliflowers were then wrapped in industry standard paper and packed into export cartons. Ten wrapped curds were put in one carton. The cartons were subjected to six days warm store at 21°C and 85-95% relative humidity. The warm store conditions were used to simulate conditions in an open air wet market in humid countries such as Malaysia and Singapore. The following measurements were taken after the fourth and sixth day in warm store:

i) weight of each curd
ii) market quality score and reason for reject
iii) quality assessment score (Table 25)

6.2.3. Results and discussion

6.2.3.1. Summer harvest (8- 19 December 1997)

The highest core temperature of cauliflower before precooling was 20.5°C and the lowest was 12.2°C (Table 40). Cauliflowers precooled in Bin 4 with bin liner and bubble wrap sheets had a maximum core temperature of 9.1°C after 22 hours of precooling. Cauliflowers in the loose bin recorded core temperatures of between 2.1°C - 3.4°C after precooling (Table 40, Figure 14).

Bins lined with plastic bubble wrap liner took longer to precool to a core temperature of 5°C than bins with no liner (Table 41). On the hottest picking day (32°C) cauliflowers in Bin 3 and 4 took 14 and 15.5 hours respectively to cool to a core temperature of 5°C. In replication three, cauliflowers stored in Bin 4 did not reach a core temperature of 5°C. Both Bin 3 and 4 did not reach core temperature of 2°C. Those bins without bin liners or bubble wrap took between 7.5 hours to 13 hours to achieve a core temperature of 2°C.

The long 'draw down' time affected percentage weight loss. After precooling, cauliflowers in Bin 4 had significantly ($p \leq 0.05$) the highest percentage weight loss of 1.58%. Followed by Bin 3 with a weight loss of 1.47%. Cauliflowers in Bin 1 (control) had the lowest weight loss of 1.15% (Table 42).

Table 40: Average core temperature of cauliflower before and after precooling, using temperature probe (summer harvest).

	Harvest 1 Date: 8/12/98		**Harvest 2 Date: 10/12/98**		**Harvest 3 Date: 12/12/98**	
	Before precooling	**After precooling**	**Before precooling**	**After precooling**	**Before precooling**	**After precooling**
BIN 1 - loose (control)	12.2°C	3.4°C	16.4°C	2.2°C	16.7°C	2.1°C
BIN 2 - bubble wrap sheets	13.6°C	3.4°C	18.7°C	3.3°C	17.2°C	4.3°C
BIN 3 - bin liner	15.6°C	5.0°C	18.4°C	3.4°C	18.4°C	3.6°C
BIN 4 - bin liner & bubble wrap sheets	19.1°C	5.3°C	20.5°C	3.5°C	19.4°C	9.1°C

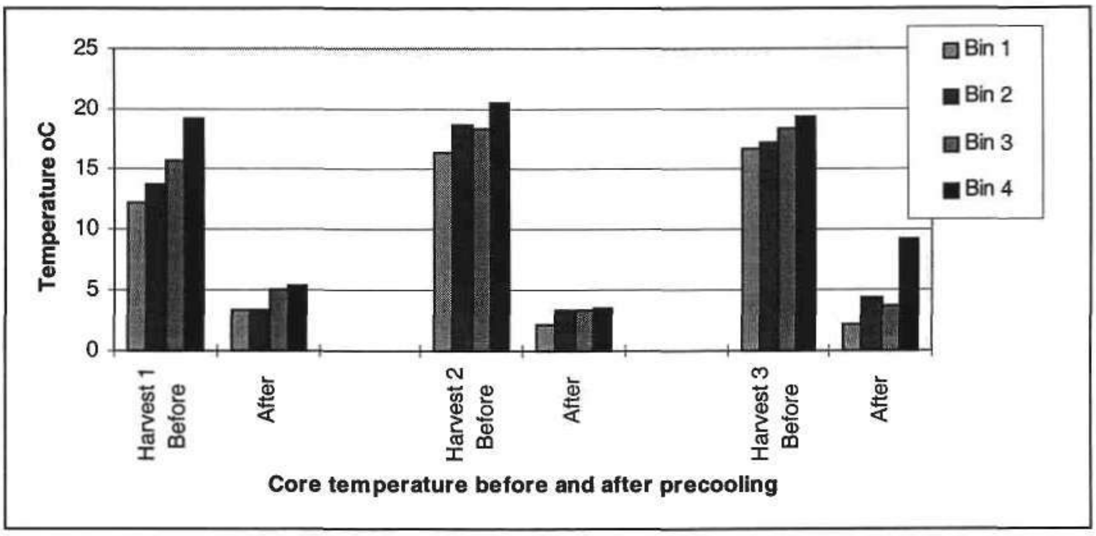


Figure 14: Mean core temperatures (°C) of cauliflowers (harvested on three separate days) before and after 22 hours of precooling stored in various bin treatments (summer harvest).

Table 41: Number of hours required to obtain a core temperature of 5°C and 2°C in cauliflower during the precooling stage (summer harvest).

Treatment	5°C	2°C
Test 1 - 8/12/97 ambient temp. 27°C		
BIN 1 - loose (control)	4 hrs	11 hrs
BIN 2 - bubble wrap sheets	6.5 hrs	11.5 hrs
BIN 3 - bin liner	16 hrs	~
BIN 4 - bin liner & bubble wrap sheets	lowest 6°C	~
Test 2 - 10/12/97 ambient temp. 32°C		
BIN 1 - loose (control)	8 hrs	13 hrs
BIN 2 - bubble wrap sheets	11 hrs	15 hrs
BIN 3 - bin liner	14 hrs	~
BIN 4 - bin liner & bubble wrap sheets	15.5 hrs	~
Test 3 - 12/12/97 ambient temp. 26°C		
BIN 1 - loose (control)	4.5 hrs	7.5 hrs
BIN 2 - bubble wrap sheets	10 hrs	19 hrs
BIN 3 - bin liner	17 hrs	~
BIN 4 - bin liner & bubble wrap sheets	~	~

~ average core temperature of cauliflower in that bin did not reach 5C or 2C

Table 42: Average percentage weight loss of cauliflower after each storage stage (summer harvest).

Treatment	After precooling (A)	After 4 days warm store	After 6 days warm store (B)	Total (A+B)
BIN 1 - loose (control)	1.15%	3.8%	6.2%	7.35%
BIN 2 - bubble wrap sheets	1.31%	3.6%	5.8%	7.11%
BIN 3 - bin liner	1.47%	3.7%	5.9%	7.37%
BIN 4 - bin liner & bubble wrap sheets	1.58%	3.7%	5.8%	7.38%
LSD ($p \leq 0.05$)	**0.07**	**ns**	**0.21**	

The average core temperature of cauliflower during the precooling stage also differed depending on the bin treatment used (Table 43). Bin 4 had an average core temperature during precooling of 13.0°C and Bin 1 had an average core temperature of 3.6°C (averages taken from figures obtained from a data logger recording core temperature at regular intervals during the 22 hour precooling period).

Table 43: Average core temperature of cauliflower during the precooling stage using data loggers (summer harvest).

Treatment	Average core temperature	Average RH% in Thermfresh
BIN 1 - loose (control)	3.6°C	94%
BIN 2 - bubble wrap sheets	5.8°C	
BIN 3 - bin liner	8.4°C	
BIN 4 - bin liner & bubble wrap sheets	13.0°C	

After 4 days warm store weight loss between the bin treatments were relatively the same ranging from 3.6% to 3.8%. Bin 1 significantly had the highest weight loss after six days warm store, 6.2% (Table 42). Quality ratings of the cauliflowers precooled in various bin treatments differed slightly (Table 44). Bin 4 showed cauliflower had a higher standard of local market quality after four and six days warm store. Cauliflowers precooled in Bin 1 and 2 were rejects after six days warm store. The severity of black spot also showed a similar pattern (Table 45). Cauliflowers precooled in Bin 1 (loose) had a higher severity of black spot after six days warm store than the other treatments.

Table 44: Mean quality rating (1: reject - 7: export standard) after each storage stage (summer harvest).

Treatment	Before precooling	After 4 days warm store	After 6 days warm store
BIN 1 - loose (control)	4.4	3.1	2.8
BIN 2 - bubble wrap sheets	4.5	3.5	2.9
BIN 3 - bin liner	4.6	3.5	3.0
BIN 4 - bin liner & bubble wrap sheets	4.8	4.1	3.3
LSD ($p \leq 0.05$)	**0.18**	**0.20**	**0.18**

Table 45: Average black spot rating (1: none - 5: very severe) after each storage stage (summer harvest).

Treatment	**After 4 days warm store**	**After 6 days warm store**
BIN 1 - loose (control)	2.9	3.8
BIN 2 - bubble wrap sheets	2.6	3.4
BIN 3 - bin liner	2.7	3.6
BIN 4 - bin liner & bubble wrap sheets	2.5	3.4
LSD ($p \leq 0.05$)	**0.16**	**0.19**

Bin liners slightly improve the quality of cauliflowers with less bruising from rubbing on the sides of the bin. However, bin liners reduce air flow within the bin resulting in more time required to remove field heat and bring the cauliflowers to a suitable core temperature for packing. This delay in removing field heat leads to a greater weight loss of over 10 grams per cauliflower.

6.2.3.2. Winter harvest (4-17 August 1998)

The core temperatures of cauliflower before precooling were between 9.1°C to 15.7°C (Table 46, Figure 15). After precooling, cauliflowers in Bin 4 again recorded the highest core temperatures over the three replications, the highest being 8.4°C after precooling harvest 1 cauliflowers.

Bin 4 with bin liner and bubble wrap between cauliflower layers has the slowest draw down rate. With all three replications core temperature of cauliflower in Bin 4 did not get down to a core temperature of 5°C (Table 47).

Table 46: Average core temperature of cauliflower before and after 19 hours precooling using temperature probe (winter harvest).

	Harvest 1 Date: 4/8/98		**Harvest 2 Date: 7/8/98**		**Harvest 3 Date: 10/8/98**	
	Before precooling	**After precooling**	**Before precooling**	**After precooling**	**Before precooling**	**After precooling**
BIN 1 - loose (control)	9.1°C	5.3°C	13.6°C	3.7°C	14.8°C	0.3°C
BIN 2 - bubble wrap sheets	9.2°C	6.6°C	14.1°C	4.0°C	15.3°C	6.5°C
BIN 3 - bin liner	9.3°C	7.4°C	13.4°C	4.5°C	15.1°C	1.4°C
BIN 4 - bin liner & bubble wrap sheets	9.4°C	8.4°C	14.1°C	6.6°C	15.7°C	7.1°C

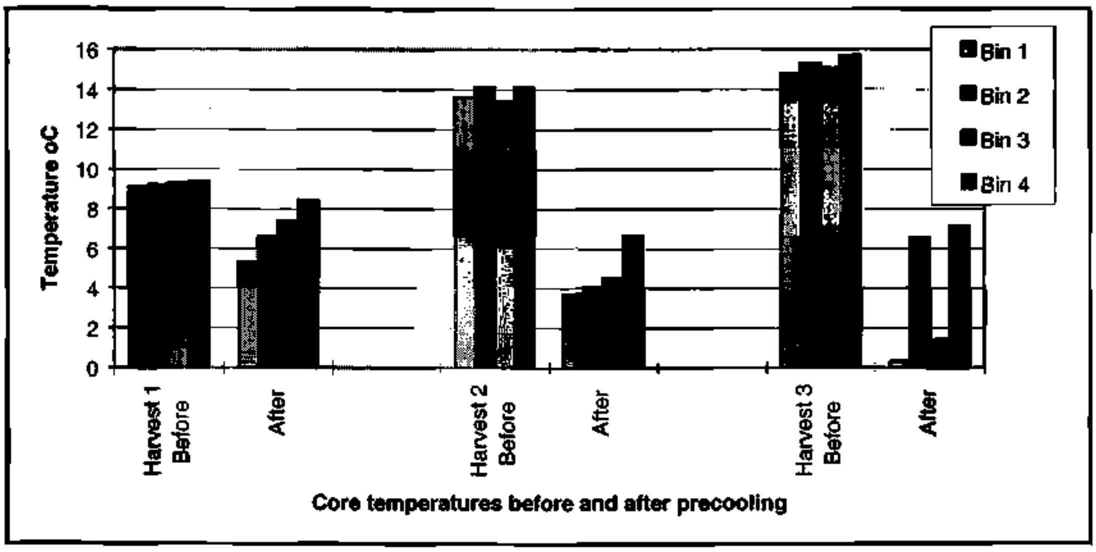


Figure 15: Mean core temperatures (°C) of cauliflowers (harvested on three separate days) before and after 19 hours of precooling stored in various bin treatments (winter harvest).

Table 47: Number of hours required to obtain a core temperature of 5°C and 2°C in cauliflower during precooling stage (winter harvest). Maximum time 19 hours.

Treatment	5°C	2°C
Rep 1 - 4/8/98 ambient temp. 13°C		
BIN 1 - loose (control)	13 hrs	~
BIN 2 - bubble wrap sheets	lowest 6.9°C	~
BIN 3 - bin liner	lowest 7.0°C	~
BIN 4 - bin liner & bubble wrap sheets	lowest 7.8°C	~
Rep 2 - 7/8/98 ambient temp. 17°C		
BIN 1 - loose (control)	5 hrs	9 hrs
BIN 2 - bubble wrap sheets	15 hrs	lowest 3.5°C
BIN 3 - bin liner	10 hrs	lowest 2.3°C
BIN 4 - bin liner & bubble wrap sheets	lowest 5.5°C	~
Rep 3 - 10/8/98 ambient temp. 17°C		
BIN 1 - loose (control)	2 hrs	4.5 hrs
BIN 2 - bubble wrap sheets	lowest 5.8°C	~
BIN 3 - bin liner	7 hrs	11 hrs
BIN 4 - bin liner & bubble wrap sheets	lowest 7.6°C	~

~ *average core temperature of cauliflower in that bin did not reach 2C*

Bin 3 appeared to perform better than Bin 2 without the bin liner. In both replication two and three, cauliflowers stored in Bin 3 with the bin liner achieved a lower core temperature in a shorter time than Bin 2. It is suggested that Bin 2 with the bubble wrap sheets in between the layers of cauliflower, reduced air flow through the bin with the same affect as a bin liner. The bubble wrap sheets used were slightly bigger than the bin itself hence the sheet overlapped up the sides of the bin thus reducing air flow. The bubble wrap sheets used in the trial are currently being used by some growers.

Percentage weight loss appears to be significantly less with Bin 4. Bin 3 with just a bin liner had the highest percentage weight loss (Table 48). During the summer trial, weight loss was directly related to the draw down rate of the cauliflowers. Bin 4 cauliflower took the longest time to reach 5°C, therefore had the highest percentage weight loss. During the winter trial, it appears that distance from the coolroom fan may have affected weight loss and not the bin treatments. Bin 3 was closer to the fan than Bin 4 therefore would have had air blowing across the bin at a faster velocity than Bin 4. This increased diffusion may explain why both bin 1 and bin 3 had higher percentage weight loss than bin 4.

Table 48: Average percentage weight loss of cauliflower after each storage stage (winter harvest).

Treatment	After precooling (A)	After 4 days warm store	After 6 days warm store (B)	Total (A+B)
BIN 1 - loose (control)	0.84%	2.76%	4.45%	5.29%
BIN 2 - bubble wrap sheets	0.84%	3.00%	4.75%	5.59%
BIN 3 - bin liner	0.93%	3.20%	4.98%	5.91%
BIN 4 - bin liner & bubble wrap sheets	0.77%	3.35%	5.03%	6.57%
LSD ($p \leq 0.05$)	**0.06**	**0.18**	**0.21**	

From Table 49, core temperature of the cauliflowers show that over sized bubble wrap sheets affect the cooling rate. Bin 1 with no treatment had the lowest core temperature and Bin 4 has the highest core temperature of 10.7°C.

A high core temperature could not be shown to result in reduction in quality after storage in warm store. Table 50 shows that Bin 2 and Bin 4 recorded better quality ratings than Bin 1 and 3 both of which had lower core temperatures. The black spot and rots/blemishes rating shows a similar pattern (Tables 51 and 52). Bin 1 and 3 had higher ratings of black spot and rots/blemishes than Bin 2 and 4. The common factor related to better outturn was the presence of bubble wrap sheets despite their negative effects on cooling rates. This tends to suggest that core temperature alone is not the most important factor affecting outturn of the product. The most likely reason for the poor result from bins without bubble wrap sheets between layers of curds is higher bruising levels.

Table 49: Average core temperature of cauliflower during the precooling stage measured with data loggers (winter harvest).

Treatment	Average core temperature	Average RH% in Thermfresh
BIN 1 - loose (control)	3.5°C	97.6%
BIN 2 - bubble wrap sheets	8.8°C	
BIN 3 - bin liner	6.5°C	
BIN 4 - bin liner & bubble wrap sheets	10.7°C	

Table 50: Average quality rating (1: reject - 7: export standard) after each storage stage (winter harvest).

Treatment	Before precooling	After 4 days warm store	After 6 days warm store
BIN 1 - loose (control)	4.8	2.5	1.9
BIN 2 - bubble wrap sheets	4.9	3.1	2.5
BIN 3 - bin liner	5.0	2.6	1.9
BIN 4 - bin liner & bubble wrap sheets	5.1	3.3	2.3
LSD ($p \leq 0.05$)	ns	0.21	0.17

Table 51: Average black spot rating (1: none - 5: very severe) after each storage stage (winter harvest).

Treatment	After 4 days warm store	After 6 days warm store
BIN 1 - loose (control)	2.9	3.8
BIN 2 - bubble wrap sheets	2.6	3.4
BIN 3 - bin liner	2.7	3.6
BIN 4 - bin liner & bubble wrap sheets	2.5	3.4
LSD ($p \leq 0.05$)	0.16	0.19

Table 52: Average rots/blemishes rating (1: none - 5 : very severe) after each storage stage (winter harvest).

Treatment	After 4 days warm store	After 6 days warm store
BIN 1 - loose (control)	3.0	4.2
BIN 2 - bubble wrap sheets	2.2	3.0
BIN 3 - bin liner	2.9	4.0
BIN 4 - bin liner & bubble wrap sheets	2.2	3.0
LSD ($p \leq 0.05$)	0.26	0.28

Loose packing (Bin 1) facilitated rapid and complete precooling but final quality of curds was poorer in summer and winter, possibly due to more bruising than other treatments. Bin liners only (Bin 3) slow the cooling rate compared to loose packing but do not slow it as much as sheets between the layers of curds. Despite having an adverse effect on cooling rate, bubble wrap sheets between the layers of curds in the bin were the best compromise treatment as long as they were cut smaller than the internal dimensions of the bin. Bubble wrap sheets plus bin liners also gave better quality scores at outturn than loose packing or bin liners alone but greatly reduced precooling efficiency.

These results suggest that measures which reduce bruising and curd damage are more important than precooling rate in maximising quality of the product at outturn after exposure to higher ambient temperatures.

6.2.4. Future research

Bubble wrap sheets and bin liners both improve the quality (appearance) of the product at outturn but increase precooling times. Work needs to be done to modify these materials to allow more airflow through bins while not compromising the positive effects of reducing bruising. The ideal material would have minimal effects on cooling rates compared to loose fill while not increasing bruising levels over those currently achieved.

7. Field handling studies

7.1. Introduction

Field handling practices for export cauliflowers vary greatly from grower to grower, particularly the time which elapses between cutting curds and delivery to coolstore. Many in the industry consider this period crucial to good outturns. Previous work by Hill 1985 (unpublished) showed that there was no difference in cauliflower curd appearance after periods of ambient storage (in the field) of durations 1 hour to 24 hours. Measurements of curd appearance were made after the field storage period plus a further 10 days in coolstore (1°C) and 3 days warm storage (22°C, 82% humidity).

The storage treatment of coolstore and warm store beyond the field holding period may have masked differences between field treatments. The 1985 work did not look at weight loss or specific quality problems such as black spot and rots. Further information on these aspects was needed to optimise cauliflower quality.

The aim of the unreplicated observations reported here was to simulate ambient temperatures expected during summer in a controlled environment and assess the magnitude of time of exposure to these temperatures on cauliflower quality. If effects were large and easily measurable it was planned to proceed to a full scale in field experiment with actual field conditions.

7.2. Simulated spring field temperatures

7.2.1. Materials and method

Sixty cauliflowers (variety *Plana*) were harvested from a crop at Manjimup Horticultural Research Centre (MHRC). The cauliflower curds were put into two 84 litre capacity crates, each holding 30 curds. To minimise bruising from the field to the MHRC, each curd was wrapped in loose cauliflower leaves and placed in the crate. The leaves were removed before the cauliflowers were put into warm store. Treatments applied to the curds were different lengths of time at 22°C and 82% relative humidity (warm store). These treatments simulated the range of conditions cauliflowers may experience during commercial handling on farms before delivery to the packing house. This period is called warm store 1 (Table 53).

Table 53: Number of hours in field simulated period (warm store 1) followed by cool storage and 3 days warm store (warm store 2).

Warm store 1 field simulation period	Cool storage period 2°C ± 1°C	Warm store 2 22°C±3°C
Treatment 1: 0 hours	10 days	3 days
Treatment 2: 2 hours	10 days	3 days
Treatment 3: 4 hours	10 days	3 days
Treatment 4: 6 hours	10 days	3 days
Treatment 5: 8 hours	10 days	3 days
Treatment 6: 24 hours	10 days	3 days

Ratings of market quality (Table 23), density (Table 24) and the weight of each curd were taken before the cauliflowers were treated. The two crates of cauliflowers were put in the warm store and each curd was reweighed after 2, 4, 6, 8 and 24 hours.

After these treatments were completed, two cauliflowers from each treatment (total of twelve) were put into cool store (2°C±1°C) for 10 days and 3 days warm store to simulate sea transport and market conditions in Singapore. The latter 3 days will be referred to as "warm store 2" in discussion. Quality measurements were recorded after each storage stage. After 10 days cool store and "warm store 2" the following was recorded:

i) weight
ii) market quality score (1: reject - 7: excellent export standard) (Table 23)
iii) severity of black spot (Table 54)
iv) severity of rots/blemishes (Table 54)

Table 54: Black spot and rots/blemishes severity ratings.

Score	Severity
1	none
2	slight
3	moderate
4	severe
5	very severe

7.2.2. Results and discussion

Weight loss after 2, 4, 6, and 8 hours was very low. Weight loss ranged from 2.2g to 5.1g per curd between 4 and 8 hours (Table 55). The 24 hour treatment recorded the greatest weight loss of 17.3g per curd. Normal commercial practice is not to leave bins of cauliflowers out in the field any longer than 8 hours.

Table 55: Average percentage weight loss of cauliflower stored in warm store at 22°C and 82% humidity.

Treatment	**CRATE 1** (Average initial weight of curd = 806g) Cumulative weight loss	**CRATE 2** (Average initial weight of curd = 867g) Cumulative weight loss
After 2 hours	1.6g (0.2%)	0.9g (0.1%)
After 4 hours	2.4g (0.3%)	1.7g (0.2%)
After 6 hours	3.2g (0.4%)	3.4g (0.4%)
After 8 hours	4.8g (0.6%)	6.1g (0.7%)
After 24 hours	16.9g (2.1%)	17.3g (2.0%)
After 10 days cool store (average all treatments)	21.7g (2.7%)	25.1g (2.9%)
After warm store 2 (average all treatments)	40.3g (5.0%)	35.5g (4.1%)

The treatment effect on quality was variable. After the 10 days cool storage period, cauliflowers from treatment 6 (24 hours) of crate 1 and 2 were no longer of export standard (Table 56 and 57). After 3 days warm store (warm store 2) these curds were rated as reject. Cauliflowers from treatment 1 (control) and 2 were of export standard after 10 days coolstore. However, after 3 days warm store (warm store 2) those cauliflowers from treatment 1 and 2 were ranging from export quality to below export quality (Table 56).

Table 56: Quality scores of cauliflowers in crate #1 after 10 days cool store and 3 days warm store (warm store 2).

CRATE #1	AFTER 10 DAYS COOL STORE			AFTER 3 DAYS WARM STORE		
Treatment curd no.	**Quality (1-7)**	**Severity black spot**	**Severity rots/ blem**	**Quality (1-7)**	**Severity black spot**	**Severity rots/blem**
0 hours						
1	5	1	1	5	2	1
2	5	1	1	5	3	1
2 hours						
3	4	1	1	4	3	2
4	5	1	2	4	3	2
4 hours						
5	5	1	2	3	5	4
6	4	1	1	2	5	4
6 hours						
7	4	1	2	4	3	2
8	5	2	1	3	3	2
8 hours						
9	5	1	1	3	3	2
10	5	2	2	3	5	5
24 hours						
11	4	2	2	2	5	4
12	4	1	2	2	5	4
Average	**4.6**	**1.3**	**1.5**	**3.3**	**3.8**	**2.8**

Table 57: Quality scores of cauliflowers in crate #2 after 10 days cool store and 3 days warm store (warm store 2).

CRATE #1	AFTER 10 DAYS COOL STORE			AFTER 3 DAYS WARM STORE		
Treatment curd no.	**Quality (1-7)**	**Severity black spot**	**Severity rots/ blem**	**Quality (1-7)**	**Severity black spot**	**Severity rots/blem**
2 hours						
1	5	1	2	5	3	2
2	4	1	2	3	3	2
4 hours						
3	4	1	2	3	3	3
4	4	1	2	3	3	2
6 hours						
5	5	1	2	2	4	5
6	4	1	2	2	5	4
8 hours						
7	4	1	2	2	5	3
8	4	1	2	2	4	3
24 hours						
9	4	2	3	2	5	4
10	4	2	2	2	5	5
Average	**4.2**	**1.3**	**2.1**	**2.6**	**4.0**	**3.3**

7.3. Simulated summer field temperatures

This observation was similar to the spring simulated trial, except that treatment 6 (24 hours) was omitted and the warm store was held at a higher average temperature of 30.7°C with 43.7% relative humidity to simulate outside summer conditions in the Manjimup area. The sixty cauliflowers (variety *Plana*) came from a commercial crop.

7.3.1. Results and discussion

At warmer temperatures, weight loss was higher (Table 58). After 4 hours, weight loss was 3.9g. After 6 hours weight loss was 9.1g. The trial also found a relationship between curd weight loss, hours in the field and temperature. At 31°C, weight loss nearly doubled every two hours.

With the higher warm store temperature of 31°C and after 10 days cool store, curds from the 8 hour treatment had a rating of 3, poor local market quality. All curds with the 8 hour treatment after 3 days cool store were considered rejects. After 10 days cool store, cauliflowers from treatment 1 and 2 were of export standard. However, after warm store 2, the same cauliflowers were also rejects or poor local market quality (Table 59 and 60).

Table 58: Average percentage weight loss of cauliflower stored in warm store at 31°C and 44% humidity.

Treatment	**CRATE 1** Average weight of curds = 983g	**CRATE 2** Average weight of curds = 979g
After 2 hours	2.0g (0.2%)	2.0g (0.2%)
After 4 hours	3.9g (0.4%)	3.7g (0.4%)
After 6 hours	9.1g (0.9%)	8.1g (0.8%)
After 8 hours	11.3g (1.2%)	8.9g (0.9%)
After 10 days cool store (average all treatments)	37.0g (3.6%)	27.0g (2.7%)
After 3 days warm store (average all treatments)	35.2g (3.6%)	29.0g (3.0%)

Table 59: Quality scores of cauliflowers in Crate #1 after 10 days cool store and 3 days warm store (warm store 2).

CRATE #1	AFTER 10 DAYS COOL STORE			AFTER 3 DAYS WARM STORE		
Treatment curd no.	**Quality (1-7)**	**Severity black spot**	**Severity rots/ blem**	**Quality (1-7)**	**Severity black spot**	**Severity rots/blem**
0 hours						
1	5	1	1	2	4	2
2	6	2	1	2	4	3
2 hours						
3	5	2	1	3	4	2
4	4	3	1	2	5	2
4 hours						
5	4	2	1	2	3	2
6	4	2	1	2	4	2
6 hours						
7	4	2	1	2	4	3
8	4	2	1	1	4	3
8 hours						
9	3	3	1	2	4	2
10	3	3	1	1	5	5
Average	**4.2**	**2.2**	**1.0**	**1.9**	**4.1**	**2.6**

Table 60: Quality scores of cauliflowers in Crate #2 after 10 days cool store and 3 days warm store (warm store 2).

CRATE #2	AFTER 10 DAYS COOL STORE			AFTER 3 DAYS WARM STORE		
Treatment curd no.	**Quality (1-7)**	**Severity black spot**	**Severity rots/blem**	**Quality (1-7)**	**Severity black spot**	**Severity rots/blem**
0 hours						
11	5	2	1	2	4	2
12	4	2	1	2	4	3
2 hours						
13	4	2	1	3	4	2
14	4	2	1	2	5	2
4 hours						
15	4	2	1	2	3	2
16	4	2	1	2	4	2
6 hours						
17	4	2	1	2	4	3
18	4	2	1	1	4	3
8 hours						
19	4	2	1	2	4	2
20	3	3	1	1	5	5
Average	**4.0**	**2.1**	**1.0**	**1.9**	**4.1**	**2.6**

Table 61: Dollars lost per bin over time in warm store at 22°C and 30°C.

	2 hours	4 hours	6 hours	8 hours	24 hours
22°C	\$0.21c	\$0.39c	\$0.63c	\$0.91c	\$3.05
30°C	\$0.35c	0\$0.67c	\$1.50	\$1.77	-

Assumptions: Price - 70c/kg, 250 curds per bin, 100% of curds are packed, no rejects

Table 61 shows that the financial loss from weight loss was small. In the worst case, at 30°C for 8 hours resulted in a loss of \$1.77 per bin.

These trials complement work done by T. Hill in 1985 and confirms that curds left in the field for up to 8 hours suffer small reductions in curd quality, weight loss and financial return. Whilst this work provides evidence of incurring loss in curd weight and quality with increasing time and temperature before cold storage, it is only after 8 hours in the field that quality deteriorates. Most growers realise the consequences of leaving cauliflowers out in the field longer than 6 hours. The cost of further field trials was deemed unnecessary.

Even though the preliminary trials did not show that hours in the field (up to 6 hours) adversely affected quality or contributed to a large loss in value, it is still recommended to deliver cauliflowers to the packing house in the quickest time possible. Transport from the field to the packing house is only one small part of the postharvest chain and each step leads to incremental deterioration in product quality.

The findings of this study reinforce those of the bruising and handling studies that temperature control and precooling are important but bruising has a greater overall adverse effect on product quality.

8. The influence of seed, seedling and nutritional factors on yield and harvest period

Harvesting is a critical phase in the cauliflower production cycle with a high labour input. Approximately 35% of the direct costs associated with the production of cauliflowers is due to labour (Gartrell 1997) and at least three harvests are required to remove an acceptable proportion of the crop. Previous studies (Shellabear 1994) found that 11% of cauliflower are left in the field because they are over mature or immature at harvest time. In some cases the cost of labour exceeds the value of the remaining curds. The value of curds that are left in the field due to non uniform maturity is substantial when considered across the whole industry.

Six experiments were conducted between November 1996 and September 1997 to investigate factors which influence the rate of maturity and the period of harvest of cauliflowers. Three trials examined seed and seedling characteristics which previous studies (Shellabear 1994) suggest have a large influence on uniformity of maturation of a crop. If a large influence from these sources on cauliflower maturity is proven, then it is possible that some of the spread associated with harvest could be reduced and crop recovery percentages increased. Phosphorus nutrition and its influence on cauliflower maturity and uniformity of harvest was also examined as well as the variability of potting mix in cell trays on seedling uniformity.

8.1. Effect of seed weight

Export cauliflower is sold by weight and light curds provide lower returns. Seed of the cauliflower cultivar *Plana* can be purchased either pre-graded, a type of seed which is known as SuperFrax®, or as ungraded seed. SuperFrax® seed has both the extremely heavy and light seeds removed, ensuring that all remaining seed has a reduced weight range than the normal (ungraded) type of seed.

8.1.1. Seed weight and germination rate

The weight of the seed may influence the time to germination. Seeds which germinate earlier may produce seedlings which are larger. The size of the seedling may influence the final yield and spread of harvest of the curds.

8.1.1.1. Materials and method

Seed of the cauliflower cultivar *Plana* from the commercial types 'normal' (no pre-grading) and 'SuperFrax®' was used in the experiment. Each seed type was graded into two further weight categories giving four treatments (Table 62).

Table 62: Treatments used in the experiment.

Treatment	Seed type	Weight category	Average seed weight (mg)
1	Normal	Heavy	4.0
2	Normal	Light	3.4
3	SuperFrax®	Heavy	4.0
4	SuperFrax®	Light	2.6

One gram of seed from each treatment was germinated on moist filter paper and observed daily for growth of the root in individual seeds. The seeds were examined daily for four days and seeds which had germinated were transferred to cell trays which contained a commercial potting mix. The germinated seed was covered with vermiculite and watered. This method of transferring seed after germination gave four times of germination for each treatment. The experiment was a randomised block design which was replicated three times.

The seedlings were grown in a commercial nursery until six weeks. This is the normal age at which seedlings are transplanted into the field. Fifteen seedlings at each time of germination for each treatment were measured for shoot weight, root weight, plant weight, leaf number and seedling height. The experiment was analysed using Genstat for Windows 3.2.

8.1.1.2. Results and discussion

A chi-square test was performed which indicated that the variance of the data for time of germination four was different from the other three times of germination ($p<0.001$). The variances for time of germination one, two and three were similar ($p = 0.367$). As the variance of time of germination four was different from the other times of germination, the data associated with time of germination four was not included in the analysis of variance and is presented in Table 63.

Table 63: Leaf number, seedling height and shoot weight for time of germination four for cauliflower seed (cv: *Plana*) at six weeks.

Seed ype	**Weight category**	**Time of germination (day)**	**Leaf number**	**Height (cm)**	**Shoot weight (g)**
Superfrax	Light	4	3.82	8.48	1.46
Superfrax	Heavy	4	3.64	8.06	1.36
Normal	Light	4	4.76	10.02	1.72
Normal	Heavy	4	4.04	9.05	1.53
			ns	**ns**	**ns**

There was no significant difference between any of the seedlings at time of germination four regardless of seed type and seed weight. The number of leaves, height and shoot weight of seedlings at time of germination four were lower compared to the other times of germination. Seedlings which germinated late were generally smaller and weaker compared to seedlings produced at other germination times. Many seeds at germination time four did not produce a seedling despite germinating normally. The least significant differences presented in Table 64 are based on data from times of germination one, two and three.

Table 64: Leaf number, seedling height and shoot Weight at four different times of germination for cauliflower seed (cv: *Plana*) at six weeks.

Seed type	Weight category	Time of germination (day)	Leaf number	Height (cm)	Shoot weight (g)
Superfrax	Light	1	5.47	12.09	2.55
Superfrax	Light	2	5.67	12.61	2.61
Superfrax	Light	3	5.51	12.14	2.37
Superfrax	Heavy	1	5.49	11.90	2.43
Superfrax	Heavy	2	5.53	12.22	2.52
Superfrax	Heavy	3	4.98	12.12	2.17
Normal	Light	1	5.56	11.78	2.45
Normal	Light	2	5.33	12.21	2.49
Normal	Light	3	5.38	12.10	2.35
Normal	Heavy	1	5.89	12.02	2.67
Normal	Heavy	2	5.53	11.92	2.44
Normal	Heavy	3	5.49	11.12	2.29
5% LSD			**ns**	**0.3121**	**ns**

Plants that geminated at time two are taller than those germinated at the other times except for normal plants in the heavy weight category. There was a significant interaction ($p < 0.001$) between seed type, weight and time of germination on the height of the seedlings at six weeks of age. There was also an interaction between the seed weight and the time of germination ($p = 0.003$) on seedling height.

Seed type and weight produced a significant interaction ($p = 0.008$) when shoot weight was examined but did not have an influence on leaf number and plant height. The leaf number of the seedlings was influenced by a significant interaction between seed weight and time of germination ($p = 0.009$) and seed type and time of germination ($p = 0.002$).

The time of germination had an influence on both seedling leaf number and height although it is not known what is causing the difference in the germination time. The time of germination can not easily be identified using the current commercial methods of germination. Currently, seed is direct drilled into its final place in the seedling trays and left in warm, moist conditions to encourage germination. As the seed is germinated in the potting mix, it is impossible to establish when the seed germinated. Emergence of the seedling from the potting mix is the first indication of successful germination but this cannot be used as an accurate indication of the time of germination due to the interacting effects of seed weight and type.

There were some significant but small differences in the shoot weight and seedling height when the weight of the seed prior to germination was compared within each seed type at the same time of germination (ie: when SuperFrax® heavy seed at time of germination two was compared to SuperFrax® light seed at time of germination two). Although some of these comparisons were significant, the difference may not occur in other seed batches making it difficult to accurately predict which seedlings will be heavier or larger from the weight of the seed prior to sowing.

In this experiment, 42.8% of the seed which germinated at time four, either produced a poor quality seedling or failed to produce a seedling. This accounted for 7.5% of the total seed included in the experiment at all times of germination. A pre-germination and seeding method which does not cause damage to the germinating seed is required to allow the identification of seeds which will germinate late, allowing nursery staff to discard seed which has the potential to produce poor quality plants. Currently, low quality plants are removed from the tray before sale, a time consuming process which requires all seedling trays to be checked. Some poor quality plants may be missed and may not be removed at the nursery. These plants may contribute towards some of the difference observed in the yield and harvest period of field grown plants.

8.1.2. Seed weight and cauliflower yield and maturity

An understanding of the influence of seed weight on seedling size and final yield of cauliflowers may allow weight graded seed to be used to identify seed which will perform poorly in the field, producing unsatisfactory curds.

8.1.2.1. Materials and method

Seed of the cauliflower cultivar *Plana* from the commercial types 'normal' (no pre-grading) and 'SuperFrax®' was used in the experiment. Each seed type was graded into two further weight categories giving four treatments (Table 65).

Table 65: Treatments used in the experiment.

Treatment	Seed type	Weight category	Average seed weight (mg)
1	Normal	Heavy	4.4
2	Normal	Light	3.7
3	SuperFrax®	Heavy	4.0
4	SuperFrax®	Light	3.5

The graded seed in each treatment was planted by a commercial nursery and grown in trays until the seedlings were six weeks old. The seedlings were transplanted into prepared 4.8m x 4.8m moist plots with a commercial mix of fertiliser banded in twin offset rows at transplanting. The trial was a randomised block design with four replications.

Yield was determined by harvesting the central 24 plants from each plot. The curds were weighed and graded on a quality scale (Shellabear 1994) to determine the yield of marketable curds. The experiment was analysed using Genstat for Windows 3.2.

8.1.2.2. Results and discussion

There was no significant difference when comparing either between or within the weight categories for the seed (Table 66). This indicates that the weight of seed cannot be used as an indication of the final yield. The spread of harvest was also not affected by the weight of the seed (5% lsd not significant) (Figure 16).

Table 66: Yield (t/ha) of cauliflower in each of two seed weight categories for two seed types.

Weight category	Seed type	
	Normal	SuperFrax®
Light	16.0	15.7
Heavy	16.2	18.7
LSD (5%) = 6.4		

There were observable differences between the seedlings at transplanting as the seedlings grown from the light seed were smaller and less vigorous than the seedlings grown from the heavy seed. However, differences between seedlings that were evident at transplanting were not visually detectable as the plants became older in the field.

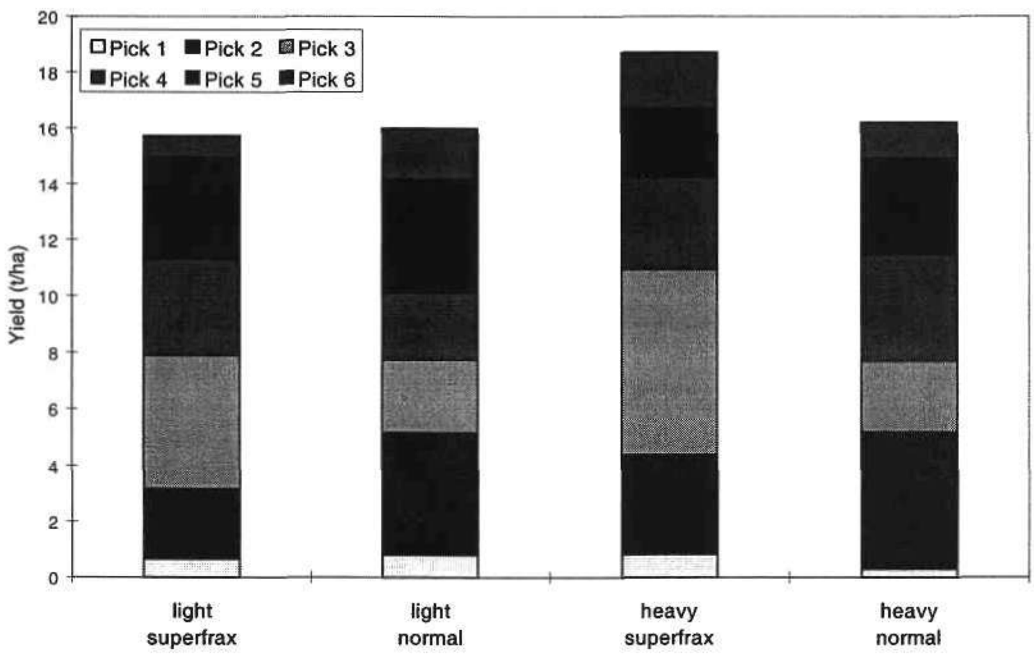


Figure 16: Spread of harvest of cauliflower in each of two seed weight categories for two seed types. Each box represents a picking date and the yield which was harvested at that date.

The overall uniformity of the crop may be due to the relatively rapid growth of cauliflowers during the summer compared to the winter months. During the colder winter months, when growth is slower, the differences which were evident in the seedlings may remain in the field, influencing the final yield of the cauliflower crop and the spread of its harvest.

8.2. Effect of seedling weight on yield and maturity

The weight of seedlings at transplanting may influence the final yield of a crop. Circumstantial evidence from commercial crops indicates that the larger seedlings may produce heavier curds. The experiment examines the effect of seedling weight on both the final yield and the spread of harvest.

8.2.1. Materials and method

Cell grown cauliflower seedlings cv. *Plana* were sorted into three categories at six weeks after sowing (Table 67). The categories were established by weighing seedlings and determining the spread of weights within a sample group. Three categories were established from the sample group and seedlings used in the experiment were sorted into one of the categories based on the weight of the seedlings once the potting mix had been washed from the roots.

After sorting of the bare rooted seedlings into categories, they were planted using a commercial transplanting machine into prepared 4.8m x 4.8m moist plots. As the temperature on the day of transplanting was 35°C, irrigation was on throughout the transplanting to minimise transplant shock. The trial was a randomised block design with six replicates and the results were analysed using Genstat for Windows 3.2.

Table 67: Treatments used in the experiment.

Treatment	Seed type	Weight category	Seedling weight (g)
1	Normal	Light	< 2.5
2	Normal	Medium	2.51 - 3.5
3	Normal	Heavy	> 3.5
4	SuperFrax®	Light	< 2.5
5	SuperFrax®	Medium	2.51 - 3.5
6	SuperFrax®	Heavy	> 3.5

Three plants were used for each sampling period to determine the fresh shoot weight. Yield was determined by harvesting the central 24 plants from each plot. The curds were weighed and graded on a quality scale (Shellabear 1994) to determine the yield of marketable curds.

8.2.2. Results and discussion

The heaviest seedlings gave the greatest yield for both the normal and superfrax seedling types although there was no difference between the yield produced when the heavy normal seedlings where compared to the heavy superfrax seedlings (Table 68). For both normal and superfrax types, the heavy seedlings had a significantly greater yield compared to the light seedlings. There was no difference in both seedling types between the medium and light seedlings or between the heavy and medium seedlings for the normal seedling type.

Table 68: Yield (t/ha) of cauliflower in each of three seedling weight categories for two seed types.

Weight category	Seed type	
	Normal	SuperFrax®
Light	12.9	13.4
Medium	15.6	14.6
Heavy	16.6	17.6
LSD (5%) = 2.8		

The production of greater yield from heavier seedlings at transplanting suggests that a method for identifying heavy seedlings before transplanting would be advantageous. If large seedlings could only be identified after six weeks growth considerable resources would be wasted growing the smaller seedlings. However, the weight of seedlings may not be completely related to seed weight and other factors such as position in the growing tray and potting mix characteristics may heavily influence the final weight of seedlings.

8.3. Influence of variations in potting mix within a cell tray on seedling characteristics

Cell trays containing approximately 200 cells are commonly used in nurseries throughout Australia to raise seedlings for transplanting into the field. Variation in the composition of the potting mix between cells within any single tray may produce non-uniform seedlings. The experiment investigated if variations within a tray existed and the influence of the variations on seedling uniformity.

8.3.1. Materials and method

Cell trays were selected from a seedling run at each of the commercial nurseries in the Manjimup area. The potting mix of five cells from three trays was sampled and placed in separate sample bags for chemical analysis. The potting mix was sampled at four different times; at seeding and at weeks one, three and six after seeding. The potting mix was taken from the same three trays each sampling time although the cells within the tray were chosen at random. The chemical analysis consisted of measurements for pH ($CaCl_2$), electrical conductivity (EC), nitrogen, phosphorus and potassium.

Plant samples were taken at weeks three and six. Prior to this the seedlings were too small to accurately measure the weight, height and leaf number. The plant samples were placed in separate sample bags and labelled so that the characteristics of each seedling could be matched to the correct chemical analysis from the potting mix.

The results were analysed using regression analysis in Genstat for Windows 3.2 which removed from the analysis plot effects such as treatment, time of sampling and replicate.

8.3.2. Results and discussion

Correlation analysis indicated their were both positive and negative relationships between the various potting mix characteristics examined (Table 69). A positive relationship indicates that as one potting mix characteristic increases (eg: phosphorus), the corresponding characteristic also increases (eg: nitrogen). A negative relationship indicates that an increase in one potting mix characteristic causes a decrease in the corresponding characteristic. The closer a number is to 1 (positive relationship) or -1 (negative relationship) then the closer the relationship between the characteristics.

Table 69: Correlation coefficient (r) of potting mix characteristics. Critical value at 5% level of significance is 0.25.

	Nitrogen	Phosphorus	Potassium	pH
Nitrogen	1.000	0.700	0.552	-0.683
Phosphorus		1.000	0.190	-0.876
Potassium			1.000	0.119
pH				1.000

The correlation's between the potting mix characteristics (nutrients and pH) prevent a particular plant nutrient examined from being allocated as the only influencing factor on either plant height, weight or leaf number. For example, the negative relationship between pH and phosphorus indicates that an increase in pH will cause a decrease in the availability of phosphorus to the plant. This was to be expected as phosphorus becomes less available as the soil pH becomes less acid. It is the interaction of at least these two factors which is influencing plant characteristics (height, weight and leaf number). To manage the availability of phosphorus to the plant, the pH of the potting mix should be maintained whilst the seedling is growing in the nursery and prevented from becoming alkaline.

However, the significance of the potting mix characteristics for some of the plant characteristics (Table 70) indicates that the potting mix in a single 200 cell tray may not have a uniform composition across the entire tray. A significant potting mix characteristic ($p \leq 0.049$) is an indication that some plants are either heavier, taller or have more leaves due to variations between cells within a single seedling tray in the potting mix characteristics. The potting mix characteristics which are significant may effect plant uniformity on their own or interact with other potting mix characteristics to effect plant uniformity.

Table 70: Significance of various potting mix characteristics on plant characteristics.

Plant characteristic	Potting mix characteristic	Significance (p)
Height	Nitrogen	0.118
	Phosphorus	0.002
	Potassium	0.049
	pH	0.630
Weight	Nitrogen	0.187
	Phosphorus	0.003
	Potassium	0.087
	pH	0.035
Leaf Number	Nitrogen	0.578
	Phosphorus	<0.001
	Potassium	<0.001
	pH	0.128

Although seedling nurseries thoroughly blend potting mix prior to placing in the tray, the results suggest that further mixing of the potting mix and its added nutrients may be required to completely ensure that the potting mix within each cell of a tray has uniform characteristics. An increase in some nutrients may also be required to ensure that each cell (and therefore seedling) receives adequate nutrient supplies to maintain growth.

Nitrogen did not significantly ($p > 0.049$) effect the plant characteristics measured. Nitrogen is often applied in sufficient quantities in commercial nurseries not to be limiting for plant growth as the symptoms of nitrogen deficiency are easily recognisable. Phosphorus and potassium had a significant effect on the plant characteristics although potassium did not significantly affect plant weight. Phosphorus and potassium deficiency are more difficult to recognise than nitrogen deficiency as the symptoms are less obvious. Mild potassium and phosphorus deficiency may only cause a slight reduction in the growth rate which can cause plants to be smaller than plants which have received adequate phosphorus and potassium. The significant effect of potassium and phosphorus on plant characteristics suggests that the amount of phosphorus and potassium which is supplied in the potting mix for each tray cell may be limiting plant growth. An increase in the supply of these nutrients may contribute to greater uniformity in the seedlings within a cell tray.

The uniformity of germination may also cause some of the difference in seedlings within a single tray. This should be considered as experiment 8.1.1. indicated that the time of germination significantly influenced the final characteristics of the seedlings. However, potting mix characteristics also significantly contribute to differences in seedling characteristics. The further blending of potting mix and an increase in the supply of some nutrients will not completely remove the variation in seedling characteristics due to germination time but may reduce the variation in seedlings making more uniform plants for transplant into a field situation.

8.4. Effect of phosphorus nutrition and placement on yield and maturity

Phosphorus is bound tightly to the loamy clay soils in the Manjimup district of Western Australia and the nutrient may be lacking in some crops. Phosphorus deficiency, if mild, is difficult to detect and often a 'satisfactory' crop is produced. Despite this, yield loss may results from mild phosphorus deficiency. Crops that do not have an adequate phosphorus supply may not grow uniformly leading to uneven maturity. Consequently, more harvests are required causing further expense to the grower due to extra labour requirements. The alternative placements of phosphorous, either as a complete replacement for the twin offset bands (which is normal practice in the Manjimup district) or as a complement to the current fertiliser placement strategy may improve the growth and uniformity of the transplanted seedlings. The purpose of this experiment was to examine the influence on crop yield and maturity of both phosphorus rates and the placement of the phosphorus relative to the seedling. The experiment was conducted during both the summer and winter months.

8.4.1. Summer transplant

8.4.1.1. Materials and method

Cauliflower seedlings (cv *Plana*) were grown to transplant stage (six weeks) by a commercial nursery in the Manjimup district. Treatments were applied as described in Table 71. Treatment numbers 20 to 26 were applied to the seedling cell trays prior to the sowing of the seed. Treatment numbers 27-32 were applied to the seedlings at six weeks prior to dispatch from the nursery. Normal practice in the Manjimup district is to apply approximately 160kg/ha of phosphorous in two bands positioned slightly below and offset on each side of the seedling. Treatment number 3 is the 'control' in this experiment as this represents the normal district practice. Treatments where the phosphorus placement is listed as 'underneath', indicates the fertiliser was placed in a single band, 10cm deep directly under the seedlings. The phosphorus applied as a 'strip' was placed in a 20cm wide strip on the soil surface and incorporated to a depth of 10cm using a small rotary hoe. This is similar to the 'broadcast' plots but the seedlings are transplanted into the narrower treated strip. Treatment number 8-10 received some phosphorus in a twin band offset from the plants. The remaining phosphorus for treatments 8-10 was applied one week after transplanting by the application of phosphorus in a liquid form.

Trace elements, nitrogen, and potassium were supplied to all treatments at transplanting in sufficient quantities to prevent them limiting growth. The crop was transplanted on 31 December 1996 and grown according to normal district practice and was ready to harvest starting on 10 March 1997. Yield was determined by harvesting the central 24 plants from each plot. The curds were weighed and graded on a quality scale (Shellabear 1994) to determine the yield of marketable curds.

Table 71: Treatments for the summer phosphorus experiment indicating rate and placement of phosphorus. *TP = Transplanting

Treat. no.	Rate P (kg/ha) at TP*	Band placement	Other P source (kg/ha)	Time of application of other P source	Other information
0	0	underneath	-		
1	0	offset	-		
2	50	offset	-		
3	160	offset	-		
4	320	offset	-		
5	50	underneath	-		
6	160	underneath	-		
7	320	underneath	-		
8	37.5	offset	12.5	foliar-week 1	
9	120	offset	40	foliar-week1	
10	240	offset	80	foliar-week1	
11	50	broadcast	-		
12	160	broadcast	-		
13	320	broadcast	-		
14	50	broadcast and band	-		Half of total P applied by each method
15	160	broadcast and band	-		Half of total P applied by each method
16	320	broadcast and band	-		Half of total P applied by each method
17	50	strip	-		incorporate strip
18	160	strip	-		incorporate strip
19		strip	-		incorporate strip
20	0	offset	0	nursery tray	incorporated into mix
21	50	offset	extra P	nursery tray	incorporated into mix
22	160	offset	extra P	nursery tray	incorporated into mix
23	320	offset	extra P	nursery tray	incorporated into mix
24	50	offset	double extra P	nursery tray	incorporated into mix
25	160	offset	double extra P	nursery tray	incorporated into mix
26	320	offset	double extra P	nursery tray	incorporated into mix
27	50	offset	extra P	nursery tray	seedling drench in one application
28	160	offset	extra P	nursery tray	seedling drench in one application
29	320	offset	extra P	nursery tray	seedling drench in one application
30	50	offset	double extra P	nursery tray	seedling drench in one application
31	160	offset	double extra P	nursery tray	seedling drench in one application
32	320	offset	double extra P	nursery tray	seedling drench in one application

8.4.1.2. Results and discussion

The highest yield of 16.8 t/ha was achieved when 160kg/ha phosphorus was applied in a 30cm wide strip into which the seedlings where transplanted (Table 72). This was not significantly different from most of the other treatments with the average yield for the statistically similar treatments being 14.08 t/ha. The data from this experiment indicates the rate of application of phosphorus is likely to have had a greater influence on the yield than its placement. Plants which received no phosphorus produced very low marketable yields compared to plants which had a similar placement of phosphorus but received a higher rate of phosphorus application. However, on different soil types (ie: sands), the placement of phosphorus may have a much greater influence on yield than the rate of phosphorus applied. There was no significant difference between the treatments when the time to harvest and the spread of harvest was examined.

Table 72: Yield (t/ha) for cauliflower treated with different rates and methods of application of phosphorus, summer transplanting.

Treatment no.	Yield (t/ha)	Treatment no.	Yield (t/ha)	Treatment no.	Yield (t/ha)	Treatment no.	Yield (t/ha)
0	1.08	8	12.85	16	14.73	24	14.01
1	6.97	9	15.11	17	10.12	25	14.55
2	16.49	10	14.40	18	16.87	26	13.79
3	14.20	11	14.10	19	12.83	27	14.09
4	14.25	12	10.42	20	8.31	28	12.76
5	10.25	13	16.16	21	14.58	29	13.55
6	13.26	14	12.96	22	15.05	30	14.25
7	11.26	15	12.31	23	13.69	31	9.28
						32	10.29
5% LSD							
When comparing all treatments (p=0.002) = 5.79							

The lack of difference in yield as well as the time and spread of harvest between the treatments may be due to the cauliflowers growing rapidly during the warm summer months. The average time to harvest (from transplanting) during summer for cauliflower cultivar *Plana* is 10 weeks compared to 16 weeks during the winter (Shellabear 1994). The fertiliser banded beneath the cauliflower would be reached by the roots more quickly during the summer months allowing the rapid growth of the seedlings compared to winter grown plants.

8.4.2. Winter transplant

8.4.2.1. Materials and method

Cauliflower seedlings (cv *Plana*) were grown to transplant stage (six weeks) by a commercial nursery in the Manjimup district. Treatments were applied as described in Table 73. Treatment numbers 18 and 19 were applied to the seedling cell trays prior to the sowing of the seed. Treatment numbers 20 and 21 were applied to the seedlings at six weeks prior to dispatch from the nursery. Treatment number 3 is the 'control' in this experiment as this represents the normal district practice. Treatments where the phosphorus placement is listed as 'underneath', indicates the fertiliser was placed in a single band, 10cm deep directly under the seedlings. The phosphorus applied as a strip was placed in a 30cm wide strip on the soil surface and incorporated. This is similar to the broadcast plots but the seedlings are transplanted into the narrower treated strip.

Trace elements, nitrogen, and potassium were also supplied to all treatments at transplanting. The seedlings were transplanted on 22 July 1997, grown according to normal district practice and were ready to harvest beginning on 20 October 1997. Yield was determined by harvesting the central 24 plants from each plot.

The curds were weighed and graded on a quality scale (Shellabear 1994) to determine the yield of marketable curds.

Table 73: Yield (t/ha) for cauliflower treated with different rates and methods of application of phosphorus, winter transplanting. *TP = Transplanting

Treat no.	Rate P (kg/ha) at TP*	Band placement	Other P source (kg/ha)	Time of application of other P source	Other information
1	0	offset	-		
2	50	offset	-		
3	160	offset	-		
4	320	offset	-		
5	0	underneath	-		
6	50	underneath	-		
7	160	underneath	-		
8	320	underneath	-		
10	0	broadcast	-		
11	50	broadcast	-		
12	160	broadcast	-		
13	320	broadcast	-		
14	0	broadcast and band	-		
15	50	broadcast and band	-		Half of total P applied by each method
16	160	broadcast and band	-		Half of total P applied by each method
17	320	broadcast and band	-		Half of total P applied by each method
18	160	offset	extra P	nursery tray	incorporated into mix
19	160	offset	double extra P	nursery tray	incorporated into mix
20	160	offset	extra P	nursery tray	top dressed in 2 equal applications at 4 and 5 weeks as a foliar application
21	160	offset	double extra P	nursery tray	top dressed in 2 equal applications at 4 and 5 weeks as a foliar application

8.4.2.2. Results and discussion

There was a significant difference ($p < 0.001$) between treatments for rate of phosphorus applied. The greatest yield was obtained when extra phosphorus was applied in the nursery potting mix prior to planting of the seed (treatment 18) although it was not significantly different from the application of phosphorus in the potting mix at double the rate (Table 74).

This indicates that a small increase over the current amount of phosphorous being used in the potting mix will increase yield which has advantages during the winter months when the colder weather slows growth of the seedlings. The extra phosphorus in the potting mix may help to encourage the faster growth of the seedlings with the roots reaching the fertiliser banded in the ground at an earlier stage than treatments which do not have extra phosphorus in the potting mix.

A comparison of treatments which yielded greater than 6.5t/ha indicated there was no difference in harvest period.

Table 74: Yield (kg/ha) for cauliflower treated with different rates and methods of application of phosphorus, winter transplanting.

Treatment no.	**Yield (t/ha)**	**Treatment no.**	**Yield (t/ha)**	**Treatment no.**	**Yield (t/ha)**	**Treatment no.**	**Yield (t/ha)**
1	0.00	6	3.94	12	4.08	17	0.00
2	6.72	7	3.51	13	6.50	18	14.21
3	7.32	8	7.77	14	4.67	19	10.08
4	6.58	10	0.00	15	8.46	20	9.60
5	0.00	11	2.72	16	6.74	21	9.67
5% LSD When comparing treatments with different rates of applied phosphorus (Treatment 1 to Treatment 17) = 4.28 When comparing treatments with 160kg/ha phosphorus applied at planting (Treatments 3, 7, 12, 16, 18, 19, 20, 21) (p = 0.002) = 4.89							

The application of phosphorus in twin offset bands at planting is the most common method used for phosphorus application in the Manjimup area. This method appears to be satisfactory during the summer to supply the phosphorus nutrition requirements of cauliflower if the rate applied is at least 160kg/ha P applied. During winter, although the current commercial method is also acceptable for applying phosphorus, the application of extra fertiliser in the potting mix at seeding may increase yields. The harvest period does not appear to be influenced during any time of the year by phosphorus nutrition and other factors must be considered such as crop uniformity, paddock topography and irrigation practices. Commercial crops are grown on undulating country throughout the Manjimup district and observations of several crops suggests that the topography of a paddock has a large influence on maturity of crops and their spread of harvest. Crops on north facing slopes are often ready for harvest four to five days earlier and require fewer picks than crops on slopes facing other directions.

9. Road transport evaluation

9.1. Background

So far in this report we have looked at factors which affect curd quality in the field and pack house including: harvest maturity, the length of time from harvest to commencement of precooling and the duration of the precooling period. This work examined postharvest beyond the packing house and investigated the efficiency of the current transport systems used by the Western Australian cauliflower industry and their effects on quality.

Several means of road transport are used to transport cauliflowers to Perth for loading onto container ship bound for Singapore or Malaysia. The most common form of road transport is by refrigerated Tautliner® and Pantech®. The Tautliner®, also known as the 'curtain-sider', is usually a B double which can hold a maximum of 30 pallets. The Pantech® (or pan) is a solid sided semi-trailer which can be loaded with 22 pallets. Both types of trailer are fitted with refrigeration units for cooling produce. Industry considers the Pantech as the more efficient way of maintaining the adequate core temperature for cauliflower. Pans® and Tautliners® involve double handling of cauliflower cartons. They are loaded and delivered to Perth, then the cartons are unloaded and reloaded into a sea container or air freight container for the journey to the overseas market.

The other form of transport is the sea container. Those packing houses that do not have separate exporters in Perth load their own sea containers at their packing houses in Manjimup. The sea containers are not cooled during the 300 km journey from Manjimup to Perth which can take up to 5 hours. Trucks transporting the sea container does not have the facilities to cool the container in transit, therefore the container is "off power" until it is connected to a power supply at the wharf. The containers are loaded by hand with cartons of cauliflowers and once the container is closed and sealed, it is not opened until arrival at destination market in Singapore or Malaysia. The container is briefly cooled before road transport to Perth but during the 4-5 hour journey to Perth, it is not cooled. Therefore, it is critical to have cauliflowers cooled to a core temperature of 0-2°C in the cartons before loading into the sea container.

Discussions with industry have shown a need to identify any weaknesses in the current cool chain. In short, the aim of this study was:

i) to monitor temperature effects of the different transport methods commonly used by export packing houses; and,
ii) to estimate the effect of these transport methods on curd quality.

There were two parts of this study. The first part was to collect and collate information on temperature monitoring done by the packing houses prior to commencement of this study. The second was to monitor temperatures in road trips to allow the transport methods to be directly compared without duplicating past work.

Interviews with each packer in Manjimup confirmed that results of past temperature monitoring of different forms of transport, ie. sea container, Pan® or Tautliner®, was minimal and of limited scope. Therefore, part two of the study was justified to gain more information.

9.2. Temperature monitoring

The aim of this study was to compare the Tautliner® and the Pantech® used to transport cauliflower cartons to Perth for export. Both methods were monitored during summer and winter to determine differences in core temperature of the cauliflowers and relative humidity of the air in the refrigerated semi trailer.

9.2.1. Materials and method

At the packing house, four cauliflower cartons were removed from the packing line. The cauliflowers packed at the time had been previously precooled for at least two days. Five cauliflower curds from each carton were weighed, core temperature recorded and packed back into the carton. In each carton, one Tinytag® temperature probe was inserted into a cauliflower and a Tinytag® relative humidity data logger placed between the cauliflowers.

The four cartons were then placed back onto the packing line for weighing of the whole carton, lidding and strapping. The four cartons were then placed on a pallet with other cartons on the fourth and fifth layer of the pallet. There are six layers of cartons on each pallet with six cartons per layer, making a total of 36 cartons per pallet. The four cartons were not placed on separate pallets due to logistical reasons. Each of the four cartons were marked with large red crosses for identification. The pallet of cartons was strapped to avoid cartons from moving. It was then put back into another coolroom to await loading into the truck. This usually was the following day.

Other notes and measurements recorded at the packing house included:

- i) cauliflower growers name and the variety packed
- ii) date the cauliflowers were harvested
- iii) length of time in precooling coolroom in bulk bin
- iv) time and date of packing
- v) length of time the cartons are cooled before loading onto truck
- vi) time and date of when the pallets are loaded
- vii) the position of the pallet with data loggers in the truck
- viii) time the truck left Manjimup
- ix) number and duration of scheduled stops
- x) what other produce was carried
- xi) estimated time of arrival at exporters in Perth

Whilst the truck was loaded, notes were recorded on how loading was done. For example, whether there was adequate space between the first pallets and the bulk head, space between pallets and the walls and space between the last pallet and back of semi trailer.

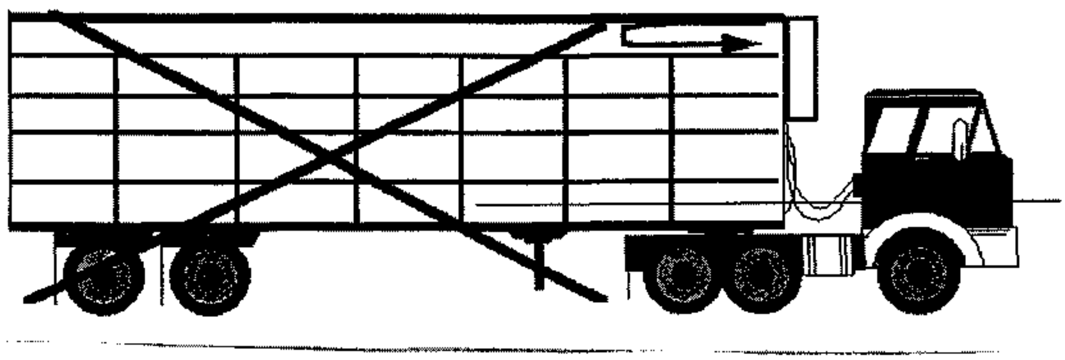
At the exporters in Perth, the pallets of cauliflowers are unloaded and stored overnight in the exporters coolroom. The four cartons were then collected from the exporters and taken to Agriculture Western Australia's postharvest laboratory, South Perth. Once at the lab, the following measurements for all curds in the four cartons were recorded: weight, core temperature, density (Table 24), quality rating (Table 23), reason for reject, severity of rots/blemishes and severity of black spot (Table 25). After the measurements, the cauliflowers were re-wrapped and re-packed in the carton. The four cartons were then subject to 21 days cool store (1-2°C, 95% relative humidity) then 4 days warm store (20°C, 85 humidity). After each storage stage the same measurements were repeated except for density because the initial density measurement of the curd does not change after cool store or warm store.

9.2.2. Results and discussion

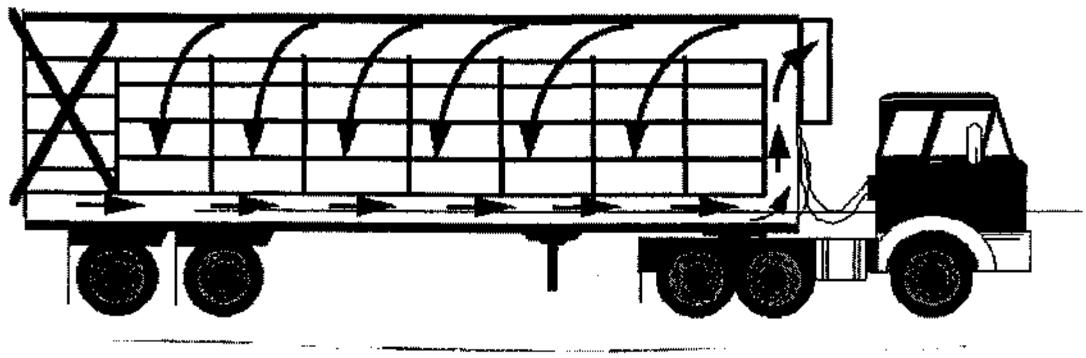
9.2.2.1. Summer trip

The two transport trips monitored in January 1998 were both Tautliner® trucks. The second monitoring should have been a Pantech® trailer, but due to reasons beyond control another Tautliner® was monitored. For both trips, the same grower and variety (*Plana*) was used. The differences between the two trips are shown in Table 75.

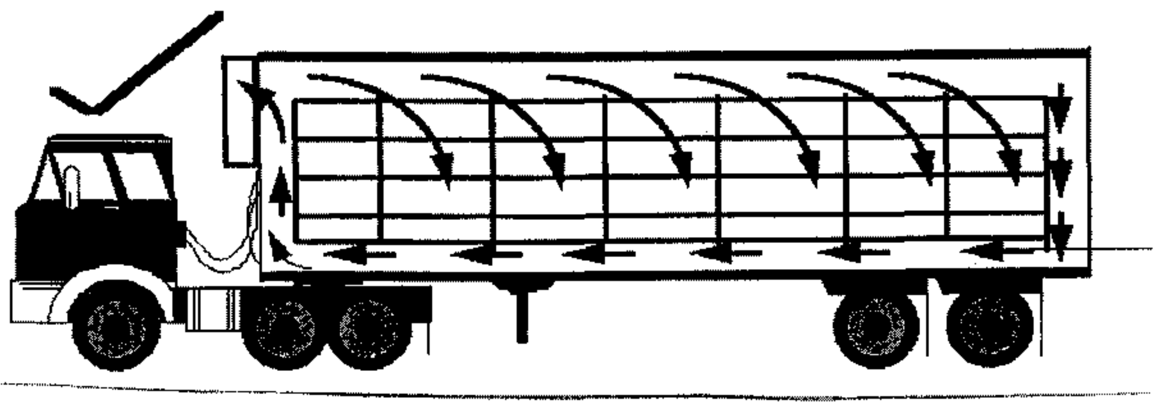
Both Tautliners® had the correct design features and fit out to assist with the unit's performance according to Story (1996). Each Tautliner® had the following characteristics: insulated flatbed floor, insulated and double skinned side walls, white curtain colour to maximise heat reflection, air delivery chute was of adequate size to allow for sufficient air flow, framed bulkhead made of mesh to keep load off the front wall of the truck, plyboards were strapped to the back pallets with rope to ensure load integrity and at least 40cm space between the back pallet and the back wall. Both trucks had sufficient space between the load and the sides and floor of the tautliner. This allows for greater air flow thus maintaining produce at the same temperature as when it was loaded. Figure 17 shows the incorrect and correct way to get the most efficient performance from a Tautliner® or Pantech® unit.



A) Air flow short circuit if there are no spaces through which it can flow. No fitted bulkhead. No path for air down the sides or rear of produce. No pallets to provide an air path under the produce.



B) An obstruction anywhere in the air circuit will choke the airflow. In this situation the rear stack prevents air circulation behind and under the pallets, allowing road and ambient heat to reach the load.



C) To ensure good air circulation there must be an air delivery chute, a free air path down the sides and rear, pallets on the floor (loaded from the rear) and a solid return air bulkhead with bottom air entry.

Figure 17: The correct and incorrect method of loading produce in refrigerated trucks. Source: Hill, J (1996) *Transporting fresh produce in refrigerated trucks*. Fact Sheet, Primary Industries, South Australia and South Australian Research and Development Institute.

Table 75: Characteristics of two Tautliner® trips monitored during summer conditions

	TRIP 1	TRIP 2
Day of trip	28 Jan 1998	1 Feb 1998
Ambient temp. & RH on day of trip	Max: 31°C Min: 11°C RH: 38%	Max: 22.5°C Min: 13°C RH: 52%
Date cauliflowers harvested	26 Jan 1998	30 Jan 1998
No. hours precooling	42 hours	19hrs
Date of packing	28 Jan 1998	31 Jan 1998
Time of packing	8:00 - 9:00AM	9:30 - 10:30AM
No. hours cooling after packing	8 hours	15 hours
Truck rig	B double tautliner	B double tautliner
Date and time depart Manjimup	28 Jan 1998 : 5:00PM	1 Feb 1998: 12:30PM
No. and duration of stops	2 stops: 1 hour, 40 mins	1 stop: 1 hour
Mixed loads	no	no
Estimated time of arrival at exporters	11:30PM	6:00PM
No. hours in truck	6 hours 30 mins	5 hours 30 mins

The average core temperatures of both Trip 1 and 2 were considered high (4.5°C and 5.3°C respectively) particularly when optimum transit temperature is 0°C (Story, 1996). Optimum relative humidity in the Tautliners® should have been 95 - 98%. (Table 76). However, it does show that both Tautliner® units maintained the core temperature during the 5-6 hour journey to Perth without fluctuations. Average core temperature before loading into Tautliner® for trip 1 and 2 were 4.0°C and 5.0°C, respectively. The core temperature rose only 0.5°C or less during transportation.

The cauliflowers packed in the four cartons were regarded as export standard according to the packer who packed them. However, during the ratings some cauliflowers were considered local market due to overmaturity. For purposes of determining quality standards before storage, severity of rots/blemishes and black spot were also recorded. There were no rots/blemishes on the curds from both trips after the 6 hour journey and only slight amounts of curd blackening were recorded mainly due to pressure bruising in the carton during transportation. Table 77 shows that cauliflowers curds from Trip 2 were of slightly better quality than Trip 1 cauliflowers. This is mostly likely due to the less number of hours cauliflowers from Trip 2 were precooled.

After 21 days cool store, small differences were recorded in curd quality and percentage weight loss between the two trips (Table 78). After 4 days warm store, curds from Trip 2 were of slightly of better quality (Table 79).

Table 76: Average core temperatures at various points of the trip.

	Average temp. at packing	Average temp. before loading	Average temp. during transport	Average humidity during transport
TRIP 1	3.4°C	4.0°C	4.5°C	86%
TRIP 2	4.8°C	5.0°C	5.3°C	75%

Table 77: Average density and quality ratings of curds after road transport.

	Density	Market quality	Severity rots/ blemishes	Severity black spot
TRIP 1	2.2	4.5	1.0	1.9
TRIP 2	2.4	5.4	1.0	1.5

Notes: Density scores - 1: loose, 3: compact; Market quality - 1: reject, 7: excellent export standard; Severity rots/blemish and black spot - 1: none, 5: very severe.

Table 78: Average quality ratings and percentage weight loss after 21 days cool store

	Market quality	Severity rots/ blemishes	Severity black spot	% Weight loss
TRIP 1	4.1	1.0	2.4	2.9
TRIP 2	4.6	1.1	2.1	2.7

Table 79: Average quality ratings and percentage weight loss after 4 days warm store

	Market quality	Severity rots/ blemishes	Severity black spot	% Weight loss
TRIP 1	2.9	3.0	3.9	3.1
TRIP 2	2.4	2.6	3.8	2.8

Unfortunately, Trip 1 and 2 are difficult to compare because the cauliflowers were handled differently prior to road transport. From the data it shows an overall trend that Trip 2 cauliflowers are of better quality after storage. This may have been because cauliflowers from Trip 2 were fresher as they had only been precooled for 19 hours not 42 hours. This resulted in Trip 1 cauliflowers recording a slightly greater black spot and a higher severity of rots/blemishes after 4 days warm store (Table 79).

Cauliflowers from Trip 1 were also approximately one hour longer in the truck due to longer time spent picking up and dropping off other produce. This combined with higher ambient temperatures and greater precooling period may have contributed to the slightly lower level of quality of Trip 1 cauliflowers after storage.

Although the cauliflower curds were handled differently prior to transportation in Tautliner® units, this study has shown that Tautliners® used by the cauliflower industry of the Manjimup area, are efficient enough to maintain the core temperature of cauliflower. The core temperature of the cauliflowers as they are loaded into the Tautliner® is maintained by the refrigeration unit throughout the journey to Perth. Precooling coolrooms must operate more efficiently to achieve a lower core temperature of 0-2°C, particularly during the summer months. It is essential that produce is precooled to the correct core temperature before loading because truck refrigeration systems have only sufficient cooling capacity to remove heat coming into the refrigerated unit from outside, for example, heat radiated from the road, heat from outside air and direct heat from the sun (Hill 1996). A refrigerated truck unit does not have the cooling capacity to reduce the core temperature of the cauliflowers once in the truck.

9.2.2.2. Autumn/winter trip

This trial focuses on the Pantech® trailer for the refrigerated transport of cauliflower. The solid sided, rear loaded Pantech® holds 20 - 22 pallets, depending on whether the Pan® is part of a B-double configuration or is a semi-trailer.

Trip 3 was fully loaded with 22 pallets of cauliflower cartons. Once loaded there was no space at the end of the Pan®. This may have affected the air flow as cooled air would have been obstructed around the rear of the stack. The cauliflower variety used for Trip 3 was *Plana*. Trip 4 was loaded with 20 pallets of cauliflower cartons. The truck used to transport these cauliflowers was a B double with a tautliner trailer for half the truck and a pan for the other half. (Figure 18). The cauliflower variety for Trip 4 was *Granite*. The differences between Trip 3 and 4 can be seen in Table 80.

Figure 18: Loading pallets of cauliflower into a B-double pantech trailer.

Table 80: Characteristics of two Pantech® trips monitored during autumn/winter conditions

	TRIP 3	TRIP 4
Day of trip	12 May 1998	5 July 1998
Ambient temp. & RH on day of trip	Max: 19.5°C Min: 8°C RH: 54%	
Date cauliflowers harvested	6 May 1998	3 July 1998
No. hours precooling	120 hours (5.5 days from harvest to packing)	21 hours
Date of packing	11 May 1998	4 July 1998
Time of packing	3:00 - 4:00PM	8:15 - 9:00AM
No. hours cooling after packing	21.5 hours	25 hours
Truck rig	45 foot pantech trailer	B-double tautliner/pantech
Date and time depart Manjimup	12 May 1998 : 3:30PM	5 July 1998 : 11:00PM
No. and duration of stops	none	i)Grower (15kms out of Manjimup) - 1 hour. ii) Hope Valley (Perth) - 30 mins
Mixed loads	no	no
Estimated time of arrival at exporters	8:30PM	5:30 PM
No. hours in truck	5 hours	6.5 hours

Table 81: Average core temperatures at various points of the trip.

	Average temp. at packing	Average temp. before loading	Average temp. during transport	Average humidity during transport
TRIP 3	4.9°C	3.8°C	3.4°C	98.8%
TRIP 4	4.0°C	4.2°C	4.6°C	94.8%

Table 82: Average density and quality ratings of curds after road transport.

	Density	Market quality	Severity rots/blemishes	Severity black spot
TRIP 3	2.2	4.7	1.0	1.6
TRIP 4	2.4	4.6	1.4	1.0

Notes: Density scores - 1: loose, 3: compact; Market quality - 1: reject, 7: excellent export standard; Severity rots/blemish and black spot - 1: none, 5: very severe.

Table 83 : Average quality ratings and percentage weight loss after 21 days cool store.

	Market quality	Severity rots/blemishes	Severity black spot	% Weight loss
TRIP 3	3.3	1.4	2.9	3.7
TRIP 4	4.0	1.5	2.7	4.1

Table 84: Average quality ratings and percentage weight loss after 4 days warm store.

	Market quality	Severity rots/blemishes	Severity black spot	% Weight loss
TRIP 3	1.7	2.5	4.0	5.2
TRIP 4	2.0	2.8	3.7	4.0

During Trip 3 average core temperature was reduced by 0.4°C and Trip 4 was increased by 0.4°C (Table 81). These core temperatures are still too high but is not because of an inefficient cooling unit on the Pantech® trailer. Again, the initial core temperature of the cauliflowers at loading were maintained by the Pan's cooling unit.

After road transport, the market quality of cauliflower from both trips were the same. The severity of black spot was higher for Trip 3 cauliflowers after road transport due to the five days of precooling prior to packing and transport (Table 82).

After 21 days coolstore, Trip 3 cauliflowers had a poorer market quality and higher severity of black spot and trip 4 had a higher percentage weight loss (Table 83). After four days warm store, there was a similar pattern with Trip 3 cauliflowers having poorer market quality and showing more severe black spot (Table 84).

Although these studies were not exhaustive, it gave enough information to suggest that road transport either by Tautliner® or Pantech® adequately maintained curd quality during the 4-5 hour journey to Perth. However, there are problems in time delays in precooling, delays in dispatching produce, incorrect loading disrupting air flow and inability of coolrooms to bring curd core temperature down to optimal levels prior to dispatch.

During both summer and winter, regardless of whether the transport used was Tautliner® or Pantech®, market quality of the cauliflowers was affected most by the length of time the cauliflowers were precooled prior to packing and transport. Core temperature of the cauliflowers was maintained by both the tautliner and pantech with a tolerance of plus or minus 0.5°C. However, to obtain improved quality at outturn, cauliflowers must be precooled to a temperature of at least 1°C prior to dispatch. This will allow for an increase in temperature of 2°C during packing which may be reduce by 1°C in the dispatch coolroom. The cauliflowers take longer to cool when packed into export cartons, therefore it is important to pack the precooled cauliflowers quickly to avoid an increase in core temperature.

9.2.3. Recommendations

The overriding conclusion of the whole study is that more attention needs to be paid to core temperature monitoring and to match precooling room capacity to the volumes of produce to be precooled so that cooling can be done faster and better.

The transport methods monitored have enough cooling capacity to maintain the initial core temperature of the cauliflowers before loading. Therefore, it is recommended to precool the cauliflowers to a core temperature of at least 1°C and storing the cauliflowers no more than 4 days, to avoid reductions in quality.

Most packers should be consulting with cooling engineers to assess the suitability of their cooling units for what they are trying to achieve. Implementation of a quality assurance process to ensure the packers are achieving the desired result is recommended.

10. Packaging for export market cauliflower

10.1. Introduction

There is now a large range of packaging materials available commercially to cauliflower growers and exporters. However, there is a lack of definitive information available to demonstrate the performance of the current range of products. This information would be useful to the growers and exporters who wish to explore the type of packaging materials they might use to extend shelf life and maintain quality.

The aim of this trial is to compare the effectiveness of various packaging materials available to extend the storage life of cauliflower for the export market.

10.2. Materials and method

A total of 19 treatments were used, 3 replicates per treatment (Table 85).

Table 85: List of treatments used in experiment

Treatment no.	Type of treatment
1	Wrap - Grease-Proof Paper - Chinese (Control)
2	Wrap - Grease-Proof Paper - Scandinavian
3	Wrap - Gease-Proof Paper - Caxton NZ
4	Wrap - Grease-Proof Paper - Detmold Medium spec
5	Wrap - Grease-Proof Paper - Detmold Heavy spec
6	Wrap - Low Density Poly-ethylene(made locally)
7	Wrap - High Density Poly-ethylene(made locally)
8	Wrap - Micro Perforated LD Poly-ethylene
9	Wrap - Stayfresh-ethylene absorbent
10	Individual Bags - Low Density Poly-ethylene
11	Individual Bags - High Density Poly-ethylene
12	Individual Bags - Micro Perforated LD Poly-ethylene
13	Individual Bags - StayFresh (ethylene absorbent)
14	Overwrap - Non porous
15	Overwrap - Porous
16	Carton Liner - Low Density Poly-ethylene
17	Carton Liner - High Density Poly-ethylene
18	Carton Liner - StayFresh (ethylene absorbent)

A random selection of uniform export quality cauliflower was sourced from Stevens Farms, Wanneroo. They were precooled to less than 2°C and packed direct from field bins in Stevens' packing shed with the growers labour (to simulate commercial conditions). Samples (a total of 54 boxes) were kept in a coolroom at 0 ± 1°C with greater than 95% relative humidity before they were transported to the Postharvest Laboratory, Agriculture WA, South Perth. The storage time in the coolroom was three weeks at 0°C.

All treatments were removed from 0°C after 3 weeks and those with sealed bags were opened. They were then stored at 20°C for another 2 days and then quality assessments were carried out. Temperature and relative humidity were monitored throughout the period of the trial starting at the point of harvest.

In order to obtain the weight loss, each box was weighed:

i) after packing
ii) after 3 weeks storage
iii) prior to 3 week + 2 days assessments.

Carbon dioxide and oxygen levels in the sealed bags were measured at regular intervals throughout the trial.

Assessment score(1-5, 1:the best; 5:the worst) was used for the following:

i) floret colour
ii) stem colour
iii) cut surface colour
iv) rots and blemishes
v) black spots
vi) overall quality/saleability

10.3. Results and discussion

10.3.1. Weight loss

The weight loss was highest in the treatment with paper wraps (Table 86) compared to other treatments. With the paper wraps, the weight loss was generally more than 2% after 3 weeks storage at 0°C and increased to more than 3% after another 2 days at 20°C. Less water loss was found in the treatments with sealed carton liners.

10.3.2. Oxygen and carbon dioxide levels in sealed bags

Almost all the individual bags and carton liners used in the treatments did not create suitable oxygen and carbon dioxide levels to achieve the beneficial effects of modified atmosphere condition for storage of cauliflower (Table 87). In the sealed low density polyethylene (LDPE) bags, the oxygen levels were too high (about 17%). The optimal level of oxygen for modified atmosphere storage of cauliflower is around 2-4%. However, in the high density polyethylene (HDPE) bags, the oxygen levels were too low and the carbon dioxide levels were too high. The optimal level of carbon dioxide for modified atmosphere storage of cauliflower is also around 2-4%. Low oxygen level in the bag will induce anaerobic respiration and high carbon dioxide level will cause carbon dioxide injury to cauliflower.

Table 86: Cauliflower weight loss during storage.

Treatments	% loss after 3 weeks at 0°C	% loss after another 2 days at 20°C
1. Wrap - Grease-Proof Paper - Chinese (Control)	4.56	5.68
2. Wrap - Grease-Proof Paper - Scandinavian	2.19	3.42
3. Wrap - Grease-Proof Paper - Caxton NZ	2.80	3.88
4. Wrap-Grease-Proof Paper-Detmold Medium spec	2.02	3.02
5. Wrap-Grease-Proof Paper-Detmold Heavy spec	1.90	3.06
6. Wrap - Low Density Poly-ethylene	1.32	1.44
7. Wrap - High Density Poly-ethylene	1.12	1.43
8. Wrap - Micro Perforated LD Poly-ethylene	2.55	3.68
9. Wrap - Stayfresh-ethylene absorbent	1.78	2.34
10. Individual Bags - Low Density Poly-ethylene	1.65	2.22
11. Individual Bags - High Density Poly-ethylene	0.54	1.12
12. Individual Bags-Micro Perf. LD Poly-ethylene	2.91	3.81
13. Individual Bags-StayFresh(ethylene absorbent)	1.69	1.99
14. Overwrap - Non porous	2.95	3.78
15. Overwrap - Porous	2.54	3.45
16. Carton Liner - Low Density Poly-ethylene	0.22	1.24
17. Carton Liner - High Density Poly-ethylene	0.58	1.04
18. Carton Liner - StayFresh (ethylene absorbent)	0.30	0.79

Table 87: Oxygen and carbon dioxide levels in sealed bags during storage

	% Oxygen			% Carbon dioxide		
	26/6/97	3/7/97	9/7/97	26/6/97	3/7/97	9/7/97
LDPE	17.7	17.7	17.6	3.4	3.2	3.4
Std Dev	2.74	2.05	2.29	2.57	1.80	2.16
HDPE	0.5	1.1	1.4	8.2	6.9	6.8
Std Dev	0.06	0.94	0.72	0.38	0.29	0.51
Stayfresh	0.5	4.9	9.5	29.8	22.5	13.9
Std Dev	0.13	2.39	2.45	0.52	2.81	3.60

10.3.3. Market quality

The results of the quality assessments are shown in Table 88. After 3 weeks storage at 0°C plus another 2 days storage at 20°C, the cauliflowers were still marketable (with quality scores around 3) except some of those in Treatment 8, 12 and 14. However, the cauliflowers in Treatment 10, 13, 17 and 18 were totally not marketable due to very bad quality. When the quality score reached 4 and above, the cauliflower is not saleable.

Table 88: Assessments of cauliflower quality after 3 weeks storage.

	Treatment		Floret colour	Stem colour	Cut surface colour	Rots/ blemishes	Black spot	Quality/ marketable
1	Wrap - Grease-Proof Paper-Chinese (Control)	Mean	2.9	2.1	2.8	3.1	2.6	3.0
		SD	0.2	0.3	0.5	0.5	0.6	0.7
2	Wrap - Grease-Proof Paper-Scandinavian	Mean	3.1	2.2	2.9	3.5	2.9	3.6
		SD	0.1	0.4	0.6	0.5	0.6	0.5
3	Wrap - Grease-Proof Paper-Caxton NZ	Mean	3.0	2.1	3.0	3.5	2.8	3.5
		SD	0.1	0.3	0.6	0.5	0.5	0.6
4	Wrap - Grease-Proof Paper-Detmold Med spec	Mean	3.0	2.3	3.4	3.2	2.7	3.2
		SD	0.3	0.4	0.5	0.6	0.5	0.6
5	Wrap - Grease-Proof Paper-Detmold Hvy spec	Mean	3.0	2.2	3.0	3.2	2.4	3.3
		SD	0.4	0.4	0.4	0.4	0.5	0.4
6	Wrap - Low Density Poly-ethylene	Mean	3.1	2.2	2.9	3.6	2.9	3.6
		SD	0.4	0.3	0.4	0.5	0.6	0.6
7	Wrap - High Density Poly-ethylene	Mean	3.0	2.1	2.8	3.3	2.8	3.3
		SD	0.0	0.2	0.4	0.5	0.7	0.6
8	Wrap - Micro-perforated LD Poly-propylene	Mean	3.2	2.6	3.4	3.8	3.4	3.9
		SD	0.3	0.3	0.5	0.5	0.7	0.7
9	Wrap - Stayfresh-ethylene absorbent	Mean	2.8	2.2	2.9	3.3	2.8	3.5
		SD	0.4	0.4	0.5	0.7	0.7	0.8
10	Individual Bags - Low Density Poly-ethylene	Mean	ND	ND	ND	ND	ND	5.0
		SD						
11	Individual Bags - High Density Poly-ethylene	Mean	2.7	2.0	2.6	2.9	2.4	2.9
		SD	0.3	0.0	0.5	0.5	0.6	0.6
12	Individual Bags - Micro-perf. LD Poly-propylene	Mean	3.0	2.4	3.1	3.8	3.0	3.8
		SD	0.0	0.5	0.6	0.5	0.6	0.6
13	Individual Bags Stayfresh ethylene absorbent	Mean	2.9	2.3	2.4	4.4	4.3	4.4
		SD	0.6	0.5	0.5	0.7	0.8	1.0
14	Overwrap - Non-Porous	Mean	3.3	2.4	3.2	3.7	3.4	3.9
		SD	0.4	0.5	0.6	0.6	0.6	0.7
15	Overwrap - Porous	Mean	3.3	2.1	2.7	3.6	3.0	3.6
		SD	0.6	0.3	0.4	0.7	0.6	0.8
16	Carton Liner - Low Density Poly-ethylene	Mean	2.7	2.0	2.6	3.2	2.9	3.4
		SD	0.5	0.1	0.5	0.5	0.6	0.6
17	Carton Liner - High Density Poly-ethylene	Mean	3.3	2.1	2.6	4.1	3.8	4.3
		SD	0.5	0.2	0.6	2.1	2.1	2.2
18	Carton Liner Stayfresh ethylene absorbent	Mean	ND	ND	ND	ND	ND	5.0
		SD						

1 = best
5= worst

Notes: Treatments applied on 18/6/97 and assessed 11/7/97.

ND: The samples were not assessed because the quality was too poor (quality scores = 5).

10.4. Conclusions

Although some of the wrapping materials used in the trials were able to extend the shelf life of cauliflowers, the beneficial effects were not great. Overall, the control treatment (Chinese paper wrap), and individual high density polyethylene bags (treatment 11) gave the best quality scores after storage but weight loss was high for the former treatment and gas composition in the bag was undesirable in the latter. More research and development needs to be carried out in order to find an ideal wrapping material for cauliflower.

11. Other activities

11.1. Chlorination and cooling method effects on postharvest quality of cauliflower

11.1.1. Introduction

Seventy percent of Australia's export cauliflowers are grown and packed in the Manjimup district of Western Australia. If the desire of the cauliflower industry is to reach distant markets such as Kuala Lumpur and Singapore with a consistently good quality product, a longer storage life would be an advantage. As with all horticultural produce, cooling of cauliflowers is done to decrease the respiration rate of the produce and prolong its shelf life. Currently most of the industry in the South West of Western Australia utilise room cooling that takes about 6-8 hours for the product to reach the desired temperature of 0-2°C, after which they are packaged and placed in the cool room to await shipment. Hydrocooling is a method that involves immersion of the produce in cold water and can drop the temperature of the produce to the required temperature in less than one hour. Hydrocooling is quicker and more energy efficient and it also cleans the product. One disadvantage of hydrocooling is the use of water which can promote postharvest rots. For this reason chlorine is added to the water to kill any bacteria that may be present.

The aim of this investigation is to study the effectiveness of chlorination and various methods of precooling techniques in extending shelf life and maintaining quality of cauliflower for export.

11.1.2. Materials and method

Cauliflowers (variety *Plana*) were grown and harvested on the morning of January 16, 1996. The cauliflowers arrived at Manjimup Vegetable Export Growers (MVEG) packing house at 1PM and the treatments applied as below. Temperatures before and after treatment were recorded. The cauliflowers were then stored overnight in the cool room (0°C), either forced air cooled or not, as applicable. The next morning they were wrapped in paper (thickness 26gsm) and packed into cartons. Ten curds were placed in each of six replicate cartons for each of the six treatments. A temperature data logger was stored in a carton to record temperature fluctuations. The cartons were then stacked randomly onto a pallet and stored at 2 +/- 2°C and 70% relative humidity for 3 weeks. After the three weeks storage time the cartons were transferred to a constant temperature room (24 +/- 2°C) and stored for 6 days. The cauliflowers were assessed at 0, 2 and 6 days after removal from the cool room for differences in floret colour, stem colour, cut surface colour, turgor, percentage weight loss per curd, severity of rots and blemishes, severity of black spot and market quality (Table 89). Data analysis was done using standard analysis of variance (ANOVA) techniques and least significant difference (lsd) analysis.

The treatments were as follows:

Treatment 1 - control treatment which involved room cooling the cauliflowers at 0°C overnight (20 hours).

Treatment 2 - forced air cooled.

Treatment 3 - forced air cooled with a 5 minute pre-dip in warm (22°C) 100ppm chlorine solution (pH = 7.5) and then a 5 minute rinse in warm water. This treatment was set up to examine if a chlorine pre-dip will reduce the amount of rots in the cauliflowers after storage.

Treatment 4 - control for treatment 3, that is a 10 minute pre-dip in warm water before being forced air cooled.

Treatment 5 - hydrocooled treatment. This involved dipping the curds for 5 minutes in cold (1°C) 100ppm chlorine solution (pH = 7.2) and then a further 55 minutes in ordinary cold water (less than 2°C) to get the curds to the required temperature (2°C). Dipping was done in a half tonne bin lined with plastic that was stored in the cool room overnight to reach the required temperature. Ice was used to keep the water at approximately the required temperature.

Treatment 6 - control for the hydrocooled treatment. This involved dipping the cauliflowers in less than 2°C water with no chlorine for one hour.

Table 89: Quality assessment criteria.

Score	Floret colour	Stem colour	Cut surface colour	Turgor	% Rots/ blemish	% Black spot	Market quality
1	White	White	White	Very turgid	None	None	Excellent
2	Trace yellow	Trace yellow	Light grey	Turgid	Slight	Slight	Good
3	Slight yellow	Slight yellow	Grey	Slight soft	Moderate	Moderate	Moderate
4	Yellow	Yellow	Dark grey	Soft	Severe	Severe	Poor
5	Very yellow	Very yellow	Black	Very soft	Very severe	Very severe	Very poor

11.1.3. Results and discussion

Table 90: Average temperatures of curds after treatment and cool storage overnight (+/- 0.5°C)

Treatment	Temperature before treatment (°C)	Temperature after treatment (°C)	Final temperature (°C)
Room cooled	22.5	6.0	6.0
Forced air	24.0	1.8	1.8
Warm Cl dip	24.0	23.5	2.0
Warm water dip	23.5	23.5	2.0
Hydrocooled Cl dip	24.0	3.0	2.0
Hydrocooled water dip	23.5	3.0	2.0

The forced air cooled curds had the lowest temperature of 1.8°C after the cooling treatment. The curds that were hydrocooled for one hour dropped to an average core temperature of 3°C. After 20 hours of room cooling, the curds from this treatment had a core temperature of 6°C, indicating that this is the least efficient cooling method examined (Table 90).

The results of the assessment are shown in Tables 91, 92 and 93. Chlorination of cauliflower curds, both in warm and cold chlorine solution, significantly decreased the amount and severity of postharvest rots and black spot after 2 and 6 days warm storage at 24°C. The market quality of the chlorine treated curds was better than the non-chlorinated curds after 2 and 6 days storage, for example the warm chlorine dipped curds had a mean quality score of 2.7 after two days storage, whereas the warm water dipped curds had a mean score of 3.1. Chlorine had no consistent significant effect on turgor, stem colour or floret colour. The cut surface colour of the warm chlorine treatment was better than the warm non-chlorinated treatment after 2 and 6 days.

Table 91: Quality after 0 days warm storage.

	Treatment	% weight loss/curd	Floret colour	Stem colour	Cut surface colour	Turgor	Market quality	% rots	Rots/ blemish	Black spot
1	**Slow cooled**	3.84	2.13	1.00	2.06	1.06	3.00	0	1.00	1.00
2	**Forced air**	4.88	2.20	1.00	2.12	1.03	2.93	0	1.00	1.00
3	**Warm Cl dip**	4.40	2.31	1.00	1.97	1.02	2.63	0	1.00	1.00
4	**Warm water dip**	2.23	2.39	1.00	2.05	1.02	2.87	0	1.00	1.00
5	**Hydrocooled + Cl**	2.40	2.47	1.00	2.00	1.00	2.68	0	1.02	1.03
6	**Hydrocooled- Cl**	1.19	2.27	1.00	1.90	1.00	2.61	2	1.06	1.20
	LSD (p≤0.05)	**0.82**	**0.16**	**NS**	**0.11**	**NS**	**0.17**	**NA**	**NS**	**0.06**

NS - not significant, NA - not available

Table 92: Quality after 2 days warm storage.

	Treatment	% weight loss/curd	Floret colour	Stem colour	Cut surface colour	Turgor	Market quality	% rots	Rots/ blemish	Black spot
1	**Slow cooled**	2.65	2.41	1.00	2.49	1.93	2.97	2	1.79	2.39
2	**Forced air**	4.93	2.60	1.03	2.24	1.97	3.13	3.3	1.71	2.60
3	**Warm Cl dip**	1.52	2.35	1.00	2.13	1.22	2.74	0	1.32	2.03
4	**Warm water dip**	2.43	2.48	1.02	2.48	1.23	3.10	20	2.01	2.83
5	**Hydrocooled + Cl**	2.84	2.45	1.00	2.22	1.07	2.76	5	1.37	2.22
6	**Hydrocooled- Cl**	1.53	2.30	1.00	2.31	1.05	2.91	14	1.60	2.53
	LSD (p≤0.05)	**0.34**	**0.18**	**NS**	**0.16**	**0.12**	**0.13**	**NA**	**0.20**	**0.17**

NS - not significant, NA - not available

Table 93: Quality after 6 days warm storage.

	Treatment	% weight loss/curd	Floret colour	Stem colour	Cut surface colour	Turgor	Market quality	% rots	Rots/ blemish	Black spot
1	**Slow cooled**	5.64	2.53	2.00	3.33	1.85	3.60	38	2.32	3.29
2	**Forced air**	8.25	2.50	2.00	3.23	1.62	3.75	45	2.67	3.34
3	**Warm Cl dip**	4.76	2.35	2.00	3.08	1.42	3.19	30	2.15	2.87
4	**Warm water dip**	5.44	2.57	2.00	3.37	2.22	3.95	68.33	2.98	3.38
5	**Hydrocooled + Cl**	5.68	2.32	2.00	3.10	1.70	3.60	36.67	2.65	3.07
6	**Hydrocooled- Cl**	4.07	2.23	2.02	3.14	1.61	4.04	54	3.16	3.37
	LSD (p≤0.05)	**0.45**	**0.17**	**NS**	**0.15**	**0.12**	**0.23**	**NA**	**0.32**	**0.14**

NS - not significant, NA - not available

Curds treated with unchlorinated water, either cold or warm, had significantly higher incidence and severity of rots and black spot. The percentage of the curds affected by rots after two days storage was 14% for the non chlorinated hydrocooled treatment and 20% for the non chlorinated warm treatment. This compares to 5% and 0% respectively for the same treatments with the addition of chlorine. Similarly, the severity of black spot was 2.5 for the hydrocooled non chlorinated treatment and 2.8 for the warm non chlorinated treatment after two days warm storage. This compares to 2.2 for the chlorinated hydrocooled and 2.0 for the warm treatment.

The chlorinated hydrocooled cauliflowers had consistently better market quality and less weight loss than the forced air cooled treatment. The forced air cooled cauliflowers showed the highest weight loss (4.9% after cool storage, 8.3% after 6 days warm storage) at all assessment times. This may be because the water treated cauliflowers gained water during the treatment stage. It is predicted that the room cooled cauliflowers would have had a higher weight loss due to the slower cooling method, but this treatment was lost in transit.

The half cooling time of a large cauliflower in water was about 20 minutes. After one hour of hydrocooling in less than 2°C water, the average curd temperature was 3°C. It is estimated that forced air cooling would take 6-8 hours to reach this temperature. After twenty hours of room cooling, treatment 1 had still not reached 2°C.

The quality of all treatments decreased in all categories as the warm storage time increased. However, stem colour was similar after 0 and 2 days at white and floret colour was similar between 2 and 6 days at trace/slight yellow. Many of the curds were still quite good after two days warm storage, when most were of moderate market quality. However, after six days few of the curds would have been saleable as many had extensive rots and black spot and in most cases the overall market quality had fallen to poor.

The temperature of the curds in the cool room was between 0-2°C as expected. During warm storage the temperature varied between 23-25°C.

11.1.4. Conclusion

Chlorine had a marked effect at reducing the rots and black spot in cauliflower curds. It is believed that if a washing system was set up using chlorinated water, then the quality of the cauliflowers at the point of sale would be significantly better. Further research could examine the optimal dipping time and concentration of chlorine to decrease the rots without adversely affecting the quality or flavour of the cauliflower. The cost of hydrocooling in comparison to forced air cooling should also be investigated.

Hydrocooling of cauliflowers has potential for the rapid removal of field heat from cauliflowers. If the water used is chlorinated then the cauliflowers have a significantly better quality than forced air cooled curds after two days warm storage in all categories except colour. However, after 6 days warm storage the hydrocooled cauliflowers have caught up to the forced air curds and they are all unmarketable.

11.2. Cauliflower market study tour

During 24-30 November 1996, two Agriculture Western Australia staff and two cauliflower industry representatives went on a cauliflower market study tour to Kuala Lumpur and Singapore. The party consisted of Dr. Soon Chye Tan, Senior Research Officer (Agriculture WA), Vynka McVeigh, Research Officer (Agriculture WA), Norm Eaton, packer/exporter formerly of Mercer Mooneys, and Toby Lambert, cauliflower grower in the Manjimup area.

The purpose of the study tour was:

i) To enable cauliflower grower and packer to see the outturn of their product and to discuss market trends with importers, wholesalers and retailers in Kuala Lumpur and Singapore.

ii) To collect market intelligence and information on consumers' requirements and preferences in Kuala Lumpur and Singapore to prepare the future strategy plan for the export of cauliflowers.

Factors and new developments that have improved the competitiveness of the Western Australian horticultural industry were:

i) Agriculture WA together with cauliflower grower and exporter have established good contacts with importers, wholesalers, retailers and fruit and vegetable marketing associations in Kuala Lumpur and Singapore. The contacts will enable the cauliflower industry to obtain market requirements, demands and supply and trends of horticultural crops in Kuala Lumpur and Singapore.

ii) The understanding of market requirements and specifications will enable the Australian cauliflower industry to export produce that will be accepted by the markets and will be able to compete with other producers such as the United States of America and China.

For more details on the cauliflower study tour to Kuala Lumpur and Singapore, refer to the report (Appendix 13.2).

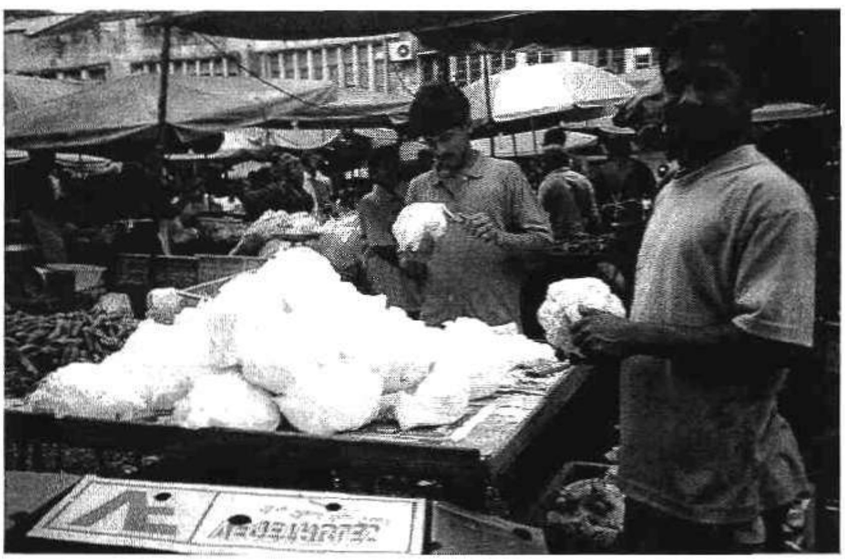


Figure 19: Removing black spot from cauliflower with a knife at wet market in Kuala Lumpur.

11.3. Australasian Postharvest Horticulture Conference - 1997

From September 27 to October 4 1997, Miss Vynka McVeigh, Project Officer, attended the Australasian Postharvest Horticulture Conference held at the University of Western Sydney, Hawkesbury, New South Wales. Attendance at the conference provided an opportunity to compare current Western Australia postharvest research with international standards. It was also an opportunity to establish valuable contacts with world leaders in postharvest technology which have been consulted throughout the completion of the project.

Miss McVeigh also contributed to the conference by publishing the trial on the seasonal effects on bruising of cauliflower in the conference proceedings. A poster of the work was also displayed during the poster sessions of the conference.

For more details on the conference, refer to the conference report (Appendix 13.3).

11.4. Cost benefit analysis of better leaf covering

This work was done to determine if more covering and/or harvest operations are needed to reduce overmature and yellow curds. Growers cover the cauliflower curds with the leaves of the plant to stop the curds turning yellow with exposure to sunlight. As a recommendation from the Shellabear report (1995), a cost benefit analysis was done to determine which would be the best option to reduce overmature, yellow and missed curds. Curds that are overmature and yellow account for 11.1% of total crop loss. This could can be prevented by better management techniques (Table 94). These management losses are predicted to cost the lower south west cauliflower industry of Western Australia approximately $1,146,000, assuming that total yield is 25 000kg/ha and farm-gate price is 85c/kg. Other management losses such as bruising, dirt and picker damage (2.7% of losses) can be reduced through careful handling and better picker training.

To reduce losses such as overmature, pink and yellow curds, growers need to cover each cauliflower curd with leaves or harvest the curds more regularly to avoid over maturity. The time taken and number of workers to perform harvest and curd cover operations is listed in Table 95. The current cover and harvest system is one cover prior to harvest, two harvest and cover operations then two harvests. Three options are outlined:

Option 1 - two additional curd cover operations to recover approximately 50% of pink/yellow losses;

Option 2 - includes one extra harvest and cover operation to recover 30% of pink/yellow losses and 50% of overmature losses; and,

Option 3 - regarded as the luxury option has two extra curd cover operations and one additional harvest and cover operation, which is expected to recover 70% of pink/yellow losses and 70% of overmature losses.

Option 3 reduces the losses of pink, yellow, overmature and missed curds to 3.32%, however, the benefits and costs of harvest management changes of option 3 has a $1 644 per hectare extra cost with $0 per hectare benefit (Table 96). Based on the assumptions of 85c/kg. Option 3 would not be a viable option as it is too expensive with no gain. Option 1 and 2 are the better options with a benefit of $320/ha and $142/ha respectively.

Some growers within the industry do realise that they should be covering more often. However, covering operations do not happen as often as it should because of the lack of time and obtaining labour to do the operation. This work gives an approximate estimation of the cost of extra covering and harvest operations to achieve a better yield recovery.

Table 94: Crop loss categories and production value estimates.

Cause of Loss	% of crop lost	$/Ha	District Value
wire stem	2.21	$470	$229,237
soft rot	0.79	$168	$81,944
downy mildew types	0.67	$142	$69,497
mould	0.02	$4	$2,075
Total micro-organisms loss	**3.69**	**$784**	**$382,753**
insect	2.54	$540	$263,467
slug	0.8	$170	$82,982
Total macro-organisms loss	**3.34**	**$710**	**$346,448**
ducks	1.82	$387	$188,783
rat	0.75	$159	$77,795
rabbits	0.01	$2	$1,037
Total by small animals loss	**2.58**	**$548**	**$267,616**
light/open/blind (sibs)	3.23	$686	$335,038
grossly immature	0.82	$174	$85,056
furry	0.19	$40	$19,708
Total genetic loss	**4.24**	**$901**	**$439,803**
small head	3.82	$812	$396,237
immature	1.33	$283	$137,957
split	0.33	$70	$34,230
Total management/genetic loss	**5.48**	**$1,165**	**$568,424**
pink yellow over mature	9.97	$2,119	$1,034,158
bruise	1.81	$385	$187,746
miss	1.08	$230	$112,025
dirt	0.54	$115	$56,013
picker damage	0.21	$45	$21,783
Total management loss	**13.61**	**$2,892**	**$1,411,725**
seedling heat stress	0.49	$104	$50,826
hail	0.48	$102	$49,789
erosion/flood	0.36	$77	$37,342
Total management/environment loss	**1.33**	**$283**	**$137,957**
stain	1.18	$251	$122,398
deformed	0.27	$57	$28,006
Total unknown loss	**1.45**	**$308**	**$150,404**

Total Yield - kg/ha	**25,000**	**$21,250**	**$10,372,702**
Total Losses - %age	**35.72**	**$7,591**	**$3,705,129**
Total Marketable Yield - kg/ha	**16,070**	**$13,660**	**$6,667,573**

Farmgate Produce Price - $/kg	**0.85**
Manjimup District Prod'n 1994	**7,844,204**

* District value = Manjimup Area only

* Production based on Warren District Export Data

Table 95: Harvest management losses.

Category	% of crop lost	$/Ha	District Value
Pink, Yellow, Overmature & Missed	11.05	2,348	$1,146,184

Time Taken to Perform Harvest & Curd Cover Operations

	Persons	Time ea (hrs)	Total
Time to cover 0.5 ha @ 16.1 t/ha	2	4	**8**
Cover & harvest 0.5 ha @ 16.1 t/ha	5	6	**30**
Time to harvest 0.5 ha @ 16.1 t/ha	4	5	**20**

Current & Optional Cover & Harvest Systems

Current Cover & Harvest System	No of Operations	Total Time hrs/ha
Cover Only	1	16
Harvest & Cover	2	120
Harvest Only	2	80
		216

Option 1		
Cover Only	3	48
Harvest & Cover	2	120
Harvest Only	2	80
		248

2 additional curd cover operations. Estimated improvement in covering to recover 50% of pink/yellow losses & 0% of overmature losses.

Option 2		
Cover Only	1	16
Harvest & Cover	3	180
Harvest Only	2	80
		276

Include 1 extra harvest & cover operation. Extra covering operation to recover
30% of pink/yellow losses. Additional harvest operation to recover
50% of overmature losses.

Option 3		
Cover Only	3	48
Harvest & Cover	3	180
Harvest Only	3	120
		348

Additional (2) curd cover operations & 1 additional harvest & cover operation.
Expected covering improvements to recover 70% of pink/yellow losses.
Expected harvest improvements to recover 70% of overmature losses.

Pink, Yellow, Overmature & Missed Losses Resulting from Operations

	Pink/Yellow %	Overmature %	Total Loss %
Current System	6.63	4.42	11.05
Option 1	3.32	4.42	7.74
Option 2	4.64	2.21	6.85
Option 3	1.99	1.33	3.32

Table 96: Benefits and costs of harvest management changes.

System of Harvest/Covering	Yield Recovery $/ha	Harvest/Cover Extra Cost/ha	Benefit or Cost $/Ha
Option 1	704	384	320
Option 2	892	750	142
Option 3	1644	1644	0

Labour Cost	12.00 $/hr	**Price $/Kg**	$0.85
Harvest Operation	30.00 $/ha		

12. References

Australian Bureau of Statistics (1997/98) Agtrade database, Agwest Trade and Development.

Boehm, R. (1995) MAP to deliver new export markets. *Good Fruit and Vegetables*, January, pp 18-23.

Emond, J., Boily, S. And Mercier, F. (1995) Reduction of water loss and condensation using perforated film packages for fresh fruit and vegetables. *Proc. Harvest and Postharvest Technologies for Fresh Fruit and Vegetables,* Mexico, February 1995.

Finch-Savage, W.E. (1986) A study of the relationship between seedling characteristics and rate of germination within seed lot. *Annals of Applied Biology*, **105**, pp 441-444.

Finch-Savage, W.E. and McKee, J.M.T. (1990) The influence of seed quality and pregermination treatment on cauliflower and cabbage transplant production and field growth. *Annals of Applied Biology*, **116**, pp 365-369.

Gallagher, J., Gartrell, P. and Eckersley, P. (1997) Cauliflower Marketing Trends and Positioning the Western Australian Industry, Agriculture Western Australia.

Gartrell, P.(1997) Vegetable Budgeting Handbook for the Manjimup District. Agriculture WA. p 16-19.

Hatton, L. (1996) Asian markets: the buyer's perspective. *Good Fruit and Vegetables* **6**(9), p 46.

Hill, J. (1996) Transporting fresh produce in refrigerated trucks. Fact Sheet, Agdex 201/56. Primary Industries, South Australia and South Australian Research and Development Institute.

Hill, T. (1985) (unpublished) Cauliflower - Time form harvest to cool storage. File 85mn32, Department of Agriculture, Manjimup, WA.

Joyce, D. and Yuen, C. (1988) Storage conditions for fruit and vegetables. Farmnote No. 28/88, Western Australian Department of Agriculture.

Mitchell, F.G. (1992) Cooling Horticultural Commodities. *In*: Kader, A.A. Postharvest Technology of Horticultural Crops. 2nd Ed., University of California, Publication 3311, p 53-68.

Phillips, D.R. *et al.* (1994) Effects of phosphorus on yield and quality of cauliflower. *In*: Export Cauliflower Improvement Project, 1993-1994. Horticultural Research and Development Corporation Final Report.

Shellabear, M. (1995) Export Cauliflower Improvement Project, 1993-1994. Horticultural Research and Development Corporation Final Report.

Story, A. (1989) Fresh Produce Manual - Handling and Storage Practices for Fresh Produce. 2nd Ed. Australian United Fresh Fruit and Vegetable Association Ltd., Victoria.

Suslow, T. And Cantwell, M. (1997) (unpublished) Etiology of a browning disorder of fresh cut cauliflower. Dept. Vegetable Crops, University of California, Davis, California.

Tan, S.C., et al. (1993) Storage characteristics and quality of four broccoli (*Brassica oleracea* var. *italica*) cultivars. *Australian Journal of Experimental Agriculture* 33, p 111-113.

Tan, S.C., Haynes, Y.S and Phillips, D.R. (1994) Postharvest handling of *Brassica* vegetables. Farmnote No. 44/94, Western Australian Department of Agriculture.

Unpublished data (1997) Nursery Figures for the SW of Western Australia, Manjimup Cauliflower Planning Committee.

Watkins, J.B. and Ledger, S. (1990) Forced Air Cooling 2nd ed. Queensland Department of Primary Industries, Brisbane.

Weir, R.G. and Cresswell, G.C. (1993) Plant Nutrient Disorders 3 - Vegetable Crops. Inkata Press, Melbourne.

Weston, L.A. and Barth, M.M. (1997) *Preharvest factors affecting postharvest quality of vegatables.* HortScience, 32(5) p 812-816.

Zong, R,J. (1990) Physiological Aspects of Film Wrapping of Fruits and Vegetables, Beijing Vegetable Research Centre, China

13. Appendix

13.1. Plant analysis of cauliflower leaves taken from the harvest maturity trial (spring harvest)

13.2. Cauliflower Market Study Tour Report of Kuala Lumpur and Singapore

13.3. 1997 Australasian Postharvest Horticulture Conference Report

13.4. Copy of Publications and Newspaper Articles

Papers

McVeigh, V (1997) Seasonal effects on bruising in cauliflower. *Proc. Australasian Postharvest Horticulture Conference*, Hawkesbury, New South Wales, September 1997.

Newsletters/industry publications

McVeigh, V (Dec., 1996) Export cauliflower improvement project update. Agricultural Memo, Agriculture WA, Manjimup

McVeigh, V (May, 1997) Cauliflower improvement group. Agricultural Memo, Agriculture WA, Manjimup

McVeigh, V (Sept., 1997) Cauliflower improvement group. Agricultural Memo, Agriculture WA, Manjimup

Lancaster, R (Sept., 1997) Cauliflower and Phosphorus. Agricultural Memo, Agriculture WA, Manjimup

McVeigh, V (Feb., 1997) Bin liners affect precooling time. Agricultural Memo, Agriculture WA, Manjimup

McVeigh, V (Apr. 1998) Cauliflower industry update. Agricultural Memo, Agriculture WA, Manjimup

General publications

McVeigh, V (1997) Improving the quality of export cauliflower. Research Report 1996/97, Horticultural Research and Development Corporation.

McVeigh, V (1998) Improving the quality of export cauliflowers Hort Report 1998, Horticultural Research and Development Corporation.

McVeigh, V (1997) Seasonal effects on bruising of cauliflower. Poster presented at Australasian Postharvest Horticulture Conference, Hawkesbury, NSW, 28 Sept. - 3 Oct. 1997.

Other technology transfer activities

Growers meetings

-Export Cauliflower Improvement Project Meetings (every month, 1995-1996) (every two months, 1997-1998), Manjimup, WA.
-Cauliflower Improvement Group, Manjimup WA (15th May 1996, 16th October 1996, 19th March 1997, 3rd September 1997)
-Cauliflower Planning Committee (every two months, 1996-1998)

Field day

-Manjimup Horticultural Research Centre Field Day, WA. (20th February 1997), approx 100 growers.

Radio interviews

-McVeigh, V. ABC Radio Rural Report, 15th April 1996.
-McVeigh, V. ABC Radio Rural Report, 18th October 1996.
-McVeigh, V. ABC Radio Rural Report, 20th February 1997.
-McVeigh, V. ABC Radio Rural Report, 17th March 1997.

Local and national newspaper articles

- Panzich, Z. (1996) 'New expert takes over'. Warren-Blackwood Times, May 1.
- Panzich, Z. (1996) 'Growers unify face of difficulty'. Warren-Blackwood Times, June 12.
- Williamson, D. (1996)'Manjimup's cauliflower growers - a marketing success story'. Farm Weekly, June 20.
- Panzich, Z. (1996) 'Study targets cauliflower exports'. Warren-Blackwood Times, October 9.
- Panzich, Z. (1997) 'Cauliflower growers report back'. Warren-Blackwood Times, March 19.
- Mayo, A. (1997) 'WA leads cauliflower exports'. Good Fruit and Vegetables, July, Vol. 8, No. 2.
- Plummer, J. (1998) 'Student excited about cauliflowers'. Good Fruit and Vegetables, July, Vol. 9, No. 2.

National Reporting

Attendance at "Australasian Postharvest Horticulture Conference" September 28 - October 3 1997 (see Appendix 13.3 for report)

"Improving the quality of export cauliflowers" HRDC Research Report 1996-97

"Improving the quality of export cauliflowers" HRDC Hort Report 1998

APPENDIX 13.1. Plant analysis of cauliflower leaves taken from the harvest maturity trial (Spring harvest)

CHEMISTRY CENTRE

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Your Ref: HBF/362/694/96MA31,96MA19
Our Ref: Lab. No. 96A314/1-4
Enquiries: B.Codling

OFFICER IN CHARGE
Department of Agriculture
District Office
Rose St
MANJIMUP 6258

ATTENTION: V McVeigh

Report on 4 samples of cauliflower parts from Manjimup
received on 9-OCT-1996 28-OCT-1996

LAB NO	SAMPLE	Nitrogen,N	Phosphorus,P	Potassium,K
96A		%db	%db	%db
314_001	S 1	5.31	0.49	2.93
314_002	S 2	3.02	0.42	4.13
314_003	S 3	5.71	0.50	2.82
314_004	S 4	3.22	0.38	4.60

%db = per cent dry basis
The results apply only to samples as received.

Cost $63.00

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CAULIFLOWER MARKET STUDY TOUR REPORT OF

KUALA LUMPUR AND SINGAPORE

AGRICULTURE WA AND REPRESENTATIVES OF THE LOWER SOUTH WEST CAULIFLOWER INDUSTRY

24 - 30 November 1996

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Senior Research Officer
Agriculture WA, South Perth

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Agriculture WA, Manjimup

ACKNOWLEDGMENTS

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We would like to thank importers, wholesalers, retailers and fruit & vegetable marketing associations both in Kuala Lumpur and Singapore, for giving their time and providing valuable industry information.

Mr Norm Eaton, formerly of Mooney Trading, Manjimup and Mr Toby Lambert, local cauliflower grower, were worthy representatives of the lower south west cauliflower industry. On behalf of Agriculture WA, we would like to thank Mr Eaton and Mr Lambert for taking part in this market study of Western Australian cauliflowers in Kuala Lumpur and Singapore.

S.C. Tan
Vynka McVeigh
Agriculture WA

24 February 1997

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1. EXECUTIVE SUMMARY

The objectives of the cauliflower market study tour in Kuala Lumpur and Singapore were:

- For representatives of the Western Australian cauliflower industry to visit two of Western Australia's major cauliflower markets to study current market trends and market specifications, and discuss marketing issues with the importers, wholesalers and retailers.
- To investigate methods of collecting information on wholesaler and consumer requirements and level of consumer satisfaction with Australian and West Australian cauliflower in Kuala Lumpur, to enable the preparation of a strategy plan for future exports of cauliflower.
- To identify a suitable market research company to carry out a consumer survey on cauliflower in Kuala Lumpur, Malaysia.

The main market information and messages that came out of the study tour were:

- Potential benefits can be achieved from promoting Western Australian cauliflower, especially in Malaysian markets. Carefully planned promotion could be the key to maintaining and expanding Australian cauliflower markets. However, we need to be careful to promote Australian products alone, and not to promote cauliflowers for our competitors. There is a need to identify our product as Australian or Western Australian. When the time is right, promotion can be done in conjunction with the supermarkets and hypermarkets and with the assistance of Austrade and the Western Australian Trade Office.
- There is a need for consistency and regularity of supply from Western Australia. We should not allow our importers to find alternatives or look too closely at our competitors.
- To maintain Australian and Western Australian cauliflower markets in Malaysia and Singapore, the industry will need to work harder. USA has already established some market share and China is ready to enter the markets. At this stage, we have the upper hand with our quality and supply. **Most of the importers and supermarket buyers said they preferred Australian cauliflower because of its superior quality compared to cauliflowers from other countries.** However, we must not provide opportunities for others. The industry needs to continue looking for white and solid varieties to ensure year round supply.
- One importer preferred the same size cauliflowers in the one carton. Development of a grading system is the responsibility of the individual packing shed. However, by having small cauliflowers in the one carton may not be economically feasible.
- Very often, the cauliflowers are cut into halves and quarters for sale in Malaysia and Singapore. Our industry needs to identify consumer preferences so that we can meet this demand and potentially recover a higher proportion of the crop. We also need to investigate demand for other forms of value-added products such as fresh cut products including cauliflower.
- At the time of market visits, including wholesale market, the quality of cauliflowers was not good. The main problems were bruises and black spotting. There is room for considerable improvement in handling and local transport in Kuala Lumpur and Singapore. Equally we need to carry out more research in postharvest handling and treatment in

1. EXECUTIVE SUMMARY (cont)

Australia, to improve quality. The time has come to re-investigate packaging materials and to develop a new carton.

- There may be an opportunity to further investigate Modified Atmosphere Packaging (MAP) to improve quality. However, importers believe the plastic wrap is not as fresh as the paper wrap. Most importers still prefer the paper wrap. This also keeps the cost of packaging to a minimum as MAP can increase costs considerably.

A consumer survey to determine market specifications and requirements in Malaysia will be done around May 1997. We have also planned to conduct a survey with major importers, wholesalers and supermarket buyers later this year.

2. CAULIFLOWER MARKET RESEARCH IN KUALA LUMPUR & SINGAPORE

2.1 Purpose

The purpose of the cauliflower market study tour in Kuala Lumpur and Singapore was:

- For representatives of the Western Australian cauliflower industry to visit two of Western Australia's major cauliflower markets to examine current trends and market specifications and to discuss marketing issues with importers, wholesalers and retailers.
- To investigate methods of collecting information on wholesaler and consumer requirements and level of consumer satisfaction with Australian and Western Australian cauliflower in Kuala Lumpur, to enable the preparation of a strategic plan for the future export of cauliflowers.
- To identify a suitable market research company to carry out consumer survey on cauliflower in Kuala Lumpur, Malaysia.
- To report back to the cauliflower industry in WA to improve industry awareness of marketing issues and trends, with a view to raising industry competitiveness and to expand market share.

2.2 Background

Western Australia's share of Australian exports has remained steady at 90% for the past five years. Fresh cauliflower accounted for 34% of total vegetable exports from WA by value in 1995/96. Malaysia is the major export destination in 1995/96 taking 57% of our product. Singapore was the main export market during the five years to 1995/96. During that time exports to Singapore increased by 30%. In 1995/96, 37% of cauliflowers were sent to Singapore.

The majority of export cauliflowers are sent by sea. However, air freight has increased considerably. Cauliflowers sent to Malaysia by air in 1993/94 accounted for only 3.7% of total exports. In 1995/96, air flown cauliflowers represented 19% of total exports sent to Malaysia.

Exporters, packers and growers have relied almost exclusively on importer and wholesalers for market information since the beginnings of trade. Supermarket trading has grown dramatically in the last 5 years as have consumers disposable incomes. These two trends may offer scope for cauliflower to be presented in new forms (for example, fresh cut products), increasing consumption and sales. Equally, they could result in the traditional marketing channels being by passed and WA suddenly losing market share if our specifications no longer meet supermarket and consumer needs.

To develop future marketing plans we need to know more about the end uses of cauliflower, consumer requirements and the requirements of growth sectors of the market such as supermarkets and possibly catering and restaurant industries.

2.3 Industry Representatives

The group consisted of four members. Two members were from Agriculture WA and two were cauliflower industry representatives (one exporter and one grower).

2.3 Industry Representatives (cont)

Name	Position/ Occupation	Employer	Postal Address	Phone	Fax
Dr. Soonchye Tan	Senior Research Officer	Agriculture WA	Locked Bag No. 4, Bentley Delivery Centre WA 6983	(09) 368 3647	(09) 367 2625
Vynka McVeigh	Research Officer	Agriculture WA	Rose Street Manjimup 6258	(097) 71 1299	(097) 71 2544
Norm Eaton	Fruit Manager	M.A.E.S	PO Box 1371 Manjimup 6258	(097) 71 1344	(097) 77 1040
Toby Lambert	Cauliflower grower	self-employed	8 Airey Street Manjimup 6258	(097) 77 1751	

Being a relatively small group, visits were conducted as a group of four.

Mr Toby Lambert has written a separate report from the point of view of the grower (see Appendix 6.1)

2.4 Itinerary

Date	Day	Location	Visits/Contacts
24/11/96	Sunday	Travel Perth - Kuala Lumpur	
25/11/96	Monday	Kuala Lumpur	Austrade Western Australian Trade Office Parkson Corporation (Head Office) Parkson Corp Supermarket (retail outlet)
26/11/96	Tuesday	Kuala Lumpur	Frank Small & Associates (market research company) Chinatown wet market Survey Research Malaysia (market research company)
27/11/96	Wednesday	Kuala Lumpur	Selayang Wholesale Market Agroquivir (Malaysia) Sdn Bhd (import) Yaohan Supermarket (retail)
28/11/96	Thursday	Kuala Lumpur Travel to Singapore	Pudu Road wet market Giant (hypermarket) Carrefour Distribution (hypermarket)
29/11/96	Friday	Singapore	Pasir Panjang Wholesale Market Tan Sng Kee Vegetable Suppliers Total Fresh (import) Wee Heng Hup Kee Pte. Ltd. (import) Chop Nam Huat Importers Enterprise Promotion Centres Pte. Ltd. Primary Production Department Singapore Daimaru (retail)
30/11/96	Saturday	Singapore Travel back to Perth	Pan Commercial Pte. Ltd. (importer/wholesaler)

3. KUALA LUMPUR

3.1 Austrade

Valerie Kelly, Trade Commissioner and First Secretary (Commercial)
Cheng Kean Meng, Senior Business Development Adviser

The following observations were made by Austrade representatives:

- Malaysian supermarkets sell cauliflower in halves or quarters. Australian cauliflowers are cut because they tend to be large. Consumers prefer small or cut cauliflower because:
  - i) most householders have limited refrigeration space to store large cauliflower;
  - ii) householders shop daily to buy fresh vegetables, therefore there is no need to buy large cauliflower as storage reduces quality.
- The proposed consumer survey should include the East Malaysian markets to get a bigger picture of consumer preferences in Malaysia. Ms Kelly explained that East Malaysian importers and retailers are different from West Malaysian. By conducting the survey in both areas a broader range of consumer responses could be gathered.
- Ms Kelly also believes there is a need to promote WA cauliflowers to increase importer and consumer awareness. Brand development is important so that importers and consumers can identify good quality with a brand name.
- Points to remember when promoting a product:
  - i) Develop a brand name to promote;
  - ii) Devise a promotional strategy, including the promotional budget, the use of different types of media, demonstrations and recipes;
  - iii) Promotion must be consistent, for example, a recipe in the local paper once every 3 months over a one year period.

3.2 Western Australian Trade Office

Amy Chin, Regional Director

Promotion of cauliflower should be mainly at point of sale, that is, in the supermarket. A promotional strategy of cauliflowers may include:

- i) Supermarket demonstrations on how WA cauliflowers can be prepared using local cooking styles. (For example, consumers prefer the cauliflower to be partly cooked so that it is slightly crunchy and crisp, not soft.)
- ii) Promote WA cauliflowers as fresh, healthy, and free of any chemical residue, which consumers in Malaysia are very concerned about.

3.3 Market Research Companies

3.3.1 Frank Small & Associates

Kong Hoo See, Associate Director

- Currently, approximately 50% of consumers buy their groceries at the wet market and 50% buy at the supermarket.
- An increasing trend in shopping behaviour is 'one stop shopping', where consumers can buy everything. The hypermarket is one such place where anything can be bought. Due to

3.3.1 Frank Small & Associates (cont)

Kuala Lumpur's traffic problems, it takes too long to travel to the different speciality stores.

- The Malaysian Government is planning to eradicate the wet market by the year 1998. They are supporting mobile night markets.
- As an incentive to remove the wet market from the streets, the Government is planning to build undercover areas in the suburbs for better shopping conditions. Wet market retailers will be encouraged to sell their produce at this central location.
- Particularly in the supermarket, Kong said branding is definitely an outlet for promoting fresh produce. Branding in the wet market is less of an issue.
- Frank Small & Associates have had research experience in other horticultural products such as pear, apples and oranges.
- Time of the survey should be March - April to avoid the Chinese New Year festive season, which would give inaccurate results.
- The age of the respondents targeted would be 21 to 49 years of age.

3.3.2 Survey Research Malaysia

Eugene Wong, Deputy Managing Director
Claire Chan, Research Manager

- Ms Chan expressed her concern about branding produce. She said it may be possible that consumers do not want to have brand names, providing they know where the produce comes from. Branding is good for promotion but it is imperative to ensure that high quality of the produce is consistent.
- Mr Wong and Ms Chan suggested that the consumer survey be extended to other areas of Malaysia, not just Kuala Lumpur. They suggested to conduct the survey in other locations such as Penang, Johor Baru, Ipoh, and Kuantan, located on the east coast.
- The interview time of the consumer survey should be no longer than 15 minutes.

3.4 Selayang Wholesale Market

Linus Ng Kar Lee, Marketing Manager of Vistamex Sdn. Bhd.

- The Selayang Markets in Kuala Lumpur are similar to those at Canning Vale. The market is a huge undercover area, three quarters of the area is taken up by vegetable sellers/importers and one quarter of the area is occupied by fruit sellers/importers.
- Each seller/importer rent their own space from which tables were set up to display their produce.
- Buyers, whether they come from large supermarket chains or the small wet market retailer, would buy what they need from the importers.

On one side of the undercover area, trucks and sea containers were unloaded and the produce distributed among sellers to be displayed in their stall area. On the opposite side, buyers had their own trucks to transport the produce they purchased to be sold at retail outlets.

3.4 *Selayang Wholesale Market (cont)*

- A few stall areas sold Western Australian cauliflower. Cauliflowers from the Eastern States were also seen. Considering the number of Manjimup packing shed cartons sighted, WA cauliflowers were more prominent.
- One seller was trimming the cauliflowers with a knife to remove any blemishes and black spot. This is considered to be normal practice.
- When asked about the cauliflowers all said they preferred cauliflowers from Western Australia because of the high standard of quality compared to cauliflowers from other countries.
- Overall, quality of cauliflowers seen was reasonably good, however some were selling better quality than others.

3.5 Agroquivir (Malaysia) Sdn. Bhd.

Mr Kelvin Leong, Managing Director, was out of the country on business therefore the group talked to Tan Soo Ngoh, Financial Controller.

- According to Tan Soo Ngoh, the cauliflower market is good but sometimes there is not enough cauliflowers available. The customer's of Agroquivir complained that there is limited stock which made the price high.
- Ms Tan said that sometimes Agroquivir must sell the cauliflowers below cost price to remove the product, being such a perishable commodity. A high price for cauliflowers is considered to be above AUS $2.00/kg import price. Low price is between AUS $1.70 - 1.80/kg. During the oversupply period the price was AUS $1.70.
- Importers prefer to buy cauliflowers that are air freighted rather than sea freighted. Although air freight is more expensive, their customers are willing to pay more for a better quality product. Sea freight is too risky because the containers can malfunction and whole shipments of cauliflowers have been known to freeze.
- Australian cauliflowers are preferred but if not available, cauliflowers from the United States of America can be easily sourced and are cheaper than Australian cauliflower. Agroquivir customers prefer Australian cauliflower as they know the product is of better quality than other countries.
- Agroquivir prefer the same size cauliflowers in the one carton. They have their own carton design in which suppliers pack their cauliflowers.
- Paper packaging is suitable and there is no need to label the paper.
- Their average cauliflower order is a minimum of 6 pallets a week.
- Agroquivir mainly supply the Selayang Markets, with 20% of their customers from Kuala Lumpur and 8% from Penang, Ipoh and other areas.

3.6 Parkson Corporation Sdn. Bhd.

Tan Kok Seng, Buyer
Jacxson Yoong, Fruit Specialist
Mohly Ng, Assistant Vegetable Buyer

Parkson Corp has 35 stores in various countries such as China and Singapore. There are 12 supermarkets in Malaysia.

3.6 *Parkson Corporation Sdn. Bhd.(cont)*

- Parkson Grand (department store including a supermarket) aims towards the lower to middle class consumer.
- Parkson's distributor is Xtra Supercentre which is involved in produce storage. Xtra uses Malaysia Storage for their coolstore requirements.
- There are also coolroom facilities at each individual supermarket. The coolrooms are about 28 square metres and operate at 4-6°C with 60-70 % relative humidity. Mixed storage of produce is the practice and accounts for the fairly high coolroom temperature. Produce is kept no longer than 2 - 3 days in coolstore.
- They prefer to buy Australian cauliflowers due to the better quality in comparison to cauliflowers from other countries. Parkson believes quality is more important than price.
- They also prefer the standard size cauliflower to be between 500 grams to 1 kg. They then cut the cauliflowers in halves at the supermarket premises, no heavier than 500 grams per piece. Each piece is wrapped in plastic wrap.
- Parkson prefer smaller cauliflowers, which is what the customer demands.
- Paper wrapping of cauliflowers is sufficient. However, Parkson believes the best packaging would be the perforated plastic bag. The plastic perforated wrap (Modified Atmosphere Packaging) have been used with cauliflowers from the United States of America.
- Mr Tan would buy 300 - 400 cartons of cauliflowers a week for Parkson's 12 supermarkets around Malaysia.
- When asked would Parkson import direct, they said they would not. Investment is considered too great and expertise would be required for ordering and programming.

3.7 Retail Outlets (Supermarkets and Hypermarkets)

3.7.1 Yaohan Supermarket

- Located in The Mall Shopping Complex on the outskirts of Kuala Lumpur city centre, Yaohan is a Japanese owned supermarket chain.
- The cauliflower halves were wrapped in a tight plastic wrap.
- Labels on the cauliflower halves did not specify the source of the product, therefore we were unsure if it was Australian produce. The cauliflowers had 'air flown' stickers on them, yet the produce was still trimmed of black spot and blemishes.
- Price: RM $8.90/kg = AUS $4.20/kg (approx.)

3.7.2 Parkson Grand Supermarket

- Located in the Sungei Wang Plaza.
- The cauliflowers were wrapped in plastic wrap and trimmed of black spot and blemishes.
- They were labelled 'Aust. Cauli'.
- Weight range of cauliflower pieces: 390 - 450 grams.
- Price: RM $6.50/kg = AUS $3.20/kg (approx.)

3.7.3 Giant Hypermarket

- Hypermarkets are large warehouse type buildings that sell almost everything, from groceries to hardware.
- The hypermarket is a growing concept in Malaysia for two reasons:
  i) It encourages one stop shopping. As Malaysia's traffic problems are worsening causing huge delays, consumers can now buy everything under the one roof without having to travel to different stores.
  ii) Products are available cheaper because the hypermarket buys in bulk which allows goods to be sold cheaper to the customer.
- Giant's fruit and vegetable section is twice the size of the fresh produce section in a supermarket.
- The cauliflowers were sold in two forms:
  - halves and quarters, no heavier than 500 grams.
  - floret pieces, packaged in a polythene tray, covered with plastic wrap.
- Price: RM $5.50/kg = AUS $2.50/kg (approx.)

3.7.4 Carrefour Hypermarket

- Carrefour is another hypermarket about the same size as Giant.
- They mainly sold small, whole cauliflowers that were of better quality than cauliflowers from Giant at the time we visited.
- The cauliflowers sold had very little trimming done.
- Price: RM $6.50/kg = AUS $3.20/kg (approx.)

3.8 Wet Market

3.8.1 Chinatown KL

- The wet market area of Chinatown appeared to be more permanent wet market, catering for the tourist together with the locals.
- There were about 20 - 25 stalls selling meat, fruit and vegetables. All of which were undercover.
- Two stalls had small refrigerated units, one a refrigerated cabinet with glass doors, the other a small coolroom 3m by 2m. Western Australian cauliflowers were stored in both units.
- Only three stalls sold cauliflower. Some stalls had better quality than others but all were trimmed of black spot. Most cauliflowers were paper wrapped and were sold whole.
- The price was AUS $3.50/kg.

3.8.2 Pudu Road

- The quality of cauliflowers at this market was fairly poor, black spot being the main problem.
- About 4 - 6 stalls were selling cauliflower, most of which were Australian.
- All cauliflowers were trimmed and sold whole.

3.8.2 *Pudu Road (cont)*

- Umbrellas and sheets of canvas covered most of the stalls which made the surroundings very humid. At one stall, the ambient temperature recorded was 30° C.
- The price was AUS $3.00/kg

4. SINGAPORE

4.1 Pasir Panjang Wholesale Markets

4.1.1 Market Tour

Dr. Leow Su Hua, Head of Foreign Farms & Plant Accreditation Section, Primary Productions Department
Tan Kai Teck, Tan Sng Kee Vegetable Suppliers

- Pasir Panjang Wholesale Markets sells the produce using an auction system. Auctions start at 9 o'clock in the morning and 3 o'clock in the afternoon. Produce is displayed on the floor and is quickly sold and cleared away, ready for the afternoon trading.
- We mainly saw local produce being unloaded from trucks such as leafy mustard. Very few Australian cauliflowers were seen.
- Tan Kai Teck of Vegetable Suppliers, showed us Western Australian cauliflowers and cauliflowers from California.
- The WA cauliflowers were packed on 15 November and stored in Tan's small coolroom for about a week. The product was of good quality, better than the quality viewed in Kuala Lumpur.
- The Californian cauliflowers were packed in a single layer carton and were wrapped in Modified Atmosphere Packaging (MAP) perforated plastic wrap. The journey from the US takes approximately three weeks. Tan had stored the Californian cauliflowers for one week. The quality of these cauliflowers was very good, considering the time they had been stored. Tan said the cauliflowers were too small for the market (They measured approximately 15 cm in diameter).
- Tan's coolroom was running at 4 - 5°C.

4.1.2 Singapore Fruits & Vegetables Importers & Exporters Association

Tang Se Oh, Wee Heng Hup Kee Pte. Ltd., Vice Chairman
John Lim, Chop Nam Huat (Importers), Association Member
Seet Tai Chai, Total Fresh (Importer/Distributor)
Chew Yoke Fun, Executive Business Facilitation, Enterprise Promotion Centres Pte. Ltd
Philip Khoo, Sales Executive, Pan Commercial (Pte) Ltd. (Importer)

The group met with the Importers & Exporters Association and several points were raised.

- Western Australia's competitors are becoming more prominent in the market, not only in cauliflower but other fresh produce lines. The US are very aggressive in their marketing.

4.1.2 Singapore Fruits & Vegetables Importers & Exporters Association (cont)

- John Lim said Australia is not as export oriented as the US. Australia also has problems with consistency of supply. The US can supply more continuously and with their use of Modified Atmosphere Packaging technology, they are leading the way. However, Australia can produce large volumes of produce and its closeness to the market is a major advantage over the US.
- Another potential competitor is South Africa. They have cheap labour and have developed a good, reliable shipping line.
- One of Australia's major disadvantages is the cost of freight.
- Future markets maybe Indonesia and the Philippines.
- Singapore market is a strict market compared to the Kuala Lumpur market. People in Singapore are more quality conscious and prefer unblemished cauliflowers. With labour costs increasing in Singapore, people cannot afford to pay someone to trim or shave the cauliflowers of black spot.
- Philip Khoo said black spot is not a major problem, however, it does occur occasionally. Black spot occurs during the change of seasons from winter to summer. A four to six week period, when large temperature fluctuations occur, is when cauliflowers tend to blow and become overmature quickly.
- Preferred size of cauliflower is 1 - 1.5 kg, 600 grams is too small.
- The best packaging is still the two piece carton consisting of individually paper wrapped cauliflowers. Eastern States do not have consistent packaging. They tend to change their cartons frequently.
- Although the wet market is still a popular way to buy fresh fruit and vegetables, the size of the wet market is decreasing. Supermarket prices are very competitive. One marketing tactic used by some supermarkets to attract consumers, is the use of loss leader pricing strategy. This is when supermarkets sell cauliflowers at below cost one day and make up the loss in another product line.

4.1.3 Pan Commercial (Pte) Ltd.

Roland Wong, Marketing Manager
Lee Teck Tong, Buyer

- Mr Lee said that the quality in the last six months has been reasonable. However, there is a need for more consistent supply. The major considerations in order of importance are:
    - i) continuity of supply;
    - ii) improved quality, and;
    - iii) the price.
- The market needs cauliflowers that are white, and can store well. Not cauliflowers that are blown (overmature). Improving the product by researching into better varieties, is one way to gain the competitive edge over other countries.
- Sea containers need to be improved as there are freezing problems particularly with the 40 foot containers. There tends to be air flow problems with the 40 foot container, therefore 20 foot containers are preferred.
- Pan Commercial mainly import from Australia and the United States of America.

4.1.3 *Pan Commercial (Pte) Ltd. (cont)*

- 20 - 30% is imported from the US. However, they try to avoid importing from the US as it takes 16 days to arrive in Singapore by sea.
- US cauliflowers do have a good shelf-life with use of Modified Atmosphere Packaging. Australia tends to pack too many cauliflowers in one carton, which reduces the quality of the cauliflowers. Mr Wong believes carton over packing is due to the high freight costs. All space within the sea container must be utilised, even if it means over packing the cartons and reducing quality.
- Consumer trends are heading towards one stop shopping. The Singapore Government will not abolish the wet market, but upgrade it. For example, have the market undercover, air-conditioned and extend the range of goods available by selling other groceries other than fresh produce.

4.2 Retail Outlet

4.2.1 Singapore Daimaru

Mr David Kong, Fresh Produce Buyer

- Daimaru is a large Japanese supermarket chain aiming towards the higher income consumers.
- Cauliflowers were sighted but in very few quantities, only four pieces of cauliflower were for sale at the time of the visit.
- The cauliflowers were plastic wrapped and labelled 'Cauliflower (Australia)'. All cauliflower pieces were trimmed of black spot and blemishes.
- The weight of the pieces ranged from 355 grams to 420 grams.
- Price S $5.50/kg = AUS $4.90/kg (approx)

5. CONCLUSION

The main messages that came out of the study tour were:

- The potential for promoting Western Australian cauliflowers, particularly in the Kuala Lumpur markets.
- The need for consistency of supply from Western Australia.
- The poor out-turns of cauliflowers shipped by sea freight, importers preferred air freight.
- The different forms of packaging and carton size.
- The mediocre quality of cauliflowers sighted at the wet markets.
- The increasing presence of our competitors, such as the Eastern States of Australia, the United States of America and China.
- All importers and supermarket buyers said they preferred Australian cauliflower because of its superior quality compared to cauliflowers from other countries.

Austrade believed that anything can be sold on the Malaysia market, but has to be a cut above the rest and gain market share. Promotion of the product is the answer, promotion being in the form brand development. However, Survey Research Malaysia warned that branding can

5. CONCLUSION (CONT)

have a negative effect, particularly if quality is not consistent. Carefully planned promotion can be done in conjunction with the supermarkets, hypermarkets and with the assistance from Austrade and the Western Australian Trade Office in Kuala Lumpur.

Both importers, Agroquivir and Pan Commercial, complained about sea freighted cauliflowers freezing in the containers. Both preferred air freighted cauliflower despite the higher prices. Agroquivir customers were willing to pay higher prices for better quality cauliflowers. They also mentioned the inconsistency of supply of Western Australian cauliflowers.

The price of cauliflowers fluctuates in Kuala Lumpur and Singapore. Price also depends on supply, demand and quality. The prices mentioned in the report were observed on the day when we visited the market and therefore can only be used as a guide.

Overall, Western Australian cauliflowers dominate both the Malaysian and Singapore markets. However, our competitors, particularly the United States of America, are becoming more prominent. To maintain Western Australia's current market share, it is imperative that the cauliflower industry keeps up with what the importer, retailer and consumer wants, in terms of product specifications, to suit market requirements.

An end consumer survey to determine market specifications and requirements will be carried out soon, probably in May 1997. We have also planned to carry out a survey on importers and wholesalers in Malaysia later this year.

6. APPENDIX

6.1 Report from Mr Toby Lambert

GROWER'S REPORT - TOBY LAMBERT

1. INTRODUCTION

The comments made in this report are based on my own inclinations according to the discussions we had during our visit to Kuala Lumpur and Singapore. These inclinations may fly in the face of other people's opinions and may be misguided. However, I feel it is important to raise these issues, if nothing else but to promote some healthy discussion which may benefit the industry.

2. FIRST IMPRESSIONS

I expected to see a lot of cauliflowers on the market floors. During our visit cauliflowers seemed to be a secondary item to leafy green vegetables (lettuce, round cabbage, celery, pak choi etc.) carrots and broccoli. Some market places only had about one carton of cauliflowers on display. This led me to believe that the average household does not consume much cauliflower. The quality was generally poor with a few exceptions. Most had been trimmed or shaved to remove marks. First impressions of quality were not good.

After going to importers and wholesaler markets my spirits rose as the quality seemed a lot better. So it appears that the produce was probably arriving in good condition but breaking down as it went towards the consumer. There are obviously a lot of problems in keeping the produce cool.

3. COOL CHAIN

Cool rooms appear to be few and far between. What cool rooms are available are used to store everything, (fruit and vegetables of all sorts) usually at temperatures not ideal for cauliflower (1°C) most were 4-5°C. One of the major importers we saw had 5-6 containers still on the semi-trailers parked in the carpark with extension cords running to the cooling units. Once the cauliflowers leave the importer there is little chance of them being kept cool for any length of time. If the cauliflower goes to the wet market it will be hot and humid all day. If it goes to the supermarket or hypermarket it will be in air-conditioning at least but this will dry the cauliflower out more. Even the fridges at the households are quite small (bar fridge size) which limits the amount of perishables that can be bought (ie. small cauliflower or halves are preferred). The cool chain problems in Kuala Lumpur are a problem for us because the product eventually looks bad which reflects on us rather than handling problems over there. If the quality is bad people will stop buying whether the problem is generated locally or in the country of origin.

4. MARKETS

4.1 Wet Markets

These struck me as the worst way to sell a cauliflower. The cauliflowers are brought out into the heat and humidity and put on a bench to sell. It may sit there for a few hours quietly dehydrating. However, every other piece of produce is treated the same way including meat and fish. To our thinking this wouldn't be healthy but it is the most popular place to shop in Malaysia. Shopping at the wet market is a tradition and is seen as the freshest way to get your food. It is not possible for us to change tradition to improve the shelf appearance of our cauliflowers. The Malaysian government intends to phase the wet markets out over the next few years but most people think it will take a very long time. There are areas being developed for an improved style of wet market which is a positive step.

4.2 Supermarkets

The supermarkets cater for people who have a bit more money to spend. The presentation of the produce on the shelves was very good. Some cauliflowers were still dehydrated and marked but mostly better here than the wet markets. There didn't seem to be a lot of people moving through the vegetable shop compared to the wet markets where it was wall to wall people.

4.3 Hypermarkets

The hypermarkets are a larger style of supermarket where the emphasis is on moving large quantities of goods at reduced prices. The idea is to encourage people to shop once a week and maybe bulk buy for other families as well. This is in contrast to the wet markets where household food shopping is done daily. This sort of shopping is becoming more popular because of the traffic problems in Kuala Lumpur. It can take hours to travel quite short distances.

The market in Kuala Lumpur is price driven. The marketers we spoke to wanted plenty of cauliflowers but cheap. They say the market responds better to price lowering than to better quality. They probably also say what they want us to hear. However, the Singapore market appears to demand quality, it is also a more affluent market so Kuala Lumpur will probably respond to quality better as it develops further, it is developing fast.

5. MARKET CONCLUSIONS

If people have small fridges they don't want to limit their space by buying a large cauliflower, which means a lot of people buy a piece of cauliflower. Therefore, the sellers, particularly of the supermarket and hypermarkets, want small cauliflowers. They don't want to pay someone to break up the cauliflowers, they just want to buy a product and take it to the shelf to resell. This is alright for them but at this stage it is not economical for us to supply a 500 gram or smaller curd.

Maybe we should look more carefully at this to see if closer spacings and smaller varieties could be economical. I think our product could be better presented in the market place. The problems that stood out to me were uneven size and poor trimming of the stalk. Uneven size is difficult to address but I think with a bit more effort in the paddock and packing shed the range of sizes would be reduced. Badly trimmed cauliflowers are unsightly so maybe we need to train our pickers more intensely and move poor pickers on quicker. However, most farmers would appreciate the difficulties faced with limited labour supply, sometimes a poor cutter is all you can get.

6. MARKET EXPANSION (RETENTION?)

To maintain our market we will need to work harder than we have in the past as we have competitors on the market floor. China, South Africa and the United States of America, have the capacity to make things very difficult for us. At this stage we have the upper hand with our quality and supply but we must not let others in. The growers need to continue looking for white, solid varieties throughout the year. This may mean timeslotting more varieties throughout the year but the result would be beneficial.

As mentioned before, the quantity of cauliflower consumed appears small in relation to other vegetables. A lot could be gained by simply raising the profile of cauliflower. I think we should look at why the profile isn't as high as it could be. It might be a matter of showing people different ways of using cauliflower so they are more likely to use them regularly rather than occasionally. From our discussions with Austrade and the Western Australian Trade Office, promotion was the key to maintaining and expanding our markets. We need to be careful to promote our product alone, we don't need to promote cauliflowers for our competitors. To this end there will need to be some way of identifying our product as Western Australian. Having done that we also need to let the market know where Western Australia is, so that consumers can associate quality with the right part of the world. Most people seemed to have little idea of which side of Australia Perth is on.

Both trade offices pushed promotion as the answer to maintaining our industry. We need to promote in any way we can and continue that promotion.
Suggested promotional ideas were:

- Arrange buyer visits, show the clean environment the cauliflowers come from.
- Make people aware of the different ways to serve cauliflower. Eating in this country is a social event, give them ideas on how to incorporate this vegetable into their diet.
- Promote in restaurant chains.
- Identify growth areas and promote there.
- Supermarkets and hypermarkets are growth areas.
- The population is becoming more health conscience. Promote our clean environment and healthy product.

The market will be loyal to a good brand particularly as the market becomes more quality conscious. We need to let them know that ours is a brand worth buying.

To carry on the industry will need to put a lot of effort in soon or we may be left behind. The pressure will always be on us to keep the price down as with any other industry. We will need to work hard to maintain our margins but remain competitive at the market place.

7. FINAL CONCLUSION

We need to approach all facets of our industry in a more professional manner and show that we really want the industry so that the market doesn't look too closely at our competitors.

1997

AUSTRALASIAN

POSTHARVEST HORTICULTURE

CONFERENCE REPORT

"Globalisation; the challenge to home and export markets"

28 September - 3 October 1997

University of Western Sydney Hawkesbury, NSW

Vynka McVeigh
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Agriculture WA, Manjimup

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I wish to acknowledge the Horticultural Research and Development Corporation (HRDC) and Agriculture WA for their financial support in allowing me to attend the 1997 Australasian Postharvest Horticulture Conference.

Vynka McVeigh
Agriculture WA

13 October 1997

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1. EXECUTIVE SUMMARY

The Australasian Postharvest Horticulture Conference 1997, held from 28 September to 3 October, is a leading conference for the evaluation and dissemination of postharvest research. It allowed postharvest researchers and related industry personnel, both nationally and internationally, to view and discuss the latest research in postharvest technology. This year's conference was held at the University of Western Sydney, Hawkesbury campus in Richmond. The conference is held every two years.

The main theme of the conference was "Globalisation; the challenge to home and export markets". The first day of the conference overviewed marketing expectations and the role of national organisations in Australia. Meeting market expectations and market access into export markets was also discussed.

Other subjects discussed throughout the five days of the conference included genetic engineering for improvement, translating technology into action, measurement and management of quality, control of postharvest diseases, arresting senescence, the use of fresh cut or minimally processed foods and postharvest floriculture.

A poster session dealt with presenting the latest postharvest research in poster form. This allowed an opportunity for delegates to discuss and ask questions directly to the researcher that was involved in the research. A poster was displayed representing the Export Cauliflower Quality Improvement Project. The subject of the poster was the work conducted on the seasonal effects on bruising of cauliflower. This generated many questions from researchers in similar fields.

An Industry Day allowed researchers and other industry members to view the latest technology in measuring equipment. A private consultant displayed the new postharvest database now available. Other companies such as Harvest Fresh Cuts displayed their packaged salads. The industry display was disappointing in terms of the small number of companies represented, however the main aim of the conference was to bring researchers, advisors and international keynote speakers to present the latest research into postharvest technology.

The establishment of valuable contacts with world leaders in postharvest technology such as Dr. Marita Cantwell from the University of California, has prompted discussions of combined future research, that will benefit both the Western Australian cauliflower industry and California's cauliflower industry. This is an excellent opportunity for Western Australia's cauliflower industry to tap into the harvesting and handling practices of Californian cauliflower growers.

2. CONFERENCE CONTENT

The majority of speakers focused more on postharvest research of fruit and less on vegetables. Some information presented at the conference was very specific and related to research done on fruit such as avocado and kiwifruit, which is obviously not directly relevant to the work done on the Export Cauliflower Improvement project. However, the first day of the conference focused on market issues which could be related to the project. Other sessions included overseas competition and opportunities, translating technology into action, stopping postharvest rots and arresting senescence.

The conference was opened by Mr. Ian Cornell, Chief General Manager of Woolworths Supermarkets. He gave a retailer's view of postharvest in marketing. Mr. Cornell mentioned that the current retail environment has become difficult with price inflation. The percentage of disposable income spent on fruit and vegetables has dropped and more is spent in other areas such as entertainment. He also mentioned the need to change the operation of their supermarkets with longer operating hours (open seven days a week), convenience of EFTPOS and the increase in the range of fresh fruit and vegetables to keep up with the demand for diversity. Technology will play a greater role at Woolworths to keep the produce fresh for the longest possible period. As consumers are more educated about quality, Woolworths has introduced Hazard Analysis Critical Control Point (HACCP) to all products.

Mr. John Baker, Managing Director of the Australian Horticultural Corporation (AHC) talked about the contribution that the AHC has made to industry such as providing market and competitor information, industry missions, building trade and retail relationships in Asia and innovative marketing programs. One market trend has been increasing growth in Asia with market access and development improving in Indonesia, Japan, Thailand and Taiwan. AHC has added value to the industry through promotion. The "Australia Fresh" brand marketing program has been developed to increase Asian consumer preference for Australian products. A similar brand promotion could be done with cauliflowers to increase the awareness and preference for Western Australian cauliflower.

Mr. Scott Ledger of Queensland Department of Primary Industries presented 'Meeting Customer Expectations: Bringing People and Technology Together'. Mr. Ledger said there should be more customer focus to improve meeting customer expectations. The limiting factor in meeting customer expectations is the knowledge, attitudes, skills and aspirations of the people involved in the myriad of marketing networks from grower to retailer. To improve performance and adopt technology in any industry, people must be motivated to "want to" use the technology, know "how to" use it and have the "means to" implement it, (Australasian Postharvest Horticulture Conference 1997 Program). This is where the role of an external agent such as state agriculture agencies assist in technology transfer and adoption through problem solving and education. Business managers with a customer focus should search for improved technology and invest in improving knowledge and skills. This will result in customer satisfaction, resulting in greater customer satisfaction.

Mr. Denis Gastin of Instate Pty. Ltd. talked about some of the principles involved with success in Asia. Mr. Gastin believed that Australia is slow to adopt new innovation. Other important issues that were raised were the continuity of supply, product specifications to provide customers with exactly what they want and overseas representation to know precisely how the market works. To achieve success in Asia constant supply, high quality produce and the most competitive price should be considered in conjunction with how the market operates, understanding of the culture and how to communicate with buyers. These factors would be best addressed by in-market support and representation.

The issue of technology transfer and adoption was also addressed at the conference. Mr. Tony Biggs, editor of Good Fruit and Vegetables and private consultant, mentioned the need for more technology transfer. Funding bodies such as the Horticultural Research and Development Corporation require more effective technology transfer. The publication of technology is relatively easy to measure in terms of the numbers of reports written and the number of field days held. It is technology adoption which is difficult to measure and researchers and extension personnel should focus on effective ways to improve technology adoption. It is important to know the constraints of technology adoption such as economics, the practicality and logistics of adoption compared with current practices.

Mr. Neil Delroy of Agribusiness Research and Management argued the Australian horticulture industry has not kept pace with its major international competitors in a dynamic and globally competitive environment. Lack of understanding of the changing global business environment, a poor appreciation and support of our research development facilities and ineffective transfer and adoption of technology are reasons why Australia has not kept up with international competitors. Mr. Delroy believes that university courses with a strong business focus built on a scientific background must form the platform from which improvements in technology adoption are to be made (Australasian Postharvest Horticulture Conference 1997 Program).

Ms. Jenny Margetts from IAMA Ltd. explained that IAMA have other interests apart from the selling of rural merchandise and realise the importance of technology adoption. Ms Margetts stated that corporate businesses and larger growers adopt technology earlier than smaller growers as they see the need and importance to kept up with competitors. She also mentioned that growers learn from other growers.

This point of view is shared by Mr. Craig Feutrill, the national coordinator for Cittgroup (a group of Australian citrus growers). He believed the key to technology adoption is to conduct 'on-farm' trials. Cittgroup initiates trials to be conducted on grower's properties, allowing growers to see for themselves if a particular treatment being tested works well on their property. This provides a better method for technology adoption.

3. POSTER PRESENTATION

All delegates of the conference were invited to either present a paper or a poster of research conducted in their field of work. As a representative of Agriculture Western Australia and working on the Export Cauliflower Improvement project, I presented a poster on the Seasonal Effects on Bruising of Cauliflower. An abstract of the trial was submitted for publication in the conference program (Appendix 1).

Sixty eight delegates presented posters some of which were relevant to the Export Cauliflower project. Bruce Tomkins from the Institute for Horticultural Development, Knoxfield presented 'Controlled atmosphere storage of broccoli florets'. The aim of this study was to determine the influence of four different controlled atmospheres on broccoli florets packed in modified atmosphere packaging (MAP). It was found that an atmosphere of 10% carbon dioxide and 10% oxygen gave a significant improvement in the quality of broccoli florets. Microperforated films can be designed to create this atmosphere.

Ms. Beverley Butler from University of Technology, Sydney, presented a poster on 'Relating programmed cell death to the end of shelf life'. This work investigated a new method of quantitatively measuring the shelf life of broccoli over a 7 day period. A group of enzymes called protease in senescent plant cells was detected which was initially present at low levels, then increased significantly as the broccoli head matured. Investigations were carried out to see if this test could be used as an indicator of senescence and therefore loss of shelf life (Australasian

Postharvest Horticulture Conference 1997 Program).

A poster that was particularly relevant to the project was 'Suitability of thin-film probes for measuring air relative humidity'. Vicki Eggleston from CSIRO compared the suitability of six commercial probes for measuring relative humidity in horticultural situations. These included Tinytag relative humidity data loggers which have been used in many project trials with unsatisfactory results. The data loggers have been recording over 100% relative humidity when put in a coolroom, although with a calibration technique provided by Ms Eggleston, more accurate relative humidity readings can be recorded.

Each paper and poster presentation will be written in full and published in the Conference Proceedings which will be available in December 1997.

4. INDUSTRY DAY

The Industry Day was an opportunity for industry personnel to display their products relating to postharvest research. The number of industry displays was small and although this was disappointing, some displays were highly relevant to the export cauliflower project. CTS Thermfresh had a display promoting their high humidity coolrooms. The Thermfresh coolroom at the Manjimup Horticultural Research Centre is used often in the project. Hastings Data Loggers were displaying data loggers used for various measurements such as temperature, humidity and the shock logger for transport and handling. Information on data logger maintenance and calibration was obtained from this display. The project uses four temperature and four relative humidity data loggers.

Stephen Morris from the Sydney Postharvest Lab displayed a database on the postharvest storage of various products. Mr. Morris has his own independent horticultural consultant business which consults on various projects such as advice regarding cargo loss, developing export systems, packaging, and refrigerated container design and analysis.

Mick Stevens of Harvest Freshcuts Pty. Ltd. also displayed some of the packaging products they have on the market. Their popular pack was the salad pack which is now a common fresh cut product in large supermarkets.

5. RESEARCH CONTACTS

Dr. Marita Cantwell, Postharvest Extension Specialist from the University of California, Davis, has extensive knowledge of postharvest handling of vegetable crops and is involved each year in the organisation of an internationally renowned postharvest short course. Currently she is working on the physiological responses of fresh cut produce, particularly lettuce. Dr. Cantwell knew of other staff from the Department of Vegetable Crops, Mann Laboratory at the University, that are currently working on a project relating to the transport of cauliflower.

After visiting the Flemington Markets in Sydney, Dr. Cantwell was surprised that Western Australian cauliflowers were exported in 15-20 kg cartons. The cauliflower cartons seen at the markets were smaller than the export carton used by Manjimup packing sheds. They were also waxed coated, with attractive colour picture of cauliflower on the outside of the box. The cauliflowers were not trimmed of leaves as they were for local market. Dr. Cantwell explained that California growers use mobile packing houses in the field to harvest, trim, wrap and pack the curds straight into single layer cartons. The cartons are then stacked on the mobile platform to await delivery by truck to a coolroom. The stacked cartons are on the platform no longer than an hour before they are stored in a coolroom.

Dr. Cantwell said that cauliflower has a relatively long shelf life compared to other horticultural produce. The research conducted on cauliflower in California has shown the key to long shelf life is in the handling and packaging which determines the amount of bruising sustained on curds. She was surprised by the results of the seasonal effects on bruising trial, conducted in Manjimup, stating that the level of maturity affects the amount and severity of bruising. Dr. Cantwell believes that there are three important factors that influence bruising in cauliflower:

i) the presence of *Erwinia*, soft rot bacteria present in the soil and on plant surfaces (McMaugh, 1993);
ii) handling temperature; and
iii) water content of the cauliflower.

Dr. Cantwell was interested in the opportunity to conduct future research in the postharvest handling of cauliflower to mutually benefit the WA and California cauliflower industry. I asked her about the chance of a group of growers visiting California to examine the Californian growing system. Dr. Cantwell did not think it would be worth while to bring a group of WA growers to California for this purpose. She did recommend that an Agriculture WA staff member to visit the University of California to view the current research done on cauliflowers. Dr. Cantwell suggested that joint research between Agriculture WA and the University be conducted to produce a growers 'best practice' manual from field to export market.

Agricultural agencies from Australian states were represented at the conference including Agriculture Victoria, NSW Agriculture, Agriculture WA, South Australian Research and Development Institute (SARDI) and the Queensland Department of Primary Industries. An informal meeting was held by Chris Hubbert from the Institute for Horticultural Development, Agriculture Victoria. The objective of the meeting was to discuss postharvest aspects of export vegetables.

Mr. John Faragher from Agriculture Victoria, mentioned the Victorian Government export incentive program known as Exphort 2000 *(pronounced 'Export')*. Mr. Faragher is developing export of cut flowers and mentioned a distribution centre at Melbourne airport for more efficient export of cut flowers by air freight. Mr. Scott Ledger from NSW Agriculture said his state has no initiatives and funding for export initiatives would come from external bodies such as HRDC. QDPI is managing a Horticulture Development Program worth $3 million dollars over three years and focused on new crops for export. QDPI is also developing a manual to encourage the efficient export of produce. A similar manual for the grower, packer, exporter and importer which can be applied to any product and the development of a market is being examined by QDPI.

Other national programs include Supermarket to Asia, Asian Market Bridge and Food for Asia. Food for Asia is a $10 million program from the CSIRO which assists companies to improve technology allowing greater access into export markets.

The various National and State export development initiatives, will provide more competition to WA in export markets as more companies and growers invest in these initiatives. The WA cauliflower industry should be aware of growing competition and provide a product to its markets which has been handled correctly before, during and after harvest. This will ensure that the quality of product exported will remain high.

APPENDIX 1

Abstract for Poster Paper

Seasonal Effects on Bruising in Cauliflower

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Curd blackening is a quality problem facing Western Australia's export cauliflower industry. Critical factors contributing to curd blackening at out-turn include bruising and dehydration. This study investigates the seasonal effects on bruising to determine, initially, the maturity stage at which cauliflowers are most susceptible to bruising and to determine the severity of bruising sustained on cauliflower harvested from different seasonal crops. Cauliflowers harvested during spring, summer, autumn and winter, were divided into four maturity stages according to the number of days before and after grower determined maturity. Due to practical limitations, whole cauliflower curds were cut into florets. The florets were bruised, using a standardised technique, and stored in warm store for 6 days at 20-22°C with 80 - 85% relative humidity. Quality assessment ratings, such as turgidity, severity of rots/blemishes and severity of black spot, were recorded for each floret after 4 and 6 days warm store. Predominately, florets from maturity stage 4 (two days after grower determined maturity) showed more susceptibility to bruising, i.e. greater severity of rots/blemishes. Significant differences were also found in the severity of rots/blemishes of cauliflower florets harvested in Autumn (April/May). To have cauliflowers arriving at South East Asian markets in excellent export quality, it is important that growers harvest cauliflowers at the correct maturity stage and minimise bruising to allow for optimal shelf life.

REFERENCES

- School of Horticulture (Ed) Australian Postharvest Horticulture Conference 1997 Program, University of Western Sydney Hawkesbury, NSW.

- McMaugh, J. (1993) What Garden Pest or Disease is That? Lansdowne, Sydney, NSW.

Seasonal Effects on Bruising of Cauliflower

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Summary

Curd blackening is a quality problem facing Western Australia's export cauliflower industry. Critical factors contributing to curd blackening at outturn include bruising and dehydration. This study investigates the seasonal effects on bruising to determine the maturity stage at which cauliflowers are most susceptible to bruising and to determine the severity of bruising sustained on cauliflower harvested from different seasonal crops. Cauliflowers harvested during spring, summer, autumn and winter, were divided into four maturity stages according to the number of days before and after grower determined maturity. Due to practical limitations, whole cauliflower curds were cut into florets. The florets were bruised, using a standardised technique, and stored in warm store for 6 days at 20-22°C with 80 - 85% relative humidity. Quality assessment ratings, such as turgidity, severity of rots/blemishes and severity of black spot, were recorded for each floret after 4 and 6 days warm store. Predominately, florets from maturity stage 4 (two days after grower determined maturity) showed more susceptibility to bruising, i.e. greater severity of rots/blemishes. Significant differences were also found in the severity of rots/blemishes of cauliflower florets harvested in Autumn (April/May). To have cauliflowers arriving at South East Asian markets in excellent export quality, it is important that growers harvest cauliflowers at the correct maturity stage and minimise bruising to allow for optimal shelf life.

Introduction

Ninety percent of Australia's export cauliflowers are grown Western Australia (B. Trhulj, unpublished data). Seventy percent of that is grown and packed in the Manjimup district of Western Australia. For the cauliflower industry to maintain existing markets and expand into new ones, a year round supply of high quality cauliflowers is essential.
Losses from transplanting to export shipment accounts for about 36% . Most of these losses were caused by harvest maturity factors which are within the control of the grower (Shellabear 1994). Curd blackening is a quality problem facing Western Australia's $22 million export cauliflower industry. Bruising and dehydration are the causes of curd blackening at outturn. Bruising can be minimised through improved management techniques implemented by the grower. This study, initiated by Agriculture Western Australia, investigates the effects of bruising on cauliflower harvested at various maturity stages during all four seasons.

Materials and methods

Cauliflowers (variety *Plana*) were harvested over a two week period at different maturity stages from November 1996 to August 1997. The cauliflowers were obtained from a grower's property in the Manjimup district of Western Australia. The cauliflowers were categorised into four maturity stages (maturity stage 1, immature curds; maturity stage 4, overmature curds).

After the cauliflowers were harvested and leaves removed, ten florets were cut off each curd. Five florets were bruised using a standardised bruising technique. The remaining five florets were not bruised (control). The florets were placed in export cartons and stored in warm store for six days (20 - 22°C, 80 - 85% RH). The florets were assessed after the fourth and sixth day of warm store. The quality criteria were turgidity (1, very turgid; 5, very soft), severity of rots/blemishes (1, none; 5, very severe), severity of black spot (1, none; 5, very severe) and percentage surface area affected by rots and spots (1, 0%; 5, 20% and over). Weight loss for each floret was also recorded.

Statistical analysis

Statistical analysis of treatments was by ANOVA with differences between means compared by l.s.d.

Results

Spring harvest trial

After four days warm store, maturity stage three of the bruised florets significantly (P>0.05) showed the highest severity of rots/blemishes (slight to moderate). Maturity stage 4 of the bruised florets significantly (P>0.05) showed the worst rating of moderate to severe for rots/blemishes after six days warm store.

Summer harvest trial

After four days warm store, maturity stage four of the bruised florets significantly (P>0.05) had the greatest severity of rots and blemishes with a rating of 2.50 (slight to moderate). Both maturity stage three and four of the bruised florets showed the highest severity of black spot (moderate to severe) after six days warm store.

Table 1. Quality assessment scores of florets after 4 and 6 days warm store (autumn harvest)

Quality parameters are scaled 1-5

Treatment	Turgor	Severity rots/ blemishes	Severity black spot	% Rots/ black spot
		Four days at 20 - 22 °C		
BRUISED				
Maturity Stage 1	2.0	2.7	3.1	2.8
2	2.3	2.8	2.9	2.6
3	2.5	3.7	3.1	2.8
4	3.3	4.9	3.8	3.8
NOT BRUISED				
Maturity Stage 1	1.8	1.1	2.9	2.4
2	1.9	1.4	2.5	2.1
3	2.1	1.8	2.3	2.2
4	2.4	3.2	3.5	3.0
l.s.d (P > 0.05)	0.2	0.4	0.3	0.3
		Six days at 20 - 22 °C		
BRUISED				
Maturity Stage 1	2.5	2.9	3.2	2.8
2	2.5	3.4	3.7	3.1
3	3.0	4.4	3.8	3.8
4	4.4	4.9	4.7	4.6
NOT BRUISED				
Maturity Stage 1	2.2	1.2	2.9	2.5
2	2.1	1.9	3.2	2.6
3	2.5	2.3	3.3	2.7
4	3.5	4.2	4.3	4.0
l.s.d (P > 0.05)	0.3	0.5	0.3	0.3

Autumn harvest trial

Maturity stage four of the bruised florets significantly (P>0.05) had a very severe rating of rots/blemishes (4.9, Table 1) and the highest severity of black spot (3.8) after four days warm store. After six days warm store, maturity stage four of the bruised florets showed the highest severity of rots/blemishes and black spot, 4.9 and 4.6 respectively (Table 1).

Winter harvest trial

Maturity stage three of the bruised florets had a slight to moderate rating for the severity of black spot after four days warm store. Maturity stage three of the bruised florets significantly (P>0.05) showed severe to very severe rating of rots/blemishes after 6 days warm store.
The autumn harvest trial significantly (P>0.05) showed the worst ratings of rots and blemishes after four and six days warm store, in comparison to all the other seasons.

Discussion

Overall, it was found florets from maturity stage four (two days after grower determined maturity) are most susceptible to bruising, in that they predominately recorded the greatest severity of rots/blemishes and black spot after warm store conditions. The incidence of black spot was more noticeable during the summer and autumn trials. Black spot is caused by dehydration. Blackened areas on the curd are usually preceded by pitting (Shellabear 1994). It appeared that rots occur as a secondary infection after black spotting.

The autumn period (April/May) was when the greatest severity of rots and blemishes occurred. It is known that *Plana* and other varieties have quality problems during April/May. It is not known why the incidence of rots occur more this time of year. Ongoing studies will be investigating the effectiveness of chlorine added to cooled water, when cauliflowers are hydrocooled. Chlorination of cauliflower curds showed a reduction in the amount and severity of postharvest rots and black spot (B. Vermey, unpublished data).

To reduce the losses which occur from harvest maturity factors, growers should harvest cauliflowers earlier and not leave them in the field. Earlier harvesting would result in higher quality cauliflowers (not overmature) less bruising and higher packout returns for the growers. Above all, maintaining Western Australia's excellent reputation for supplying SE Asian markets with cauliflowers in optimum export condition.

References

Shellabear, M. 1994, Export Cauliflower Improvement Project 1993 & 1994, Western Australian Department of Agriculture and Horticultural Research and Development Corporation, p 2.

Vasse - A New Oat for Hay

Kerry Hawley

Vasse was bred by Plant Breeder with Agriculture Western Australia, Robyn McLean. It was registered in 1997 and is protected by Plant Breeding Rights.

Plant Characteristics

It is an extremely late maturing oat, compared with other Western Australian varieties, maturing up to two weeks later than Mortlock and a week later than Dalyup.

Although containing the same semi dwarf gene as Dalyup, in good conditions it will grow much taller. It has finer and weaker straw than that usually associated with semi-dwarf varieties.

Yield

Vasse is expected to fill a niche for hay in the very high rainfall areas in the South West, where its very late maturity will be an advantage.

Hay yield of Vasse at Mount Barker Research Station - kg/ha

	1993	1994
Vasse	17883	14983
Esk	14690	13878
Hay	12973	11530
Kalgan	11543	11563
Mortlock	7908	9043
Swan	10815	10070
Winjardie	10133	12058

Grain yield is considerably lower than that of alternative semi-dwarf varieties, such as Dalyup, but animal feed quality is higher because of improved groat (dehulled grain) percent.

Quality

In a trial at Vasse Research Station in 1994, Vasse showed superior quality to Swan, another variety commonly sown for hay.

	Yield (kg/ha)	Digestible Dry Matter %	Metabolizable Energy MJ/kg	Crude Protein %
Vasse	13048	69.4	9.9	7.2
Swan	14781	63.3	8.9	5.8

Disease Resistance

Vasse has good crown rust and septoria resistance and has shown outstanding resistance to barley yellow dwarf virus. These are important attributes in disease-prone high rainfall districts.

Seed availability

A small quantity of seed has been available from Paramount Seeds in Esperance for $12 per 40 kg bag. If you want to test the variety, you will have to be quick. If you miss out this year, remember it is worth trying for next season.

Paramount Seeds can be contacted on (08) 9071 1053.

CAULIFLOWER INDUSTRY UPDATE

CAULIFLOWER IMPROVEMENT GROUP MEETING

Vynka McVeigh, Research Officer (Vegetables)

The Cauliflower Improvement Group meeting held on the 18th February 1998 covered two important issues facing the cauliflower industry.

• Local Cauliflower Levy

Chairman Toby Lambert asked the meeting to consider the future of the local cauliflower levy. All cauliflower growers currently pay the compulsory national AUSVEG levy. As this levy is in place, growers questioned whether the local levy should be reduced or completely removed.

The growers who attended the meeting voted that the local levy be reduced to 5 cents per carton effective from the 1st March 1998.

• Malaysian Consumer Survey

Dennis Phillips of Agriculture WA presented the findings of the consumer survey conducted in Malaysia late last year. The aim of the survey was to determine who was buying Australian cauliflowers, how consumers prefer to buy the cauliflowers and if Malaysian consumers can recognise where the cauliflowers they buy are produced.

Of the total number of consumers surveyed, 98% had bought fresh cauliflower and only 31% bought frozen. Consumer profiles indicated that 41% were 45 years or older. Women are the main food buyers in the family and 94% of women over 40 years old shop at the wet market. Consumers use cauliflower in stir fry with other vegetables (87%), or with meat or seafood (78%).

Each person questioned was shown a set of photographs of cauliflowers at different levels of quality (ie. colour, maturity, blemishes). The majority of consumers are not willing to buy cauliflower with black spots, blemishes or dirt even if the product was discounted. Therefore there is a need to keep bruising to a minimum and improve handling, which is being investigated in the *Export Cauliflower Quality Improvement* project. The photographs also showed cauliflower packaged and presented in different forms. Sixty three percent of consumers are more likely to buy whole or halved, unwrapped cauliflowers without a logo. However, if the cauliflower were packaged, transparent plastic with logo is preferred to paper (29% vs 22%). When the origin and brands of cauliflowers were considered, 48% were not sure from what country the cauliflower they bought came from. Product brands were not recognised by 99% of consumers.

Consumers 29 years or younger shop at night markets (50%) or supermarkets (40%). The night market is popular with the busy working consumers. Those who shop at supermarkets are in the higher income bracket. The survey suggests that there is a need to attract younger consumers to buy cauliflowers especially those who shop at supermarkets. Promotion of Australian cauliflowers in Malaysia should be directed towards the younger consumers who shop at supermarkets.

A copy of the survey is available at the Manjimup District Office. If anyone would like to read it contact Vynka McVeigh on (08) 9771 1299.

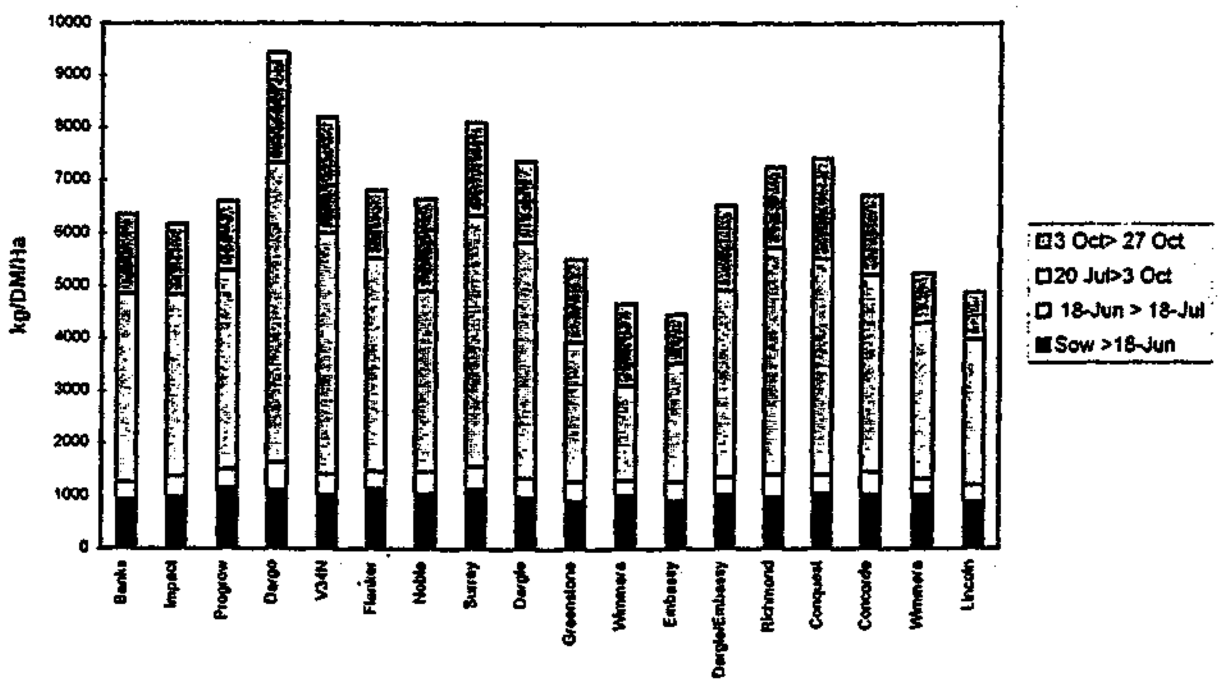
Which Ryegrass Variety?

John Lucey

A great example of how producers can benefit from forming an alliance with private industry, is the results from last year's Ryegrass Variety trial sponsored by Don Lyster & Co. (Wesfarmers) on Lindsay and Maureen Carroll's dairy property.

As a dairyfarmer Lindsay was keen to evaluate some of the new ryegrass varieties and when approached by Grant Johnson from Wesfarmers he jumped at the opportunity to provide a trial site. With technical assistance supplied by Ian Guthridge of Agriculture WA, the results clearly demonstrate the benefits of the new late maturing ryegrass varieties in our long growing season compared to Wimmera.

Wesfarmers Pasture Variety Trial -Cumulative Ryegrass Variety Yields



The trial was sown on 7 April, at 25 kg/ha seeding rate (significantly higher than the commercial recommended rate of 10 kg/ha for ryegrass) and topdressed with 50 kg/ha urea on 8 July.

Dargo is an Italian ryegrass that features good establishment vigour, strong Winter growth and high forage yield. Like all of the new ryegrass varieties, Dargo responds well to nitrogen and controlled grazing will provide the best results and allow the crop to realise its full potential.

Export Cauliflower Quality Improvement
Bin liners affect precooling time

Vynka McVeigh, Vegetable Research Officer

From the latest trial, precooling method effects on shelf life (part 2), plastic bin liners considerably increase the amount of precooling time required to achieve a core temperature of 5°C in cauliflowers.

The trial examined the effects of bin treatments on core temperature, weight loss and shelf life. The treatments were:

i) Bin 1 - loose bin, control (no liners or bubble wrap)
ii) Bin 2 - bubble wrap sheets between the layers of cauliflowers
iii) Bin 3 - plastic bubble wrap bin liner
iv) Bin 4 - plastic bin liner and bubble wrap sheets

Four bins of cauliflowers were picked and 30 cauliflowers in the middle of each bin were weighed, core temperature taken and quality ratings recorded. The bins were then put into the Thermfresh coolroom at MHRC for precooling (about 23 hours). Once taken out of the coolroom, the cauliflowers were measured again, then subject to warm store conditions (22-25°C, 85% humidity) for 6 days.

Table 1 shows the bin treatments from each replication and the number of hours required to achieve a core temperature of 5°C and 2°C.

Table 1: No. of hours required to obtain a core temperature of 5C and 2C in cauliflower during precooling stage

Treatment	5C	2C
REP 1 - 8/12/97 ambient temp. 27C		
BIN 1 - loose (control)	4 hrs	11 hrs
BIN 2 - bubble wrap sheets	6.5 hrs	11.5 hrs
BIN 3 - bin liner	16 hrs	~
BIN 4 - bin liner & bubble wrap sheets	lowest 6C	~
REP 2 - 10/12/97 ambient temp. 32C		
BIN 1 - loose (control)	8 hrs	13 hrs
BIN 2 - bubble wrap sheets	11 hrs	15 hrs
BIN 3 - bin liner	14 hrs	~
BIN 4 - bin liner & bubble wrap sheets	15.5 hrs	~
REP 3 - 12/12/97 ambient temp. 26C		
BIN 1 - loose (control)	4.5 hrs	7.5 hrs
BIN 2 - bubble wrap sheets	10 hrs	19 hrs
BIN 3 - bin liner	17 hrs	~
BIN 4 - bin liner & bubble wrap sheets	~	~

~ average core temperature of cauliflower in that bin did not reach 5C or 2C

Cauliflowers in bin liners, did not achieve the ideal 2°C core temperature, even though Thermfresh operated at temperatures between 0.2°C and 4°C with 94% relative humidity for 23 hours. On the hottest harvesting day (32°C), it took 15.5 hours for the core temperature of cauliflowers precooled in bins with liners to reach 5°C.

The long 'draw down' time significantly affected weight loss of the cauliflowers. Bins lined with plastic sheeting had the highest percentage weight loss, ranging from 1.43% to 1.53%. Weight loss equated to 12.6g to 13.6g for an average cauliflower weighing 890 grams.

One advantage of bin liners is they slightly reduced the incidence of bruising from cauliflower rubbing on bin sides. Therefore Bins 3 and 4 recorded better quality ratings than Bin 1 (control).

Conclusion:
Bin liners only slightly improve the quality of cauliflowers through less bruising. However, bin liners reduce air flow within the bin. More time is needed to remove field heat and bring the cauliflowers to a suitable core temperature for packing. This results in a weight loss of over 10 grams per cauliflower.

More details of this trial will be provided at the next Export Cauliflower Quality Project Committee meeting on 3rd February 1998, 7:30 PM, Overlander Hotel. New members welcome.

For any queries contact Vynka McVeigh on (8) 9771 1299.

Cauliflower Improvement Group

Vynka McVeigh, Vegetable Research Officer

The last Cauliflower Improvement Group meeting was held on 3 September 1997. The meeting was chaired by Mr. Toby Lambert. The following items were discussed at the meeting:

Phosphorus Research Update
The phosphorus trial looked at the effects of phosphorus rate and placement on yield and harvest maturity in cauliflowers. The results were presented by Rachel Lancaster (refer to article in this issue).

Postharvest Research Update
Vynka McVeigh presented the results of the seasonal effects on bruising trial and the pre-cooling effects on shelf life trial. The main findings of the seasonal effects on bruising was that bruised florets from over mature (two days after grower determined maturity) cauliflowers grown in Autumn (April/May) showed the greatest severity of rots/blemishes after four and six days warm store.

A report is available outlining the method and results of the pre-cooling effects trial completed in June. For a copy of the report, please contact Vynka McVeigh (08) 9771 1299.

Industry Levies and HRDC Update
David East briefly explained how the Australian Vegetable Industry Research and Development plan was developed and the type of projects the vegetable levy money will fund. David emphasised the need for the cauliflower industry to maintain its grower groups and committees. Grower organisations are an important way for industry to communicate their needs to funding bodies

Irrigation Water - Its Availability and Cost in the Future
Dianne Fry was invited to talk to growers about proposed changes to regulations covering the capture and use of irrigation water. Eric Phillips informed the group about a workshop meeting to be held on the 17 September about the issue. Invitations have gone out to interested growers to attend the meeting.

New Chairman for the Export Cauliflower Project Committee
Toby Lambert took nominations for the Chairman of the project committee. Brad Ipsen was unanimously elected as the project committee chairman . The group thanked the former chairman, Norm Eaton, for his excellent efforts during his time with the committee.

The Export Cauliflower Project Committee is keen for new members to attend the next meeting. The purpose of the committee is to set the direction of research done by the export cauliflower project and to provide feedback on progress. The committee currently consists of Brad Ipsen (Chair), Toby Lambert, John Ryan, Eddie Rose, Brad Wren, David East, James Sykes, Mark Heap, Rachel Lancaster and Vynka McVeigh.

The next meeting is to be held on 7 October 1997, Overlander Hotel at 7:30 pm.

Cauliflower and Phosphorus

Rachel Lancaster - Research Officer (Vegetables)

A trial examining the relationship between phosphorus fertiliser and yield was conducted over the summer months. The influence of phosphorus fertiliser on the number of harvests required was also measured.

Three different rates of phosphorus and eight different ways of applying the nutrient were included in the trial. Results for some of the treatments are shown in Graph 1. The yield in graph 1 is in t/ha and each different pattern within a column represents a picking date. The control in the trial, which represents normal practice, is 160 kg/ha phosphorus applied in offset bands at transplanting (column 1 on Graph 1).

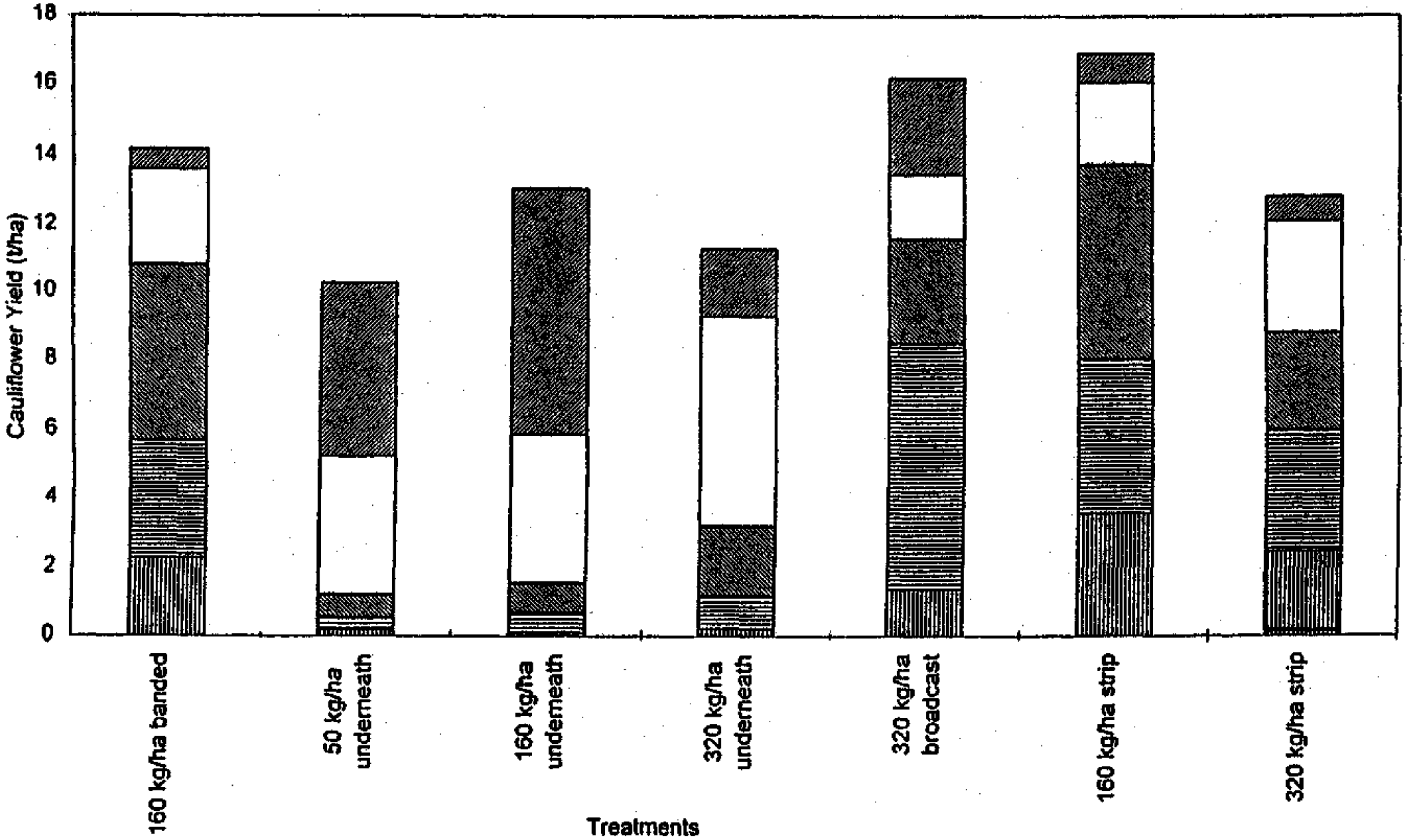
The following refer to actual rates of phosphorus applied, not fertiliser applied.

The highest yield was achieved when 160 kg/ha phosphorus was broadcast in a 30 cm wide strip and incorporated. The cauliflower seedlings were planted in the middle of the phosphorus strip. This produced a yield of 16.8 t/ha which is 2.6 t/ha greater than the control. When the phosphorus was applied at 320 kg/ha in a strip and incorporated, the rate was too high and caused toxicity which reduced the yield. The next best treatment, when phosphorus was broadcast at 320 kg/ha across the plot and incorporated, produced 16.2 t/ha which is 2 t/ha more than the control.

It is important to remember that although the yield was increased when the phosphorus was broadcast or placed in a strip, this may not occur on all soil types as phosphorus can be bound tightly by clay particles or organic matter in the soil (ie: the more clay or organic matter in a paddock then the more phosphorus that will be bound to it if you broadcast the nutrient). If the clay content of the soil is high then the best option would be to continue banding the fertiliser.

The number of harvests required can be influenced by how the phosphorus is applied. When the fertiliser was banded directly underneath the plants in a single band, the number of harvests required was reduced. This is particularly evident when phosphorus was applied at 50 kg/ha and 160 kg/ha underneath the plants (ie: the first three picks were very small, however there were two very large picks). A problem with applying the phosphorus underneath the plants is that it can be toxic and burn the roots of the seedlings. As a result, the overall yield is reduced. Research currently in progress is examining other methods that will supply early phosphorus to the seedlings which will increase yield and reduce the number of harvests required.

Graph 1. Phosphorus Treatments and Cauliflower Yield



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Clubroot update

Rachel Lancaster
Research Officer (vegetables)

An experiment examining the effect of fertiliser and lime when they are placed in the same band, on the growth and yield of cauliflowers has been completed at MHRC. Initial results suggest that the spread of harvest is reduced by the placement of some types of lime and fertiliser together which means that the costs associated with harvesting the crop may be reduced.

The phytotoxicity experiment examining different clubroot management techniques has also been completed. Some treatments appeared to cause damage to the cauliflower plants and the rate and application method will need to be adjusted. An identical experiment is located on a clubroot infected property which will allow the assessment of the treatments for their potential for managing clubroot. A summary of the trial results will be published in the next AgMemo.

The fifth cauliflower clubroot newsletter was posted last week. The newsletter examines different types of lime and gives an explanation of how lime reacts to raise the soil pH. If you did not receive a copy of the newsletter and would like one, please contact Agriculture WA at Manjimup.

Cauliflower Improvement Group

Vynka McVeigh, Research Officer

The last Cauliflower Improvement Group meeting was held on the 19 March 1997. About 30 - 35 grower/packers attended the meeting Items discussed were:

New Chairman
John Ryan called for expressions of interest in the position of Chairman of the Improvement Group. The group decided that a chairman should be appointed at this meeting while everyone was together. Nominations were put forward, a vote was taken and Toby Lambert was appointed.

Export Cauliflower Improvement Project Update
The latest results of the trials Harvest Maturity and Seasonal Effects on Bruising of Cauliflower and the Pre-cooling Method Effects on Shelf Life were presented. Future trials were also discussed. The Seasonal Effects on Bruising (Autumn harvest) is currently being repeated. The Pre-cooling method effects trials will be repeated soon using the MHRC Thermfresh coolroom. The trial to determine the effect of different types of paper wrap on dehydration and shelf life is also being investigated by Rob Klemm, Technical Officer at South Perth.

Modified Harvest Practices
Losses due to pink/yellow, overmature and missed cauliflowers cost the industry $1.7 million per annum. Peter Gartrell, Regional Economist, presented three options to decrease losses due to pink/yellow and overmature curds by changing the number of curd covers and/or harvest practices. Each option accounted for changes in labour and other input costs. Assuming 70% of pink/yellow losses are recovered, option 1, which was the best option and involved two extra covers compared with current practice, netted $486 more per hectare. For more information, contact me or Peter Gartrell on 71 1299.

Cauliflower Market Study Tour Report of Kuala Lumpur and Singapore
Dr. Soon Chye Tan discussed the progress of the consumer survey, which is to be conducted by Survey Research Malaysia. The survey will be done in Kuala Lumpur and interviews will begin in May 1997. Toby Lambert and Norm Eaton also presented their points of view on what they saw in Kuala Lumpur and Singapore back in late November 1996.

If anyone is interested in receiving a copy of the Cauliflower Market Study Tour Report, please contact me on 71 1299.

The next Cauliflower Improvement Group Meeting will be held early June 1997.

Cauliflower news

Rachel Lancaster, Research Officer (vegetables)

Several trials are being conducted over the summer as part of the export cauliflower improvement project. The aim of the trials is to examine several 'production' issues, in particular the role of phosphorus on crop establishment and the effect of both seed and seedling size on the maturity and yield of cauliflowers.

The phosphorus trial will examine different rates and application methods for phosphorus. Previous work indicated that cauliflower plants may not be reaching their maximum phosphorus use until several weeks after transplanting. The plants may be able to utilise phosphorus earlier if it was applied by a different method which could have an effect on the yield and the spread of harvest.

Two trials have been established to determine the effect of seed size and seedling size on the yield of the crop and their influence on the spread of harvest.

If you require more information about these cauliflower trials, please contact Rachel Lancaster at Agriculture WA, Manjimup.

Clubroot news

Rachel Lancaster, Research Officer (vegetables),

The 1996/97 clubroot experiments commencing over the next two months will involve,

- assessing clubroot management techniques which will include the best treatments determined from last years trials in both Manjimup and Victoria. The trials this season will examine various lime, chemical and fertiliser treatments.
- assessing the growth of cauliflowers when different types of lime and fertiliser are placed in the same band.
- monitoring the pH of different types of lime in order to determine the peak pH, rate of reaction and the length of time that the peak pH is maintained for particular soil types.

Trial sites are required for the 1996/97 clubroot experiments. If you have clubroot on your property, will be irrigating the affected area throughout the summer and are interested in the clubroot trials, please contact Rachel Lancaster at Agriculture WA, Manjimup.

Soil samples are required to determine the buffering capacity for soils throughout the Manjimup and Pemberton regions. Buffering capacity is a measure of how resistant a soil is to changes in pH. The higher the buffering capacity then the greater the amount of lime that is needed to raise the soil pH. The soil samples will allow a better estimate of buffering capacity for the district providing a more accurate indication of the amount of lime required to raise soil pH. It is important that as many samples as possible are collected to establish an accurate figure for different areas of the district.

The latest edition of the cauliflower clubroot newsletter was published two weeks ago. This edition featured an explanation of pH and soil buffering capacity. If you did not receive a copy and would like to or want further information about the soil samples please contact Agriculture WA, Manjimup.

Export cauliflower improvement project update

Vynka McVeigh

Seasonal Effects on Bruising Trial

The main points from the winter harvest trial were:

- After 4 days warm store, bruised florets from maturity stage three recorded the greatest severity of black spot, rated at moderate severity. Maturity stage three was referred to as 3 days after 50% of cauliflowers of the same planting had been harvested (curds collected had blown shoulder florets).
- After 6 days warm store, bruised florets from maturity stages two and three recorded the highest scores of turgor, severity of rots/blemishes and black spot. Maturity stage two represented the maturity at which growers pick their cauliflowers.

These results suggest that bruised florets from maturity stages two and three were significantly more susceptible to rots/blemishes and black spot. Therefore, it would be advisable for growers to harvest their cauliflowers earlier to avoid rots/blemishes and black spotting, which tend to occur in bruised cauliflowers that are picked at a more mature stage.

The trial involved cutting cauliflowers into florets, dividing them into three maturity stages and bruising them. The florets were then put into warm store (20-22°C, 80-95% humidity). After the fourth and sixth day in warm store, the florets were rated according to colour, turgidity (softness), severity of rots/blemishes and black spot. Percentage weight loss was also measured.

Both the winter and the spring harvests of this trial have been completed. The spring harvest results are currently being analysed. The winter harvest results were presented and discussed at the last Cauliflower Improvement Group meeting held on the 16th October 1996

Overseas Study Tour

Norm Eaton, Toby Lambert, Dr Soonchye Tan and myself went to Kuala Lumpur and Singapore from the 24 to 30 November, 1996.

The main activities were:

i) Discussed conducting a consumer survey with market research companies. The survey is to be run at the supermarkets and the wet markets in Kuala Lumpur during April/May 1997;

ii) Visited with importers/agents and wholesalers and discussed where our cauliflowers go (eg. wet market, supermarket), and how our cauliflower presentation can be improved (eg. packaging, cut into florets);

iii) Collected information for future marketing strategies to increase market share and increase returns for growers.

A Cauliflower Improvement Group meeting will be held soon to present the outcomes of the trip.

7 VEGETABLES AND OTHER CROPS

Improving the quality of export cauliflowers

This cauliflower project is tackling quality and productivity issues and working with industry to provide market specifications for existing and new export markets. By the end of 1998, a best practice production and handling manual for quality-assured cauliflowers will be provided to nursery operators, growers, packhouses and transporters.

Best practice guidelines promise to maximise profit

Seventy percent of Australia's export cauliflower is grown and packed in Western Australia's Manjimup district. A year-round supply of quality cauliflowers is essential for the WA cauliflower industry to retain existing markets and expand into new ones.

Currently, cauliflower curd pitting and blackening associated with dehydration and bruising are common faults in South East Asian markets. Establishing guidelines for best practice handling and production procedures in the field, packhouse and in transit will maximise quality and minimise harvest and postharvest losses. These guidelines will be used as benchmarks for the cauliflower industry.

If field losses can be halved from 14% to 7% with improved management, and if losses at the packing shed can be reduced from 2.5% to 2%, the expected extra annual return to growers is $600, 000.

Improving quality and productivity

Quality improvement
Experiments relating to postharvest handling of cauliflowers are being conducted to improve quality. The severity and extent of bruising at each season of harvest is being examined. Work with *Plana* cauliflowers showed bruised florets from over-mature cauliflowers had significantly more severe rots and blemishes after four and six days' warm store for spring and summer-picked produce.

Researchers also tested the influence of pre-cooling methods on the shelf-life of cauliflowers. Current commercial practice is to remove field heat by pre-cooling cauliflowers before packing them in export cartons. Four commercial coolrooms were tested to assess the influence of temperature and humidity on weight loss.

Hydrocooling has the potential for the rapid removal of field heat from cauliflowers, however the practice can promote postharvest rots. To counter this, chlorine can be added to the water to kill any bacteria or spoilage microorganisms present. Preliminary results showed cauliflowers hydrocooled with chlorinated water had significantly reduced rots and black spot compared to cauliflowers pre-cooled using forced-air coolrooms.

Productivity improvement
Suitable cauliflower varieties for the September - October (spring) harvest period needed to be identified. The variety *Plana*, from Royal Sluis, while strictly speaking a summer variety, is still the main variety harvested at this time.

Spring production trials identified *Arctic* (Yates) and *Chaser* (S & G Seeds) as outstanding varieties. Both had high total yields of 30t/ha with 27-29t/ha export quality curds. Plana yielded 19t/ha of which 18t/ha were export quality. The average curd weight for *Arctic* and *Chaser* was 1156g and 1175g respectively, compared with 748g for Plana. However, a disadvantage of the *Arctic* and *Chaser* varieties is the long growing season of 140 days, compared to *Plana* which matures in 123 days. Following the trials, *Chaser* is another variety now commercially grown in spring.

Current nutrition research is concentrating on the influence of phosphorus on the yield and spread of harvest. Two aspects of phosphorus nutrition are being considered - phosphorous availability to plants and application methods.

The influence of seed and seedling weight on the spread of harvest and yield are also being examined. If a correlation between weight and harvest characteristics exists, seedlings or seed could be graded so plants of similar weight could be transplanted at the same time. This would improve uniformity in growth and reduce harvesting costs.

A harvest predictor, developed as part of an earlier project, is now being fine-tuned. It is designed to help growers plan crops to maintain a continuous supply of cauliflowers for export. It currently predicts the day of the year *Plana* cauliflowers should be harvested from the transplanted date.

Meeting market specifications and new markets

Growers and packers travelled to Malaysia and Singapore as part of a cauliflower study tour to see the quality of their product in the marketplace and establish contacts. They discussed market requirements, product specifications and consumer requirements and preferences with importers, wholesalers and retailers. This information will help them and the industry export cauliflowers more acceptable to markets and competitive with those from producers in the United States and China.

FURTHER INFORMATION

Contact: Dennis Phillips
Ph: (08) 9250 9432 Fax: (08) 9250 1859
email: dennisp@agml.agvic.wa.gov.au
Project No: VC443

Improving the quality of export cauliflowers

Industry-driven research by a team from Agriculture Western Australia is committed to further improving cauliflower handling, evaluating commercial pre-cooling methods, monitoring the cool chain from packing shed to exporter and investigating the buying habits of cauliflower buyers in Malaysia, Western Australia's main export cauliflower market.

Improved handling pays

Tests on commercial produce simulated the effects of different lengths of time in the field between harvest and pre-cooling. Curds (cauliflower heads) were badly discoloured if pre-cooling was delayed for more than eight hours after harvest at 22°C and 31°C.

Pre-cooling methods

Work to test temperature and humidity conditions in export packing shed coolrooms in the Manjimup district identified problems in maintaining ideal pre-cooling conditions of 0-1°C at 95-100% relative humidity. During Summer, only one of four commercial coolstores was found to be operating at the ideal temperature. Many sheds exceeded this by as much as 5°C during the test period. Packing shed managers have been contacted to discuss where improvements might be made.

Other research is examining the plastic bulk bin-liners used by some packing sheds and their effects on pre-cooling rate and curd quality. Tests on produce harvested in Summer showed bin-liners greatly increased the time it took to reduce produce temperatures to that desired for export packing. The core temperature of cauliflowers pre-cooled in a bulk bin with a plastic bubble wrap bin-liner was too high, at 5°C after 16 hours in the coolroom. Air flow was greatly affected by the bin-liner, resulting in significantly higher weight loss and poorer quality cauliflowers.

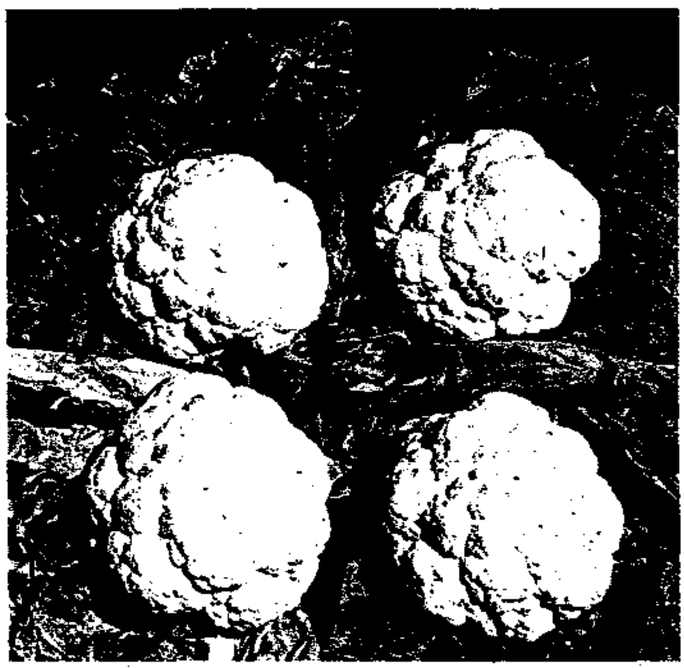
Monitoring the cool chain

In Summer, the team began pioneering research on core temperature monitoring of cauliflowers beyond the packing shed. Using two temperature and humidity data loggers, two consignments of cauliflowers were monitored during road transport from the shed in Manjimup to the exporter in Perth (about 300km by road taking up to seven hours). The ideal transit temperature for cauliflower is 0-2°C. Core temperatures of packed cauliflowers at loading were about 5°C. The cooling units in the Taut liner trucks used on these trips were unable to lower the core temperature of the produce below loading temperature and could not prevent a small rise in product core temperature. This resulted in cauliflowers at outturn in Perth being rated at below export standard.

Meeting consumer demands

Following a market study tour to Kuala Lumpur and Singapore, a consumer survey by Agriculture Western Australia was conducted in Kuala Lumpur in July and August 1997. Findings indicated that there was a need to attract young housewives to buy cauliflowers, particularly in the supermarket. Most housewives interviewed were more than 40 years old and bought cauliflower at the traditional place of purchase, the wet market. To increase cauliflower consumption in Malaysia, younger working people should be targeted to promote the buying of Australian cauliflower. The survey also revealed cauliflower buyers would not tolerate black spot or blemishes on curds, even with a price discount.

Contact: Dennis Phill
Ph: (08) 9250 94
Fax: (08) 9250 18
email: dennisp@agml.agric.wa.gov
Project No: VC4



Farm Weekly, Section 2, June 20 1996

Manjimup's cauliflower growers — a marketing success story

By DEREK WILLIAMSON

MANJIMUP'S $18 million export cauliflower industry is an undisputed success story.

Manjimup growers account for almost 70pc of Australia's cauliflower exports, with about 90pc of the produce finding its way into Asian markets such as Singapore and Malaysia.

Like all export-orientated industries in this day and age, product quality and consistency of supply are the foundations on which Manjimup has developed its markets.

Maintaining and developing these markets into the 21st century is one of the industry's major challenges and to this end a number of people are working on programs aimed at improving post-harvest crop quality and disease research.

Agriculture WA vegetable research officer Rachel Lancaster is responsible for research into club root, the disease touted as the biggest potential threat to the industry's continued success and viability.

Club root attacks the Brassica family of vegetables (broccoli, cauliflower,) by causing root swelling which impedes the plant's ability to uptake water and nutrients.

"Club root has been in the area for around five years and at the moment there are no satisfactory control measures," Ms Lancaster said.

"If it spreads throughout the district it could be a real disaster for the export industry.

"We can't control it as such but we can manage it."

Soil liming is a key element of any effective club root management as the disease is not as prevelant in alkaline soils.

"Soils with a pH of 7.2 and above are best," she said.

"My trials are looking at the useage of differing lime rates and types along with some preliminary work on fungicides."

MsLancaster said the other most effective management technique appeared to be the inclusion of a simple non-brassica crop rotation.

Her research is being carried in conjunction with similar work which is being performed by Agriculture Victoria and at present, her only advice to cauliflower growers on club root control is to keep liming and keep rotating.

The latest addition to the team at Agriculture WA's Manjimup district office is vegetable research officer Vynka McVeigh.

Ms McVeigh was employed to carry out work on the department's export cauliflower quality improvement project and is specifically working on the post-harvest aspects of the industry.

As she is industry-funded — half her funding comes from a local cauliflower levy which is matched by money from the Horticultural Research and Devlopement Corporation — she wants to know what the growers want researched.

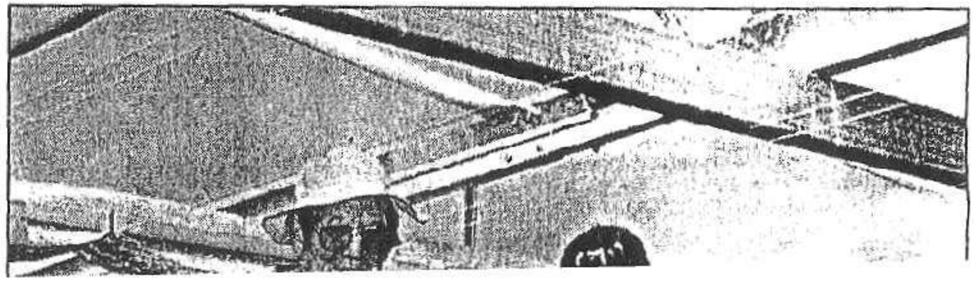
"I will take on-board what they are concerned about and come back with some trial results," Ms McVeigh said.

"At the moment I am looking at trials to ascertain bruising susceptibility in relation to curd maturity."

She said that as cauliflower curds grow from the "inside out" a whole curd had areas of different maturity and hence different levels of bruising susceptibility. She hopes her work will eventually lead to the development of improved packing techniques.

Another area attracting her attention include the impact of different pre-cooling techniques and systems. She is also focusing on the study of possible shed handling improvements and the relationship between fertiliser application and susceptibility to bruising.

■Freshlink Manjimup manager Neil Poultney is pictured inspecting the quality of local cauliflowers destined for the Singapore market with Agriculture WA vegetable research officer Vynka McVeigh.



Warren Blackwood Times, June 12 1996

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CAULIFLOWER UNITY: Agriculture WA Manjimup vegetable adviser Lloyd Williams, left, Cauliflower Export Improvement Group research officer Vynka McVeigh and Westcorp Manjimup operator Fred Downton packing cauliflowers for export.

Growers unify in face of difficulty

OVER the past six months cauliflower growers have shown a united front as a result of problems faced.

One of their biggest concerns has been an oversupply of cauliflowers into South East Asian markets.

Another situation which has demanded attention has been the need to develop better winter cauliflower varieties.

This effort has been boosted as a result of a 29 variety trial planted at Manjimup Senior High School's farm.

Agriculture WA Manjimup vegetable adviser Lloyd Williams, who is pleased that growers have become unified, said that dealing with the local levy and changing to a national levy had been difficult.

Mr Williams said growers were now trying to work out how to have their money contributed under the national levy returned to the Manjimup district and spent locally.

"The industry is expected to flourish when work by Cauliflower Export Improvement Group research officer Vynka McVeigh and Agriculture WA research officer Rachel Lancaster is combined with growers showing a united front."

Research levy causes concern

By ZORAN PANZICH

CAULIFLOWER producers are concerned at a national levy for research and development into their industry.

At a meeting in Manjimup last week producers demanded that the money locals paid should be used in WA.

In addition, local producers aired their disappointment about the lack consultation from the governing body over the levy.

The producers also demanded that the national levy of 0.5 per cent of the value of the produce should be charged at the 'farm gate'.

No mention was made about the local levy, which was due to be reviewed at the end of this year.

Agriculture WA Manjimup vegetable adviser Lloyd Williams said producers were concerned about an oversupply of cauliflowers on the export market.

Mr Williams said it would take some time for the price of cauliflowers to return to economic levels.

No agreement was reached although there was a realisation that problems such as a lack of commitment and cooperation among agents and growers, needed to be resolved so oversupplies did not occur.

Much of the export cauliflower figures were based on speculation which resulted unwanted production and oversupply along with a lowering of the price for each unit.

"Wrongly, growers think that they are only a small part of a cauliflower production chain but it will be up to them to express their feelings in a constructive manner so the whole industry can function more efficiently," Mr Williams said.

RESEARCH: Cauliflower Export Improvement Group research officer Vynka McVeigh, left, Agriculture WA vegetable research officer Rachel Lancaster and vegetable adviser Lloyd Williams.

Growers compare 29 cauliflower varieties

A SUCCESSFUL field walk for local cauliflower producers was held at the Manjimup Senior High School last week.

Producers viewed 29 different varieties of cauliflowers, some of which were expected to be promising for an early winter crop.

Agriculture WA Manjimup vegetable adviser Lloyd Williams said it would not be possible to say which varieties

opportunity for them to make direct comparisons between varieties.

Such comparisons would not otherwise be available.

Producers appreciated the work undertaken by the school's agriculture wing students, the South West Development Commission in organising the trial and local agricultural merchandise suppliers and nurseries.

WESFARMERS Bunnings has been called on by Warren MLA Paul Omodei to locate a future $1.9 billion paper pulp mill somewhere between Bridgetown and Manjimup.

By ZORAN PANZICH

For the past four years the company has been considering siting the mill and its focus has been narrowed down to a site at Wilga in the Boyup Brook shire, a site in the Warren area and the Kemerton Industrial Park north of Bunbury.

Time lines for announcements about the location of the mill have come and gone several times over without the public having any clearer view of where it will be located.

The Manjimup Shire Council is eager for facility to be situated somewhere in the shire or close to it.

Company chief Warren Murphy is due to have talks with the council in the next few weeks.

As well the Bridgetown-Greenbushes Shire Council has expressed a desire for it to be located within its boundaries.

Mr Omodei, who has been lobbying the company for the past six months, said there was a great deal of support to be gained for the company if it favours a 'greenfields' site near Yornup which would be adjacent to a railway line, water and roads to the east and west for resource transportation.

A result would be less log trucks on shire roads.

If the company were to settle on the Wilga site it would be an expensive exercise with the need to put in 45km of rail.

A disadvantage of that site was a lack of infrastructure.

As well, the trend wor
was for 'greenfield' sites

"However, Wilga woul
better proposition from th
point of Warren-Blackw
sidents than Kemerton
Omodei said.

"In the Manjimup area
the infrastructure wh
necessary to sustain a m
dustry and for a sign
population to be housed.

"We will have a multi-
school campus, a new
is under construction in
jimup along with the
established infrastructure
could be needed by a ne
stantial industry."

New expert takes over

MANJIMUP Cauliflower Export Improvement Group has a new research officer Vynka McVeigh who will be out to maximise the group's post harvest marketing.

Miss McVeigh's task is to ensure the product reaches markets such as Asia in an excellent condition.

As part of the research work Miss McVeigh will look at cauliflower packaging, cartons and sea containers to find ways to better methods to handle the product.

Miss McVeigh said temperature and relative humidity were important factors which need to be controlled to limit cauliflower deterioration on export routes. The temperature needs to be between one and two degrees Celsius and the humidity needs to be between 95 and 100 per cent to stop dehydration.

Miss McVeigh, who has a Bachelor of Business from Curtin University, will continue her work till about December 1997.

BETTER MARKETING: Vynka McVeigh, who will be looking for ways to maximise returns to producers.

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