Further developing technologies to export vegetables in bulk

Dr Dennis Phillips
Department of Agriculture & Food
Western Australia

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Level 7
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Telephone: (02) 8295 2300
Fax: (02) 8295 2399
E-Mail: horticulture@horticulture.com.au

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FURTHER DEVELOPING TECHNOLOGIES TO EXPORT VEGETABLES IN BULK

Dennis Phillips, *et al.*

Department of Agriculture and Food, Western Australia (DAFWA)

HORTICULTURE AUSTRALIA
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FURTHER DEVELOPING TECHNOLOGIES TO EXPORT VEGETABLES IN BULK - VG04007

Project Leader: Dennis Phillips, Senior Development Officer, Department of Agriculture and Food, Western Australia, Locked Bag 4, Bentley Delivery Centre WA 6983.
Phone: (08) 9368 3319. Fax: (08) 9368 2958
Email: dphillips@agric.wa.gov.au

Researcher: Shane Trainer, Research Officer, Department of Agriculture and Food, Western Australia, Locked Bag 7, Manjimup WA 6258
Phone: (08) 9777 0132. Fax: (08) 9777 0167
Email: strainer@agric.wa.gov.au

Researcher: Aileen Reid, Development Officer, Department of Agriculture and Food, Western Australia, Locked Bag 4, Bentley Delivery Centre, WA 6983.
Phone: (08) 9368 3393. Fax: (08) 9368 2958.
Email: areid@agric.wa.gov.au

PURPOSE

The result of two years of research and development work on methods to prepare and ship fresh vegetables in bulk packages are presented in this final report. The report is intended to inform the Australian Vegetable Industry and others of the reasons for doing this work, methods used and results produced. It is hoped that the report will provide sufficient detail that the methods described can be adopted by growers and exporters in the future, or researchers can build upon the techniques easily to further improve the techniques.

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1. MEDIA SUMMARY

This project was initiated because Australian vegetable exports to traditional South East Asian markets have declined significantly over the last decade. The combination of increased market competition, a strong Australian currency and increased production costs have decreased the ability of Australian suppliers to compete in global markets. The result is that Australian producers now rely heavily on domestic markets that are easily over-supplied, and strategies need to be developed to recapture lost export markets for the Australian industry to continue to grow.

A previous Horticulture Australia project, (VG99014) developed and tested a method to reduce the cost of exporting iceberg lettuce through bulk handling and shipping. The project reported on here, 'Exporting Vegetables in Bulk' was initiated to take this work further and investigate the potential of bulk shipping for other vegetable crops.

This project tested eight vegetable products for their suitability to bulk handling and transport in 'custom made' disposable pinewood bulk bins. Specifically, work concentrated on the following:

- Exploratory investigations of pre cooling and storage methods for three vegetable products, sweetcorn, broccoli, and cauliflower in simulated sea container conditions in a humidified coolroom.
- 'Land based static' storage trials in a refrigerated sea container for Cos lettuce, iceberg lettuce, cauliflower, broccoli, celery, cabbage and Chinese cabbage. Thirteen trials were completed in the sea container comparing different cooling and packing methods to identify practices that best suited each individual product.
- Test shipments of broccoli, cauliflower, cabbage, iceberg lettuce and cos lettuce to Asian and Middle East markets. Bulk bins of produce were exported in trial quantities on seven separate occasions, with varying success. Of the five vegetables exported four performed well, with broccoli performing best, closely followed by cabbage.

The project demonstrated that bulk shipping was technically feasible for most of the vegetables tested, requiring only minor adjustments to a common bin design and cooling method for each different product. Significant cost savings and quality benefits could be gained through the use of this technique in both packing and transport. The project has produced a blueprint showing how each of the products should be packed, cooled and handled to maximize out turn quality, or recommendations are made for further improvement of techniques.

2. TECHNICAL SUMMARY

Australian vegetable exports have declined significantly during the last decade in traditional markets. The combination of increased market competition, a strong Australian currency and increased production costs have decreased the ability of Australian vegetables to compete. The result has been that Australian producers have come to rely heavily on a relatively small domestic market that is too often over-supplied.

Identifying and dealing with inefficiencies in the supply chain to export markets is one way that the Australian vegetable industry can achieve a substantial improvement in competitiveness and recapture lost market share. A study of the current production and exporting methods for iceberg lettuce in HAL project VG99014 identified packaging, packing and freight to market as links in the export supply chain that offered good potential for improvement in efficiency and cost savings.

The traditional method of packing in small cardboard cartons rarely results in produce being exported at it's optimum storage temperature, because the produce generates heat through respiration while in transit and this heat is not able to be fully removed from sealed cartons in a pallet stack once loaded into a sea container. In Western Australia, traditional export handling is a two stage process, with produce harvested and cooled in bulk bins before being repacked into cartons at an exporter's premises. This practice is inefficient, detrimental to product quality and unnecessarily costly because of the double handling involved which leads to produce heating up while being packed and the costs associated with building and running the packing house.

Investigations in project VG99014 concentrated on developing a disposable bulk handling container (bulk bin) and low cost cooling method which reduced these inefficiencies. At the conclusion of this work three successful trial shipments of lettuce in bulk bins were completed to Singapore and Malaysia. Out turns from these shipments gave the research team sufficient encouragement to explore modifications to bin design and handling to further improve the marketability of out turned produce, and to initiate a study of products similar to lettuce.

The project reported on here continued on where project VG99014 left off with the aims of:

- Identifying and investigating other vegetable products which would suit the bulk handling technology for export.
- Improving the bulk handling process to achieve better out turns of a range of vegetable products in 'land based static' simulated shipping trials.
- Testing the techniques with a number of vegetable products in a real time situation through trial shipments to export destinations.
- Increasing the awareness of bulk handling technology to the vegetable industry.

The project demonstrated that most of the vegetables tested could be exported using this technology. Vegetables that were successful in static trials included broccoli, cauliflower, celery, cabbage, Chinese cabbage and iceberg lettuce. Each product required minor modifications to packing methods to out turn produce with a marketability at or better than traditional means. Results for sweetcorn and cos lettuce however were variable, showing that these products need more testing to identify a suitable cooling or bulk handling method. Test shipments produced varying results but suggested that this method would be acceptable for exporting the majority of head forming vegetable products to Asian or Middle East markets.

The project demonstrated that costs could be reduced in the packing and packaging of vegetables through bulk handling and pre cooling methods. Further efficiencies could be achieved by increasing nett weights of produce in sea containers compared to cartons, due to less space being taken up by packaging materials. Broccoli showed the greatest potential cost savings of the products studied through elimination of expensive air freight, ice and polystyrene carton packaging. This would result in significant reductions in freight costs per kilogram of product transported in sea containers.

The conclusion from this work is that a range of vegetables can be successfully transported using bulk handling technology potentially making Australian vegetable exports more price and quality competitive in export markets.

3. GENERAL INTRODUCTION

Australian grown vegetables have steadily lost market share in traditional export markets over the last two decades and the problem has accelerated since the 2002/03 season. A number of factors have contributed to the down turn, including increased competition in these markets from China, a rise in value of the Australian dollar, increased transport costs as well as the cost and availability of labour in Australia. Western Australia has been impacted more than other states by these changes, because it has been Australia's major vegetable exporting state since the 1970's. This project, and it's predecessor (VG99014) anticipated these problems and have attempted to find solutions through reducing supply chain costs in exporting.

Labour currently represents approximately thirty percent of production costs for a number of vegetable crops in Western Australia. Much of this cost is in harvesting and packing. For export produce, the cost is increased further by the practice of re-packing produce from field bins into small cardboard cartons at an export packing house. Removal of this double handling (repacking) step has the potential to significantly reduce the costs of exporting vegetables.

Harvesting vegetable produce direct into 'non returnable' bulk bins in the field and shipping to export markets in these bins is a transport method that eliminates double handling and the costs associated with maintaining and staffing export packing houses. This method was originally investigated for lettuce and found to be technically feasible and cost competitive for exports to Singapore and Malaysia. The success of two commercial shipments in bulk to these markets posed the question whether this transport method could be a viable shipping alternative for not only lettuce, but also other vegetable crops.

The bulk shipping method was based around a light weight custom made pinewood bin, lined with a plastic pallet bag. The bag was secured in the bin by fitting a sheet of thin cardboard inside the bag and securing it to the floor of the bin. This cardboard sheet which had 24 holes 40mm in diameter cut into it to allow ventilation in the bin will be referred to as the 'base' of the bin throughout this report. Ventilation holes were cut through the plastic bag to line up with the holes in the base allowing for pre cooling and constant airflow in a sea container during transport. Much of the work described in this report investigated ways of restricting the air flow rate through bins in a sea container to reduce dehydration of produce on the top and bottom layers of the bins. To achieve this, the same cardboard sheets used for bases, but with different levels of air permeability were placed over the top of bins. These bin top covers are referred to as 'lids' throughout the text that follows.

The bulk handling and shipping method has the following advantages over cartons, which are the industry standard packaging for export.

- Reduced costs of shipping produce by decreasing the number of times produce is handled. Once packed into bulk shipping containers in the field, produce does not need to be repacked into cartons, for export. This eliminates the need for a packing shed and staff to perform this extra function.
- Elimination of manual loading of produce into sea container. Bulk bins can be loaded directly into sea containers using a forklift, versus the traditional method of individual hand loading of cartons.
- Bulk bins can be used on mechanical harvesters for in-field filling.
- Bulk bin handling can eliminate breaks in the cool chain typical of traditional methods. Ventilation holes in the base of the bins allow the vertical movement of air through the produce while performing pre cooling and during the sea voyage. During pre cooling (figure 4.2) cool air flows through produce, removing the field heat quickly and efficiently. In transit, air flow inside a sea container is circulated, starting from the base at the refrigerated end of the container. Airflow then moves toward the filling end, then vertically up through the container and back to the refrigerated end. Warm air is then released from the container. Ventilation in the base of the bulk bins takes advantage of the airflow by maintaining produce at a consistent temperature throughout transit.
- Bins designed and built as part of this project were of a light weight, inexpensive pinewood construction designed for a single use. At a similar cost to cardboard cartons, the pinewood used for the construction presents fewer problems for disposal at the destination.

- Higher sea container weights are achievable using bulk bins. Bins can take advantage of the whole sea container internal volume, whilst reducing the amount of packaging required, allowing more room for produce. Small variations in internal dimensions of different sea containers can be easily and cheaply adjusted for in pinewood construction, but not with traditional packaging materials.

4. RE-COOLING METHOD FOR BULK BINS

A range of bin designs and configurations were tested in the previous HAL project (VG99014) and a standard modular design was adopted for exporting lettuce. The criteria for bin design and the bulk handling and cooling process were as follows:

1. process must reduce the costs of exporting without compromising product quality
2. s must be cost effective and the process must be low cost and simple but effective.
3. s to be made of materials that could be easily customised for different size sea containers.
4. Bins capable of being easily loaded and unloaded into a sea container.
5. The contents of the bin must be protected from contamination.
6. The bins must be adaptable to a cooling process that doesn't require high capital or operating costs and cooling must be able to be done on the farm, for example forced air cooling.

The result was a light weight pine modular bin, lined with a pallet bag. At the base of the pallet bag is a cardboard layer with ventilation holes (figure 4.1). A modular design allowed for the bottom half and then the top half to be filled without damage to ether packer or produce.

Figure 4.1. Bulk handling bin prototypes. Half bin on the left, Full bin on the right.

It was important to have a method of cooling a large volume of produce quickly in these bins, with low capital expenditure. Forced air cooling (FAC) of produce was developed previously during project VG99014 for iceberg lettuce in bins and this proved to be cheap and effective.

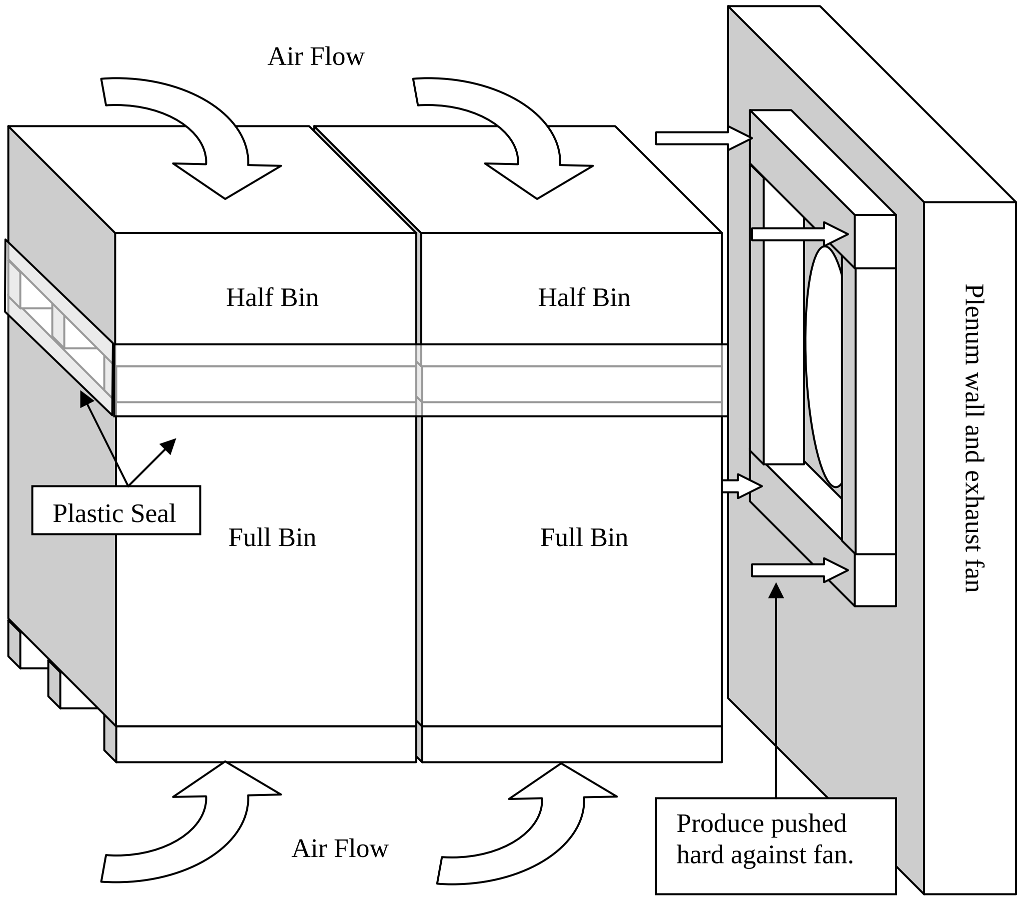


Figure 4.2. Pre cooling methodology used for bulk bin handling.

Once packed, bulk bins are transported to a fan forced cool room, preferably incorporating a humidifier, stacked two high and pushed hard against the fan as shown in figure 4.2. During stacking, the fork gap of the upper bin is aligned with the fan, once pushed against the fan this will allow cool air movement between the gaps. A layer of plastic is secured over the fork gap to form a seal. The seal stops airflow through the fork gaps at the back of the stack. Doing so creates a flow of cold air down through the product on the top bin and up through the ventilation holes on the bottom bin. This method allows the rapid cooling of large volumes of produce in bulk bins. Once cooled produce can be loaded directly into sea containers.

Figure 4.3. Pre cooling using an experimental portable fan and humidified air.

5. BULK SHIPPING - PRELIMINARY TRIALS

General introduction

Investigations into the suitability of vegetables other than lettuce for bulk handling commenced in 2005 with storage trials in a humidified cool room with airflow through bins, simulating conditions expected in a refrigerated sea container. Three products were chosen for this initial work, Cauliflower, Broccoli and Sweetcorn. The primary aim of the work at this time was to test different packing methods for their effect on marketability after a period of storage equating to a sea voyage to Singapore or Malaysia.

It was expected at the outset that the weight of the produce in the bins (approximately 1 meter internal depth) would push down on produce towards the bottom of bins and could render some of it unmarketable. Possible ways of minimising this included testing shallower bins than the standard design previously used for lettuce, (figure 4.1) or wooden support structures secured half way up a full bin (figure 5.1.1) to take the weight of produce in the top half of the bin. This work commenced with cauliflower.

5.1 Cauliflower development

MATERIALS AND METHODS

The initial cauliflower bulk handling trial began on Friday the 18th of March 2005 with produce sourced from a Manjimup grower. Cauliflowers where harvested, graded and packed into the pinewood bins on a field harvester. During packing, temperature loggers were placed in each bin. Harvesting and packing was done around mid day to increase the infield temperature of curds, hence testing a worst case scenario for produce handling.

Four treatments were applied in field. These were then compared to cauliflowers packed in cartons in the packing shed.

1. Commercial cartons.
2. Full depth bin with no load bearing supports.
3. Full depth bin with load bearing supports.
4. Half depth bin export cut (no leaves surrounding the curd).
5. Half depth bin Domestic cut (leaves surrounding the curd as a buffer against bruising).

During packing, load bearing supports were secured at the centre point of the full bin (vertically) and placed across half of the bin (horizontally). The supports were made of lightweight pine wrapped in thin plastic (pallet wrap) to minimise damage to produce. The opposite side of the full bin did not have any load bearing boards (Figure 5.1.1).

Commercial cartons (control) were also picked, cooled and packed on Friday, 18 March 2005. These were packed by the grower in his packing house. Once packed, bulk bins and cartons were transported 15 km by road to the pre cooling facility at Manjimup Horticultural Research Institute (MHRI).

Once at the Research Institute, bins were removed, weighed and stacked in a humidified cool room (Therm fresh®) in a ‘two bin’ stack with a full bin on the bottom and half bin on top (Figure 5.1.1). Produce was then cooled to 2.5ºC. Cooled produce was removed from the ‘Plenum fan’ and placed up against a smaller portable fan (Ventilation fan) in the cool room. This fan was used to simulate air flow through the bins, as it would happen in a sea container. Cartons were stored adjacent to bulk bin treatments in the cool room without ‘flow through’ ventilation. The produce remained in storage for 18 days until 5 April 2005, to simulate a sea voyage.

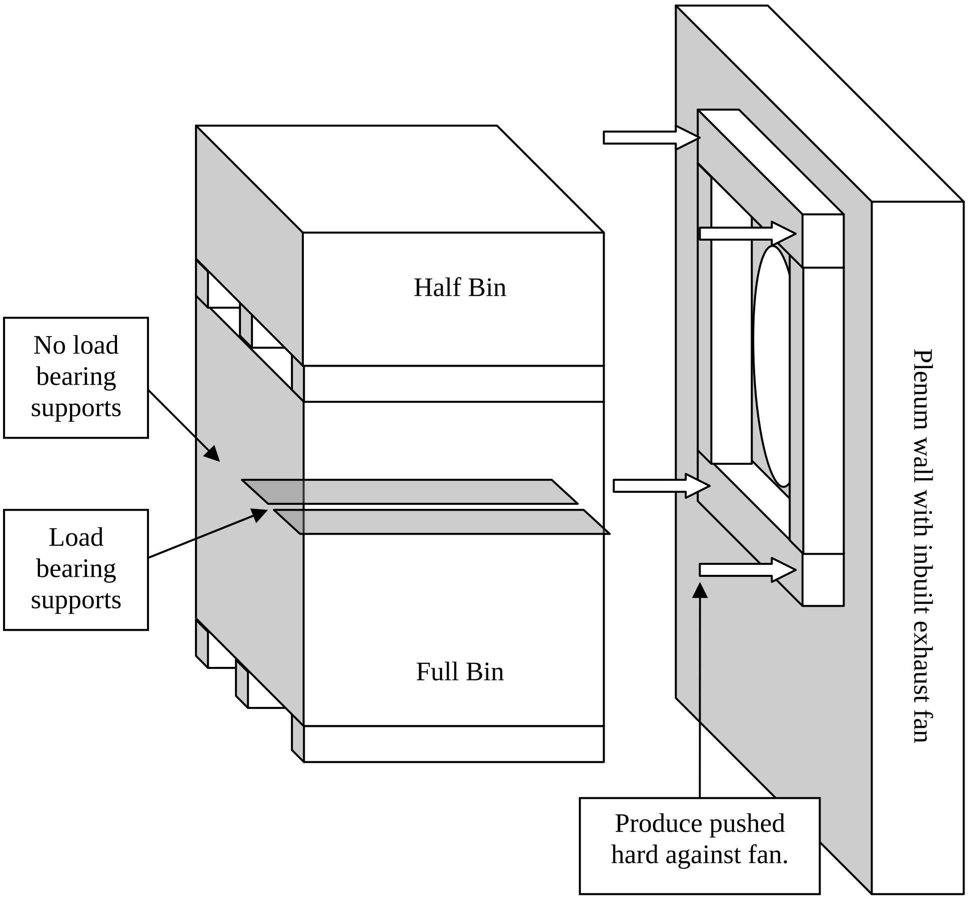


Figure 5.1.1. Cauliflower pre-cooling technique.

Assessment for marketability

After 18 days bulk bins where removed from the coolroom, weighed and assessed. Samples of produce were removed and assessed for the following characteristics (in order of importance).

1. Overall marketability (ranked on a scale of one to seven, one = worst and seven the best).
2. Bruising (ranked on a scale of one to seven, seven the worst and one the best).
3. Dehydration (ranked on a scale of one to seven, seven the worst and one the best).
4. Black spot and other defects (ranked on a scale of one to seven, seven the worst and one the best).

In essence, the more of a characteristic present, the higher the score eg more marketable and more bruising both record higher scores.

Sampling involved removing produce from each layer vertically down the bin, 10 layers for a full bin and 5 for a half bin (Figure 5.1.2). Five cauliflowers where removed at each layer and assessed. Cartons where sub sampled at the same ratio used for bulk bins.

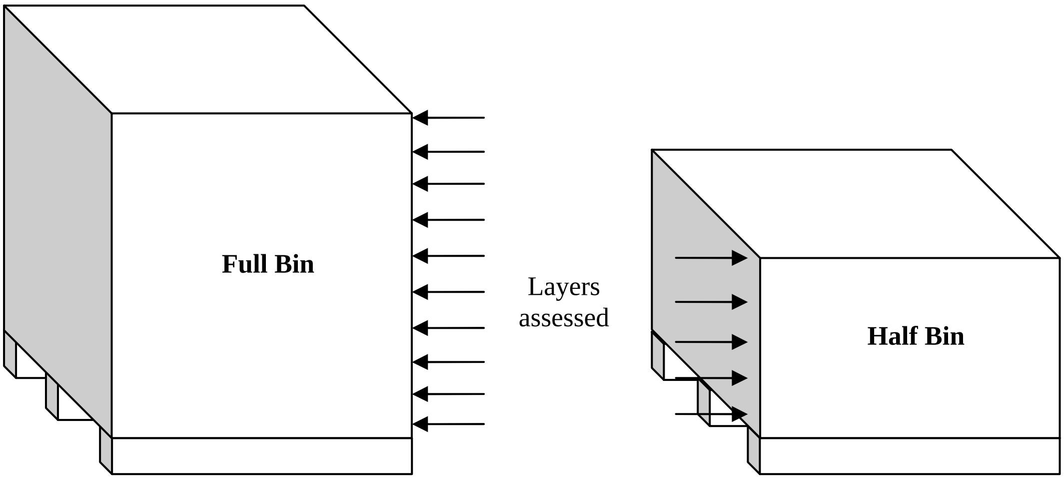


Figure 5.1.2. Layers of assessment for cauliflower bulk bin treatments.

After the initial assessment the sampled cauliflowers were again stored for 3 days at 20^{0}C in a humid laboratory to assess shelf life. Cauliflower curds were placed on a flat surface in single layers. After the storage period, all curds were again assessed for marketability overall and scored for bruising, dehydration or black spot (Figure 5.1.3).

Figure 5.1.3. Shelf life test for cauliflowers sampled from bins after 18 days bulk storage and then held in a laboratory at a constant temperature of 20ºC.

RESULTS

Pre cooling trends of the half bin differed substantially from commercial cartons (Figure 5.1.4). Temperature probes indicated produce at the top (T) of the bin cooled to below 3.0°C more rapidly than produce in the middle of the bin (M). Once cooled, the produce temperature remained stable until it was moved to the ventilation fan. During repositioning the temperature of the half bin increased slightly but rapidly returned to transport temperature.

Cauliflowers packed into half (pre-cooling time: 8 hrs 15 mins) and full (pre-cooling time:13 hrs 45 mins) bulk bin treatments needed more time to remove the field heat from produce at the centre of the bin than required for produce packed into cartons (pre-cooling time: 6 hrs 50 mins) (Figures 5.1.4 and 5.1.5). The commercial cooling system was able to reduce produce temperature below that possible in the pre-cooling room located at Manjimup Horticultural Research Institute (MHRI). Repacking of produce into cartons had the effect of increasing cauliflower temperature to a level similar to produce in the bulk bin treatment. Transporting the cartons to MHRI was similar to moving the bulk bins to the ventilation fan with respect to temperature increase. Once secured to the fan, produce in the bulk bins returned to pre cooling temperatures while the cartons did not.

The full bulk bin (Figure 5.1.5) required longer to remove the field heat from produce located at the centre of the bin compared to produce at the centre of the half bin (Figure 5.1.4). This trend was consistent when the bulk bin treatments were moved onto the simulator fan. The full bin required longer to restore pre cooling temperatures. Throughout the trial, produce temperatures were higher than expected (> 2.0°C) suggesting a need to reconsider the simulation method used in bulk handling work, up to this time.

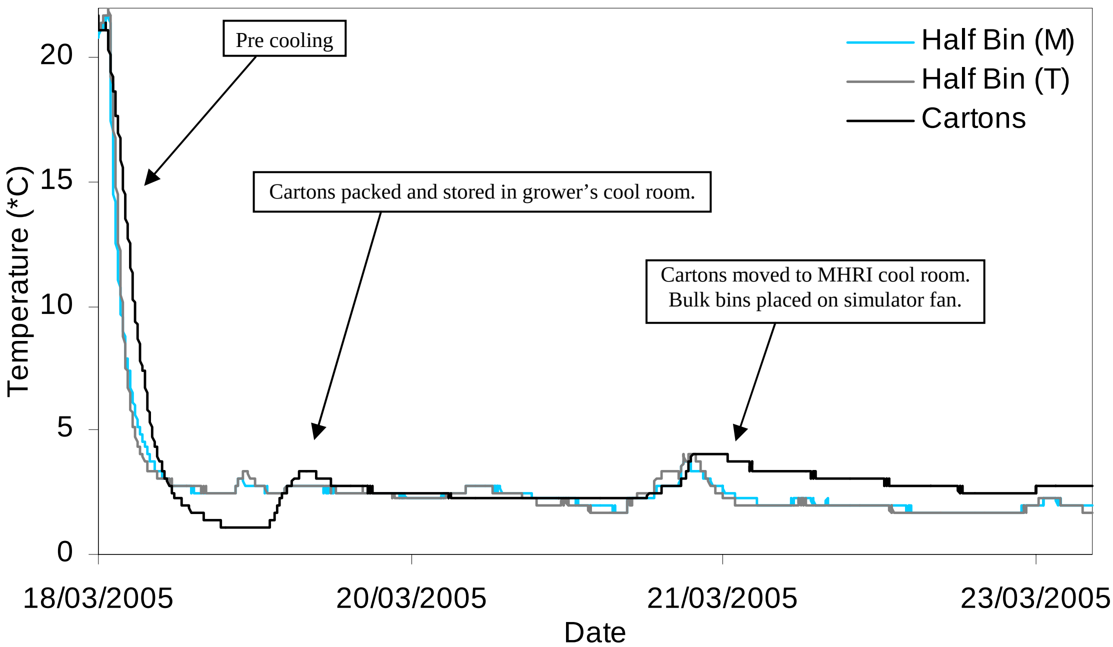


Figure 5.1.4. Cooling trends for cauliflowers pre cooled and stored in cartons or a half bulk bin treatment. Temperature was taken at two points in the bulk bin middle (M) and Top (T).

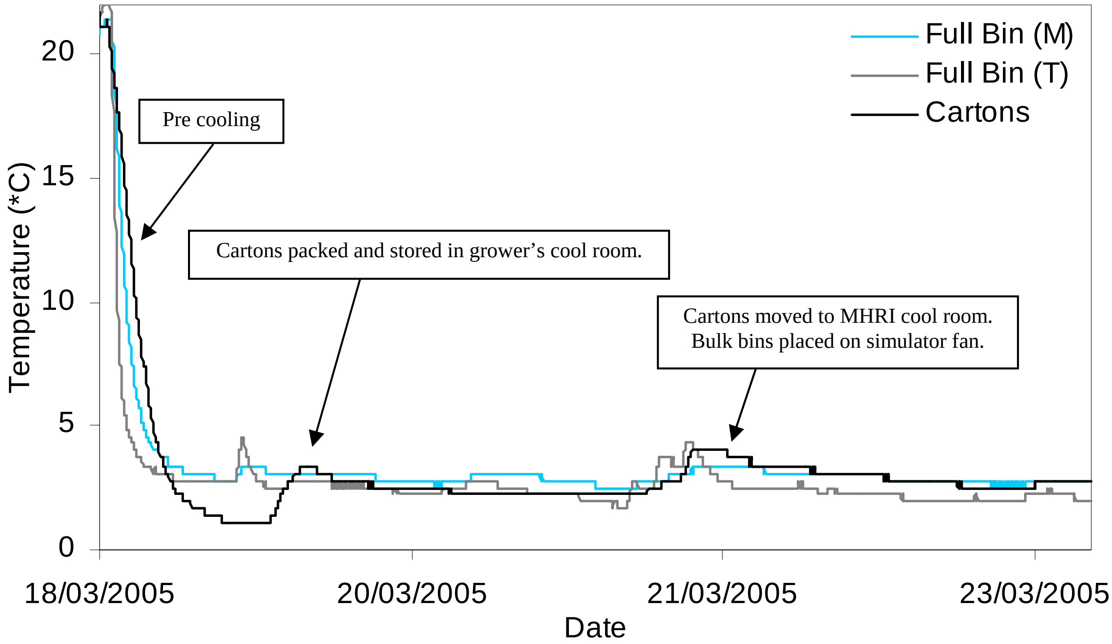


Figure 5.1.5. Cooling trends for cauliflowers pre cooled and stored in cartons or a full bulk bin treatment. Temperature was taken at two points in the bulk bin, middle (M) and Top (T).

Table 5.1.1. Treatment weights of cauliflowers following each handling process

Treatment	Harvest weight (kg)	Post FAC[b] weight (kg)	Weight loss during FAC (%)	Post storage weight (kg)	Weight loss during storage (%)	Total weight loss (%)
Full bin	538	532	1.12	521	2.06	3.15
Half bin	299	295.5	1.17	294	0.05	1.69
Commercial cartons (ave)	0[a]	20.51	0[a]	20.22	1.41	1.41

a Treatment was pre-cooled prior to packing, so individual harvest weights of cartons where not available.
b FAC = Forced Air Cooling.

Full bin and half bin treatments recorded similar weight loss (moisture) during forced air cooling (FAC). The percentage weight loss during storage was the highest in the full bin, followed by commercial cartons and then the half bin immediately post storage. The full bin treatment recorded the highest total weight loss followed by the half bin and commercial cartons. Cartons appeared damp after storage.

Table 5.1.2. Average marketability, dehydration and bruising for the five packaging options after 18 days storage

Treatment	Average marketability	Dehydration	Bruising
Commercial cartons	5.314[c]	2.680[ab]	2.920[c]
Full bin with no load bearing beams	4.740[ab]	3.320[c]	2.340[b]
Full bin with load bearing beams	4.360[a]	3.640[c]	2.260[b]
Half bin export cut	5.240[bc]	2.480[a]	1.880[a]
Half bin Domestic cut	4.480[a]	3.120[bc]	2.200[ab]
p-value (lsd)	0.002 (0.5161)	0.002 (0.5631)	< 0.001 (0.3708)

Statistical analysis using Anova showed that commercial cartons resulted in a similar marketability to the export half bin treatment, but cartons were significantly better than all other treatments. The export half bin treatment recorded similar marketability to the full bin with no load bearing treatment, but was significantly better than all other treatments. The full bin with no load bearing was not significantly better than the two treatments, full bin with load bearing and half bin domestic cut. Both full bin treatments recorded significantly higher dehydration than the commercial cartons. The commercial cartons gave significantly higher produce bruising than all other treatments.

Table 5.1.3. Comparison of layers vertically down the full bin treatment (no load bearing) after 18 days storage

Treatment (layer)	Average marketability	Dehydration	Bruising
1	3.4[a]	4.60[d]	3.00[b]
2	5.00[bc]	2.80[ab]	1.6[a]
3	4.60[bc]	2.60[a]	1.6[a]
4	5.40[c]	3.20[abc]	2.4[ab]
5	4.40[b]	3.80[bcd]	2.4[ab]
6	5.40[c]	2.80[ab]	2.2[ab]
7	5.00[bc]	3.20[abc]	2.8[b]
8	5.00[bc]	3.20[abc]	2.6[b]
9	4.80[bc]	3.00[abc]	2.4[ab]
10	4.4[b]	4.00[cd]	2.4[ab]
p-value (lsd)	0.006 (0.948)	0.006 (1.015)	0.036 (0.8575)

In the full bin with no load bearing, layer 1 recorded an average marketability significantly ($P < 0.05$) lower than all other all other layers when analyzed using Anova. Layer 10 recorded the next lowest average marketability, but not significantly. Layer 1 recorded a significantly higher dehydration score than all layers except layers 10 and 5. Although layers 10 and 5 recorded the second and third highest dehydration respectively, this was not significant ($P > 0.05$). Bruising was evenly distributed vertically down the bin, with layers 2 and 3 recoding the lowest. Layer 1 recorded the highest bruising of all layers. Layers 2 to 8 (Table 5.1.3) recorded a similar average marketability to the commercial cartons (Table 5.1.2).

Table 5.1.4. Post storage marketability of cauliflowers when stored at 20°C and high humidity for 3 days

	Marketability	Dehydration	Bruising	Turgidity	Black spot
Commercial cartons	4.514[a]	2.257[a]	3.343[c]	0.829	1.229[ab]
Full bin with no load bearing beams	4.580[a]	3.320[c]	2.060[a]	0.520	1.700[c]
Full bin with load bearing beams	4.620[ab]	3.040[c]	2.360[b]	0.480	1.560[c]
Half bin export cut	4.840[b]	2.680[b]	2.120[a]	0.520	1.080[a]
Half bin Domestic cut	4.480[a]	3.280[c]	2.200[b]	0.960	1.480bc
p-value (lsd)	0.024 (0.2212)	< .001 (0.3115)	< .001 (0.1761)	0.069 (0.4002)	0.005 (0.3283)

The half bin export cut treatment recorded the highest overall marketability following storage at high temperature and humidity. Marketability of the full bin no load bearing treatment was similar to commercial cartons. Dehydration was significantly ($P < 0.05$) lower in cartons than all other treatments when analyzed using Anova. Bruising was significantly higher in cartons than all other treatments. The development of black spot in both full bin treatments was significantly ($P < 0.05$) higher than the commercial carton and half bin export cut treatment, but similar to the half bin domestic cut treatment.

Discussion and recommendations

Initial work on cauliflowers showed that it was possible to remove the field heat from both the full and half bulk bins relatively quickly using inexpensive 'forced air cooling'. The half bin treatment proved to be the most sensitive to temperature fluctuations, but it could be readily returned to adequate temperatures when ventilated with cold air. The full bin was not as sensitive to temperature increases but once having heated up, it took longer to cool down again. Cartons took longer to reach an adequate transport temperature in the simulated sea container than both bulk bin types. This was because the bulk bins had better active ventilation with cold air than the cartons once loaded into the simulated sea container.

The marketability of the full bin with no weight bearing was significantly lower than commercial cartons. However the majority of the damage was through dehydration of curds as a result of air flow (Table 5.1.2). Alternatively damage to curds in commercial cartons was mechanical damage resulting from physically pushing curds into the cartons. When layers were compared vertically down the full bin, the majority of the dehydration was located in the top and bottom layers. Reducing the dehydration within these layers to improve marketability of cauliflowers to levels comparable to cartons became the challenge for later storage work with cauliflower reported here.

Economically, a full bin is more cost effective per kg of cauliflower shipped than a half bin because it wastes less space in the sea container and less timber is used per kg of cauliflower packed than a half bin. A full bin would allow 9.75 tonne or 20 full bins weighing 488kg to be exported in a 20 ft sea container versus 8 tonne or 30 half bins weighing 269 kg each. However, results for half bins showed faster pre cooling and better out-turns for export cut cauliflowers than for those packed in full bins.

Shelf life assessment followed a similar trend to post storage assessments with bulk bin treatments suffering from dehydration and commercial cartons suffering from bruising damage. The damage recorded post storage would have been exacerbated by the high temperatures and humidity over the three day 'shelf life' period. A strong relationship exists between black spot and dehydration, suggesting that the black spot is a result of excessive water loss from the product.

This preliminary work suggested that it was possible to increase the marketability of cauliflowers in full bins to levels similar to commercial cartons by reducing curd dehydration. It was considered important therefore to investigate different bin flooring types and lids on bins that may reduce water loss during transport. Limiting dehydration during transport would increase marketability at the destination.

Temperatures during the storage phase (shipping simulation) of the work suggested that it was important for future trials to reassess the simulation technique and make it more like a voyage in a sea container. The use of an actual refrigerated sea container in conjunction with pre cooling was considered essential to get more meaningful results.

5.2 Broccoli development

MATERIALS AND METHODS

Broccoli work began with produce sourced from the Manjimup district on 21 March 2005. Broccoli was harvested and sorted in the field into two bulk bins. During field packing, temperature loggers where placed in each bin. The bulk bin trial harvest was left to late in the day to increase the in-field temperature of the broccoli and create a worse case scenario. Immediately following harvest, filled bins were transported to Manjimup Horticultural Research Institute and pre cooled.

Three treatments were created in the field and each was then compared to Broccoli packed in polystyrene boxes, together with ice.

1. Broccoli in cartons.
2. Full depth bin without load bearing supports.
3. Full depth bin with load bearing supports.
4. Half depth bin.

During packing, load bearing supports were secured at the mid point of the full bin (vertically) and placed half way across the bin (horizontally) to create treatment 3. The load bearing supports were made of lightweight pine covered in plastic to reduce damage to produce. The opposite side of the full bin did not have any load bearing boards (Figure 5.1.1).

Broccoli heads for packing in commercial cartons made from polystyrene (control) were also harvested, cooled and packed on Monday, 21 March 2005. These were packed by the grower at his packing house, after which they transported to Manjimup Horticultural Research Institute (MHRI). At the Institute these were stored in the cool room next to the bulk bin treatments

Once at the Research Institute, bins were removed, weighed and stacked in a humidified cool room (Therm fresh®) in a ‘two bin’ stack with a full bin on the bottom and half bin on top. Produce was then cooled to 2.5ºC. Cooled produce was removed from the ‘Plenum fan’ and placed up against a smaller portable fan (Ventilation fan) in the cool room. This fan was used to simulate air flow through the bins, as it would happen in a sea container. Cartons were stored adjacent to bulk bin treatments in the cool room without ‘flow through’ ventilation. All produce remained in storage for 17 days until 6 April 2005 to simulate a sea voyage.

Assessment for marketability

After 17 days, bulk bins were removed, weighed and assessed for the following characteristics (in order of importance).

1. Overall marketability (ranked on a scale of one to seven, one = worst and seven the best).
2. Turgidity (classed into very turgid = 0, average turgidity = 1 and poor turgidity = 2).
3. Bruising or mechanical damage.
4. Yellowing of buds on heads.

Sampling involved removing produce from each layer vertically down the bin, 11 layers for a full bin and 6 for a half bin. Ten broccoli heads where removed at each layer and laid out on the floor (Figure 5.2.1) for assessment. Cartons were sub sampled at the same ratio used for bulk bins.

Figure 5.2.1. Sub sampling of broccoli layers for sampling.

Following the initial assessment broccoli was stored to test shelf life. Broccoli florets were stored for 3 days at 20°C in a humid laboratory separated into assessment layers. After 3 days, produce was assessed for overall marketability and downgraded for blemishes. Rejection reasons noted included yellowing and rots.

RESULTS

Pre cooling trends recorded for each packaging method showed a vast difference between commercial cartons and bulk handling treatments. Commercial cartons packed with ice, reduced the temperature of broccoli florets to below 1°C, initially. Cooling in half and full bin treatments required 1 hr 15 mins and 3 hrs 15 mins respectively to remove field temperature. Bulk bin treatments recorded slight increases in temperature during weighing, but returned quickly to prior temperatures when put back on a ventilation fan.

Four days into storage the temperature of iced broccoli in cartons started to increase, by day 9 temperatures were above 3°C and rising. Both bulk bin treatments experienced temperature rises to above 3°C at day 10 and 11, but recovered quickly.

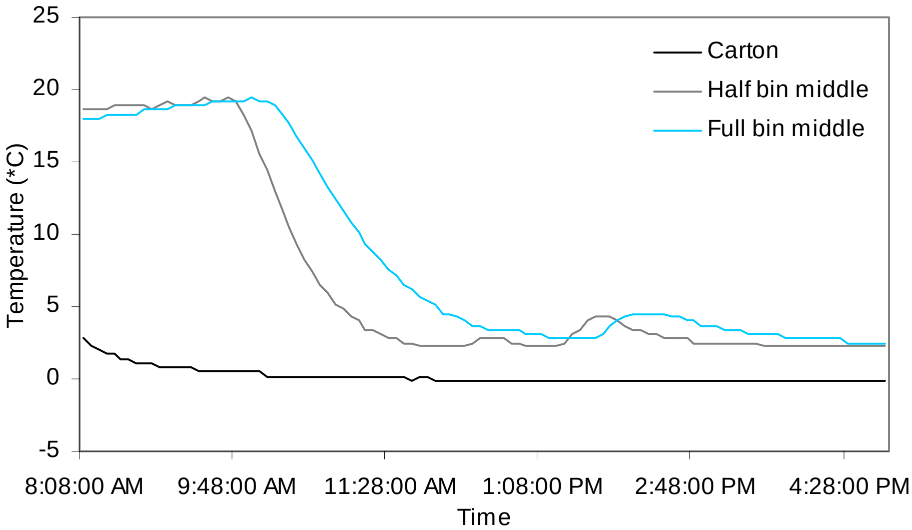


Figure 5.2.2. Pre cooling trends for broccoli packed in cartons or bulk bins. Broccoli core. Temperatures are from the middle of bins are shown for the two bulk bin treatments.

Table 5.2.1. Treatment weights of broccoli following each handling process

Treatment	Harvest weight (kg)	Post FAC[b] weight (kg)	Weight loss during FAC (%)	Post storage weight (kg)	Weight loss during storage (%)	Total weight loss (%)
Full bin	335.5	333	0.75	328	1.50	2.2
Half bin	179	176.5	1.39	173	1.983	3.35
Commercial cartons (ave)	8	8	0	8	0	0

a FAC = Forced Air Cooling.

Full bin and half bin packaging options both recorded weight loss. The half bin treatment experienced greater weight loss than the full bin treatment during each segment of the cool chain. Commercial cartons did not record weight loss because of the impermeable foam containers, and the presence of free ice sealed into the cartons.

Table 5.2.2. Average marketability, dehydration and bruising for the four packaging options after 17 days storage

Treatment	Average marketability	Average turgidity (%)	Poor turgidity (%)	Yellowing (%)	Mechanical damage (%)
Commercial cartons	5.150[c]	2.5[a]	0.0[a]	10.0[a]	65.0[c]
Half bin	4.983[bc]	21.7[c]	11.67[c]	30.0[b]	6.7[a]
Full bin with no load bearing supports	4.691[a]	13.6[bc]	5.45[b]	41.2[b]	22.6[b]
Full bin with load bearing supports	4.864[ab]	7.3[ab]	4.55[ab]	33.6[b]	21.0[ab]
p-value (lsd)	0.005 (0.2485)	0.006 (10.72)	< 0.001 (4.7528)	< 0.001 (12.61)	< 0.001 (14.55)

Average marketability of heads in commercial cartons was significantly ($P<0.05$) higher than in both full bin treatments but not the half bin treatment when analysed using Anova. Average and poor turgidity of heads in the full bin with no load bearing supports and half bin was significantly higher than in commercial cartons. Bulk bin treatments had significantly more yellowing of heads when compared to commercial cartons. Mechanical damage to florets in cartons was significantly higher than any damage resulting from bulk bin treatments.

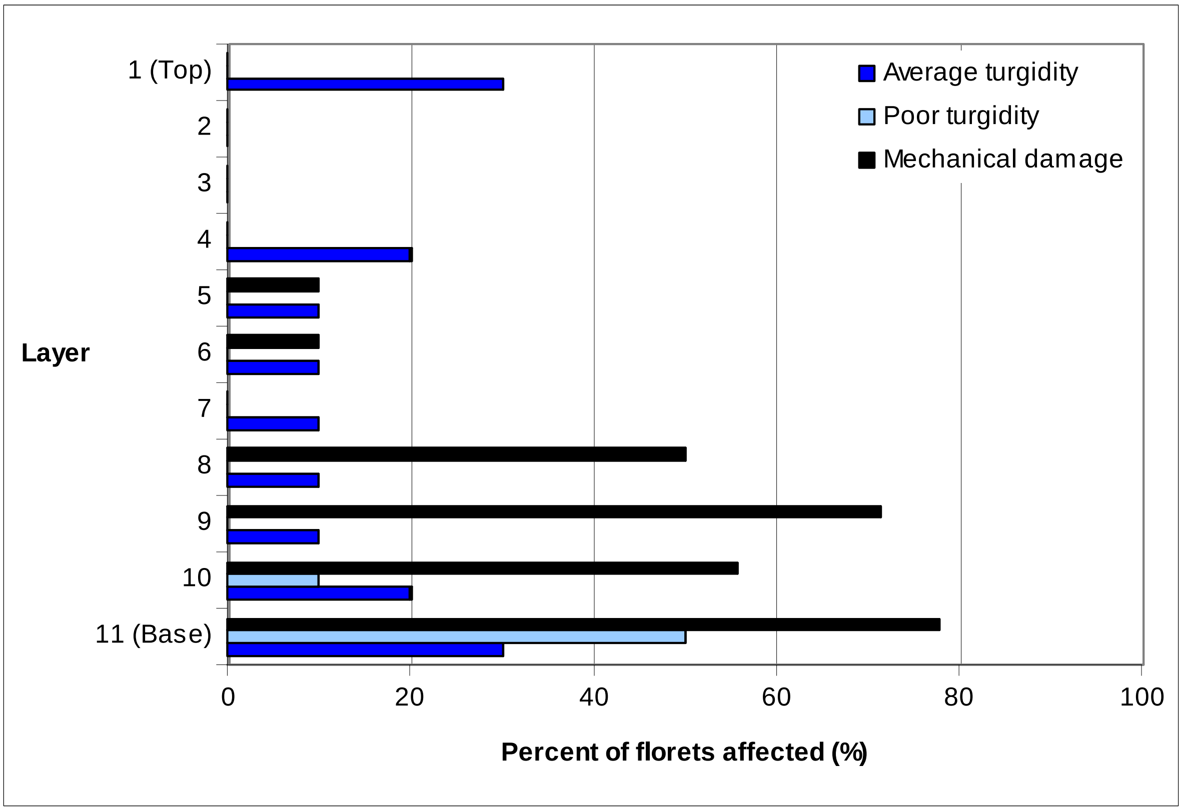


Figure 5.2.3. Cmparison of turgidity and mechanical damage to heads in layers vertically down the full bin treatment (no load bearing) after 17 days storage.

Comparison of heads in each layer of the full bin with no load bearing showed more turgidity damage in the top and bottom layers. Poor turgidity was significantly higher $X^2(10, \underline{N}110) = 43.670$, $p<0.05$ in the bottom layers of the bulk bin treatment. Mechanical damage recorded a similar $X^2(10, \underline{N}=110) = 42.776$, $p<0.05$ trend for heads affected when analysed using Kruskal - Wallis test.

Table 5.2.3. Marketability of broccoli following storage at high temperature and humidity for 3 days after the transport period

Treatment	Average marketability	Average turgidity (%)	Poor turgidity (%)	Yellowing (%)	Rots (%)
Commercial cartons	4.125[bc]	7.5	5.0	40.0	30.0[ab]
Half bin	4.317[c]	11.7	3.3	46.7	18.3[a]
Full bin with no load bearing supports	3.736[a]	21.8	9.1	28.2	40.0[b]
Full bin with load bearing supports	3.891[ab]	15.5	7.3	24.5	46.4[b]
p-value (lsd)	0.001 (0.2873)	NS	NS	NS	0.008 (16.40)

***NS - no significant difference.**

Following three days storage, the broccoli in the half bin was significantly ($P<0.05$) more marketable than in full bins, but was similar to commercial cartons. The full bin with no load bearing supports recorded the lowest marketability following storage. Average turgidity, poor turgidity and yellowing did not show significant differences, but the full bin recorded the highest percentage of heads in both turgidity categories, whilst heads in cartons recorded a high percentage of yellowing. A significantly greater occurrence of rots in the full bin treatment was recorded than in half bin treatments, but was similar to commercial cartons.

DISCUSSION AND RECOMMENDATIONS

Initial investigations on bulk bins for exporting broccoli proved very encouraging. Cooling rates of the broccoli in bins were sufficiently fast to remove the field heat from the produce, whilst minimising weight loss. In the event of temperature fluctuations during storage (transit), the temperature of the produce would quickly draw down again. Commercial cartons showed a rising temperature trend after 4 days storage, suggesting that as the ice packed into these cartons melted, the temperature would rise steadily. These cartons are very well insulated and are not able to dissipate unwanted heat of respiration, unlike the ventilated bulk bins.

An average ‘20 foot’ sea container loaded with full bulk bins can hold approximately 6.7 tonnes of broccoli, compared to only 5.4 tonnes if loaded with half bins. By contrast, only 3.6 tonnes of broccoli can be loaded into the same container when packed in standard commercial cartons topped with ice. The large difference in net weights between bulk bins and cartons for this product is the result of the poor space efficiency inherent in thick walled polystyrene boxes. Bulk bins remove the need to transport this inefficient, and high cost, packaging to the market.

The average marketability of broccoli heads in full bulk bin treatments were significantly below the conventional carton method. Heads in bulk bins were rejected for lacking turgidity while heads from commercial cartons, showed more mechanical damage. Produce was significantly more flaccid at the tops and bottoms of the bins.

From the results of this preliminary work, the major challenge that broccoli handling presented for the remainder of the project was to increase the turgidity of heads at the top and bottom of bins to levels acceptable to the market. Changes to the size and number of ventilation holes in the base of bins and including a top or lid on bins to manage the airflow rates while in transit were considered to be possible ways to address this problem.

Yellowing of buds on some heads after the 17 day storage period suggested that the bulk bin treatments had an adverse effect on shelf life. However, the maturity of produce packed in the bins appeared to have an effect on the occurrence of yellow buds. It was observed that small heads picked at the optimum maturity did not yellow in storage, while large heads beyond the optimum maturity did.

Initial work suggested that it was possible to transport broccoli using the bulk bin method and that minor adjustments are required to increase the marketability of the produce. Also noted was the large difference in sea container weight between conventional cartons and bins which is a significant benefit attributable to bulk handling.

5.3 Sweetcorn development

MATERIALS AND METHODS

Sweetcorn was originally sourced from the Manjimup district on 30 March 2005. Corn cobs were harvested and graded in the field into two bulk shipping bins. During packing, temperature loggers were placed in each bin. Immediately following harvest, one full bin was transported to Manjimup Horticultural Research Institute and pre cooled using forced air cooling (FAC). The other was taken to a local packing company and vacuum cooled (VAC) using a 'Hydrovac' cooler. Extra cobs were pre cooled using VAC, after which it was packed into commercial cartons at Manjimup Horticultural Research Institute.

Figure 5.3.1. Vacuum cooler used to pre-cool sweetcorn in commercial cartons and bulk bin treatments.

During packing, load bearing supports were secured at the centre point of both full bins (vertically) and half way across the bin (horizontally) as described previously for cauliflower and broccoli. Load bearing supports were made of lightweight pinewood covered in thin plastic pallet wrap to reduce damage to produce. The opposite side of the full bin did not have any load bearing boards (Figure 5.1.1). Bulk bins were weighed at each stage of the handling process.

The extra VAC cooled cobs were used to pack commercial cartons after they had been pre cooled. Each carton was packed after cooling and stacked adjacent to bulk bin treatments in a cool room at Manjimup Research Horticultural Research Institute.

The treatments were as follows:

1. Cartons.
2. FAC no load bearing supports.
3. FAC load bearing supports.
4. VAC no load bearing supports.
5. VAC load bearing supports.

Following pre-cooling, bulk bins were weighed and stacked on top of each other in the humidified cool room. A smaller portable fan (ventilator fan) was placed up against the fork gaps of the bin and plastic wrapped around to form a seal (Figure 5.3.2). This fan was used to simulate the air flow that would move through the bins if they were in a sea container. The produce remained in storage for 20 days to simulate a sea voyage until 19 April 2005.

Figure 5.3.2. Sweetcorn bulk handling treatments with ventilator fan attached to rear.

Assessment for marketability

After 20 days, bulk bins were removed, weighed and the produce was assessed for the following characteristics (in order of importance).

1. Overall marketability (ranked on a scale of one to seven, 1 = worst and 7 = the best)
2. Burst kernels (scored as: none = 1, average = 2 and severe = 3)
3. Pinching of individual kernels (scored as: no pinching = 1, average pinching = 2 and severe pinching = 3).

Sampling involved removing produce from each layer vertically down the bin. Layers were removed from each treatment, and laid out on the floor (Figure 5.3.3) for assessment. Three cobs were assessed for every three layers of the bulk bins (21 layers total) for each treatment. Cartons were sub sampled at the same ratio used for bulk bins.

Figure 5.3.3. Assessment of corn from bulk bins.

Following the initial assessment cobs were stored to test shelf life. Sweetcorn cobs were stored using the same method as for cauliflower and broccoli for 3 days at approximately 20°C in a humid laboratory to assess shelf life. After 3 days, produce was assessed for marketability overall and downgraded for blemishes. Rejection reasons were noted included bruising, pinching and rots.

RESULTS

There were large differences between the pre-cooling methods in their effectiveness. FAC cooling was very slow to remove the field heat from the full bin treatment requiring 1 day 3 hours and 45 minutes to reach 3°C. VAC cooling of full bins required 1 hr 45 minutes to remove field heat. However, probes in the centre of the VAC bin suggested that the temperature quickly rose again once the vacuum was removed. The residual heat was subsequently slowly removed over 8 days. Temperatures recorded at the top of the bin did not rebound to the same extent as those recorded at the centre of the bin.

The sweetcorn used in commercial cartons only required 1 hour to remove field heat. When repacked into cartons temperatures rose, requiring nearly two weeks for core temperatures to decrease to 3°C. Commercially packed cobs in cartons reached higher temperatures during shelf life assessment than both bulk bin treatments.

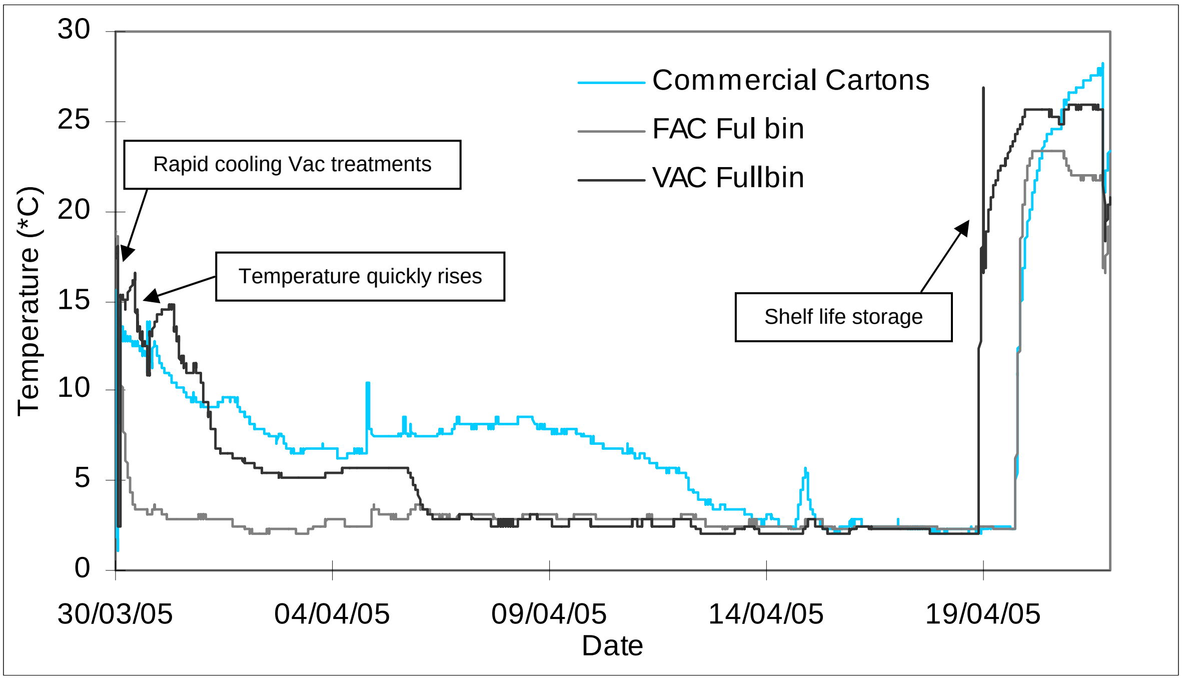


Figure 5.3.4. Pre cooling trend of sweetcorn packed into cartons or bulk bins that were pre-cooled using FAC or VAC cooling methods.

Table 5.3.1. Sweetcorn treatment weights following each handling process.

Treatment	Harvest weight (kg)	Post pre-cooling weight (kg)	Weight loss during FAC (%)	Post storage weight (kg)	Weight loss during storage (%)	Total weight loss (%)
Full bin	391.5	379.5	3.065	366.5	3.32	6.38
Half bin	406.5	404.5	0.5	387.5	4.2	4.67
Commercial cartons (ave)	0	10.7	0.5	10.3	4.3	4.8

All treatments experienced weight loss. The full bin FAC recorded the highest weight loss of all treatments. The VAC cooled full bin recorded the lowest weight loss, with the majority of this occurring during storage in the cool room.

Table 5.3.2. Average marketability for the four packaging options after 20 days storage.

Treatment	Average marketability
Cartons	5.150^{c}
FAC no load bearing beams	4.983^{bc}
FAC load bearing beams	3.190^{a}
VAC no load bearing beams	4.190^{c}
VAC load bearing beams	4.762^{d}
p-value (lsd)	< 0.001 (0.2545)

The full bin with load bearing beams vacuum cooled recorded a significantly (P<0.05) higher marketability than all other treatments when analysed using Anova. Full bin treatments that were forced air cooled recorded the lowest marketability. Cartons of corn recorded similar marketability to vacuum cooling in a bin with no load bearing beams.

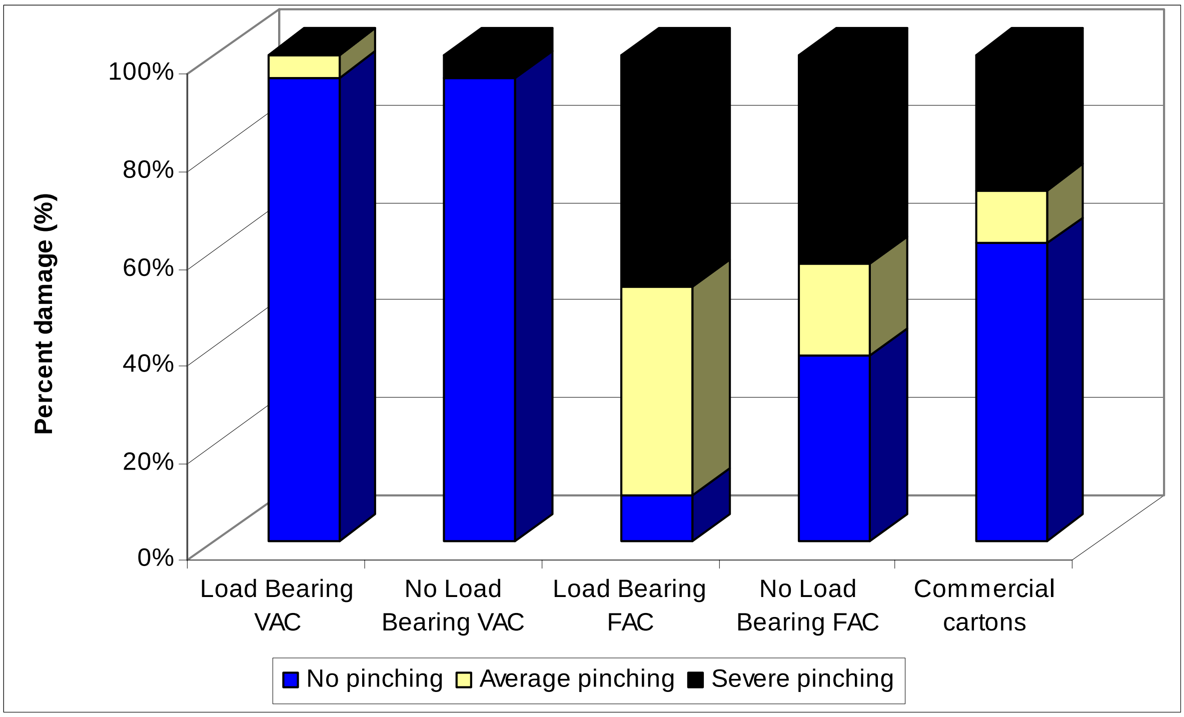


Figure 5.3.5. Percentage of sweetcorn cobs with varying levels of pinching (kernel dehydration) for each packaging method.

A significantly ($P<0.05$) higher percentage of corn cobs with no pinching was recorded for both vacuum cooled full bin treatments. Occurrence of severe and average pinching was highest for treatments cooled using forced air (FAC). Commercial cartons also recorded a high percent of corn cobs with pinching damage even though these had been pre cooled using VAC.

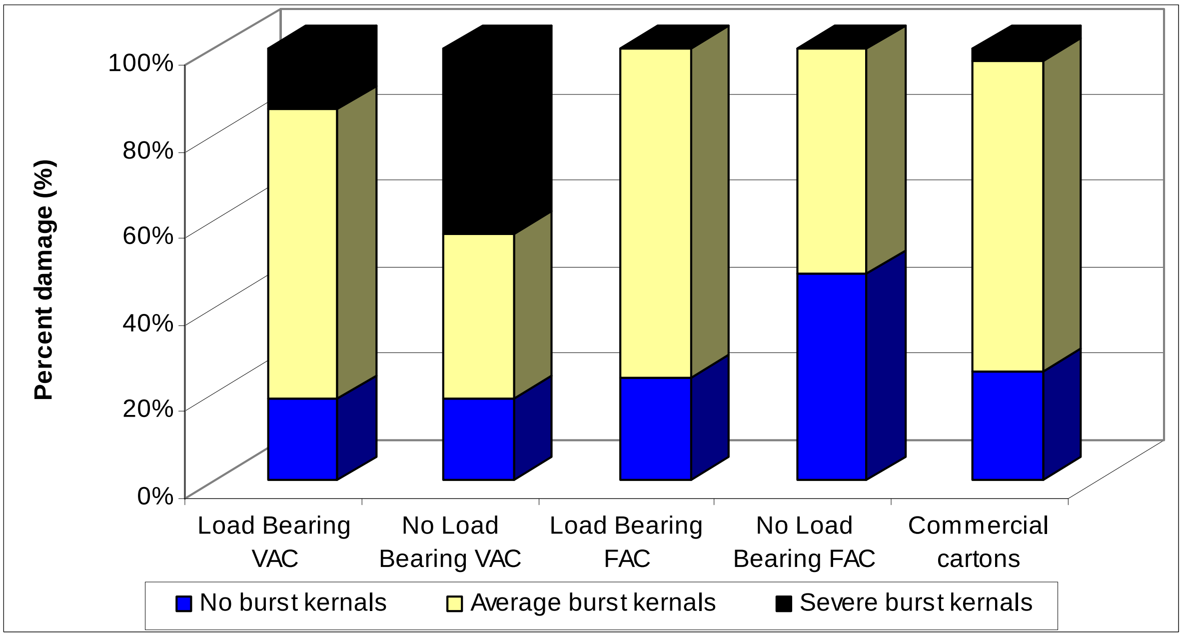


Figure 5.3.6. Percentage of sweetcorn cobs with varying levels of burst kernels for each packaging method.

Severely burst kernels were only recorded in treatments cooled using vacuum cooling, including those in commercial cartons. Forced air cooled treatments also recorded burst kernels but at a lower severity. The number of corn cobs that had not burst for all treatments was similar, excluding the full bin no load bearing FAC.

Table 5.3.3. Average marketability and incidence of rots for the four packaging options after the 3 day shelf life test

Treatment	Average marketability	Incidence of rots (%)
Cartons	3.70[b]	33.3[b]
FAC no load bearing beams	2.72[a]	40.0[b]
FAC load bearing beams	2.97[a]	45.0[b]
VAC no load bearing beams	4.35[c]	10.0[a]
VAC load bearing beams	4.52[c]	12.5[a]
p-value (lsd)	< 0.001 (0.4273)	< 0.002 (20.08)

Vacuum cooled bulk bin treatments recorded a significantly (P<0.05) higher average marketability than all other treatments including commercial cartons when analysed using Anova. Forced air cooled bulk bin treatments recorded a significantly (P<0.05) lower average marketability than commercial cartons after the shelf life test. Incidence of rots was significantly lower in VAC cooled bulk bins than all other treatments.

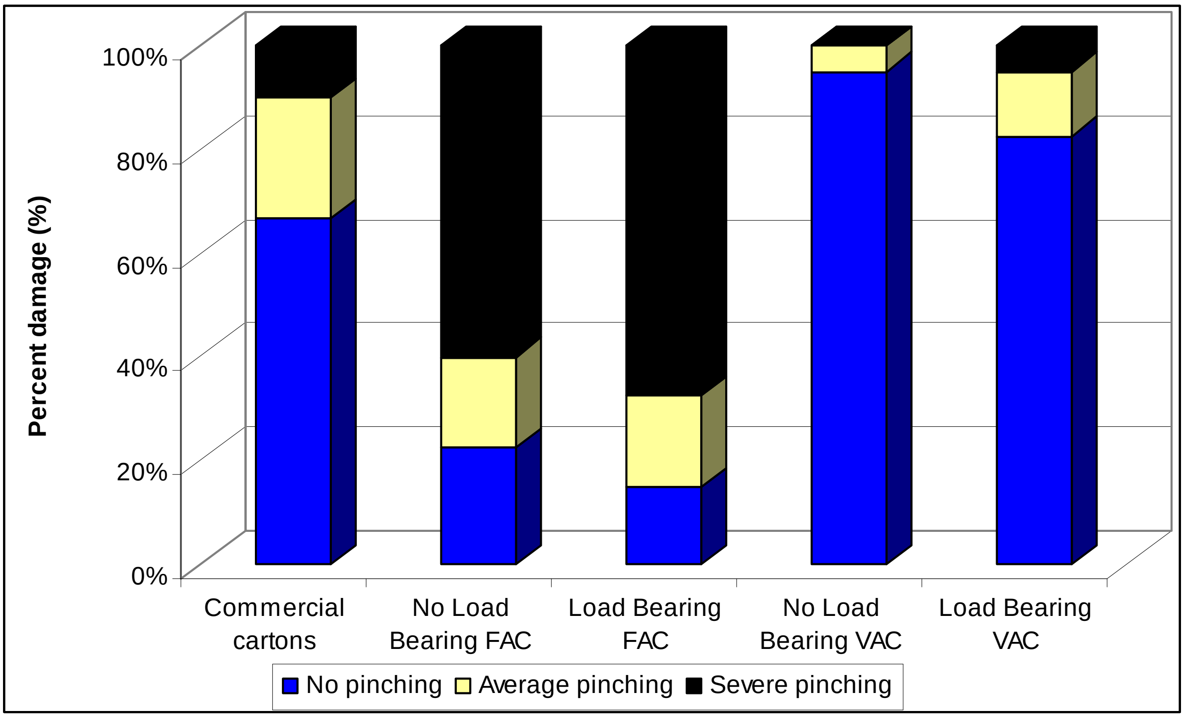


Figure 5.3.7. Percentage of sweetcorn cobs with varying levels of pinching (kernel dehydration) for each packaging method after the shelf life storage test.

Following shelf life storage both FAC cooled bulk bin treatments recorded significantly higher percentages of pinching than all other treatments. Ninety five per cent and 82.5% of cobs in the VAC cooled bulk bin treatments showed no signs of kernel pinching.

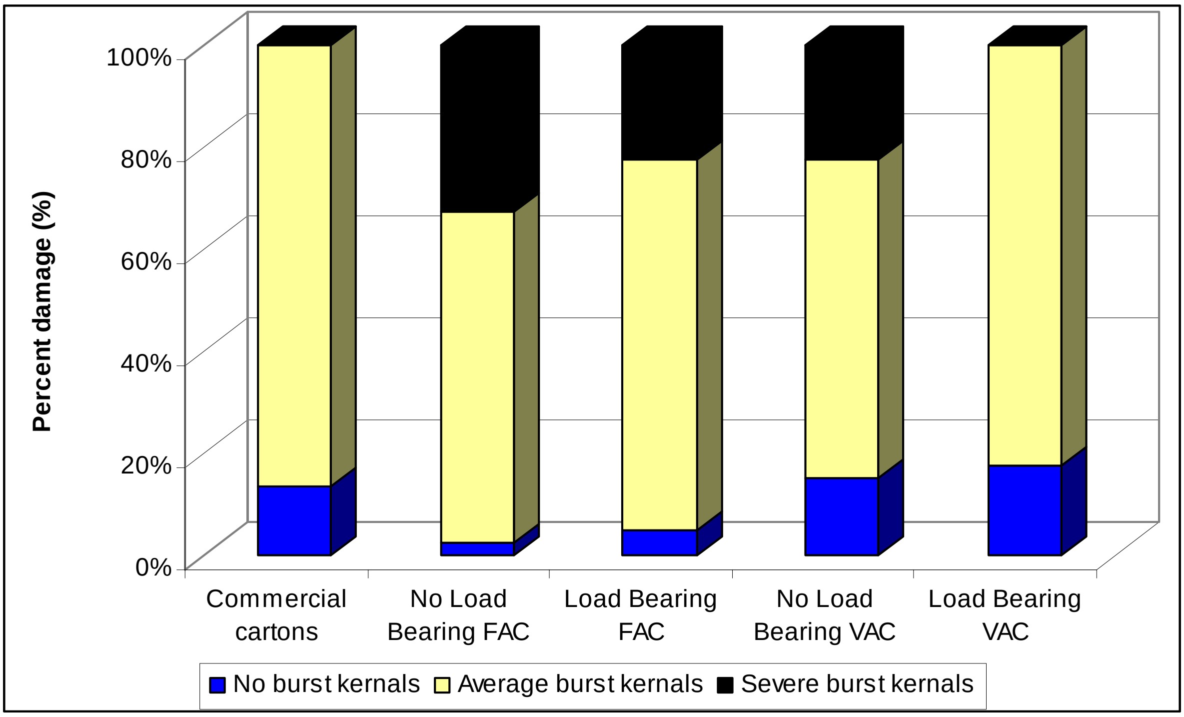


Figure 5.3.8. Percentage of sweetcorn with varying levels of burst kernels for each packaging method after the shelf life storage test.

After shelf life storage, three of the five treatments showed severely burst kernels in both the FAC bulk bin treatments and the VAC no load bearing treatment. The percentage of ‘average burst kernels’ and ‘no burst kernels’ were similar for all treatments.

DISCUSSION AND RECOMMENDATIONS

Vacuum cooling of sweetcorn in bulk bins was effective in lowering the temperature of the produce quickly after harvest. Temperature monitoring of this trial sample suggests that VAC cooled sweetcorn in bulk bins needs to be kept at a low temperature ($1^{O}C$) for a significant period of time before the product is removed from the vacuum cooler. Doing so may prevent the sudden increase in core temperature of the product that was observed in this experiment immediately after the vacuum was removed.

Vac cooling in bulk bins produced corn cobs at, or superior to, those stored in commercial cartons and far superior to cobs that were FAC cooled in bulk bins. This difference was correlated with the higher percentage weight loss (generally moisture) during the cooling process of the FAC bin treatments. The FAC process for corn removed any excess moisture from around the cobs, effectively dehydrating them. The result was large percentages of corn cobs with average and severely pinched corn kernels.

Vacuum cooling was successful at producing corn cobs with a higher marketability. However it did produce higher numbers of severely burst kernels, due the low pressure conditions used in vacuum cooling. Burst kernels were consistently found across all treatments suggesting that crop maturity was a major factor associated with this damage. VAC cooling exacerbated the severity of this disorder.

Shelf life studies showed similar trends to the storage tests. VAC cooling again recorded higher marketability than commercial treatments, due to low pinching and similar bruising levels. Assessment of rot incidence also suggested that rots occur significantly less in VAC cooled produce. Vacuum cooling is recommended as the preferred method of cooling of sweetcorn in bulk bins.

6. 'LAND BASED' SEA CONTAINER TRIALS

General introduction

Preliminary work carried out on broccoli and cauliflower showed that bulk packing and handling of these products from the field followed by prompt pre cooling using modified forced air cooling (FAC) gave promising out turns after periods of storage that simulated sailing times to export markets in Australia's region. However, refinements to the techniques would be required to increase the marketable percentages of these products to acceptable levels.

Past experience with iceberg lettuce and the preliminary studies indicated that heading vegetables such as lettuce, broccoli and cauliflower packed in bulk bins had higher levels of dehydration on out-turn compared to traditional methods (cardboard or polystyrene cartons). The latter produced higher levels of mechanical damage than produce packed in bulk bins, and this damage was mostly incurred during the packing process. Damaging levels of dehydration were located mainly in the top and bottom layers of the bulk bins. The new aim of the work from this point on in the project became a quest to reduce dehydration in bulk handled produce to levels equal to or less than that found in conventionally handled products in cartons.

The preliminary work with broccoli showed that the maturity level of the produce was very important in determining the quality of out-turn after storage and transport. Over -mature broccoli heads showed excessive yellowing of buds and the advanced degradation of produce during the simulated sea shipment described earlier. The effects of product maturity and size on the quality of out-turn for bulk shipments needed further study and this became a secondary aim of work conducted after this time.

Preliminary work that attempted to simulate sea container conditions in a humidified coolroom with forced ventilation were considered to not adequately represent the conditions that would be experienced in a sea container. Work conducted after this time was done in a rented 20' refrigerated sea container which had recently been taken out of service. This container remained land based (static) for the trial work that was conducted in it, and trial shipments using best management techniques were shipped to selected export destinations as separate exercises together with conventionally packed commercial produce. The reason for choosing an old sea container to do the work was that handling techniques developed from this research had to be robust enough to work with the oldest and the newest sea containers in service to be ready for adoption by industry.

6.1 Packing methods for iceberg lettuce

INTRODUCTION

Observations made on trial shipments of iceberg lettuce completed during project VG99014, suggested that improvements to marketability of the product could be made by relatively minor changes to packing and handling methods. Essential requirements for any modifications to practices were that they should incur minimal extra cost and could be incorporated easily into the current process while significantly improving the quality of the produce at out-turn.

The main problem identified was excessive levels of dehydration of wrapper leaves on heads at the top and bottom of bulk bins. The possible causes of this were considered to be excessive ventilation rates through the bins in transit in the sea container and a possible drying effect from un-waxed cardboard bases in the bins.

The problem at the bottom of bins could be addressed by testing a waxed cardboard base versus a conventional un-waxed base, while dehydration of the top was to be targeted by testing different cardboard lids for the bins. Ventilation rate could be inexpensively managed by restricting airflow through the floor and top of the bins by the size and number of holes in the base and lid cardboard sheets in the bins.

Dehydration of lettuce was mostly wilting of the outer wrapper leaf. A reduction in dehydration of the wrapper leaves of heads located at the top and bottom of the bulk bin would lead to a lower labour requirement to remove these leaves on arrival at the destination.

Another problem specific to lettuce transported in full depth bulk bins was that heads at the bottom of the bin tended to be squashed and deformed by the weight of produce above them. It was considered that head density, head size and variety of lettuce may influence the degree to which this was a problem. Research was planned to investigate these aspects also.

6.1.1 Bin base comparison

Materials and methods

Iceberg lettuce grown at Medina Research Station was sourced on Friday, 14 October 2005 and packed into a full depth bulk bin. During packing, a logger was located to measure the core temperatures of lettuce in the middle and at the top of the bulk bin. Produce in the full bin was pre cooled using the method outlined in Chapter 4. After pre-cooling, the produce was removed and placed in a refrigerated sea container set at 0.5°C for 20 days to simulate a sea voyage.

The floor of the full bin was divided into two halves, consisting of a waxed base on one half and un-waxed cardboard base on the other side (Figure 6.1.1.1).

Figure 6.1.1.1. Un waxed (left) and waxed (right) base treatments.

Following 20 days storage, the produce was removed and assessed. Assessment involved removing five heads each from the waxed and un-waxed sides of the bin for seven layers spaced evenly vertically down the bin. Once sorted, produce was given a marketability rating (ranked on a scale of one to seven, one = worst and seven the best) and a reason for rejection (given for a score of 4 and below).

Results

The marketability of produce with a waxed cardboard base was not significantly different ($P>0.05$) to produce with an un-waxed base in the bulk bin. A similar trend occurred when produce was compared from the bottom two layers only. The majority of produce was down graded due to the incidence of rots, not dehydration.

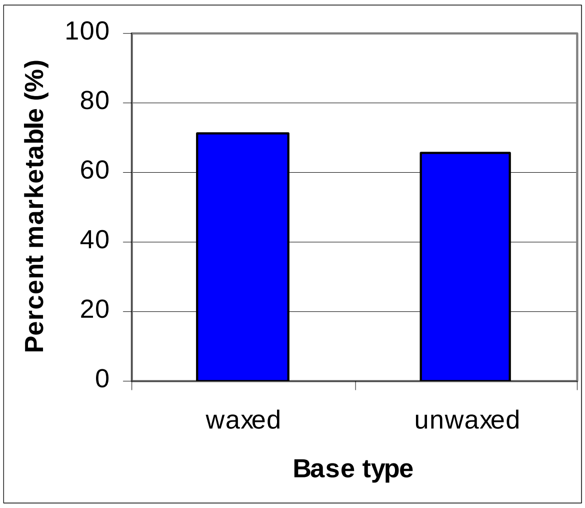


Figure 6.1.1.2. Percent marketable produce for the entire bulk bin.

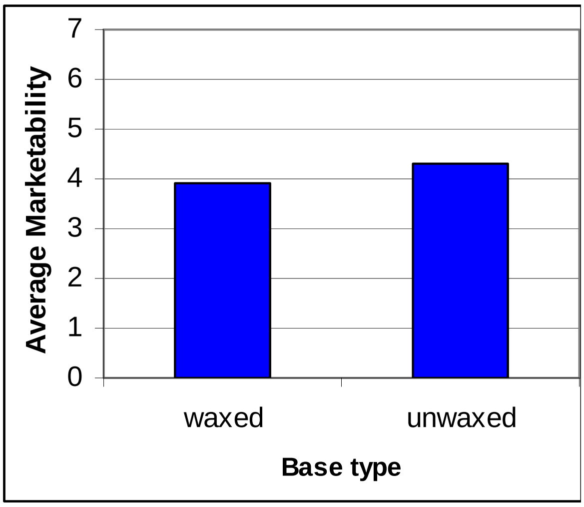


Figure 6.1.1.3. Average marketability of produce in the bottom two layers of the bulk bin.

Figure 6.1.1.4. Produce located at the top of a full bulk bin.

Discussion and recommendations

Produce out turned from bulk bin treatments (waxed or un-waxed bases) was very little different with respect to overall marketability. Produce was mostly rejected due to the incidence of rots. This suggests that either a waxed or un-waxed base is suitable for lettuce exported in bulk bins, but a degree of wrapper leaf dehydration cannot be overcome by modifying bases alone.

Dehydrated wrapper leaves were observed on lettuce at the top layer of the bin for both base types. It is possible that these could be removed at the destination to provide a near perfect lettuce using lower cost labour than available in Australia. However further work to control the dehydration is required.

6.1.2 Harvest time, storage time, bin depth and variety comparison

Introduction

A bulk planting of lettuce was grown at the Manjimup Horticultural Research Institute in the summer of 2005/06 with the aim of supplying enough iceberg lettuce for a trial export shipment. Problems experienced with dehydration of top and bottom layers in bulk bins in preliminary storage trials led to a change of plan and the produce was redirected to Medina Research Station near Perth where the 'land based' trial sea container was located. The bulk planting included two different lettuce cultivars, and it was able to be harvested at a number of consecutive dates to assess the effects of crop maturity on packing and transportability of the product.

Currently, lettuce is transported in waxed dipped cardboard cartons and heads are individually wrapped with waxed paper. This method does not allow any airflow through the produce unlike the bulk bins, but it does result in less dehydration of head wrapper leaves overall than we had noted on the top and bottom layers of bulk bins. The bulk crop of lettuce provided sufficient product to test a range of bin treatments in large enough quantities to fill the trial sea container. Treatments that restricted the ventilation rate in bins and reduced dehydration were thus able to be tested in commercial quantities, as well as different storage durations representing different export destinations.

Materials and methods

A single planting of 17,000 iceberg lettuce was made on 11 and 12 October 2005. Of the seedlings 11,000 were cv. Toronto and 6,000 cv. Ardinas. The crop was grown according to current best practice management techniques for the Manjimup region.

To determine the maturity effect on the marketability of iceberg lettuce, harvest was completed on three different dates - 7 December 2005 (early), 12 December 2005 (mid) and 15/16 December 2005 (late). The mid harvest was determined as the optimum timing for lettuce harvest in terms of maturity. Lettuce was packed directly into bulk bins on the harvester. Once full, the bulk bins of lettuce were pre-cooled to 2.5°C. Treatments that required sealing (Table 6.1.2.1) were sealed. The full bins were transported to Medina using refrigerated trucks arriving late in evening, a road trip taking around 5 hours 30 minutes. The bins were then stored in an exporters' cool room overnight and relocated a short distance to Medina Research Station the next morning. Once at Medina, all bulk bin treatments were immediately loaded directly into the sea container for storage.

As well as crop maturity, storage time, cultivar, bin size and restricted ventilation using sealed or unsealed bin lids, were tested to determine their effect on marketability. The treatments combinations for each bulk bin are outlined in table 6.1.2.1.

Table 6.1.2.1. Iceberg lettuce treatments for a simulated sea voyage

Treatment	Variety	Harvest maturity	Modular bulk bin size	Sealed or unsealed top	Storage time (days)
1	Toronto	Mid	Half	Open	21
2	Toronto	Mid	Full	Open	21
3	Ardinas	Mid	Half	Open	21
4	Ardinas	Mid	Full	Open	21
5	Toronto	Early	Half	Open	21
6*	Ardinas	Mid	Full	Closed	21
7	Ardinas	Early	Half	Open	21
8	Toronto	Early	Full	Open	21
9	Ardinas	Early	Full	Open	21
10	Toronto	Mid	Half	Closed	7
11	Toronto	Mid	Full	Closed	7
12*	Toronto	Early	Full	Closed	21
13	Toronto	Mid	Full	Closed	28
14	Toronto	Mid	Full	Open	28
15	Toronto	Late	Half	Open	21
16	Ardinas	Late	Half	Open	21
17*	Toronto	Mid	Full	Closed	21
18	Toronto	Late	Full	Open	21
19	Ardinas	Late	Full	Open	21
20*	Ardinas	Late	Full	Closed	21
21*	Ardinas	Early	Full	Closed	21
22*	Toronto	Late	Full	Closed	21

*** Bulk bins for these treatments were split vertically to accommodate further treatments.**

After the designated storage period, bulk bins were removed, weighed and assessed. A sample of produce was assessed for the following characteristics (in order of importance).

1. Marketability 1, with wrapper leaves on (ranked on a scale of one to seven, one = worst and seven the best).
2. Marketability 2, with wrapper leaves removed (ranked on a scale of one to seven, one = worst and seven the best).
3. Mechanical damage (ranked on a scale of one to three, 1 = grazing, 2 = squashing and 3 = breaking.).
4. Presence of a wilted wrapper.
5. Presence of pink vein.
6. Presence of rots.
7. Rots on wrapper leaf.

Sampling involved removing produce from layers vertically down the bin, 6 layers for a full bin and 4 for a half bin. Sampled layers were 0, 20, 40, 60, 80 and 100cm deep from the top for full bins. Half bins were only sampled to 60cm (bottom). Ten lettuce heads where removed at each layer and assessed as a sub sample.

Results

Table 6.1.2.2. Average head counts and bin weights at each storage time

Modular bulk bin size	Variety	Harvest maturity	Weight prior to storage (kg)	Weight post storage (kg)	Head count	Average head weight (g)
Full	Ardinas	Early	388	388	849	457.01
Full	Ardinas	Mid	414	409	664	615.96
Full	Ardinas	Late	538	534	658	811.55
Full	Toronto	Early	353	347	704	492.90
Full	Toronto	Mid	429.75	425	566.5	750.22
Full	Toronto	Late	500	498	648	768.52
Half	Ardinas	Early	210	200	395	506.33
Half	Ardinas	Mid	260	230	317	725.55
Half	Ardinas	Late	350	327	409	799.51
Half	Toronto	Early	200	195	389	501.29
Half	Toronto	Mid	272.5	268	368	728.26
Half	Toronto	Late	324	314	408	769.61

Toronto packaged in full bins at the perceived optimum harvest time produced near the maximum average head weight, but were still considered suitable for a processing end use. Lettuce from a late harvest recorded higher average head weights, but heads were considered too dense for processing.

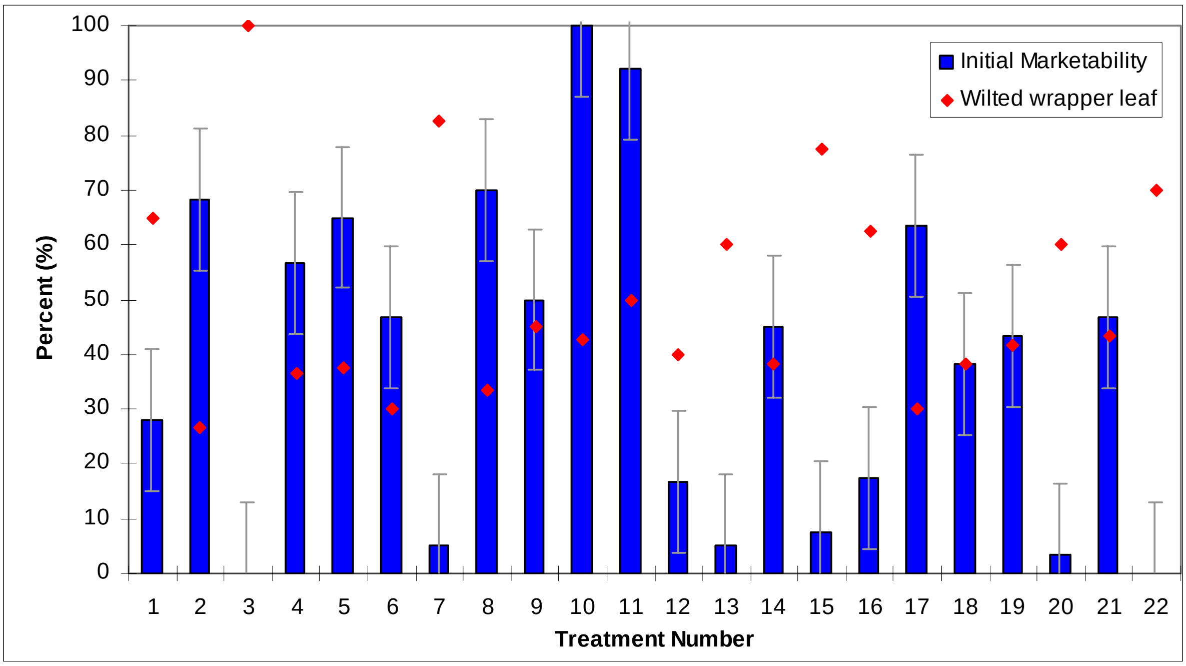


Figure 6.1.2.1. Percentage initial marketability wrapper leaf on (+/- LSD) and percentage of lettuce with wilted wrapper leaves post storage.

Significant differences ($P<0.05$) were recorded in the marketability of each treatment with wrapper leaves left on when analysed using Anova. Treatments 10 and 11 were both Toronto stored for 7 days. Toronto treatments 2, 5, 8 and 17 recorded similar marketability following 21 days storage. Ardinas in treatment 4 also recorded similar marketability to 2, 5, 8, and 17. High percentages of wilted wrapper leaves were generally recorded on treatments with low marketability.

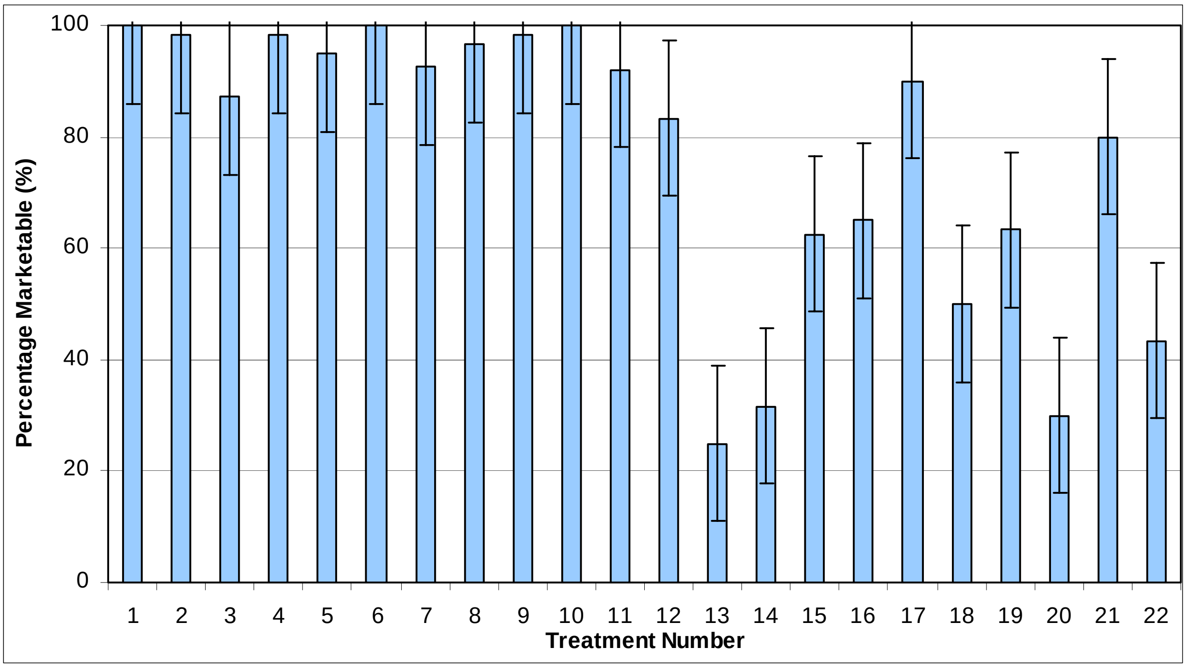
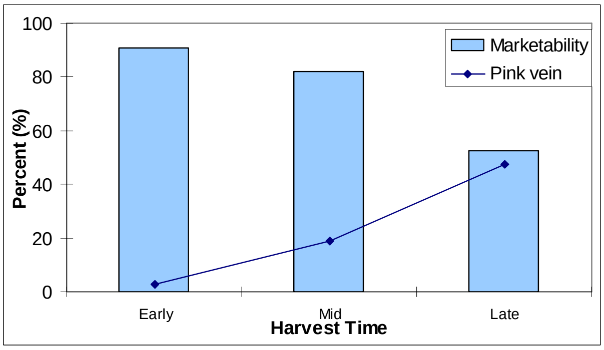


Figure 6.1.2.2. Percent marketability of lettuce with wrapper leaf removed (+/- LSD).

Removing wrapper leaves after the storage period increased the marketability of treatments 1 through to 12, 17 and 21. Treatments that were either stored for 28 days or harvested with a late maturity (13, 14, 15, 16, 18, 19, 20 and 22) had significantly lower marketability than treatments (P<0.05) harvested at an optimum time or that were stored for 21 days only.



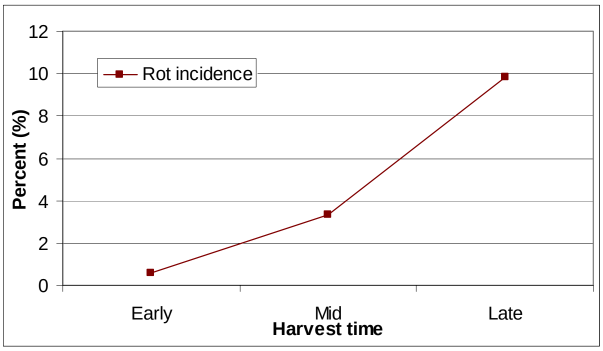


Figure 6.1.2.3. Post storage marketability and pink vein incidence of lettuce with wrapper leaf removed for each harvest time.

Figure 6.1.2.4. Post storage incidence of rots in lettuce with wrapper leaf removed for each harvest time.

The post storage marketability of lettuce decreased significantly (P<0.05) when harvested past its optimum date i.e. late harvest (Figure 6.1.2.4). Late harvested lettuce recorded a significantly higher (P<0.05) percentage of heads with pink vein symptoms. The percentage marketability decreased rapidly as pink vein incidence increased r = -0.882. The incidence of rot increased significantly (P<0.05) with the delay in harvest timing, i.e. late maturity.

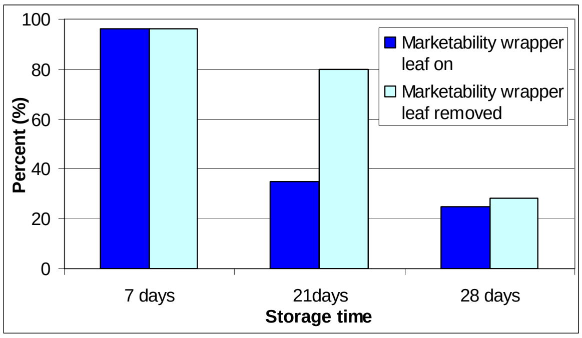


Figure 6.1.2.5. Post storage marketability of lettuce stored for different times.

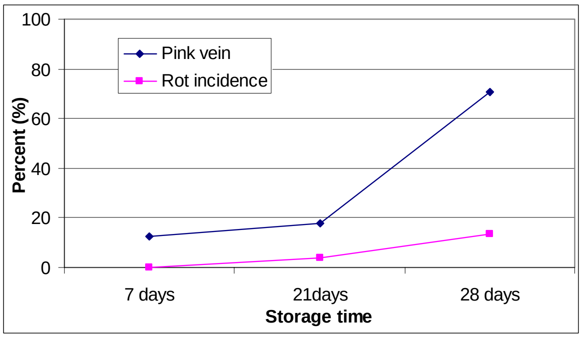


Figure 6.1.2.6. Post storage incidence of rots and pink vein for lettuce stored for different times.

The marketability of lettuce with 'wrapper leaves on' stored for 21 and 28 days declined significantly between the two dates ($P<0.05$). The removal of the wrapper leaf after removal from storage significantly increased the percentage marketability of lettuce stored for 21 days. At 28 days marketability of lettuce decreased significantly even with the wrapper leaves removed. The incidence of pink vein and rots significantly increased ($P<0.05$) after 28 days of storage.

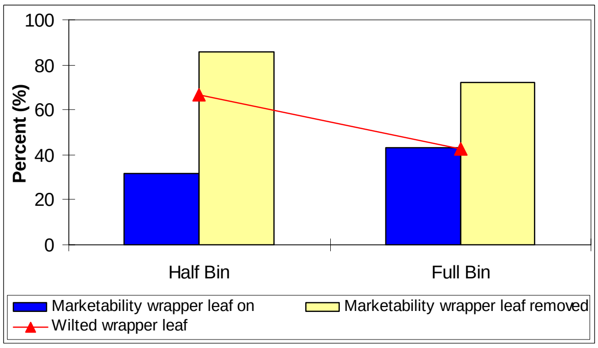


Figure 6.1.2.7. Post storage marketability and incidence of wilted wrappers for lettuce stored in two bin types.

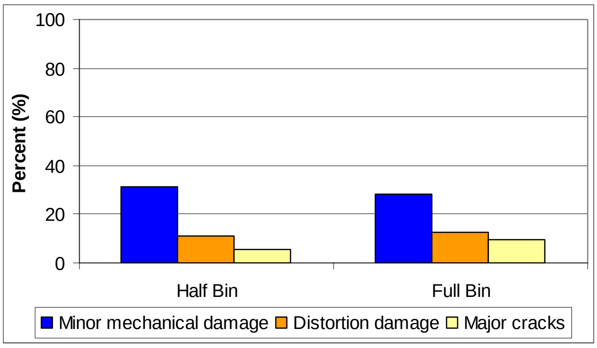


Figure 6.1.2.8. Post storage mechanical damage to lettuce stored in two bin types.

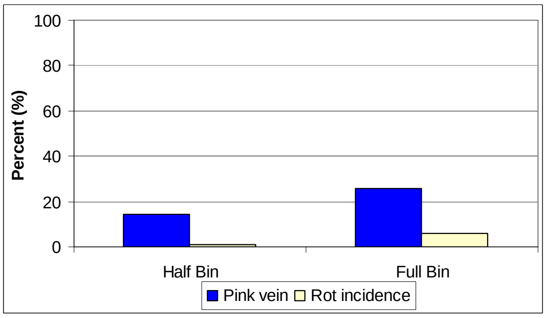


Figure 6.1.2.9. Post storage pink vein and rot incidence for lettuce stored in two bin types.

Lettuce with their wrapper leaves on recorded a significantly higher marketability ($P<0.05$) when stored in full bulk bins. Lettuce stored in half bins recorded a significantly higher marketability ($P<0.05$) when the outer wrapper leaves were removed. Lettuce recorded a significantly higher ($P<0.05$) percentage of wilted wrapper leaves when stored in half bins.

Half and full bin treatments recorded similar minor mechanical and distortion damage. A significantly higher (P<0.05) percentage of major cracks were recorded for lettuce stored in full bins. Lettuce stored in full bins also recorded a significantly higher (P<0.05) incidence of pink vein and rots after storage.

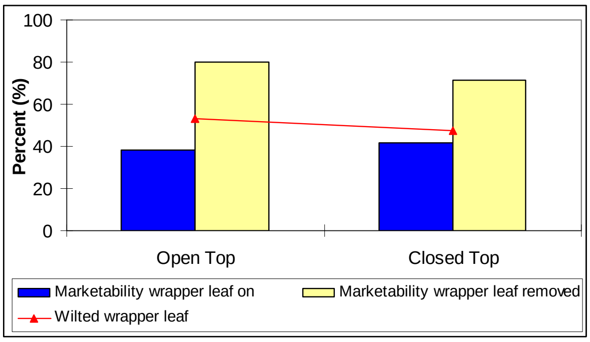


Figure 6.1.2.10. Post storage marketability and incidence of wilted wrappers for lettuce stored in bulk bins with an open or closed top.

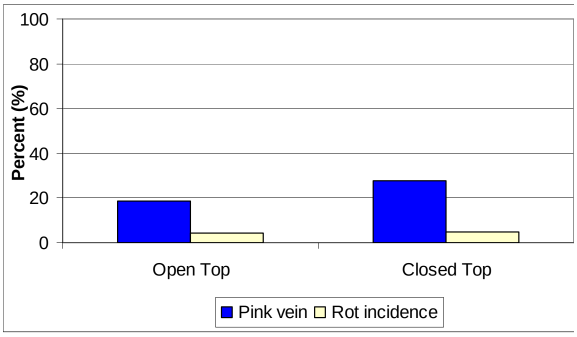


Figure 6.1.2.11. Post storage pink vein and rot incidence for lettuce stored in bulk bins with an open or closed top.

Lettuce stored with an open top (no lid or covering) recorded similar (P>0.05) marketability and incidence of wilted wrapper to a closed top. The incidence of pink vein and rot were also similar (P>0.05) for both covered and uncovered tops.

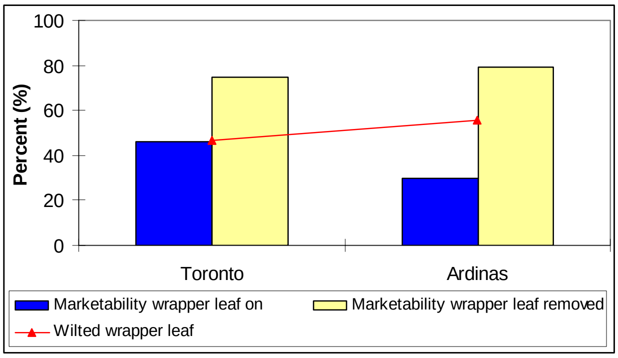


Figure 6.1.2.12. Post storage marketability and incidence of wilted wrappers for two cultivars of iceberg lettuce.

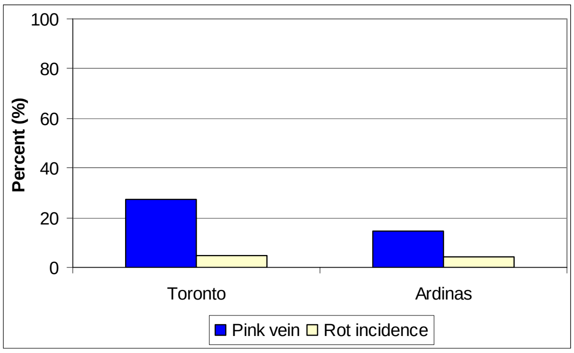


Figure 6.1.2.13. Post storage pink vein and rot incidence for two cultivars of iceberg lettuce.

Toronto recorded a significantly higher (P<0.05) marketability with the 'wrapper leaf on' compared to Ardinas. There was no significant difference (P>0.05) between the marketability with wrapper leaf removed and the percentage of wilted wrappers for the two lettuce cultivars. Toronto recorded a significantly higher (P<0.05) incidence of pink vein than Ardinas.

Discussion and recommendations

The marketability (wrapper leaf on) of lettuce stored for 21 days was dominated by four treatments, Toronto mid harvest full bin open top, Toronto early harvest half bin open top, Toronto early harvest full bin and Toronto mid harvest full bin closed. Despite recording significantly lower incidences of rot and pink vein an early harvest has limitations in an economic sense. An earlier harvest results in lower head weights, consequently requiring more lettuce heads to fill the bin, reducing profitability.

Removal of the outer wrapper leaf increased the overall marketability of most treatments. Removal of the outer leaf at the destination port transfers costs to the importer, but it does increase waste product and the need to further handle produce. Treatments with a high initial marketability (wrapper leaf on) will decrease the handling required and the amount of waste product at the destination.

Late harvested lettuce recorded a similar effect on the marketability and defects as did length of storage. As maturity and storage time increased, so did the incidence of rots and pink vein. At 21 days or mid harvest the incidence of defects was at a level considered unimportant to overall marketability. When the storage time was lengthened to 28 days and lettuce was harvested at late maturity the incidence of defects was beyond optimum.

Although packaging in the form of full bins produced higher incidences of cracking, rots and pink vein, full bins do provide benefits with respect to initial marketability, wilted wrappers and economies of scale. Benefits include increased volume of produce able to be exported in each sea container (minimising space taken up by packaging), reduced handling costs to remove wilted leaves and lower waste at the destination.

Comparisons of closed and open tops of bins showed there was little difference between a closed bin and an open bin for exporting lettuce. However two trends were evident; the first was that the percentage of wilted wrappers decreased and initial marketability increased going from an open to a closed top. The second trend was that marketability (wrapper leaf removed) decreased as the incidence of rots and brown vein increased in going from an open to a closed top. These trends suggest that there may be a compromise level of partially open top that would maximise both marketability through less wilted wrapper leaves whilst decreasing the incidence of other defects.

With respect to marketability of the two cultivars, the main effect recorded was the higher initial marketability of Toronto. This is most likely associated to the lower incidence of wilted wrappers.

Results of this work suggest that Toronto harvested at optimum maturity will out-turn in very good marketable condition if shipped in full bins for a sailing period of up to 21 days, providing that the cool chain remains intact. There is a need to further investigate a range of ventilation restricting bin lids to further increase the marketability, whilst limiting the incidence of wilted wrappers, rots and pink vein.

6.1.3 Packaging materials, bin liners and ventilation control

Previous work indicated the need to further investigate permeable lids for the tops of bins to improve the marketability at out-turn through limiting the incidence of wilted wrappers, rots and pink vein in produce. The underlying principles outlined in the introduction to this report that underpin the development of bulk bin handling were to reduce the cost of exporting vegetables and to minimise the handling required to prepare consignments for shipping. Any changes to the bin design and packing methods aimed at improving marketability of the product would therefore also need to be inexpensive and require minimal changes to the handling procedure.

Materials and methods

Iceberg lettuce was sourced from a lettuce trial harvested on 17 and 18 January 2006 at Medina Research Station. This lettuce was packed into eight half bulk bins (because the quantity of lettuce was insufficient for full bins) and pre cooled to below 2°C. On 19 January bulk bins were removed and treatments were applied (Table 6.1.3.1). A number of bins had two or more treatments imposed on them by placing a sheet of cardboard vertically down the middle of the bin. Once packing and treatments were completed, the bins were loaded into the sea container where they remained for 21 days. The temperature of the sea container was set at 0.5°C with $11m^3$/hr of ventilation.

Figure 6.1.3.1. Examples of top covering treatments applied to lettuce bulk bins. Treatments 1, 2, 7/8, 12, 11 and 4 clock wise from top left hand corner.

Table 6.1.3.1. Iceberg treatments for simulated shipping

Number	Treatment
1	Plastic liner open top.
2	Plastic liner closed top (plastic).
3	MCT liner closed top (Moisture Control Technology material)
4	Plastic liner closed top using MCT material.
5*	Plastic liner pre wet solid waxed cardboard top
6*	Plastic liner pre wet solid un waxed cardboard top
7*	Plastic liner pre wet waxed cardboard top with 12, 60mm holes cut
8*	Plastic liner pre wet un waxed cardboard top with 12, 60mm holes cut
9*	Plastic liner dry solid waxed cardboard top
10*	Plastic liner dry solid unwaxed cardboard top
11	Commercial - lettuce wrapped in wax paper and packed into cartons.
12	Lettuce packed into cardboard cartons lined with MCT material.

***Bulk bins for these treatments were split vertically to accommodate further treatments.**

Pre wet cardboard lid treatments were soaked on the 18th of January 2006 and stored in a cool room for 24 hours prior to fitting to bins. These were fitted to designated bins on the 19th of January 2006.

On 9 and 10 February 2006 iceberg lettuce treatments were removed from the sea container and assessed. A sample of produce from each treatment was assessed for the following characteristics (in order of importance).

1. Marketability 1, with wrapper leaves on (ranked on a scale of one to seven, one = worst and seven the best).
2. Marketability 2, with wrapper leaves removed (ranked on a scale of one to seven, one = worst and seven the best).

3. Turgidity of three outermost wrapper leaves. (Each of the three leaves was ranked individually for turgidity on a scale of one to three, 1 = minor flaccidity, 2 = average flaccidity, 3 = very flaccid). If leaves were perfectly turgid they would be zero).
4. Mechanical damage (ranked on a scale of one to three, 1 = grazing, 2 = squashing and 3 = breaking.)
5. Presence of pink vein.
6. Presence of rots.

Sampling involved removing produce from layers vertically down the bin, 4 layers for a half bin. Sampled layers were 0, 20, 40, and 60 cm (bottom) deep from the top. Ten lettuce heads where removed at each layer and assessed as a sub sample.

Results

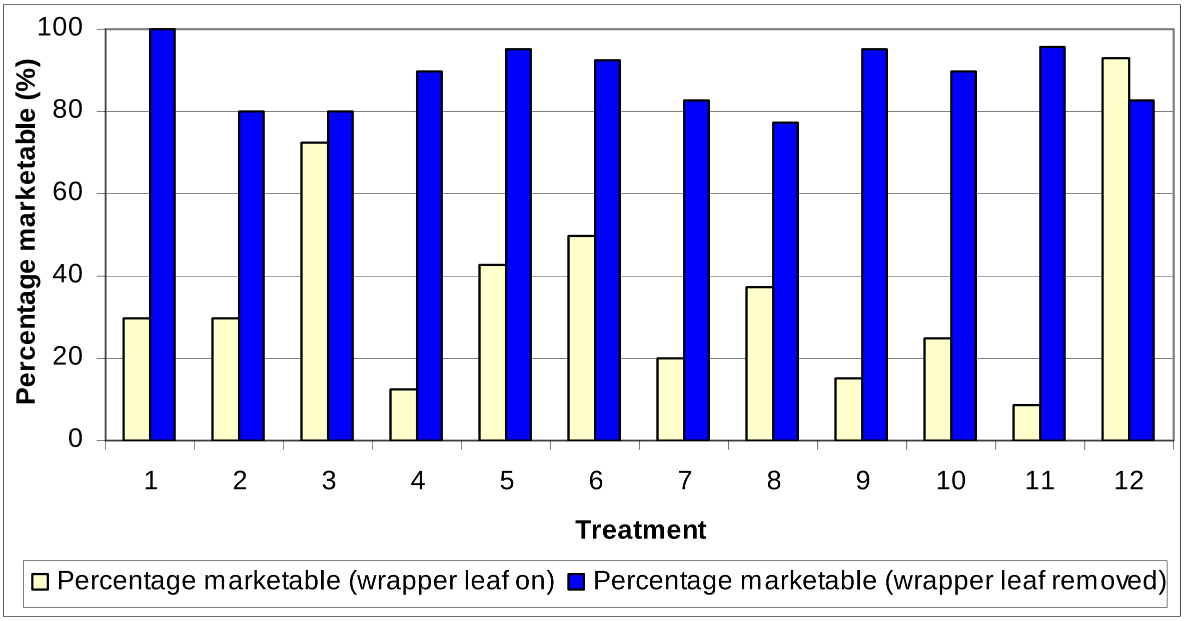


Figure 6.1.3.2. Marketability of lettuce heads with wrapper leaves on and wrapper leaves removed (up to three).

Treatment 12 recorded post storage marketability (wrapper leaf on) significantly ($P<0.05$) higher than all treatments. Treatment 3 had significantly better marketability (wrapper leaf on) than all treatments excluding treatment 12. Treatments 5 and 6 recorded marketability in excess of 40% without removing any wrapper leaves. Commercial cartons (treatment 11) recorded a marketability of 8.6 per cent. Treatments 1, 4, 5, 6, 9, 10, and 11 (commercial cartons) had similar marketability once their outer wrapper leaf was removed.

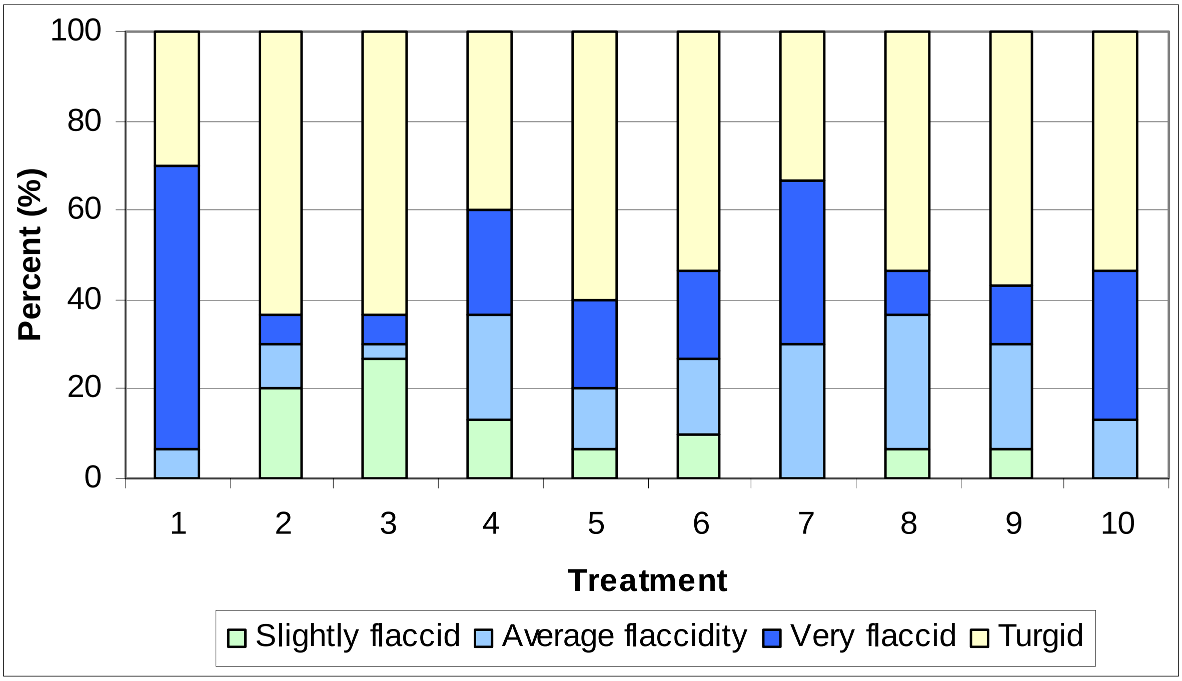


Figure 6.1.3.3. Percentage of the outer three wrapper leaves with varying degrees of turgidity for lettuce on the top layer of bulk bin treatments. Treatments 11 and 12 were packed into cardboard cartons, and hence had no top layer to compare.

Treatment 1 recorded a significantly (P<0.05) higher portion of very flaccid wrapper leaves when compared to other treatments. Treatments 2 and 3 recorded the lowest total percentage of flaccid wrapper leaves of all treatments. Treatments 5, 6, 8, and 9 recorded average numbers of flaccid wrapper leaves for the top layer of lettuce.

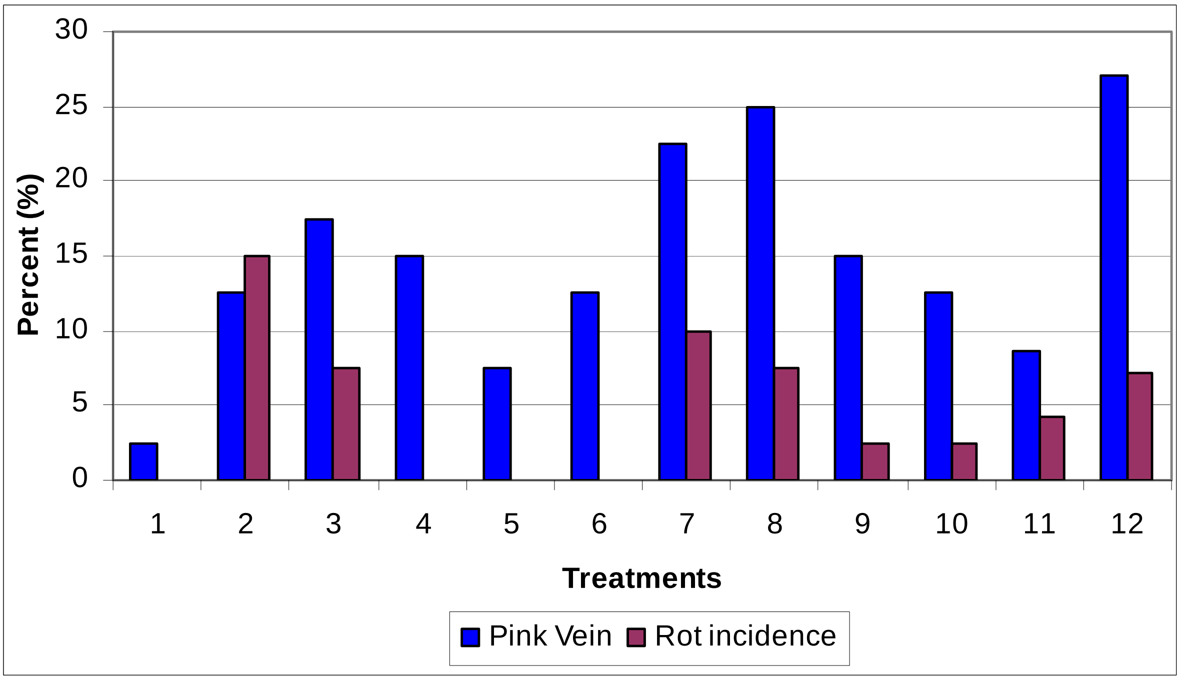


Figure 6.1.3.4. Incidence of rots and pink vein for each packaging treatment.

No significant difference was detected for incidence of pink vein (P>0.05). However treatments 1, 5 and 11 all recorded less than 10 per cent incidence. Four treatments recorded no incidence of rots 1, 4, 5, and 6.

Discussion and recommendations

Bulk bin treatments, plastic liner open top (1), plastic liner MCT cover top (4), plastic liner pre wet solid waxed cardboard top (5), plastic liner pre wet solid un waxed cardboard top (6), plastic liner dry solid waxed cardboard top (9), and plastic liner dry solid un-waxed cardboard top (10) recorded marketability (wrapper leaf removed) similar to or better then commercial cartons. However the high initial (> 40 per cent) marketability of treatments 5 and 6 allow a distinct economic advantage when received at the destination. Economically, minimising dehydration (wilting of wrapper leaves) will incur lower handling costs and reduced waste through lower labour requirements to remove the outer wrapper leaf at the destination.

The aim of incorporating various top treatments was to significantly reduce the dehydration of wrapper leaves of individual heads in the top layer below the dehydration experienced in an open bin (Treatment 1). Treatments 2, 3, 5, 6, 8, 9, and 10 were able to significantly ($P<0.05$) reduce the total dehydration including the severity of flaccidity recorded in the top layer. However treatments 5 and 6 were the only treatments that did not increase the incidence of rots and brown vein at the same time.

Treatments with a MCT liner closed top (3) and packed into cardboard cartons lined with MCT material (12) recorded high initial marketability, but where later rejected through rot and pink vein development. Moisture control technology used for lettuce may create a micro environment with excess free moisture, whilst minimizing air flow through produce. An environment with warmer temperatures and free moisture are conducive to enhanced bacterial breakdown.

Two treatments (plastic liner pre wet solid waxed cardboard top (5), plastic liner pre wet solid un-waxed cardboard top (6)), gave levels of marketability similar to or better than commercial cartons and an open bulk bin. Both treatments also had the effect of decreasing damage to the top layer whilst not increasing the incidence of pink vein and rots significantly. The treatment with a plastic liner with a pre wet solid waxed cardboard top was the better of the two.

6.2 Packing methods for broccoli

6.2.1 Bin bases and lids

Introduction

Preliminary trials with broccoli packed, cooled and stored in bulk bins proved to be very encouraging, but there were a number of areas requiring further investigation in order to improve the marketability of the out turned produce at the destination. These included the effect of head maturity at harvest on out-turn and methods to minimise dehydration of heads on the top layer and the bottom layer of the bulk bin.

A limitation to the number of treatments that could be compared at one time in broccoli bulk handling trials was the amount of produce required for each treatment. Each full bin treatment required 1400 heads of around 300 grams each to complete. Combined with the requirement of this produce to be selectively harvested, gathering enough heads to complete a treatment was difficult. For these reasons limited treatments could be compared at any one time, and were staggered to fit in with harvest timing.

Materials and methods

Broccoli for storage trials was sourced from other field trials conducted from time to time at Medina Research Station. As harvest was staggered to fit in with selective harvesting, the first full bin treatment was filled on 24 August 2005 and another half bin on 26 August 2005. Once full, each bin treatment was pre cooled to 1°C. Treatments one to four in the first experiment consisted of two base types, a single cardboard sheet which was either waxed or un-waxed combined with two bin types; a full and a half bin. The fifth treatment investigated a solid waxed cardboard cover in comparison to a bin open at the top (treatment 4). Treatments are outlined in Table 6.2.1.1.

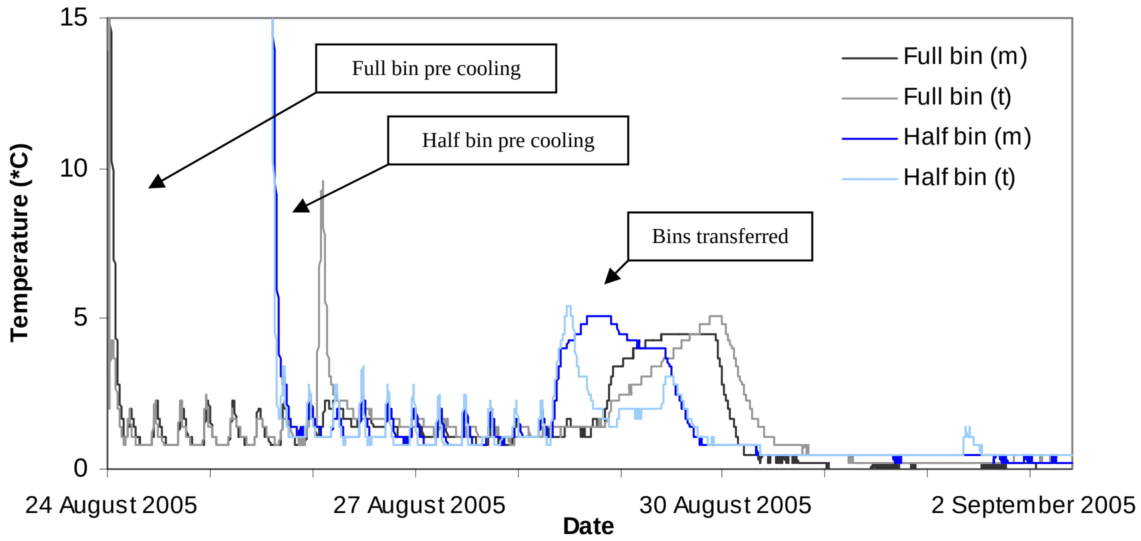


Figure 6.2.1.1. Pre cooling profiles of broccoli packed in bulk bins. Temperatures from probes located at the middle(m) and top(t) of the bulk bins shown.

Table 6.2.1.1. Broccoli treatments 24 August 2005

Number	Treatment
1	Full bin un waxed base
2	Full bin waxed base
3	Half bin un waxed base
4	Half bin waxed base
5	Half bin waxed base covered top

Figure 6.2.1.2. Examples of treatments applied to broccoli bulk bins. Split unwaxed and waxed base (left) cardboard lid (right).

On 29 August 2005 treatments were transferred to the 'land based' sea container for a voyage simulation. On 15 September 2005 treatments were removed and assessed. A sample of produce was scored for the following characteristics (in order of importance).

1. Marketability (ranked on a scale of one to seven, one = worst and seven the best).
2. Turgidity (each of the floret was ranked individually for turgidity on a scale of one to three, 1 = minor flaccidity, 2 = average flaccidity, 3 = very flaccid). If florets were perfectly turgid they would be zero).
3. Mechanical damage (ranked on a scale of one to three, 1 = grazing, 2 = squashing and 3 = breaking.).
4. Presence of rots.

Sampling involved removing produce from layers vertically down the bin, 6 layers for a full bin and 4 for a half bin. Sampled layers were 0, 20, 40, 60, 80 and 100 cm deep from the top for full bins. Half bins were only sampled to 60 cm (bottom). Ten broccoli heads were removed at each layer and assessed as a sub sample.

Results

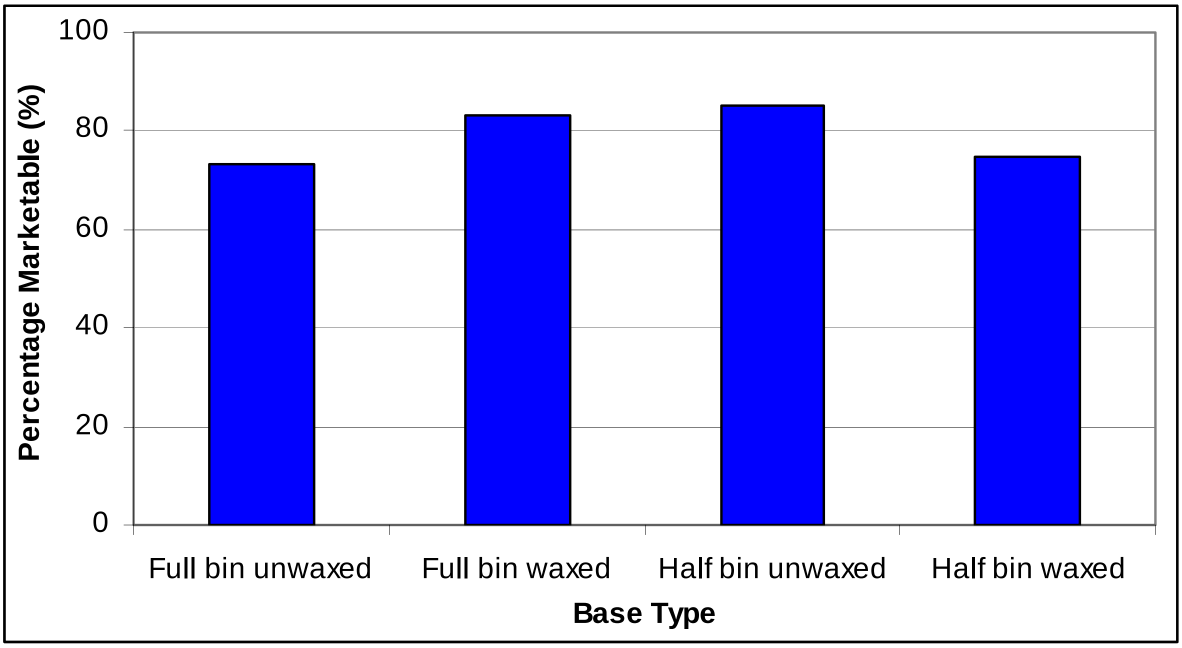


Figure 6.2.1.3. Post storage marketability of broccoli heads stored in bins with different Cardboard bases.

Analysis of percentage marketability for each treatment showed no significant difference ($P>0.05$) in base types.

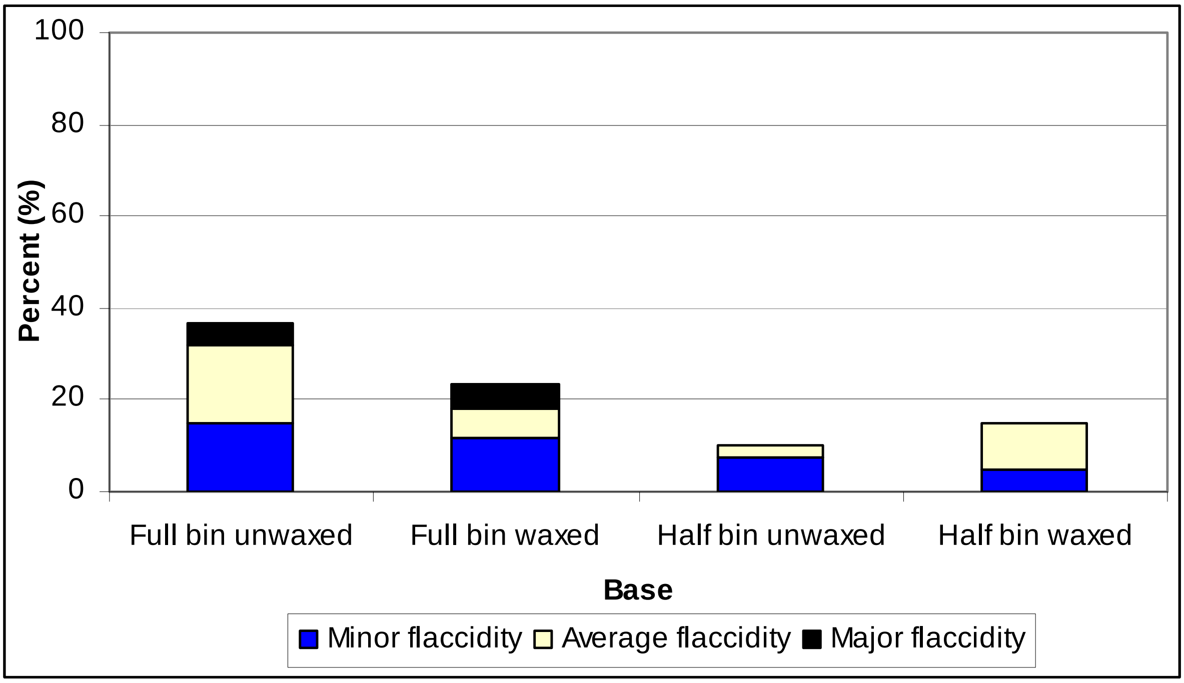


Figure 6.2.1.4. Post storage turgidity of broccoli heads in bulk bins lined with different cardboard bases.

The full bin un-waxed treatment recorded a significantly higher total ($P<0.05$) flaccidity than all other treatments. All three remaining treatments recorded similar levels of flaccidity.

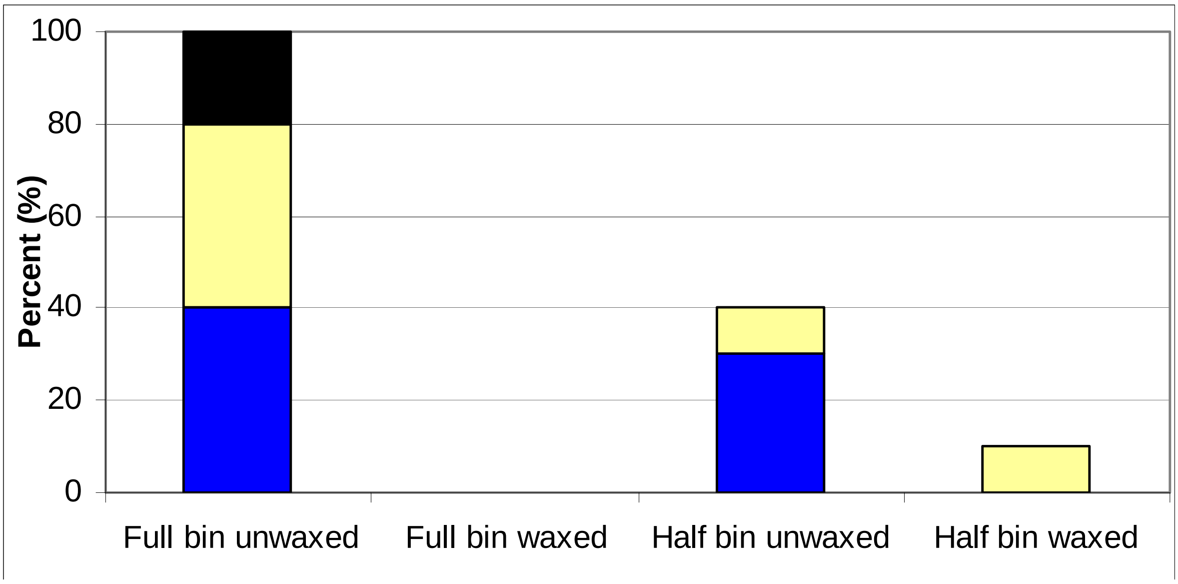


Figure 6.2.1.5. Post storage turgidity of broccoli heads on the bottom layer of bulk bins lined with different cardboard bases.

Analysis of the data using Anova showed a higher percentage (P<0.05) of flaccid heads at the bottom of the full bin with an un-waxed base than all other treatments. Heads in the half bin un-waxed treatment were significantly more flaccid (P<0.05) than both waxed base treatments.

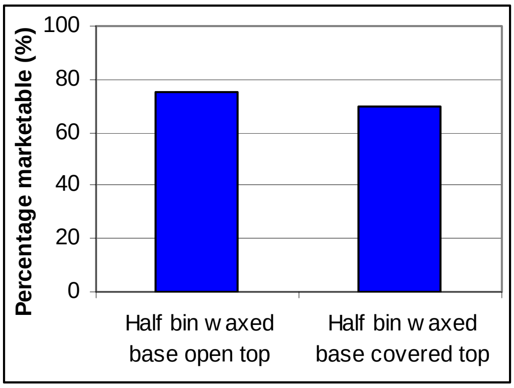


Figure 6.1.2.6. Post storage marketability of broccoli for the two top treatments.

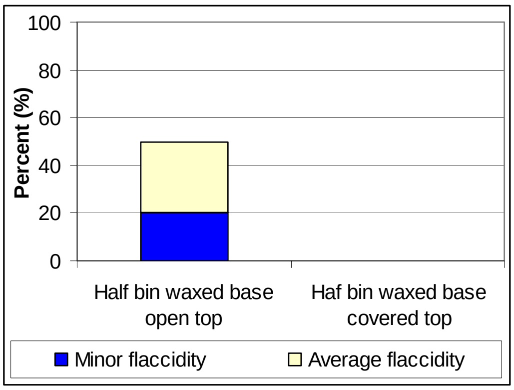


Figure 6.1.2.7. Post storage turgidity for the top layer of the two top treatments.

Post storage marketability of broccoli heads was not significantly different between covered and uncovered bin tops (P>0.05). A comparison of head turgidity in the top layer for the two top types, recorded a higher percentage of flaccid heads in the open bin.

Discussion and recommendations

The marketability and overall turgidity was reasonably similar for all four treatments. However, closer examination of the bottom layer showed a significant difference in turgidity. A waxed cardboard base increased the turgidity and hence the marketability of heads in this layer. An un-waxed base is able to absorb moisture from the broccoli heads, exacerbating the dehydration caused by airflow. Any further broccoli work should use a waxed base to reduce dehydration in the bottom layer.

Comparison of a solid top versus an open top produced no overall difference in marketability, but when the top layer of heads were compared for turgidity a difference of 50 per cent was found. Results suggest an effect on the airflow by having a solid cardboard top. Interference to airflow by the top may increase the chances of rot development or head yellowing in a sea container transported in real time. Impaired air flow through the bins could allow heat of respiration to accumulate and result in an unwanted temperature increase.

6.2.2 Ventilation control

Introduction

The first attempt to manage dehydration of the top layer of broccoli in bins compared a solid waxed cardboard top against a completely open top. The solid top reduced the dehydration of individual heads in the top layer and decreased airflow through the bulk bin, when compared to an open topped bin. However, a partial impedance of airflow through the bins may provide a better compromise between product temperature while in transit and turgidity of heads on top of the bins at out-turn.

Materials and methods

Broccoli heads meeting export specifications were harvested from a crop grown at Medina Research Station, in close proximity to where the sea container used for storage trials was located. A single bulk bin was filled on 2 March 2006, pre cooled to 1°C on site and loaded into the sea container on 3 March 2006. Because of limited produce only two treatments were compared, an open bin versus a covered bin. The covered treatment consisted of a half bin divided down the middle with one half covered with a waxed cardboard top with 22 holes 40 mm (+/- 5 mm) in diameter (Figure 6.2.2.1) and the other half, half bin left entirely open.

Figure 6.2.2.1. Examples of treatments applied to a broccoli bulk bin. Open (left), cardboard lid (right).

Broccoli samples were removed from the bin on 24 March 2006 following a 21 day simulated sea voyage. The sample was assessed for the following characteristics (in order of importance).

1. Marketability (ranked on a scale of one to seven, one = worst and seven the best).
2. Turgidity (each of the floret was ranked individually for turgidity on a scale of one to five, 1 = turgid, 2 = slight flaccidity, 3 = average flaccidity, 4 = very flaccid, 5 = extremely flaccid).
3. Mechanical damage (ranked on a scale of one to three, 1 = grazing, 2 = squashing and 3 = breaking.).
4. Presence of rots.

Sampling involved removing 10 heads at random from four layers vertically down the bin. Sampled intervals were 0, 20, 40, and 60, cm below the top of the bin.

Results

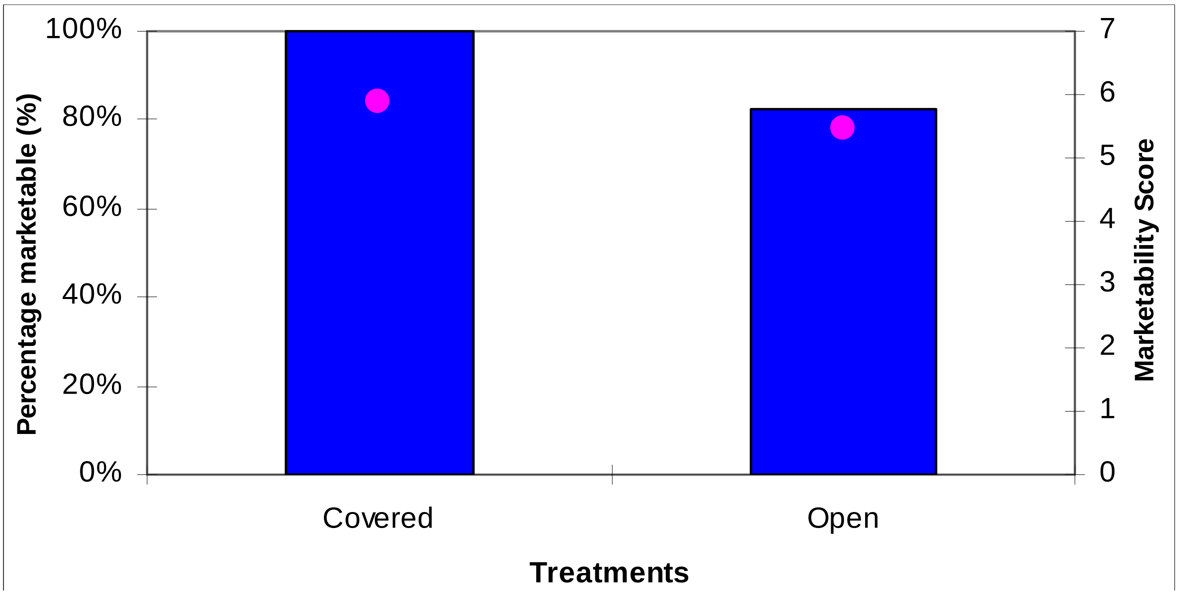


Figure 6.2.2.2. Post storage marketable percentage and marketability score of broccoli heads stored in bins open at the top or covered with a permeable cardboard lid.

Broccoli had a significantly higher (P<0.05) percentage of marketable heads and a higher mean marketability score when stored with a permeable lid than with no top cover.

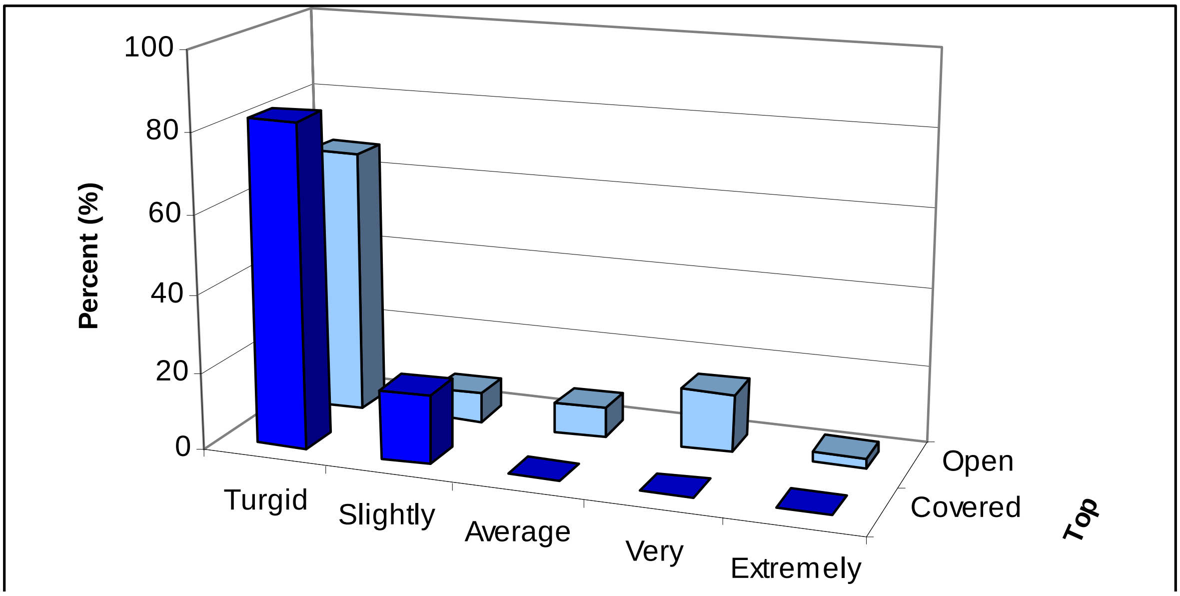


Figure 6.2.2.3. Post storage turgidity of broccoli heads stored in bulk bins open at the top versus covered with a permeable cardboard lid.

The covered bin produced significantly (P<0.05) higher numbers of turgid broccoli heads than the uncovered bin, while the uncovered bin had a higher percentage of average, very and extremely flaccid heads after storage than the covered bin.

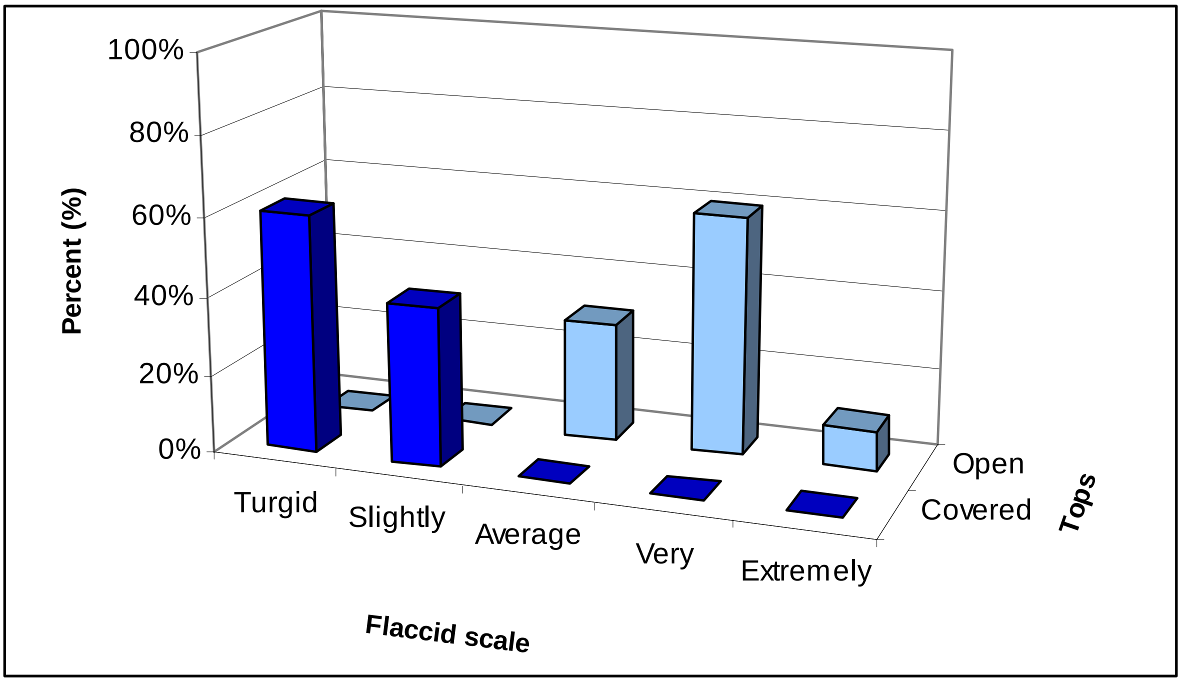


Figure 6.2.2.4. Post storage turgidity of broccoli heads on the top layer of bulk bins open at the top versus covered with a permeable cardboard lid.

The top layer of the open bin treatment recorded a greater percentage of heads in the 'very' or 'extremely' flaccid categories than the covered treatment. Most of the dehydration recorded in the covered treatment was in the 'slightly flaccid' category.

Discussion and recommendations

The marketable percentage of broccoli heads from the half of the bulk bin covered by a permeable waxed cardboard lid was 100 per cent and the marketability score averaged 5.9 on a scale of 0-7. The ventilated lid reduced the airflow through the bin sufficiently to reduce the level of dehydration experienced in the top layer. This trend was also evident throughout the half of the bin that was covered. The trial showed that it was possible to reduce dehydration whilst not significantly increasing the incidence of premature breakdown and associated rots in the broccoli heads by fitting a semi permeable cardboard lid to the bin.

Any further work should repeat these treatments on a full bin of broccoli that is fully covered to confirm the results. This preliminary work suggests that a waxed cardboard base and a waxed cardboard lid with 44, 40 mm holes (as laid out in Figure 6.2.2.1) be incorporated into any trial export shipments using bulk handling technology.

6.3 Packing methods for cauliflowers

6.3.1 Bin bases

Introduction

Preliminary investigations with cauliflower suggested that only minor changes to handling and packing practices were required to bring bulk bin handled produce up to the standard of traditional commercial methods using cartons. A closer look at produce throughout the bulk bin indicated that modifications to the base and top layer were required if this aim was to be achieved.

Modifications began with a comparison between a waxed and an un-waxed cardboard base for both full and half bins. These were compared to current commercial practice.

Materials and methods

Cauliflowers for the storage trial were harvested from a crop grown at Medina Research Station, in close proximity to where the sea container was located on Friday, 26 August 2005. Curds were packed into the bulk bins for each treatment, and pre cooled to 1.5°C on site. Treatments tested consisted of two base types, a single cardboard sheet with either a wax coating or no wax. This was then combined with the two bin types, full and half bin. The fifth treatment was the traditional commercial export method, namely pre cooling cauliflowers in bulk bins, followed by wrapping in waxed paper and repacking into cardboard cartons. The cartons were then transferred into the sea container on 29 August along with the bulk bin treatments. The full set of treatments are outlined in Table 6.3.1.1

Table 6.3.1.1. Cauliflower sea container treatments

Number	Treatment
1	Full bin unwaxed base
2	Full bin waxed base
3	Half bin unwaxed base
4	Half bin waxed base
5	Commercial cartons

(a) (b) (c)

Figure 6.3.1.1 (a) Waxed and unwaxed split base treatments on either side of the bin; (b) commercial carton; and (c) treatments loaded into the sea container.

Following 17 days storage, bins and cartons were removed from the sea container on 15 September 2006 and assessed. A sample of produce was assessed for the following (in order of importance).

1. Marketability (ranked on a scale of one to seven, one = worst and seven the best).
2. Turgidity (each of the curds were ranked individually for turgidity on a scale of one to five, 1 = slightly flaccid, 2 = average flaccidity, and 3 = very flaccid).
3. Mechanical damage (ranked on a scale of one to three, 1 = grazing, 2 = squashing and 3 = breaking.).
4. Presence of Brown spot (dehydration damage).

Sampling involved collecting produce from layers vertically down the bin, 6 layers for a full bin and 4 for a half bin. Sampled layers were 0, 20, 40, 60, 80 and 100 cm below the top of full depth bins, and to a depth of 60 cm (bottom) for the half depth bins. Ten curds where removed at each layer and assessed as a sub sample.

Results

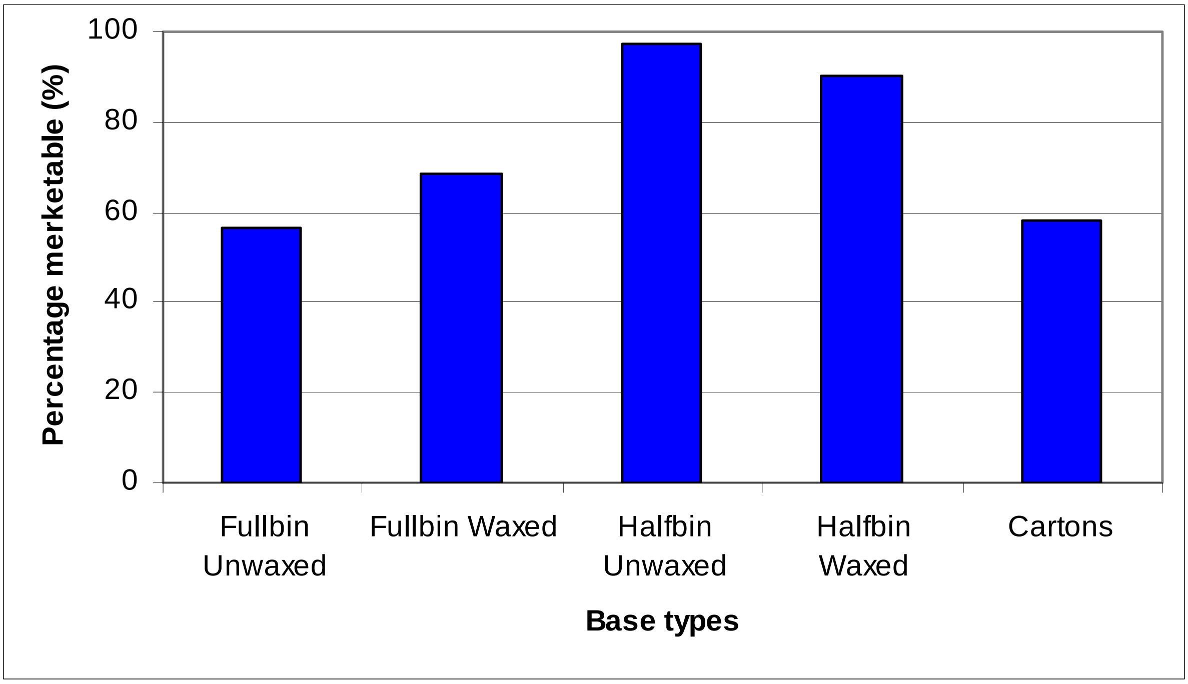


Figure 6.3.1.2. Post storage marketable percentage of cauliflower curds stored in bins with waxed and unwaxed cardboard bases.

There was a significantly (P<0.05) higher percentage of marketable cauliflowers after storage in both half bin treatments than all other treatments when analysed using Anova. There was no significant (P>0.05) difference between full bin treatments and commercial cartons.

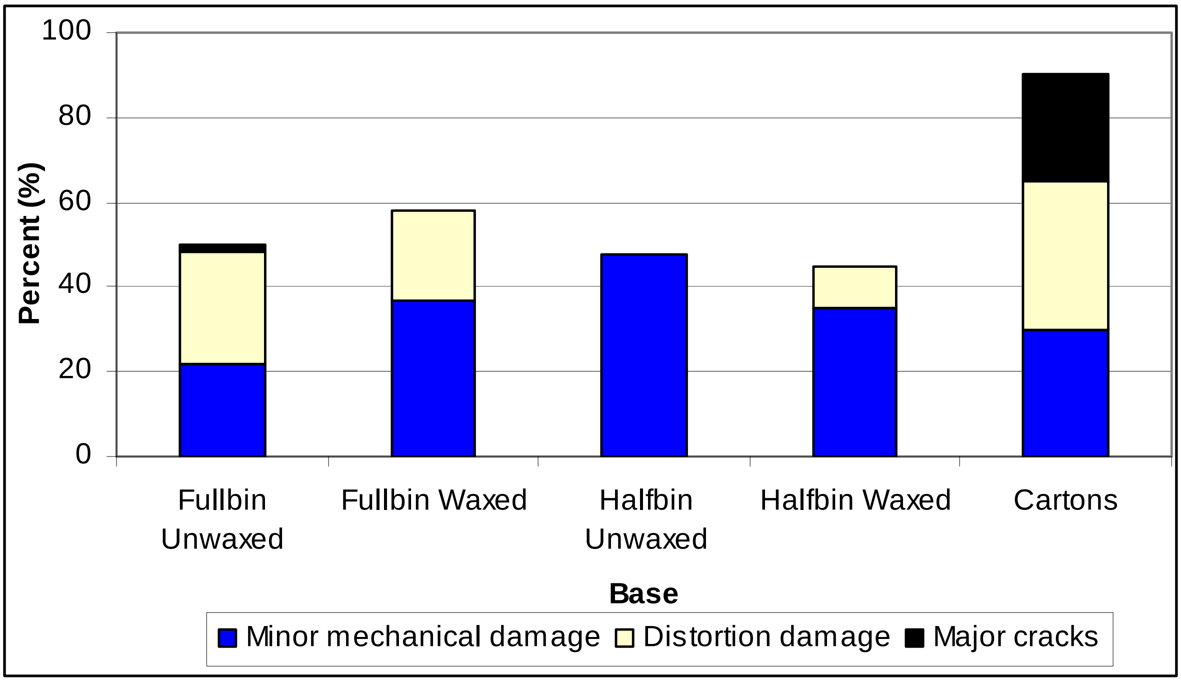


Figure 6.3.1.3. Post storage mechanical damage to Cauliflower curds stored in bins with waxed and unwaxed cardboard bases.

The half bin un-waxed treatment recorded no distortion damage to curds. Cartons had significantly more major cracks than all other treatments. Both Full bin treatments had similar levels of mechanical damage to the half bin treatments.

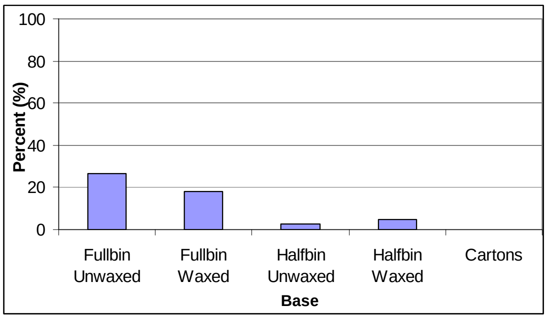


Figure 6.3.1.4. Incidence of brown spot on cauliflower curds stored in bins with waxed and unwaxed cardboard bases.

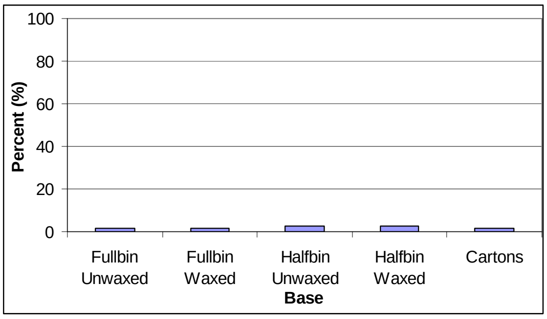


Figure 6.3.1.5. Percentage flaccidity in cauliflower curds stored in bins with waxed and unwaxed cardboard bases.

Full bulk bin treatments recorded a significantly higher percentage of brown spot incidence compared to all treatments. Half bin treatments and commercial cartons recorded similar incidences of brown spot. The overall turgidity of all treatments was not significantly different ($P>0.05$).

Discussion and recommendations

The marketability of cauliflowers after a simulated voyage of 17 days duration for all bulk bin treatments was at least as good as commercial cartons. The levels of mechanical damage experienced for all bulk bin treatments were similar, while curds in commercial cartons had more mechanical damage due to the way cartons are packed. When packed commercially, cauliflowers are wrapped and forced into the confines of the cardboard carton inflicting more major cracking damage than recorded in all bulk bin treatments, where curds are placed in layers next to each other. Bulk bins allow some movement of the curds after packing seeing them settle into place during transport without inflicting major damage or bruising.

The high percentage of brown spot incidence recorded in the full bin is most likely associated with having packed these treatments at two different times. In doing so, these treatments were pre cooled when the bin was half full and again when it was full, thus increasing the airflow over curds at the centre of bin. This possibly resulted in more dehydration damage to this layer and the top layer.

There was no difference in the turgidity level of cauliflowers stored on a waxed or un-waxed base. It is therefore recommended to use a waxed base to allow for ease of handling in cool rooms.

Overall, the marketability, mechanical damage, and brown spot incidence recorded in both half bin treatments suggested that this bin type is better for transporting cauliflowers in bulk, than a full depth bin. However a half bin does not provide the best economic benefit, because thirty bins are required to fill a 20’ sea container, each of which has a fork gap. Full bulk bins require only 20 fork gaps in a sea container. The extra fork gaps throughout the container for half bins waste space that would be filled with layers of cauliflower curds in full depth bins, or as much as 1500 kilograms more cauliflower in the full sea container.

6.3.2 Ventilation control

Introduction

The next step after dealing with bases for bins was to concentrate on the produce at the top of the bin. This meant investigating a range of lids or liners that could potentially reduce the adverse effects of airflow on curd turgidity.

Not long before this work was done, CSIRO had completed work on moisture control (MCT) material to be used in cardboard cartons for exporting cauliflowers. These MCT liners were created to improve the quality of out-turn for sea freighted produce. The bulk bin storage trials created an opportunity to investigate this technology both as an entire bulk bin liner and a top cover option for transporting vegetables in bulk.

Covering the top layer of cauliflower curds in field bins with cauliflower leaves is a method commonly used to transport bins from farms to export packing sheds. This practice is believed to give sufficient protection to the curds from climatic factors, including wind and sunlight for short road trips.

Cardboard lids have been shown to be beneficial for other vegetable produce such as broccoli in research reported here. Different vegetable types may require different levels of air flow restriction to optimise out-turn quality and it was therefore considered to be important to investigate a range of waxed cardboard bin lids for cauliflower as well.

Materials and methods

Cauliflowers where obtained from a trial being conducted at Manjimup Horticultural Research Institute. Produce was harvested over 9 and 10 March 2006 directly into bulk bins. At the time of harvest, temperature loggers were placed in a full bin that was left open at the top and a half bin with an MCT liner inside. Once packed, bins were removed from the harvester and transported to the cool room where they were pre cooled using forced air cooling as previously described for other products.

Immediately after pre cooling, individual treatments were applied to each bulk bin (Figure 6.3.2.1). Bulk bin treatments were then loaded on to a truck and transported 300 km to Medina Research Station where they were re-cooled and loaded into the trial sea container on Tuesday, 14 March 2006.

Table 6.3.2.1. Cauliflower treatments 9 March 2006

Number	Treatment
1	Half bin open top
2	Half bin MCT top cover
3	Half bin solid waxed lid
4	Half bin leaves on top
5	Half bin MCT liner
6	Half bin medium holes (40 mm) lid
7	Half bin small holes (20 mm) lid
8	Full bin open top

Figure 6.3.2.1. Cauliflower treatments: (a) MCT top cover; (b) MCT bin liner; (c) ventilated cardboard lid – small and large holes; (d) solid waxed cardboard lid and leaves on top; and (e) open top.

On 3 April 2006 treatments were removed from 21 days storage and assessed for the following (in order of importance).

1. Marketability (ranked on a scale of one to seven, one = worst and seven the best).
2. Turgidity (each curd was ranked individually for turgidity on a scale of one to three, 1 = slightly flaccid, 2 = average flaccidity, and 3 = very flaccid).
3. Brown spot (each curd was ranked individually for incidence of brown spot on a scale of one to three, 1 = Minor brown spot, 2 = average brown spot, and 3 = major brown spot).
4. Mechanical damage (ranked on a scale of one to three, 1 = grazing, 2 = squashing and 3 = breaking.).

Sampling involved removing produce from layers vertically down the bin, 6 layers for a full bin and 4 for a half bin. Sampled layers were 0, 20, 40, 60, 80 and 100 cm deep for full bins. Half bins were only sampled to 60cm (bottom). Ten curds were removed at each layer and assessed as a sub sample.

Results

All treatments were applied after cooling with the exception of the MCT liner. The MCT liner proved to be difficult to work with in the field because it was subject to contamination with soil. All other treatments were easily applied after cooling.

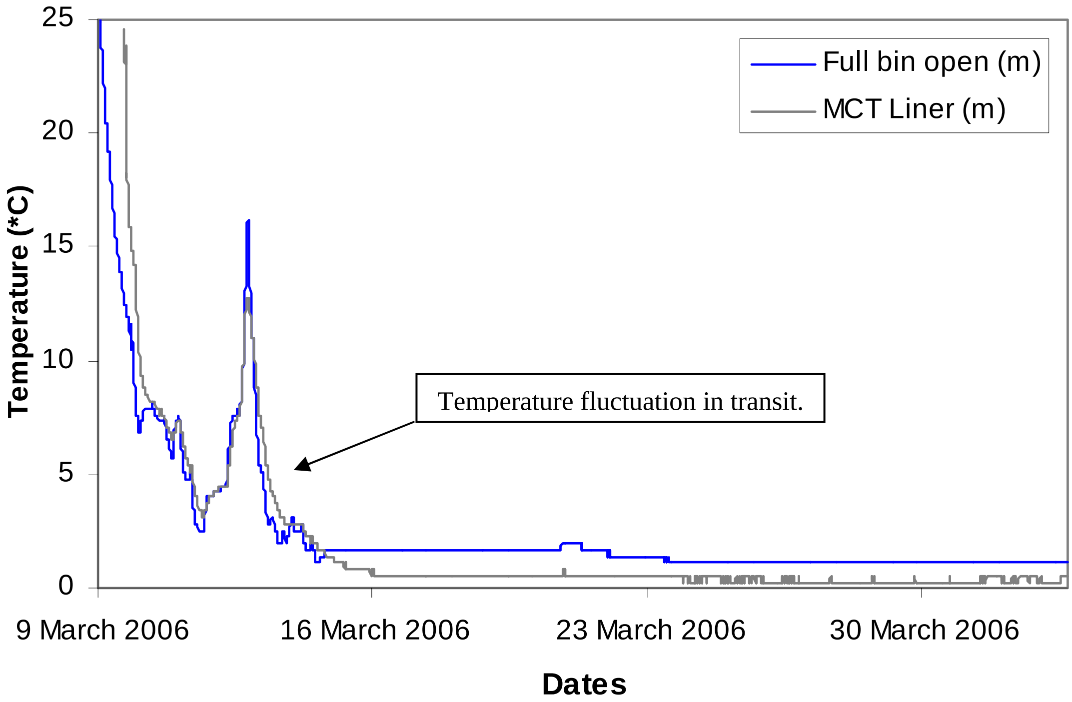


Figure 6.3.2.2. Cooling trends for cauliflowers packed into bulk bins , pre cooled, then transported 300 km by road prior to storage in a sea container.

Cold chain integrity of the two treatments in transit between Manjimup and Perth, was compromised with a rise in produce temperature of up to 15 degrees during the road trip. Once the bins were loaded into the sea container, temperatures quickly returned to desirable levels again and produce remained cool for the entirety of the trial.

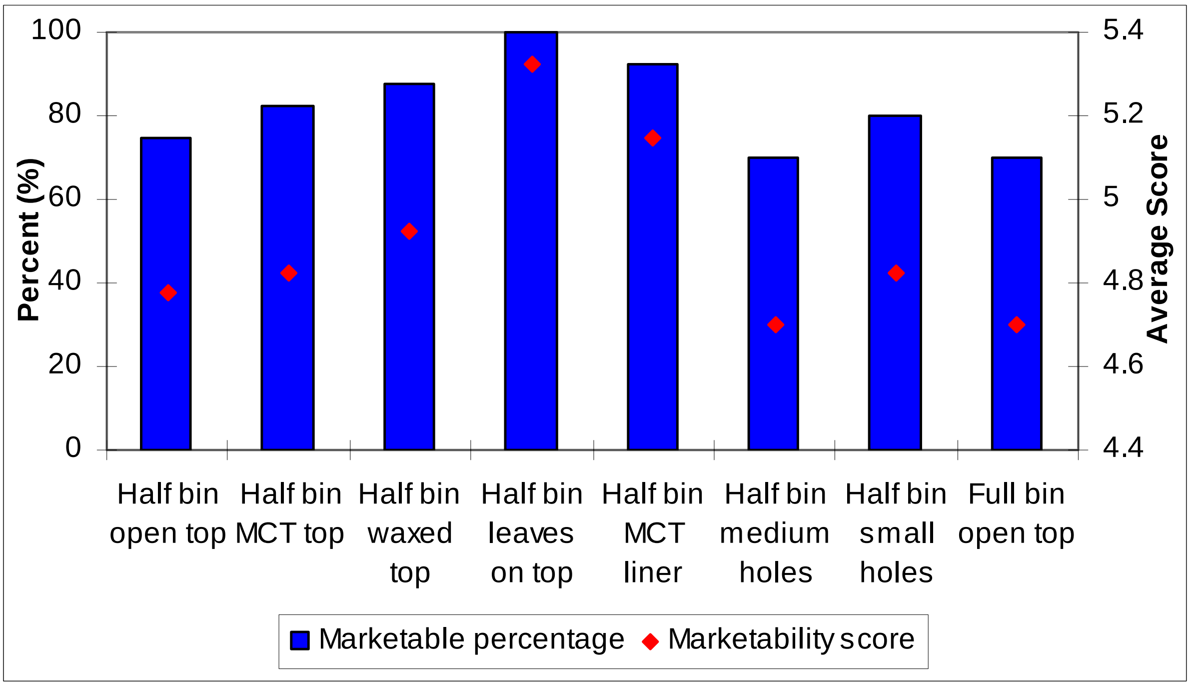


Figure 6.3.2.3. Post storage marketability of cauliflower curds treated with different top covers.

The marketable percentage of cauliflower curds following 21 days storage was significantly (P<0.05) higher for the half bin with 'leaves on' compared to all other treatments excluding the half bin with an MCT liner. The half bin with an MCT liner recorded significantly (P<0.05) higher marketability than the half bin with an open top, the half bin with medium holes and the full bin with an open top. Average marketability scores of curds recorded a similar trend.

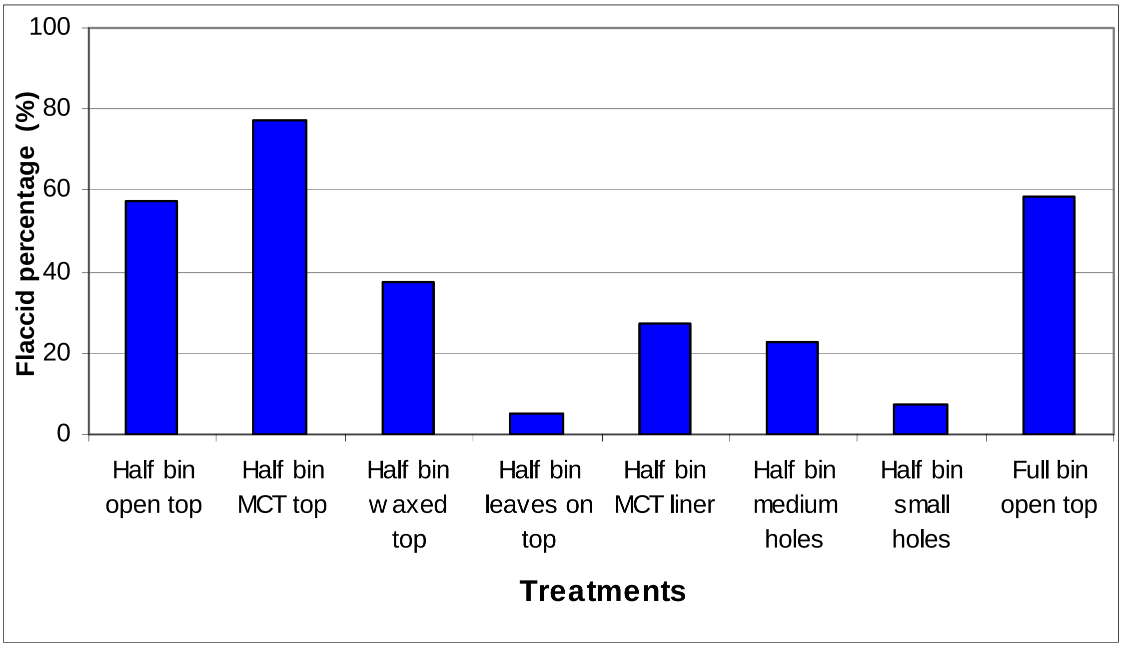


Figure 6.3.2.4. Post storage percentage of all cauliflowers curds sampled scoring 1 or greater for flaccidity for the eight bin treatments.

Analysis using Anova of the total number of curds that were not fully turgid showed significantly higher turgidity (low percentage flaccid in Figure 6.3.2.4) in the half bin with 'leaves on' than all other treatments, except the half bin with small holes treatment. The half bin with MCT liner, the half bin with medium holes and half bin with small holes all recorded similar levels of flaccid curds. Both open top treatments had more flaccid curds than the other treatments.

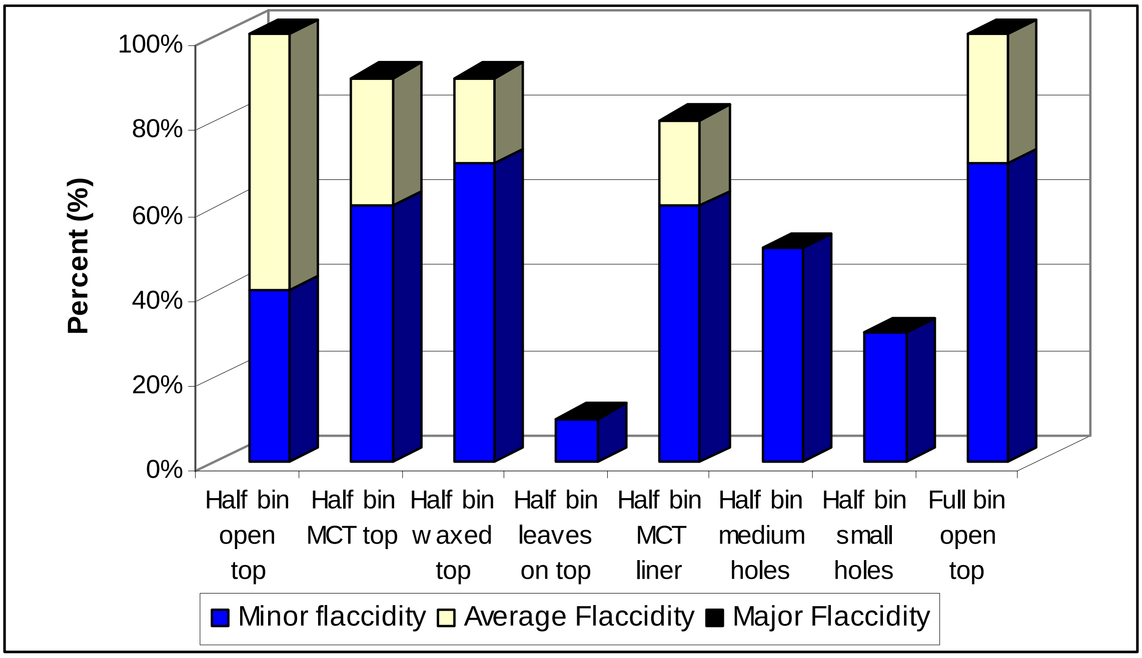


Figure 6.3.2.5. The degree of dehydration (flaccidity) of cauliflower curds on the top bin layer for each treatment.

The turgidity of cauliflower curds on the very top layer of bins assessed by treatment showed a similar trend to overall turgidity. The half bin with leaves treatment recorded only low levels of minor flaccidity in curds on the top layer of the bin. The half bins with medium and small holes in the bases recorded only minor flaccidity of curds, but there were more curds affected than for the 'leaves' treatment. The half bin MCT liner treatment produced curds with both minor and average flaccidity, and resulted in a cumulative 80 per cent flaccidity for the top layer.

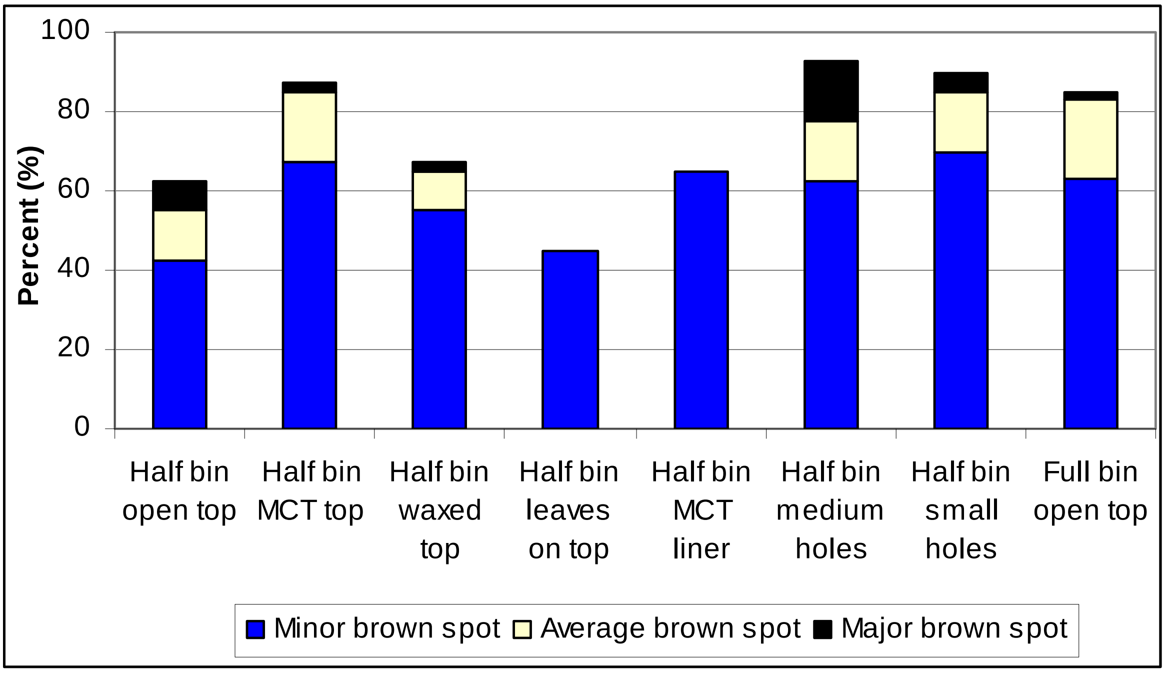


Figure 6.3.2.6. Post storage incidence of brown spot for each top treatment.

Brown spot on curds in the half bin with leaves on was lower for occurrence and severity than all other treatments. Both half bins with holes in the cardboard lid recorded a higher incidence and severity of brown spot than other treatments.

Discussion and recommendations

Disruption to the cool chain during road transport soon after pre cooling did not allow the full potential of the bulk handling treatments to be realised, and this break in the cool chain could not be tolerated in a commercial shipment. Despite the inadequate cool chain, all treatments were able to withstand the large fluctuations in temperature early on and the quality of produce at out turn for most was still acceptable and marketable. This result suggests that the bulk handling method for cauliflowers is relatively robust and able to cope with short periods of imperfect temperature control.

Overall, the half bin 'with leaves on treatment' was best for quality (marketability) and minimisation of defects. However, the use of cauliflower leaves on the top of bins potentially has positive and negative effects associated with it. Leaves are a simple and effective method of improving out-turn quality because they can be collected from the crop at harvest time at no cost, and they require no fabrication and transport, as is the case for cardboard and MCT materials.

The most obvious negative to using leaves on the top of bulk bins, is they must be completely free of contaminants, pests and diseases. This is not always possible as the speed of picking and packing may interfere with the ability to check for these conditions on the under sides of leaves. Leaves also pose an aesthetic problem when arriving at the destination, as they wilt and dehydrate over the shipping time. Any movement of the leaves against curds in transit could possibly mark the curds with green chlorophyll.

MCT Material performed well for cauliflower marketability, but it was unable to reduce the flaccidity of curds to levels similar to using leaves or ventilated cardboard tops. The cost of this material may also outweigh the benefits that it offered.

A ventilated waxed cardboard top with small holes performed well in respect to marketability and turgidity in comparison to a completely open top, however it's weakness was that it was associated with high levels of black spot on the curds. It was thought that this may have been caused by contact between the waxed cardboard and curds on top of the bins resulting in abrasion while bins were being transported.

Further work is required to refine the methods for transporting cauliflowers in bulk, and some of the methods reported here need to be tested again with better control of the cool chain after pre-cooling. The recommended packing and transport method, after taking account of the strengths and weaknesses of all the methods tested, is for a waxed cardboard lid with small (20mm diameter) holes to be placed on the top of bins while they are being transported in a ventilated sea container.

6.4 Packing methods for celery

6.4.1 Bin depth, plastic sleeves, bin bases, and pre-cooling techniques

Introduction

Celery is a vegetable traditionally exported in cardboard cartons, and sea freight is commonly used. Celery is most often packed into individual plastic sleeves after pre-cooling and the trimmed, sleeved heads are then packed into cartons in a separate operation.

Current commercial celery packaging and packing methods have a number of disadvantages including poor ventilation of produce inside cartons, double handling in the packing process, and a relatively high cost of packaging. Before this study commenced, it was not known how plastic sleeves would affect pre-cooling efficiency and subsequent transport of celery in bulk bins. If sleeves were not beneficial in transport, the cost of the sleeving operation could be shifted to the market destination to take advantage of lower labour costs by transporting heads of celery without sleeves.

Bins used in this study were designed so that twenty of the full height (deep) bins would fit into an average 20 foot sea container. A shallower option which was approximately half the height was also used. The sea container would be filled by approximately 30 of these half bins.

Every bulk bin used in this study, irrespective of depth has a gap at the base which is used for moving the bin on a forklift. These gaps plus the wooden bearers on the floor of each bin are a minimum height of 100 mm. Each of these forklift gaps constitute waste space in the container that cannot be used to hold marketable produce and the greater the number of gaps, the greater the loss in produce weight in the container. Sea containers are leased on a volume basis, and it is up to the purchaser to maximise the weight of marketable produce contained within them up to a total maximum weight limit.

Deep bulk bins that stack two high in a sea container make better use of the internal space in the container than shallower bins and potentially offer a significant saving in transport costs. The optimum bin depth for different types of produce was not known prior to this study and it needed to be investigated.

Initial work on broccoli and cauliflower highlighted two zones within the bulk bin in which dehydration of produce could be a problem. These zones were the top and bottom layers. It was likely that this problem would also be evident in celery and that strategies would need to be explored to minimise it. For this reason bin base and lid types, as well as techniques such as wetting down of the top layer of produce needed to be investigated.

Working commercial cool rooms typically fluctuate in temperature between 1 and 6^{o}C. This is mainly as a result of constant opening and shutting of doors when produce is moved in and out. It was considered important to determine if produce temperatures of 6^{O}C when loaded into the sea container would impact adversely on the marketability of produce at it's destination.

Materials and methods

Celery for use in pre cooling and storage trials was harvested over 6, 7 and 8 July 2005 at Medina Research Station. Not all of the produce required for all treatments was available on a single day because produce was sourced from trial plots grown for another project that was harvested over the four days shown. As celery became available, bulk bins were filled, and their respective treatments (Table 6.4.1.1) were applied. These were then pre cooled to the appropriate temperature and loaded into the sea container. All celery was trimmed to 30 cm in length to remove excess leaf and stem prior to sleeving and packing into respective treatments. Treatment 9 did not have excess leaf removed as it was packed directly into bulk bins in the field.

Table 6.4.1.1. Celery treatments 6 July 2006

Treatment	Bin size	Celery sleeves	Bin base	Pre cooling conditioning treatment	Pre cooling finishing temperature
1	Full	Yes	Unwaxed	No wetting	1ºC
2	Full	No	Unwaxed	No wetting	1ºC
3	Full	No	Waxed	Wet down prior	1ºC
4	Half	Yes	Unwaxed	No wetting	1ºC
5	Half	No	Unwaxed	No wetting	1ºC
6	Half	No	Waxed	Wet down prior	1ºC
7	Half	Yes	Unwaxed	No wetting	6ºC
8	Half	No	Unwaxed	No wetting	6ºC
9 (unsleeved)	Half	No	Unwaxed	No wetting	6ºC

Because of the large volume of produce required to complete the trial schedule, treatments were pre cooled progressively and transferred into the sea container at the designated temperature while other treatments were being pre cooled. Treatments that were wet prior to pre cooling had water liberally applied to the tops of the bins through a hose until water could be seen visibly draining from the bottom of the bin.

(a)

(b)


Figure 6.4.1.1. Celery treatments: (a) sleeved; and (b)unsleeved.

On 25 and 26 July 2005 treatments were removed from storage and assessed for the following (in order of importance):

1. Marketability (ranked on a scale of one to seven, one = worst and seven the best, a score of 5 was considered the minimum marketable score).
2. Turgidity (each head was ranked individually for turgidity on a scale of one to three, 1 = turgid, 2 = slightly flaccid, and 3 = moderate flaccidity).
3. Mechanical damage (presence or absence).
4. Incidence of rots.
5. Incidence of *septoria apii*.
6. Yellowing.

Sampling involved removing produce from layers vertically down the bin, 6 layers for a full bin and 4 for a half bin. Sampled layers were 0, 20, 40, 60, 80 and 100 cm deep from the top for full bins. Half bins were only sampled to 60 cm (bottom). Ten heads where removed at each layer and assessed as a sub sample

Results

Table 6.4.1.2. Bulk bin weights for celery following each handling process

Bin size	Pre cooling	Post cooling	Post storage	Percent weight loss (%)
Full bin	467.5	468.2	463.5	0.8%
Half Bin	246.3	247.7	245.3	0.4%

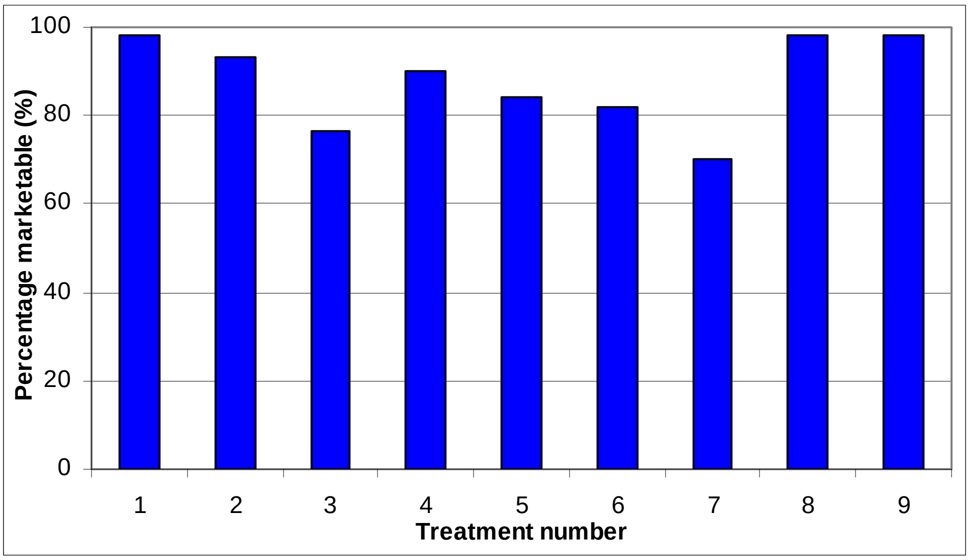


Figure 6.4.1.2. Post storage marketability of celery bulk bin treatments stored in a sea container for 20 days.

Treatments 1, 2, 8, and 9 recorded a significantly ($P<0.05$) higher percentage of marketable heads (score of 5 or greater) than all other treatments. Treatment 4 recorded similar marketability to treatments 1, 2, 8, and 9. Treatment 7 recorded the lowest overall marketability.

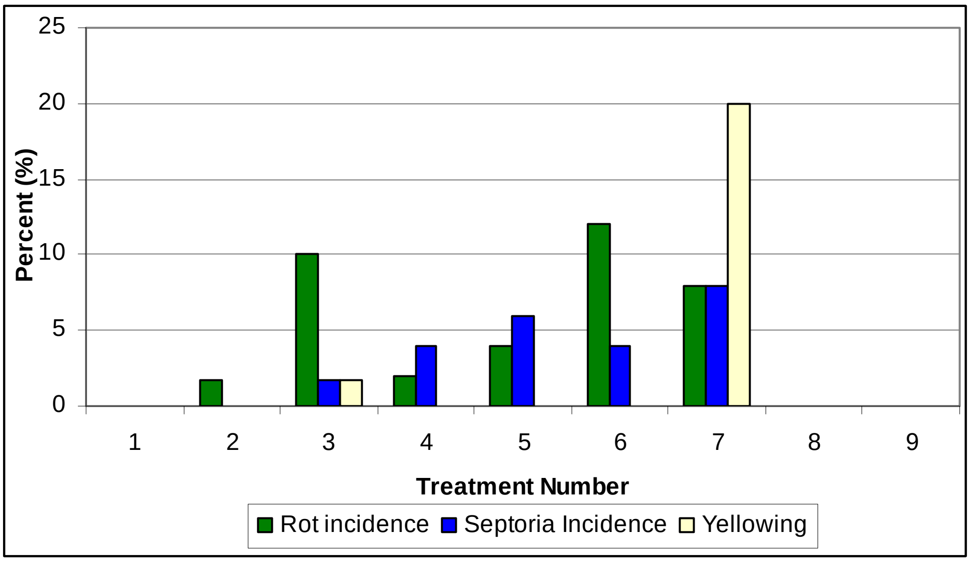


Figure 6.4.1.3. Post storage incidence of rots, septoria and yellowing for each bulk bin treatment.

Treatments 1, 8, and 9 recorded no incidence of rots, septoria and yellowing while treatment 7 recorded a significantly higher incidence of yellowing compared to all other treatments.

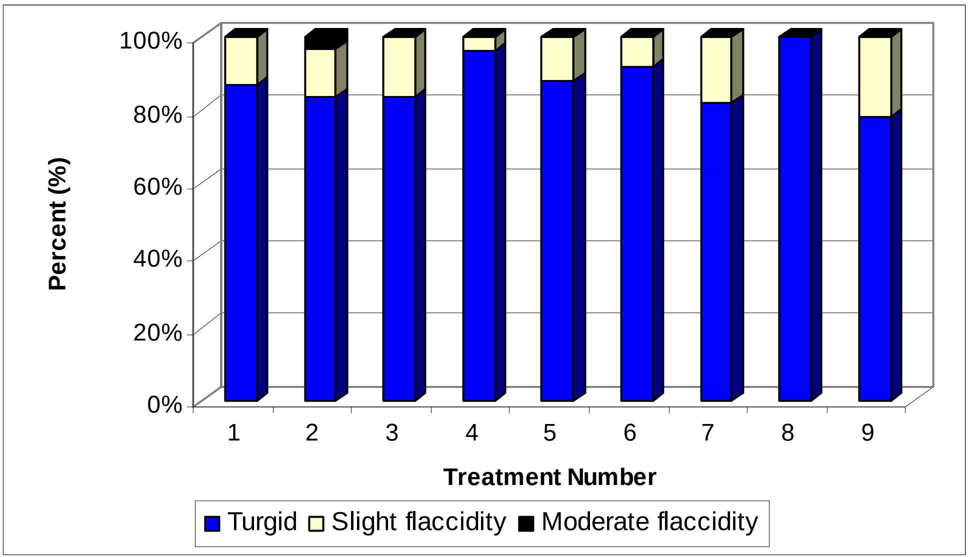


Figure 6.4.1.4. Flaccidity of celery heads in each treatment following simulated storage.

Treatment 8 recorded a significantly ($P<0.05$) higher percent of turgid heads than all treatments with the exception of treatments 4 and 6. Treatment 2 was the only one to record moderate flaccidity.

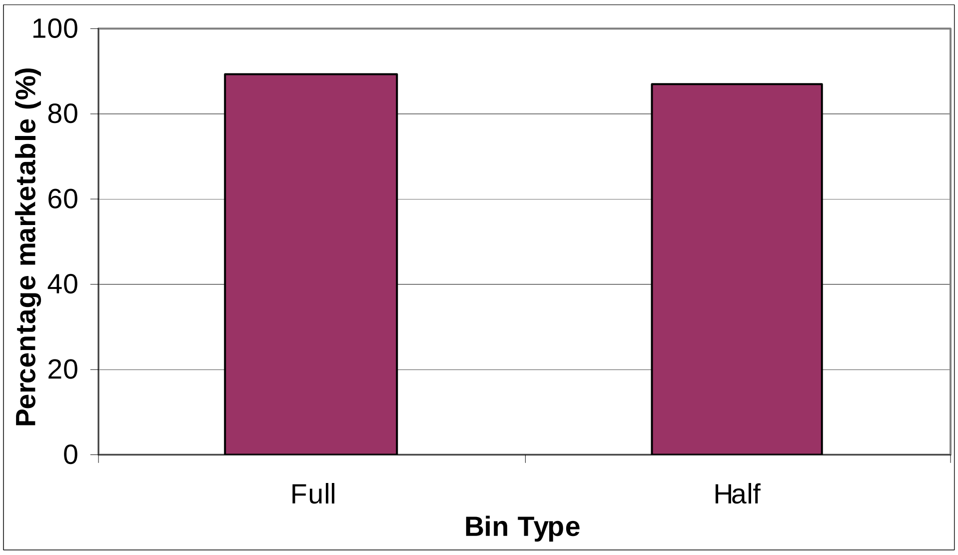


Figure 6.4.1.5. Percentage marketability of celery stored in two different bulk bin types.

No significant differences in marketability were recorded when the two different bin types were compared.

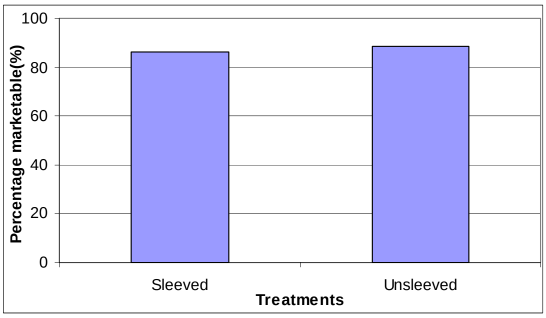


Figure 6.4.1.6. Post storage marketability of celery stored with and without sleeves.

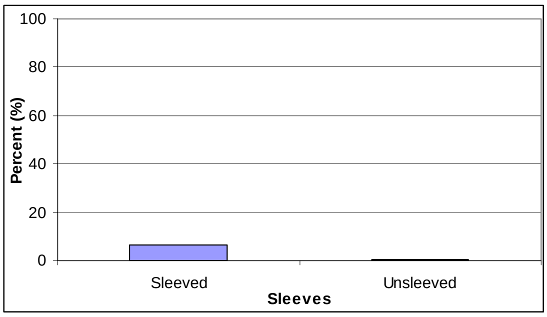


Figure 6.4.1.7. Incidence of yellowing recorded for celery stored with and without sleeves.

No significant (P>0.05) differences in marketability were recorded when sleeved and un-sleeved heads were compared using t-tests. Sleeved treatments recorded a significantly higher (P<0.05) number of heads showing yellowing than un-sleeved treatments.

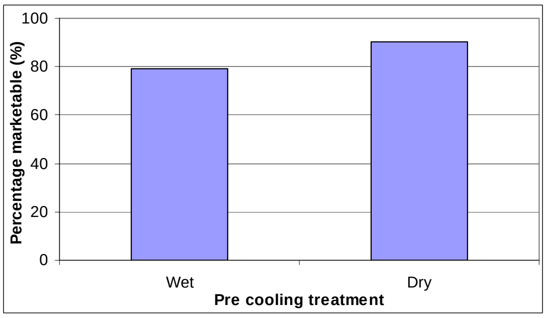


Figure 6.4.1.8. Post storage marketability of celery celery in bins that were wet or dry when pre-cooling commenced.

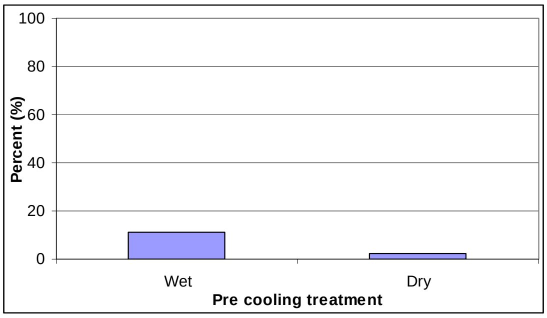


Figure 6.4.1.9. Incidence of rots recorded for in bins that were wet or dry when pre-cooling commenced.

Treatments that were wet prior to pre cooling recorded a significantly (P<0.05) lower number of marketable heads than treatments left dry. Pre wet treatments also recorded a significantly (P<0.05) higher percentage of rotten sticks than treatments left dry when compared using t-tests.

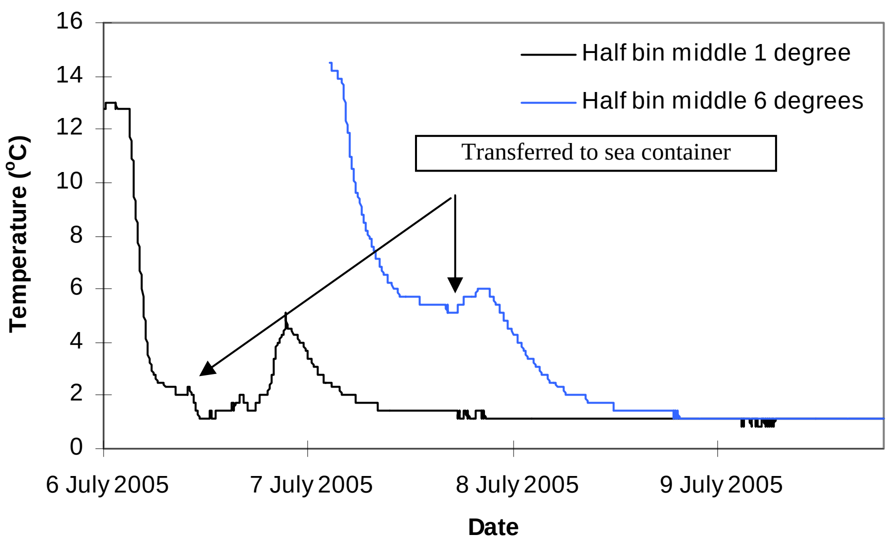


Figure 6.4.1.10. Cooling trend of celery pre cooled to either 1°C or 6°C.

The cooling trend of treatments cooled to 1°C before transferring into the sea container increased to just over 4°C at loading. Once loaded, the container was able to efficiently decrease the produce temperature to below 2°C in 6 hours and 20 minutes. Treatments cooled to six degrees before loading increased slightly when moved into the sea container, but once in the container required 8 hours and 15 minutes to draw down to 2°C.

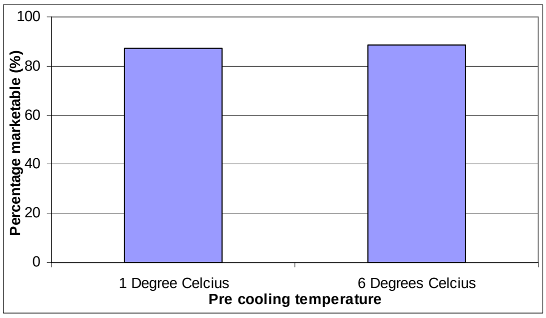


Figure 6.4.1.11. Post storage marketability of celery stored pre-cooled to either 1°C or 6°C.

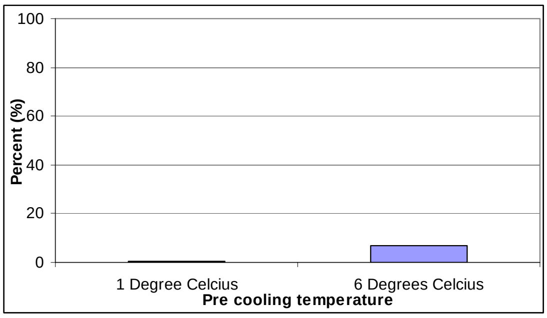


Figure 6.4.1.12. Incidence of yellowing recorded for celery pre-cooled to 1°C or 6°C.

No significant ($P>0.05$) difference was recorded for the marketability of produce cooled to 1°C versus produce cooled to 6°C. Yellowing of treatments cooled to 6°C and transferred into the sea container was significantly ($P<0.05$) higher than produce cooled to 1°C when compared using t-tests, but the incidence of yellowing was relatively low.

Discussion and recommendations

The marketability of celery stored for 20 days was highest for four treatments: (1) Full bin sleeved regular base no pre wetting cooled to 1°C; (2) Full bin un sleeved regular base no pre wetting cooled to 1°C; (8) Half bin unsleeved regular base no pre wetting cooled to 6°C; and (9) Half bin un sleeved regular base no pre wetting cooled to 6°C untrimmed.

The common factors among these treatments that were associated with good quality out-turn were transporting celery without sleeving it and not wetting the celery before pre cooling it in the bulk bins. Surprisingly, an incomplete pre cooling process that led to celery being loaded at 6°C did not have serious adverse effects on out-turn.

Despite treatment 8 recording the highest turgidity of all treatments, the lack of marketability differences between a half bin and full bin, would favour the economics associated with using full bins. As an example of the relative efficiencies of the two methods, full bins in a 20 foot sea container will carry 9.3 tonne of produce versus 7.3 tonne with half bins.

Treatment 2 recorded a lower marketability, 1.6 per cent incidence of rots and a similar turgidity to treatment 1. The difference between these two treatments was the sleeving of individual celery heads. Sleeving was associated with a significantly higher incidence of yellowing. The majority of yellowing was recorded in treatment 7 which was also only cooled to 6°C before storage. Produce in treatment 8 was not sleeved, but was also cooled to only 6°C, without incidence of yellowing.

Sleeving would interfere with the circulation of air around individual heads having a dual effect on the produce. The first is that produce would not respond to temperature fluctuations as rapidly as un-sleeved sticks, i.e. if temperature increased it would take longer for produce to return to optimum storage temperature. Secondly, sleeves could interfere with the dispersion of gases (such as ethylene) from around individual heads, which could potentially lead to increased maturity or colour loss.

Wetting of produce immediately prior to pre cooling did not prove to be a good management strategy. The marketability of produce that had been deliberately wet prior to pre cooling was significantly lower than dry celery, whilst rot incidence was significantly higher than produce left dry. Free moisture made available throughout the bin probably could disperse bacterial and fungal organisms and encourage their development.

The results suggest that if the cool chain was maintained as in treatment 1 by cooling produce to 1°C then it is possible to sleeve celery prior to transit, however if this can not be maintained then the best option to use for transporting celery would be a full bin un-sleeved, with a regular cardboard floor, no pre wetting and cooled to 1°C.

6.4.2 Celery plastic sleeve comparison

Introduction

Initial work with celery showed that a full bin with sleeves, a regular cardboard base and pre cooling to 1°C would out turn celery at optimum marketability. Another opportunity to test this result with celery from a commercial grower occurred in April 2006. On this occasion, a full bulk bin of un-sleeved celery was compared to a full bin of sleeved celery.

Materials and methods

Celery were packed, or sleeved and packed, into two full bins on 18 April 2006, after which they were pre cooled to 1°C. During packing, excess leaves were trimmed from each individual head, including trimming the tops to a standard length. Heads in the sleeved treatment where sleeved at this time. On 19 April, bins were loaded into a sea container, at which time temperature loggers were placed in each bin.

(a) (b)

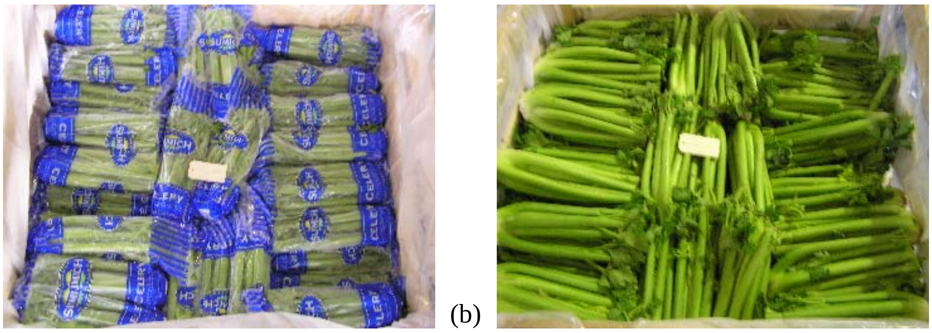


Figure 6.4.2.1. Celery treatments in half filled deep bins: (a) sleeved; and (b) unsleeved.

On 15 May 2006 treatments were removed from storage and assessed for the following (in order of importance):

1. Initial marketability with outer petioles remaining (ranked on a scale of one to seven, one = worst and seven the best).
2. Trimmed marketability with outer petioles removed (ranked on a scale of one to seven, one = worst and seven the best).
3. Turgidity (each head was ranked individually for turgidity on a scale of one to three, 1 = slightly flaccid, 2 = average flaccidity, and 3 = major flaccidity).
4. Mechanical damage (each head was ranked individually for mechanical damage on a scale of one to three, 1 = minor mechanical damage, 2 = distortion damage, and 3 = major cracks).

Sampling involved removing produce from 6 layers vertically down the bin. Sampled layers were 0, 20, 40, 60, 80 and 100 cm deep from the top. Ten heads where removed at each layer and assessed as a sub sample.

Results

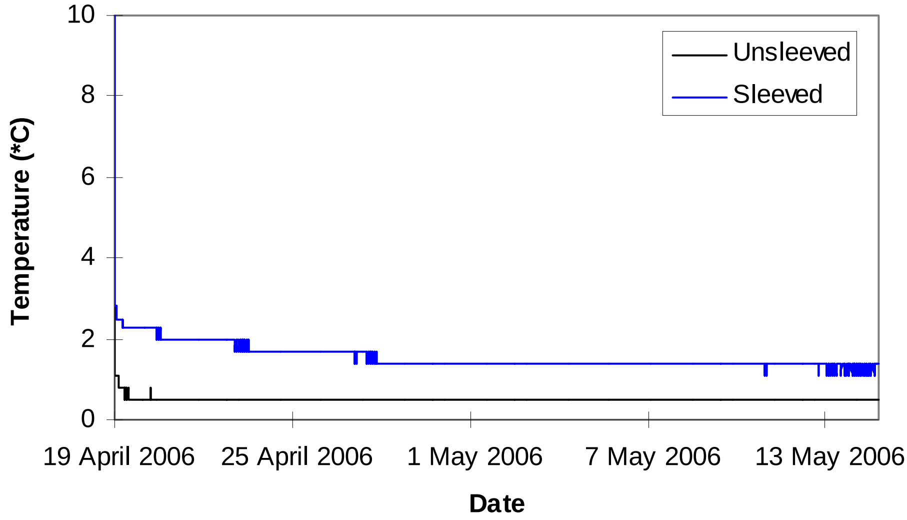


Figure 6.4.2.2. Cooling trend for sleeved and un-sleeved celery treatments stored for 26 days.

Sleeved celery recorded 1°C higher average temperatures than un-sleeved sticks for the entirety of the storage period.

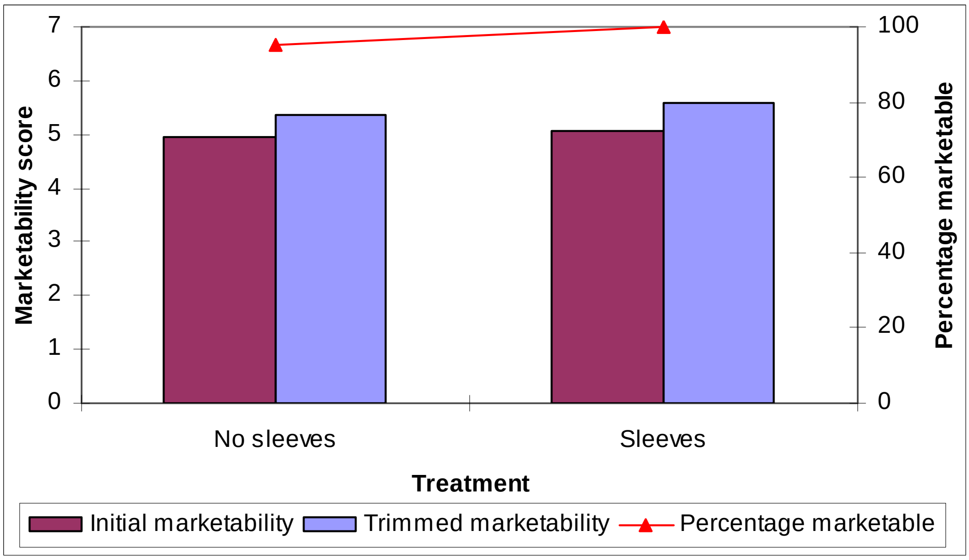


Figure 6.4.2.3. Post storage assessment of initial and trimmed marketability scores and percentage marketable for sleeved and un-sleeved celery treatments stored for 26 days.

The initial and trimmed marketability for sleeved heads was significantly ($P<0.05$) higher than un-sleeved heads when compared using t-tests. The marketable percentage of celery heads was marginally higher when sleeved, but not significantly ($P<0.05$).

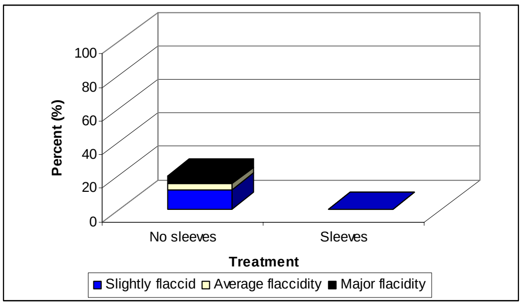


Figure 6.4.24. **Post storage turgidity of sleeved and unsleeved celery.**

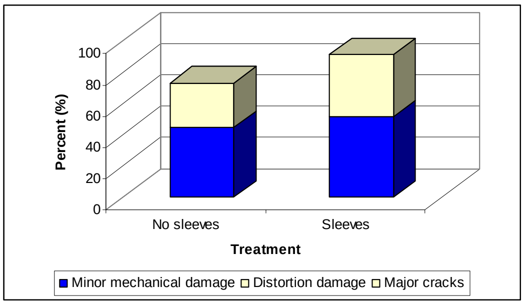


Figure 6.4.2.5. Post storage mechanical damage to sleeved and unsleeved celery.

Un-sleeved celery heads were significantly ($P<0.05$) more flaccid than sleeved heads when compared using t-tests. The severity of flaccidity in un-sleeved heads was also greater than sleeved heads. Total mechanical damage to sleeved celery heads was significantly greater than damage to un-sleeved heads.

Figure 6.4.2.6. Example of flaccid petioles prior to post storage trimming.

Flaccid petioles similar to those in figure 6.4.2.6 were removed to complete a trimmed marketability score.

Discussion and recommendations

A side by side comparison of sleeved and unsleeved celery in full bulk bins reinforced the findings of the previous celery trial. The sleeved produce out turned with higher marketable head numbers and individual marketability scores over all. The more turgid heads in the sleeved treatment resulted in a greater percentage of mechanical damage. Their very crisp nature would allow individual heads to break and crack, rather than allow for some give.

Although sleeving requires more time at their origin, unsleeved heads would need to be trimmed at their destination to remove flaccid petioles from the heads. Extra trimming would add cost to importing, but would do so at a location where labour was less expensive.

Sleeved celery heads maintained on average 1°C higher temperatures than un-sleeved heads. As mentioned in the previous trial, celery in sleeves may be less able to cope with fluctuating temperatures. In a static sea container this did not prove to be a problem, however it is important to investigate this in test shipments in the future.

6.5 Packing methods for cos lettuce

6.5.1 Bin depth, bin bases, and ventilation

Introduction

Storage trials in export bulk bins with a range of vegetable products in a coolroom and a land based sea container proved very encouraging. However two areas of concern were noted, dehydration to the top and very bottom layers of produce in the bulk bins. Trials were conducted investigating bin bases made of cardboard for control of dehydration in a range of vegetables. The main comparison was between waxed and un-waxed cardboard flooring (bases). It was considered that this would also be a problem for cos lettuce in storage, and it was important for this to be the starting point for bulk handling work with this product.

Although not as cost effective as the deep bins that had proven suitable for other vegetable products, shallower bins may be better for cos lettuce because it is vulnerable to crushing or flattening injury. Full bins could impair the quality of produce toward the bottom of the bin through excess weight causing mechanical damage to lettuce heads.

Most vegetable produce is packaged in sealed cardboard cartons for export. But it was not known whether bulk bins of cos lettuce could be sealed during transport, and what affect that would have on marketability. It was considered important to compare the marketability of transporting produce in sealed bins versus fully ventilated bins, because cos lettuce has a high propensity to lose moisture and for leaves to become flaccid.

Materials and methods

Waxed and unwaxed base treatments were fitted to the inside of bulk bins prior to packing. Bins were then packed on 14 October 2005 with cos lettuce sourced from field trials at Medina Research Station. All bins were then pre cooled to 1°C using forced air cooling as described for other crops elsewhere in this report. Once produce had reached 1°C bulk bin treatments were loaded into the 'land based' sea container on 17 October 2005. The 'sealed bin liner' treatment was sealed at this time, by folding over the plastic top and securing this with packing tape.

Table 6.5.1.1. Cos lettuce treatments 14 October 2005

Number	Treatment
1	Full bin waxed base open top
2	Full bin unwaxed base open top
3	Half bin unwaxed base open top
4	Half bin unwaxed base covered top
5	Half bin waxed base covered top

(a) (b)

Figure 6.5.1.1. Cos lettuce treatments: (a) fully ventilated; and (b) covered.

On 7 November 2005 treatments were removed from storage and assessed for the following (in order of importance):

1. Marketability (ranked on a scale of one to seven, one = worst and seven the best).
2. Mechanical damage (each head was ranked individually for degree of flattening on a scale of one to three, 1 =normal, 2 =flat, and 3 =very flat).
3. Incidence of rots.

Sampling involved removing produce from layers vertically down the bin, 7 layers for a full bin and 4 for a half bin. Sampled layers were 0, 17, 34, 50, 67, 84 and 100 cm deep from the top for full bins. Half bins were only sampled to 60 cm (bottom). Five heads where removed at each layer and assessed as a sub sample.

Results

Cooling trends for all treatments were as expected until late on 17 October 2005 when they were transferred to the sea container. Produce at the centre of the full bin required 15 hours 20 minutes of pre-cooling to reach 2°C compared to 9 hours 50 minutes for produce at the centre of the half bin. Following transfer of produce to the sea container and the sealing of the half bin, the produce in the centre of the full bin decreased to a temperature slightly higher (0.3°C) than the ambient temperature of the sea container. The produce at the centre of the sealed bin required longer to fall below 2°C and remained 0.3 to 0.6°C warmer than produce in the full bin for the entire simulated voyage.

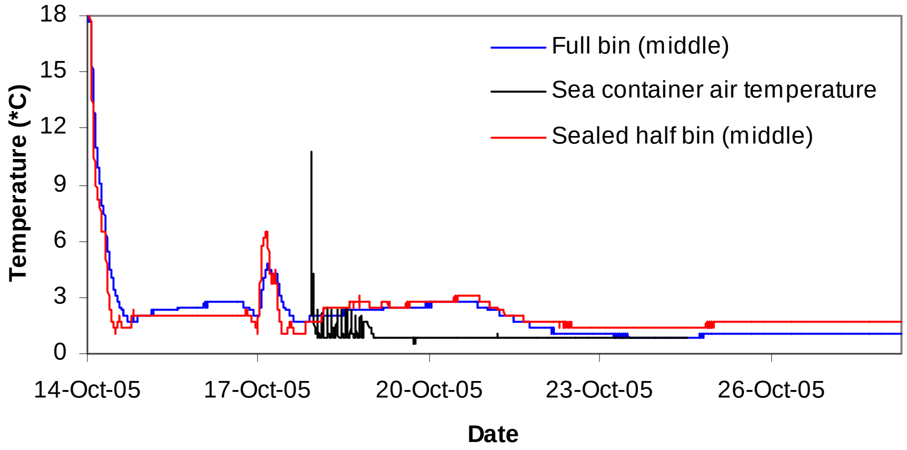


Figure 6.5.1.2. Core temperatures of cos lettuce treatments compared to the refrigerated air temperature in the 'land based' sea container.

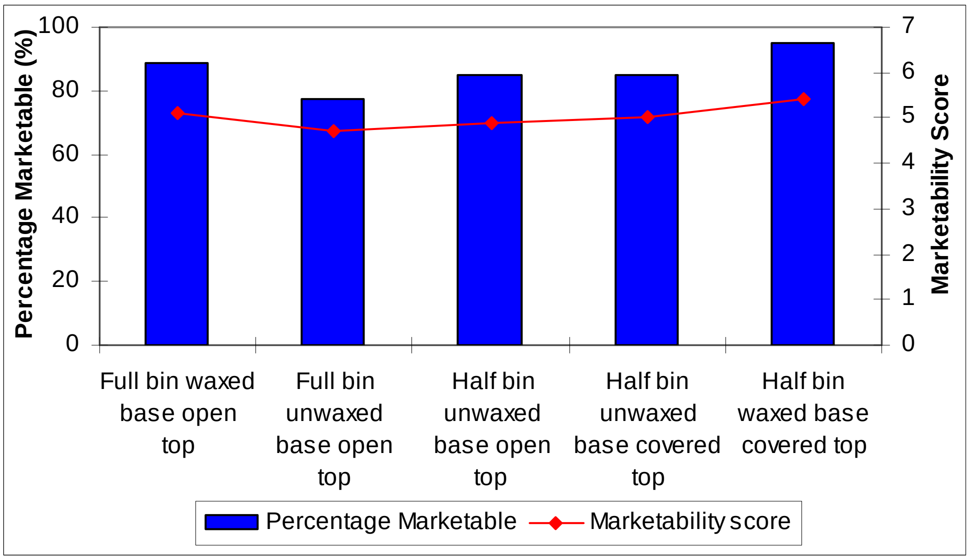


Figure 6.5.1.3. Post storage marketable percentage and marketability scores for cos lettuce treatments stored for 21 days.

Analysis of the marketability using Anova failed to show any significant (p>0.05) differences between the percentage of marketable heads and the mean marketability scores for all five treatments. Waxed base treatments recorded higher scores than un-waxed bases. Covering (sealing) treatments were not significantly different than ventilated treatments for marketability scores.

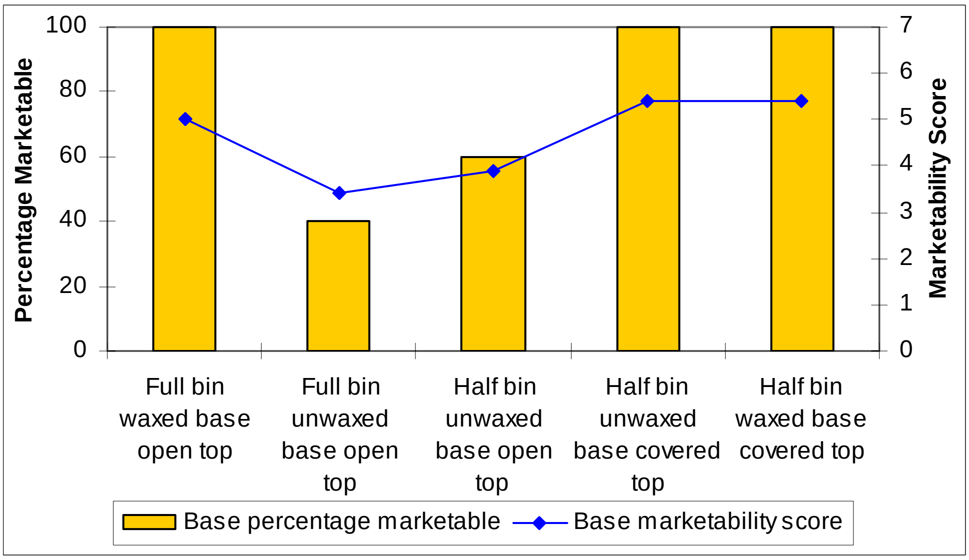


Figure 6.5.1.4. Post storage percentage marketable and marketability score of cos lettuce heads on the bottom layer of each treatment stored for 21 days.

The percentage marketable and marketability score for the bottom layer of cos lettuce were lower in two of the three un-waxed base treatments than in the waxed base treatments.

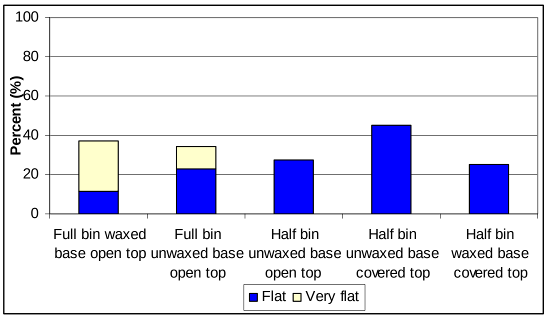


Figure 6.5.15. Post storage mechanical damage to cos lettuce treatments stored for 21 days.

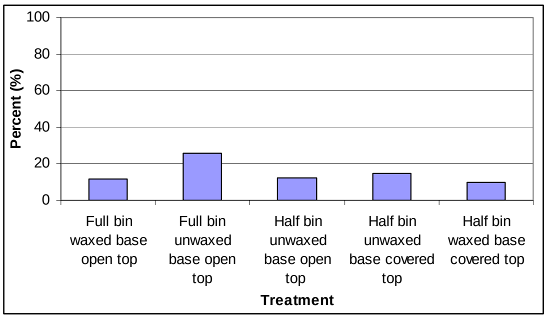


Figure 6.5.1.2. Incidence of rots in cos lettuce treatments stored for 21 days.

(a) 

(b) 

Figure 6.5.1.7. (a) Compaction or sinking of produce in the full bin treatment after storage; and (b) Example of flattening noted at the bottom of the full bin treatment.

All treatments experienced a high percentage of flattening of heads, however both full bin treatments recorded a significantly ($P<0.05$) higher percentage of very flat heads when compared using Anova. All treatments recorded statistically similar levels of rot incidence ($P>0.05$) but un-waxed base treatments all recorded slightly higher rot levels than waxed treatments. Covering did not significantly increase the incidence of rots.

During assessment of the full bin treatment, sinking or compaction of produce down the bin was noted. Figure 6.5.1.7(a) shows produce had sunk half the way down the width of the first horizontal rail of the bulk bin. Bins were initially filled slightly above the level of this rail, before the period of storage. Figure 6.5.1.7(b) indicates the extent of flattening to individual cos heads in the full bulk bin treatment. This flattening may still be acceptable for processing if other defects, such as crushing were not present.

Discussion and recommendations

Although significant differences in marketability were not recorded between treatments, bulk bins with waxed bases generally recorded higher levels of marketability and lower incidence of rots for cos lettuce. This was consistent with findings in the bottom layer of the bulk bins. Results suggest that both base types would provide a good marketable result but waxed bases generally would be slightly better.

Constantly ventilated produce did not perform better than produce that was sealed in a plastic liner. In the controlled conditions of the static sea container there was little fluctuation in temperatures allowing the sealed produce to remain at a temperature constantly between 0.3 and 0.6°C higher than ventilated produce. An actual voyage may have more fluctuations in temperature than the static container which could affect sealed produce more than ventilated produce.

A comparison of a full bin and half bins indicated that a greater severity of mechanical damage in the form of flattening would occur in the full bin. Compaction within the bin would increase the density of produce and decrease the air pockets around the produce. Reduced spaces would reduce the ability of cold air to flow freely around produce to cool it. Mechanical damage in the static trials did not lead to an escalation in secondary problems such as rots. Severe flattening may be acceptable to an importer using produce for processing if there was no stem cracking or crushing of the produce.

The rots sustained in all treatments detract from the potential of cos lettuce for bulk shipping. For cos lettuce to have a future as a bulk shipped product, it will be important to focus on handling methods that limit the incidence of rots.

6.5.2 Ventilation control.

Introduction

Initial investigations for cos lettuce showed that rots were the most common reason for losses when it was handled and transported in bulk bins. The incidence of rots did not significantly differ between treatments stored in a static sea container. The temperature trends observed in the October 2005 trials for sealed bins suggested that any upward fluctuations experienced in a sea voyage could adversely affect cos lettuce in a sealed bulk bin more than a better ventilated bin because produce temperature was always higher in sealed bins. It was important therefore to investigate top covers and bin linings which enable enough airflow through the produce to decrease the chances of rots whilst minimising dehydration of outer leaves.

Economically, the use of deep bins that maximise the quantity of product that can be loaded into a sea container whilst minimising transport costs per tonne is a good proposition. However, previous work showed that cos lettuce packed in full bins experienced a higher percentage of severe flattening than produce in half bins. This severe flattening could potentially result in secondary problems if optimum temperatures were not maintained throughout the voyage. These considerations were taken into account in planning this work on ventilation control, and the work was consequently all done with half depth bins.

Materials and methods

All treatment bins used in this trial were lined with the standard polythene pallet bag used in all previous trials with other vegetable types except treatment 3 which was lined with an MCT liner. Limitations on the volumes of produce available to conduct these trials led to bins being divided vertically by a waxed cardboard divider to allow two different ventilation control treatments to be compared in each bin (see Figure 6.5.2.1).

Figure 6.5.2.1. Two ventilation treatments in a bin separated by a cardboard divider.

All treatments were packed on 30 January 2006 with lettuce grown on site at Medina Research Station. Treatments were pre cooled to 2°C after harvesting using forced air cooling as previously described.

Once produce had reached 2°C cardboard lids of various types were placed on the top of bins to impose the ventilation treatments that were tested during the storage period in the static sea container. Treatments with wet cardboard lids were saturated with water using a hose and placed in the cool room for 24 hours whilst treatments were being pre-cooled to equilibrate with the humidity level of the coolroom. All treatment bins were loaded into the sea container on 31 January 2006. Sealed top treatments, for example treatments 2 and 3. were sealed at the time of loading.

Two control treatments representing conventional practice in cardboard cartons (Treatments 11 and 12) were also packed and loaded into the sea container. A full list of treatments is shown in Table 6.5.2.1. Loggers were placed in treatments 3 and 4 during packing, one probe was placed in a lettuce core at the centre of the bin, while the other was in the core of a lettuce at the top of the bin. Another logger was placed in the centre of the sea container on top of produce to collect information on ambient air temperature.

Table 6.5.2.1. Cos treatments 14 October 2005

Number	Treatment
1	Open top
2	Sealed plastic top
3	MCT liner sealed top
4	MCT top, standard liner
5	Solid waxed top – pre-wet
6	Solid unwaxed top – pre-wet
7	60 mm holes waxed top – pre-wet (12 holes per half)
8	60 mm holes unwaxed top – pre-wet (12 holes per half)
9	Solid waxed top – dry
10	Solid unwaxed top – dry
11	Commercial cartons – unwrapped
12	Commercial cartons – MCT liner
13	40 mm holes waxed top – dry (12 holes per half)
14	60 mm holes waxed top – dry (12 holes per half)
15	20 mm holes waxed top – dry (22 holes per half)
16	40 mm holes waxed up – dry (22 holes per half)

The diameter of holes for treatments with holes cut in the tops varied by up to 5 mm due to differences in hole saws.

Figure 6.5.2.2. Examples of treatments: (a) treatment 1; (b) treatment 2; (c) treatment 3; (d) treatment 4; (e) treatments 7 and 8; (f) treatment 9 and 10; (g) treatment 12; (h) treatments 14 and 13; (i) treatments 15 and 16.

On 22 and 23 February 2006 treatments were removed from storage in the sea container. A sample of produce was removed and assessed for the following (in order of importance).

1. Initial marketability (ranked on a scale of one to seven, one = worst and seven the best).
2. Marketability with the outer leaf removed (ranked on a scale of one to seven, one = worst and seven the best).
3. Turgidity of outer leaves.
4. Incidence of rots.
5. Mechanical damage (each head was ranked individually for degree of flattening on a scale of one to three,
   1 =no flattening, 2 =flat, and 3 =very flat).
6. Incidence of pink vein.

Sampling involved removing produce from four layers vertically down the bin. Sampled layers were 0, 20, 40 and 60 cm (bottom) deep from the top of the bin. Ten heads where removed at each layer and assessed as a sub sample.

Results

Temperatures in the sealed MCT liner treatment (treatment 3) were between 0.9°C and 1.2°C higher than the unsealed treatment (treatment 4) throughout the storage period in the sea container, despite the entry temperature for both sealed and unsealed treatments being the same on loading into the sea container. Continual spikes in ambient temperature in the sea container resulted in an accumulation of heat in lettuce in the MCT sealed bins that was not fully removed after the spikes ended. One spike in particular around 9 February (Figure 6.5.2.4) resulted in a permanent rise in produce temperature in the MCT sealed bins.

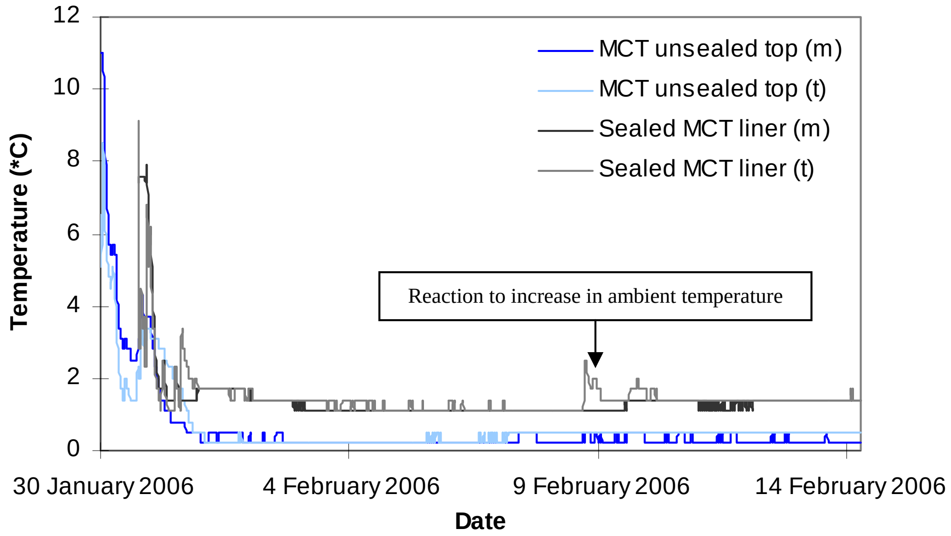


Figure 6.5.2.3. Storage temperature of the sealed MCT lined treatment versus unsealed MCT top.

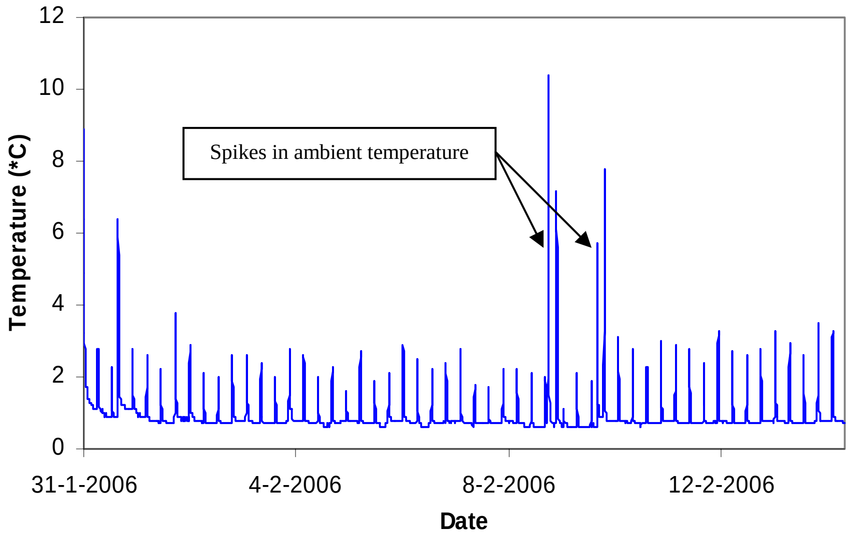


Figure 6.5.2.4. Ambient storage temperature inside the sea container during cos lettuce bulk handling trial.

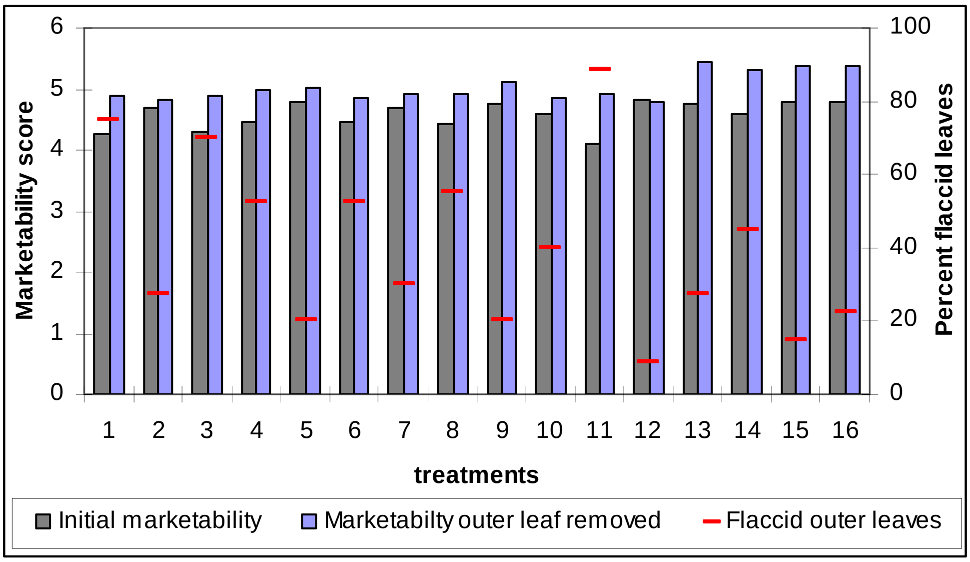


Figure 6.5.2.5. Post storage initial marketability, marketability (outer leaves removed) and percent flaccid leaves for all cos lettuce treatments.

Treatments 12, 15, 16 and 5 recorded the top four initial marketability scores (before removal of the outer leaves) for all treatments. These scores were not significantly higher than treatments 13 and 9. Initial marketability scores correlated strongly (r = -0.94) with the percentage of flaccid outer leaves for each treatment. Treatments 12 had the lowest level of flaccid outer leaves of all treatments, whilst treatment 15 was the second lowest. Treatments 13, 14, 15 and 16 recorded significantly ($P<0.05$) higher marketability scores after the outer leaves had been removed than all other treatments.

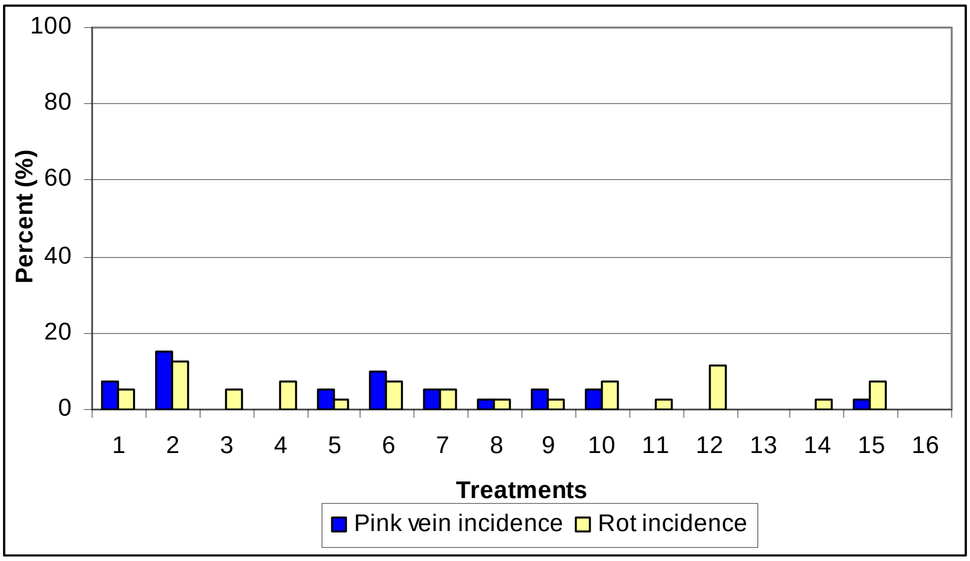


Figure 6.5.2.6. Post storage incidence of rots and pink vein for all cos lettuce treatments.

Of all 16 treatments only treatments 13 and 16 did not record any incidence of rot or pink vein. Treatments 2 and 12 recorded the highest incidence of rots. Treatments 2 and 6 recorded the highest incidence of pink vein.

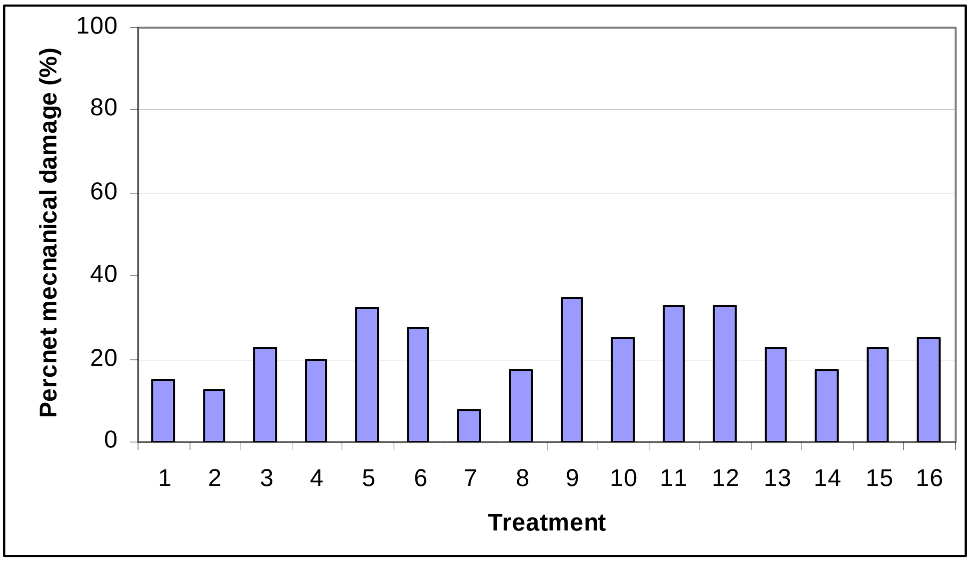


Figure 6.5.2.7. Post storage mechanical damage (flattening) for all cos lettuce treatments.

Although no significant differences were recorded (P>0.05), treatment 7 recorded the lowest level of mechanical damage, followed by treatments 2 and 1 respectively.

Discussion and recommendations

A comparison of different ventilation packaging highlighted two options as commercial possibilities. Both treatments had waxed cardboard tops perforated with ventilation holes 40 mm in diameter. Treatment 13 was ventilated with 12 holes in the half bin lid (24 per full bin lid equivalent) and treatment 16 was ventilated with 22 holes per half (44 for a full bin lid). Neither lid type was pre wet.

Treatments 13 and 16 recorded higher initial marketability, higher marketability (with outer leaves removed), lower flaccid outer leaves, no incidence of rots or pink vein and similar mechanical damage to the open bulk bin treatment. All of these features are desirable for exporting produce because it reduces waste at the destination.

The sealed bin (2) and the MCT sealed liner (3) did not improve the quality of out turned produce above that seen in the open bin. Given the reaction of produce to temperature increases (figures 6.5.2.3 and 6.5.2.4) in a static sea container, it is possible to speculate that the temperature fluctuations experienced in a normal sea voyage could be greater on occasions and adversely affect the quality of out-turned produce.

Commercial cartons recorded similar results to the open bin treatments for all characteristics with two exceptions, flaccid outer leaves and mechanical damage. The flaccid leaves are most likely a result of moisture loss to the cardboard cartons during storage. The increased mechanical damage is likely to have been inflicted as a result of squashing produce into the cartons. Both quality defects resulted in significantly lower produce marketability than treatments 13 and16. Prior to commercialisation, these results would require verification through repeat static trials and further test shipments.

6.6 Packing methods for Chinese cabbage

6.6.1 Ventilation control

Introduction

Previous work testing bulk handling for vegetables showed that produce could be shipped successfully using these techniques and bulk bins. Trials also indicated that two main areas within the bin should be targeted to decrease in-transit dehydration and improve the quality of out-turn. These include modifications to the cardboard bases in bins and the incorporation of bin lids which reduce the rate of ventilation of produce while in storage in the sea container.

The majority of work on bin bases with other vegetables compared an un-waxed base to a waxed version. The results of this have not been conclusive, but the trend has been for a waxed base to reduce dehydration of produce on the bottom layers of the bins compared to an un-waxed base. For this reason a waxed base was used in all Chinese cabbage work.

Investigations of bulk bin lids for various vegetables have shown that reduced ventilation rates will out turn produce at, or better than open bins or cartons. It is for this reason ventilation control with bin lids and liners were investigated as a first priority for Chinese cabbage.

Materials and methods

All treatment bins used in this trial were lined with the standard polythene pallet bag used in all previous trials with other vegetable types except treatment 3 which was lined with an MCT liner. Limitations on the volumes of produce available to conduct these trials led to bins being divided vertically by a waxed cardboard divider to allow two different ventilation treatments to be compared in each bin (see Figure 6.6.1.1).

Figure 6.6.1.1. Vertical segregation of bulk bin ventilated treatments.

All treatments were packed on 20 March 2006 with lettuce grown on site at Medina Research Station. Treatments were pre cooled to 2°C after harvest using forced air cooling as previously described.

Once produce had reached 2°C cardboard lids of various types were placed on the top of bins to impose the ventilation treatments that were compared during the storage period in the static sea container. Treatments with wet cardboard lids were saturated with water using a hose and placed in the cool room for 24 hours whilst treatments were being pre cooled to equilibrate with the humidity level of the coolroom. All treatment bins were loaded into the sea container immediately after pre-cooling. Sealed top treatments, for example treatments 2 and 3 were sealed by taping the liner over the top layer of produce in the bin at the time of loading. Two control treatments representing conventional practice in cardboard cartons (Treatments 11 and 12) were also packed and loaded into the sea container. A full list of treatments is shown in Table 6.6.1.1. Loggers were placed in treatments 3 and 4 during packing, one probe was placed in a lettuce core at the centre of the bin, the other was in the core of a lettuce at the top of the bin. Another logger was placed in the centre of the sea container on top of produce to collect information on ambient air temperature.

Table 6.6.1.1. Chinese cabbage treatments 20 March 2006

Number	Treatment
1	Half bin open top
2	Half bin closed top
3	Half bin MCT Liner
4	Half bin MCT top
5	Half bin un waxed solid top
6	Half bin waxed solid top
7	Half bin 60mm holes un waxed top – wet (12 holes per half)
8	Half bin 60mm holes waxed top – wet (12 holes per half)
9	Half bin un waxed solid top – pre wet
10	Half bin waxed solid top – pre wet
11	Cartons
12	MCT lined Cartons
13	Full bin open
14	Full bin closed

The diameter of holes for treatments with holes cut in the tops varied by up to 5mm due to differences in hole saws.

Figure 6.6.1.2. Examples of Chinese cabbage treatments: (a) treatments 1 and 13; (b) treatments 2 and 14; (c) treatment 3; (d) treatment 4; (e) treatments 9 and 10; (f) treatments 7 and 8; and (g) treatment 12.

On 10 April 2006 treatments were removed from storage. A sample of produce was removed, weighed and assessed for the following (in order of importance).

1. Initial marketability (ranked on a scale of one to seven, one = worst and seven the best).
2. Marketability with the outer leaf removed (ranked on a scale of one to seven, one = worst and seven the best).
3. Incidence of rots.
4. Mechanical damage (each head was ranked individually for degree of flattening on a scale of one to three,
   1 = no flattening, 2 = flat, and 3 = very flat).

Sampling involved removing produce from layers vertically down the bin, 6 layers for a full bin and 4 for a half bin. Sampled layers were 0, 20, 40, 60, 80 and 100cm deep from the top for full bins. Half bins were only sampled to 60cm (bottom). Five heads where removed at each layer and assessed as a sub sample

Results

All Chinese cabbage treatments out turned with high levels of a physiological condition known as gomasho that resulted in the produce automatically being deemed unmarketable and given scores of less than 5.

Overall weight loss through dehydration during pre-cooling was negligible, with no change in gross bin weights before and after pre-cooling. It is expected that there would have been some weight loss from the produce during pre cooling that may have been offset by an equivalent uptake of moisture by the pinewood bins. On average, a half bin of Chinese cabbage held 168 kg or 150 heads and a full bin 318 kg or 281 heads.

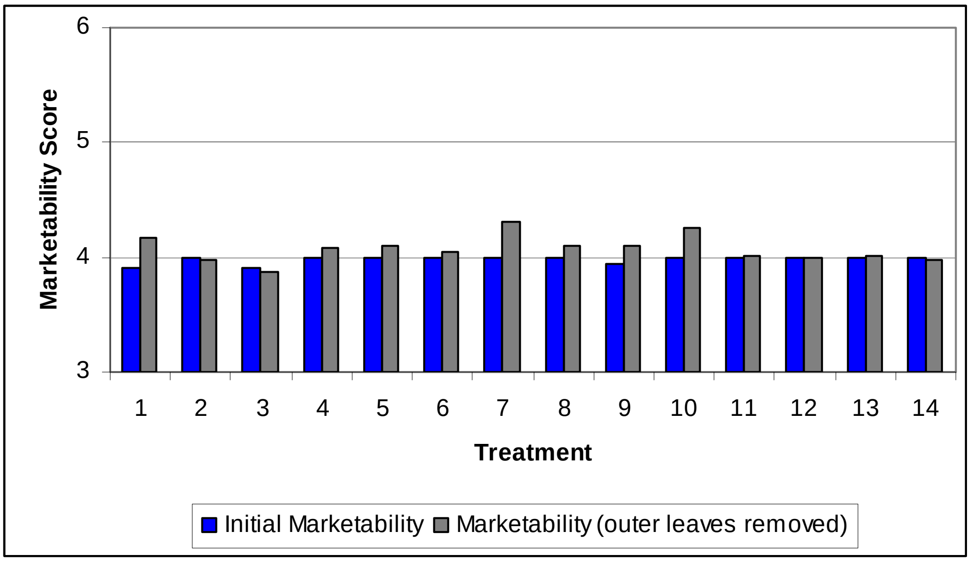


Figure 6.6.1.3. Post storage initial marketability score, and marketability score (outer leaves removed) for all Chinese cabbage treatments.

Initial marketability scores (before removal of outer leaves) showed no significant difference (P<0.05) between all treatments. After removal of the outer leaves, treatment 7 had a higher marketability score than the others. Treatments 7 and 10 recorded a significantly higher marketability (P<0.05) score than treatments 11 (commercial cartons), 12, 13, and 14.

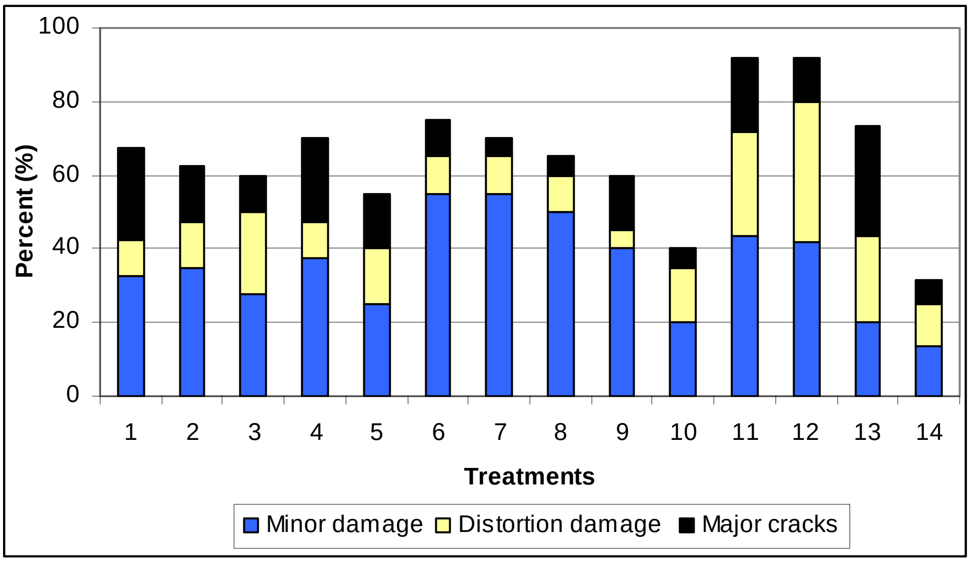


Figure 6.6.1.4. Mechanical damage to individual Chinese cabbage heads during storage.

Treatment 14 recorded significantly less mechanical damage than all treatments excluding treatments 10 and 5. Chinese cabbage packed and stored in cartons (treatments 11 and 12) recorded total mechanical damage in excess of all other treatments. Treatment 13 (open full bin) and treatment 1 (open half bin) did not show significant differences in severity and total damage to Chinese cabbage after storage.

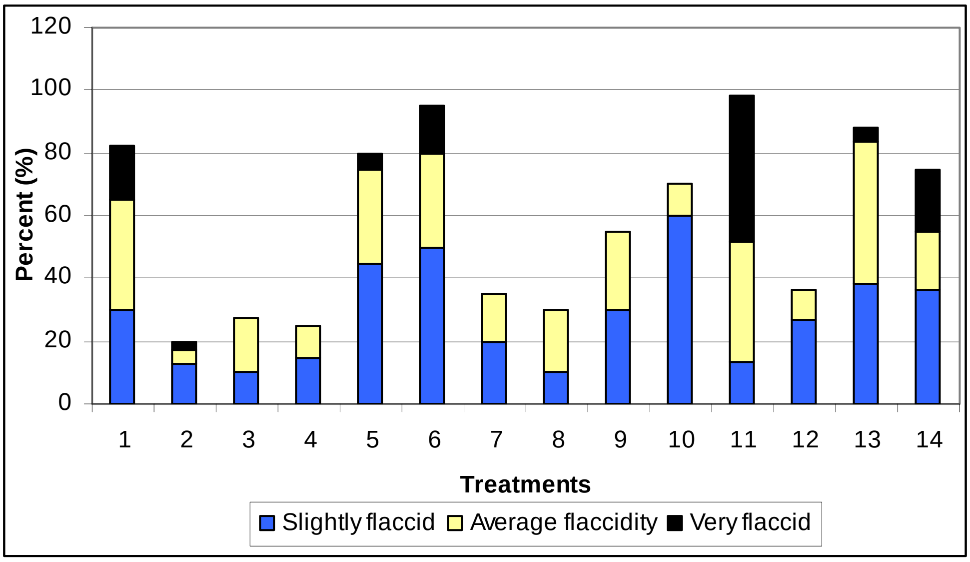


Figure 6.6.1.5. Flaccidity of individual Chinese cabbage heads post storage.

Treatments 2, 3, 4, 7, 8, 9, 10, 12, and 14 recorded significantly ($P<0.05$) lower total flaccidity than Chinese cabbage stored in commercial cartons (treatment 11). Open bin treatments recorded similar total flaccidity and severity to commercial cartons.

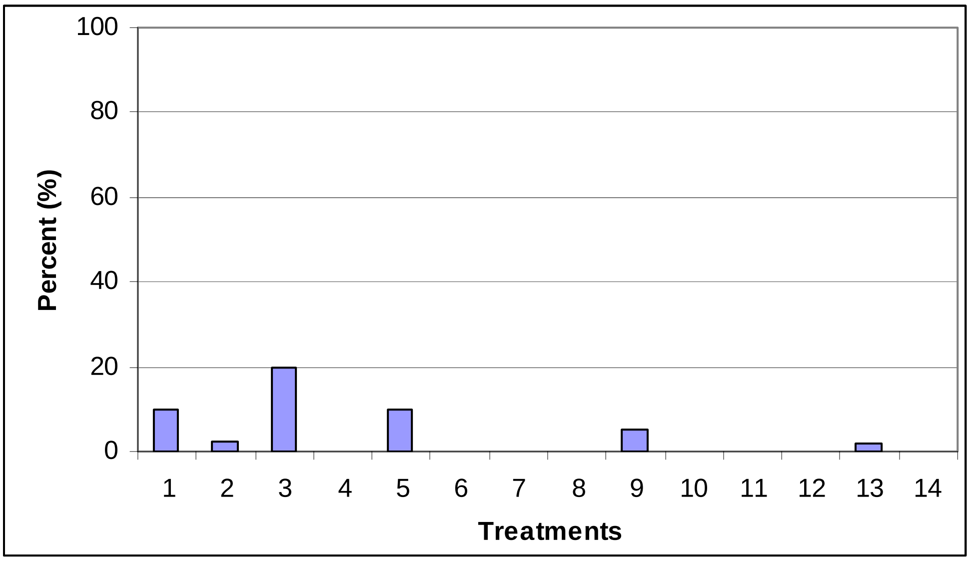


Figure 6.6.1.6. Post storage incidence of rots for all Chinese cabbage treatments.

Treatment 3 recorded a significantly higher incidence of rots than all other treatments excluding treatments 1 and 5.

Discussion and recommendations

Despite the low quality scores of all produce caused by the development of gomasho in storage, two treatments gave better quality out-turns than the commercial standard cardboard cartons. The treatments with a pre wet un-waxed cardboard lid perforated with 12, 60 mm holes per half (treatment 7) and a pre wet waxed solid cardboard top (treatment 10) gave the best marketability scores at out-turn. The levels of mechanical damage and the incidence of flaccid leaves differed between the two treatments.

The total mechanical damage experienced in treatment 7 (70 per cent) was not significantly different to commercial cartons (91.7 per cent) or the open bin treatment (67.5 per cent). Mechanical damage was mostly minor however, and not likely to significantly impair marketability. The total percentage of heads with flaccid outer leaves for treatment 7 at 35 per cent was significantly lower than commercial cartons (98.3 per cent) and an open half bin (82.5 per cent). The severity of flaccidity was also relatively lower for treatment 7.

Treatment 10 had significantly less heads with flaccid outside leaves (70 per cent) than commercial cartons (98.3 per cent) but similar levels to the open half bin treatment (82.5 per cent). Mechanical damage was significantly lower (40 per cent) than commercial cartons (91.7 per cent) and the open half bin (67.5 per cent). Both treatments recorded no rots.

Deep bins that stack ‘two high’ in a sea container are more cost effective than the shallower bins used in these trials because 6.4 tonnes of Chinese cabbage can be transported in a 20 foot sea container using deep bins compared to only 5 tonnes using the shallow bins. The quality of produce out-turned from a deep bin with an open top compared to the equivalent shallow bin was minimally different. The only significant difference was for the percentage of very flaccid leaves, with the full bin recording 5 per cent and half bin 17.5 per cent. This difference is likely to be associated with the speed of airflow through the produce in the half bin being greater due to lower resistance offered by a shorter vertical column of Chinese cabbage.

The results for a ventilated pre wet un-waxed top or a pre wet waxed top need to be confirmed on a bigger scale before full commercialisation could be recommended. Further work should also include testing these bin lids on full bins for commercial test shipments.

Research effort also needs to be put into finding the causes and control measures for gomasho to avoid failed shipments.

6.7 Packing methods for cabbage

6.7.1 Bin type and base comparison

Introduction

As discussed previously two areas within the bulk bin required attention the very top layer and the bottom layers of produce. Produce to be used for this work was limited, so it was deemed important to investigate if bulk handling was possible for cabbage. At the same time it would also be possible to determine if a waxed or un-waxed cardboard base would be preferential for use with cabbage.

Another aim which is consistent for all vegetables was to determine what, if any, differences there may be between produce transported in a full bin and in a half bin. It was assumed that the weight of cabbage would inflict mechanical damage on heads at the base of the full bin.

Materials and methods

One half of the floor of a shallow bin was covered with a waxed cardboard base and the other half with an un-waxed base prior to filling. This treatment was compared to a deep bin with a waxed base secured to its floor. Both bins had a standard plastic liner fitted. Treatments were packed on 27 October 2005 with cabbage grown on site at Medina Research Station. Treatments were pre cooled to 2°C as per normal practice using forced air cooling in a humidified coolroom. Once produce had reached 2°C treatments were loaded into the sea container.

Loggers were placed in treatments during packing; one probe was placed in the core of a cabbage head at the centre of the full bin and the other in the core of a cabbage at the centre of the half bin.

Table 6.7.1.1. Cabbage treatments 27 October 2005

Number	Treatment
1	Full bin waxed base
2	Half bin unwaxed base
3	Half bin waxed base

On 14 November 2005 treatments were removed from storage. A sample of produce was removed, weighed and assessed for the following (in order of importance).

1. Marketability (ranked on a scale of one to seven, one = worst and seven the best).
2. Mechanical damage (damage was classified into squashing, grazing and cracking).

Sampling involved removing produce from layers vertically down the bin, 6 layers for both bins. Sampled layers were 0, 20, 40, 60, 80 and 100 cm deep from the top of the full bin. The half bin was sampled at 0, 12, 24, 36, 48, and 60 cm. Five heads where removed at each layer and assessed as a sub sample.

Results

Post storage weights of the bin treatments showed that the full bin was more cost effective than the half bin, holding 427 kg and 234 kg of produce respectively. In a 20 ft sea container 20 full bins would transport 8.5 tonne of produce compared to 30 half bins transporting 7 tonne.

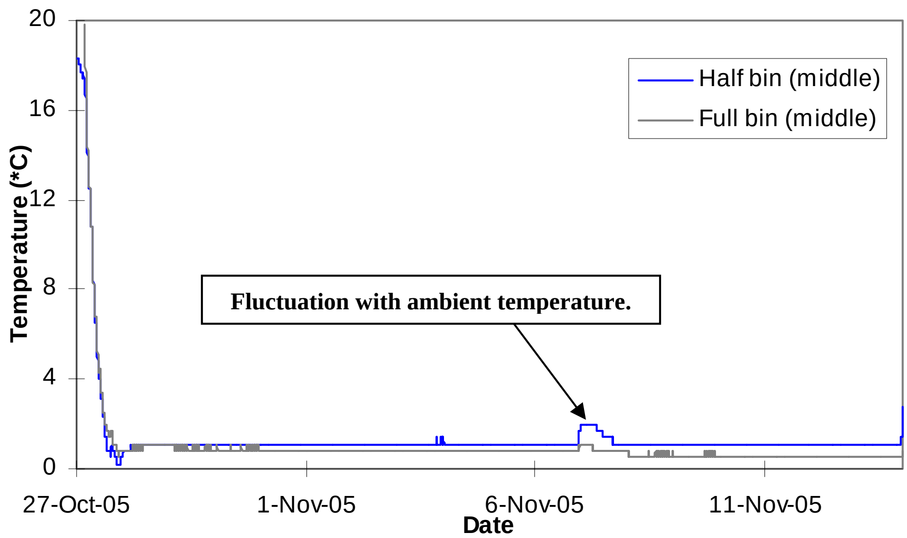


Figure 6.7.1.1. Storage temperature of the full bin versus the half bin treatment.

The temperature record for the cabbage during storage showed that the half bin was less well buffered against temperature changes than the full bin (Figure. 6.7.1.1).

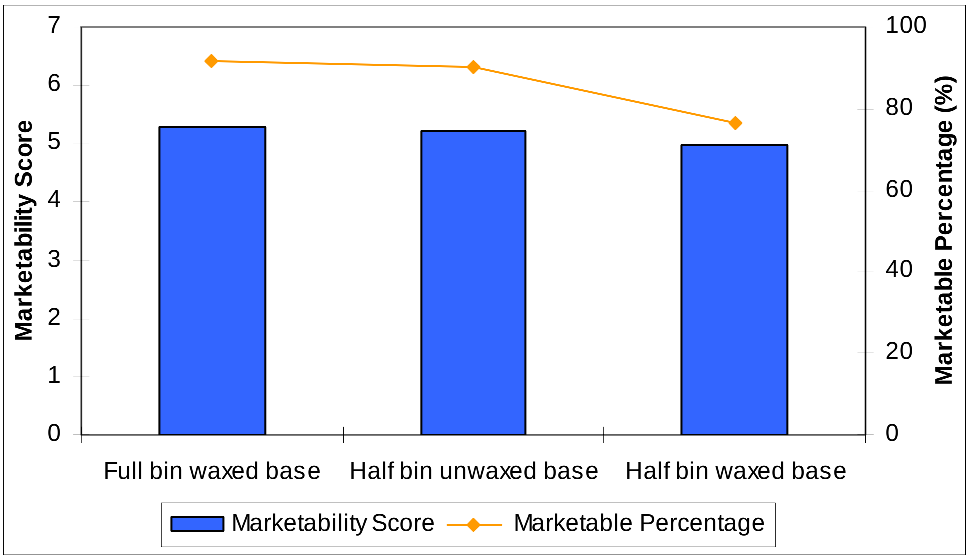


Figure 6.7.1.2. Post storage marketability score and marketable percentage of cabbage heads for each treatment stored for 17 days.

A significant difference ($P<0.05$) in marketability score was recorded between the full bin with a waxed base and the half bin with waxed base treatments. No significant differences were recorded for marketable percentage.

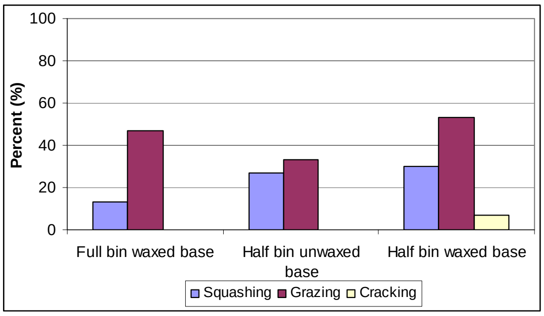


Figure 6.7.1.3. Post storage mechanical damage % to cabbage treatments stored for 17 days.

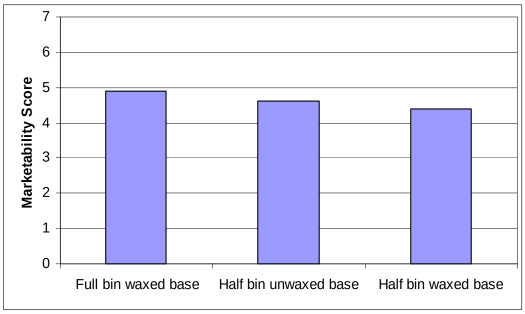


Figure 6.7.1.4. Marketability scores for cabbage waxed and unwaxed base treatments for 17days.

Figure 6.7.1.5. Post storage squashing damage to individual cabbage heads stored for 17 days.

Post storage mechanical damage was individually rated for the different types of damage. There was no difference in the levels of, squashing, grazing or cracking recorded between any of the treatments. However the half bin waxed base treatment experienced the most severe damage in the form of cracking. Damage levels in the full bin were no more severe than either of the half bin treatments.

The marketability score of cabbage heads at the base of each treatment were similar for all treatments, but the full bin treatment recorded the highest absolute score.

Discussion and recommendations

Results from this work suggest that it is possible to use bulk handling methods and bulk bins to transport cabbage to export markets effectively. The types of base to be used in bulk bins however was not as clear cut, with produce in the full bin waxed base treatment performing the best for all measurable aspects and the half bin waxed base treatment performing the worst. Consequently the inconsistencies in these results suggest that further work is required to improve confidence.

Economically using the full bin packaging for transporting cabbage is preferable. During the simulated voyage there was a fluctuation in temperatures which the half bin reacted to very quickly; however the full bin did not react to the same extent, suggesting that the quantity of produce in the full bin was able to maintain a stable temperature when there were minor fluctuations in temperature. Furthermore, produce out turned from the full bin treatment with quality at or better than that stored in a half bin with similar levels of mechanical damage. It is therefore recommended that any future work be done using deep bins that stack ‘two high’ in a sea container.

7. TRIAL SHIPMENTS OF PRODUCE USING BULK HANDLING TECHNIQUES

Introduction

Over the course of this project trial shipments of produce were transported to Malaysia and Dubai with assistance from Western Australian exporters. The trial shipments aimed to demonstrate to exporters that bulk bins could be used successfully for transporting vegetable produce to export markets. ‘Real time shipments’ also provided feed back from exporters and importers on the bulk handling process , quality standards, and allowed for any differences between real sea voyages and ‘land based’ static trials to be identified. Through completion of trial shipments it was envisaged that it would be possible to build up grower and exporter confidence to a point where they could adopt this method of exporting vegetable products.

Test shipments were done opportunistically, taking advantage of availability of produce from research station trials and growers and ‘piggybacking’ with shipments of other produce such as carrots by a local exporter. Most often a full bin and half bin of produce was sent in a 20 ft sea container together with cartons of carrots to importers who were likely to be receptive to bulk shipped produce.

Test shipments were designed to incorporate the cool chain process developed for bulk bins. Typically this was packing into bulk bins the day prior to export followed soon after by pre-cooling to 2°C using forced air cooling in a high humidity rapid draw down cool room located at Medina Research Station.

Once cooled, produce was transported approximately 5 kilometres to the exporters’ packing sheds and stored in their cool rooms until packing. Sea containers were packed with carrots in cartons first, with enough room left for bulk bins closest to the sea container doors. Bulk bins were then loaded last before the container’s doors were closed.

7.1 Test shipment 1 – Broccoli to Malaysia

Broccoli was selectively harvested during the week ending 19 August 2005. The Full bin of broccoli was originally half filled on the Monday and pre-cooled. The remainder of the full bin and the half bin were packed on the Thursday and re cooled. At this time loggers were placed in the centre of the full bin. Both bin treatments were left without any top covering for the entirety of the journey.

After being delivered to the packing house, broccoli bulk bins were loaded on Saturday, 20 August 2005 for transport to Penang in Malaysia. The half bin was stacked on top of the full bin in the sea container prior to closing. Broccoli arrived in Penang on 1 September 2005 where it was subsequently unloaded.

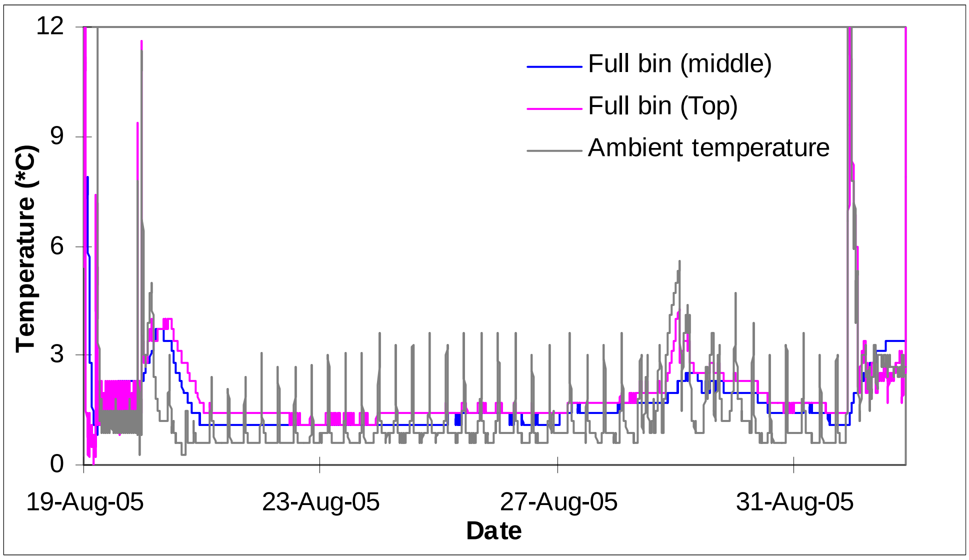


Figure 7.1.1. Storage temperature of Broccoli in the centre and top layers of the full bin during transport to Malaysia.

The cooling curve of broccoli transported to Penang highlights the differences between produce transported at the centre (middle) of the full bin and the top of the full bin. Broccoli at the top of the full bin was more sensitive to fluctuations in temperature than produce in the centre of the full bin. An example of this is the sudden increase in ambient temperature on 29 August that resulted in an almost instant increase in broccoli temperature at the top of the bin. Produce at the centre of the bin did react to this temperature fluctuation but not to the same extent.

Another interesting trend was that produce at the top in general recorded consistently higher temperatures than the centre for the entire trip. The explanation for this is that the top layer always had air movement across it increasing the fluctuations and the average temperature.

Figure 7.1.2. Unloading of bulk bin treatments in Malaysia.

Figure 7.1.3. Broccoli transported in a half bin on arrival in Malaysia.

Figure 7.1.4. **Mechanical damage to florets sustained during transport.**

Figure 7.1.5. **An example of good quality broccoli following transport in bulk bins.**

Despite a minor amount of mechanical damage to heads at the bottom of the bin, the exporter claimed that the customer was "pleasantly surprised by the quality of the out turn" and that it was rated "above Chinese broccoli". Comments were also expressed about the dehydration to the top layer of the bin. Overall the test shipment of broccoli in bulk containers was considered a success, with modifications to bin ventilation rates required to decrease dehydration.

7.2 Test shipment 2 – Cauliflower to Malaysia

Cauliflower was selectively harvested in the same manner as the broccoli during the week ending 9 September from a field trial at Medina Research Station. The full bin of cauliflower was half filled on the Monday of that week and pre-cooled. The remainder of the full bin and the half bin were packed three days later on Thursday and re cooled. At this time loggers were placed in the centre and top of the bin. The full bin was left without any top cover for the entirety of the journey; the half bin had a fixed ventilated waxed cardboard top secured after the bin had been pre cooled. The ventilation consisted of 24, 60 mm holes in the same configuration as the ventilation holes in the cardboard at the base of the bin.

Cauliflower bulk bins were delivered to the packing house on 9 September 2005 and loaded into a sea container the next day for transport to Penang. The half bin was stacked on top of the full bin in the sea container prior to closing. Cauliflowers arrived in Penang on 22 September 2005 where it was subsequently unloaded.

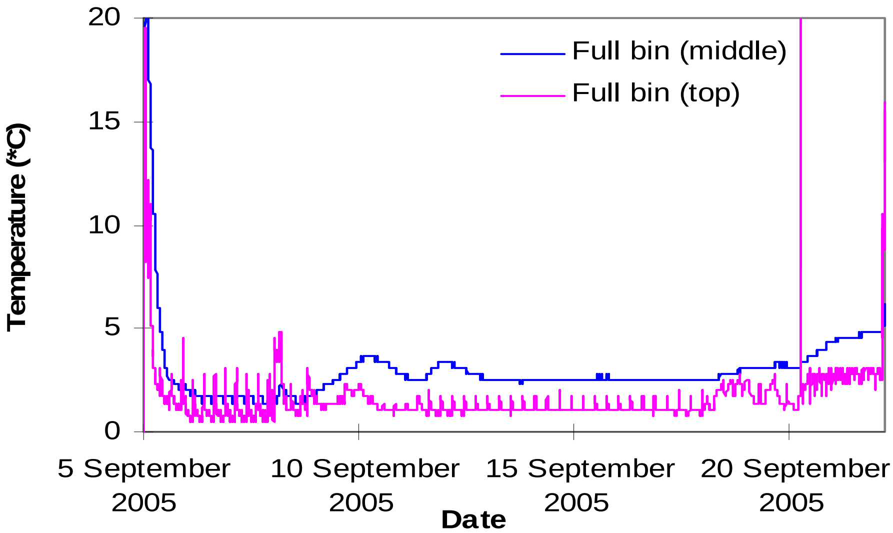


Figure 7.2.1. **Storage temperature of cauliflower in the centre and top layers of the full bin during transport to Penang.**

The temperature graph of Cauliflowers at the centre of the full bin transported to Penang indicates the importance of maintaining the cool chain during the handling process. Initial pre-cooling started on the Monday and exhibited a good steady removal of heat from the consignment. Bulk bins were then transported to the exporter on 9 September during which time produce temperatures rose. The produce then remained at 2.5°C in the sea container until its arrival in Penang. The temperature of the produce increased during transport to the exporter and loading, but never recovered to a satisfactory temperature while being shipped.

The probe at the top of the bin recorded unusual temperature events for the core of produce. Until 8 September 2005 the probe located at the top of the full bin was in free air, recording the air temperature and defrost cycles of in the cool room. After this time it was inserted in to a cauliflower curd during the final filling of the full bin. Initially the probe recorded a steady temperature, but around the 11^{th} the temperature began to fluctuate rapidly, similar to the readings when the probe had not been placed within a curd. It is possible that the transport of the produce either allowed the probe to fall out, or it was pushed further through the curd and out into free air. Consequently it appears to have recorded air temperature during the voyage instead of produce temperature.

Figure 7.2.2. Unloading of bulk bin treatments in Penang.

Figure 7.2.3. Dehydration of cauliflower curds half way down the full bin post transport.

Figure 7.2.4. Cauliflower curds at the top of the half bin post transport.

Figure 7.2.5. Minimal damage to cauliflowers located in the half bin during storage.

Post storage outturn of cauliflower curds in the full bin was generally poor. Curds located at the top of the bin only suffered minor dehydration. However this increased the deeper curds were in the bin (Figure 7.2.3). The half bin however did not have the same amount of dehydration damage to curds an appeared to outturn significantly better (Figures 7.2.4 and 7.2.5).

There are two possible explanations for the increased dehydration observed in the full bin. The first is the two step pre cooling process. The marked increase in dehydration half way down the bin coincides with the filling point reached on Monday, 5 September. Cauliflowers at this point remained exposed to cool room air until Thursday, 8 September when the bin was filled to the top and pre cooled again.

Another possibility is that the bulk bin provided a preferential pathway for air movement through the sea container as the majority of the container was filled with cardboard cartons, which do not allow air movement and would force air in the direction of least resistance. Either of these two explanations or a combination would be sufficient to inflict dehydration damage to curds at the base of the full bin.

Although the exporter and importer considered the cauliflower test shipment to be a failure because of the inconsistent out-turn, there were significant deficiencies in the handling process that suggest that it should be done again with more attention paid to detail. Future work should focus on removing these impediments. The only way to eliminate the possible preferential ventilation pathway problem would be to test cauliflower in a sea container in which all produce was loaded in bulk bins. The result being minimal chance of inducing preferred pathways.

7.3 Test shipment 3 – Cabbage to Malaysia

Cabbage was harvested from a field trial completed Medina Research Station during the week ending 4 November 2005. A full and a half bulk bin were packed. Once packed, bulk bins were pre-cooled using forced air cooling. Once cooled an ambient temperature and relative humidity logger was placed on top of cabbage in the full bin.

The full bin was left open for the entirety of the journey; the half bin had a fixed ventilated waxed cardboard top secured to the top following pre-cooling. The ventilation consisted of 24, 60 mm holes in the same configuration as the ventilation holes in the cardboard at the base of the bin.

Cabbage in bulk bins was delivered to the packing house on 5 November 2005, to be loaded the same day for transport to Malaysia. The half bin was stacked on top of the full bin in the sea container prior to closing. The shipment arrived in Malaysia on 18 November 2005 where it was subsequently unloaded.

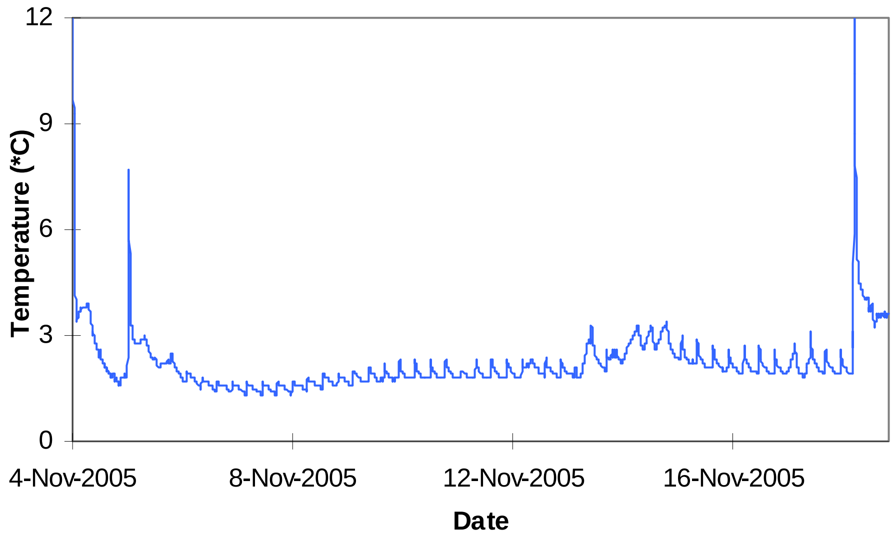


Figure 7.3.1. Ambient temperature inside the sea container carrying cabbage bulk bins to Malaysia 2005.

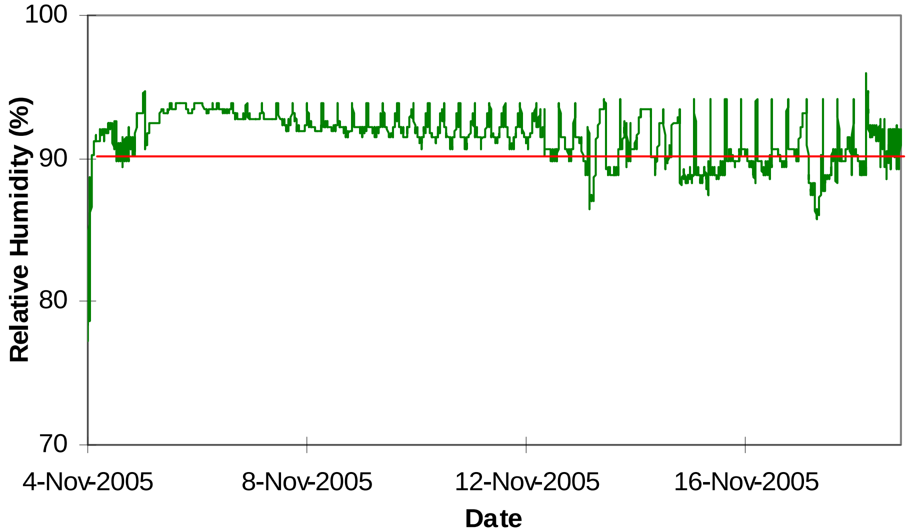


Figure 7.3.2. Relative humidity inside sea container carrying cabbage bulk bins to Malaysia 2005.

Cooling trends for cabbage were as expected for the beginning of the trip. On 9 November a warming trend began as humidity also began to fluctuate more rapidly. The humidity within the sea container toward the end of the voyage was sub-optimal for fresh vegetable transport.

Figure 7.3.3. Unloading of bulk bin shipment in Malaysia.

Figure 7.3.4. Ventilated lid placed and secured to half bin using electrical ties.

Figure 7.3.5. Produce on top of full bin post transport. Template® ambient logger in view.

Figure 7.3.6. Produce on top of half bin post transport.

Figure 7.3.7. There was a small amount of sclerotinia development during the voyage.

Despite the sub-optimal humidity late in the voyage and an increase in temperature the exporter reported a good out turn for the test shipment of cabbage. The minor incidence of sclerotinia was reported as of little consequence and did not detract from the overall outcome of the trial shipment. These results suggest that cabbage is fairly tolerant of unwanted fluctuations in temperature and humidity over a short period. It also highlights the suitability of cabbage for bulk shipping and future potential to transport it this way and reduce shipping costs.

7.4 Test shipment 4 – Iceberg lettuce to Malaysia

On 7 December 2005 Iceberg lettuce was harvested from a field trial completed at Manjimup Horticultural Research Institute. A full bin and a half bin were harvested early in the day to decrease the field temperature of the lettuce heads prior to pre-cooling. During harvest one probe of a Cox® logger was inserted into a lettuce core at the centre of the full bin and the remainder of the bin was filled. A second probe was then inserted into the core of a lettuce at the top of the bin.

After the two bins were filled they were transported to a cool room located at the Institute where they were pre-cooled. The lettuce was cooled to below 5°C before being loaded onto a refrigerated truck that afternoon and transported to an exporter in Perth (300 km road trip). At the exporter’s property the bins were unloaded and placed in a cool room. These were then stacked into a sea container on 9 December 2005. Produce arrived on 22 December 2005 in Malaysia.

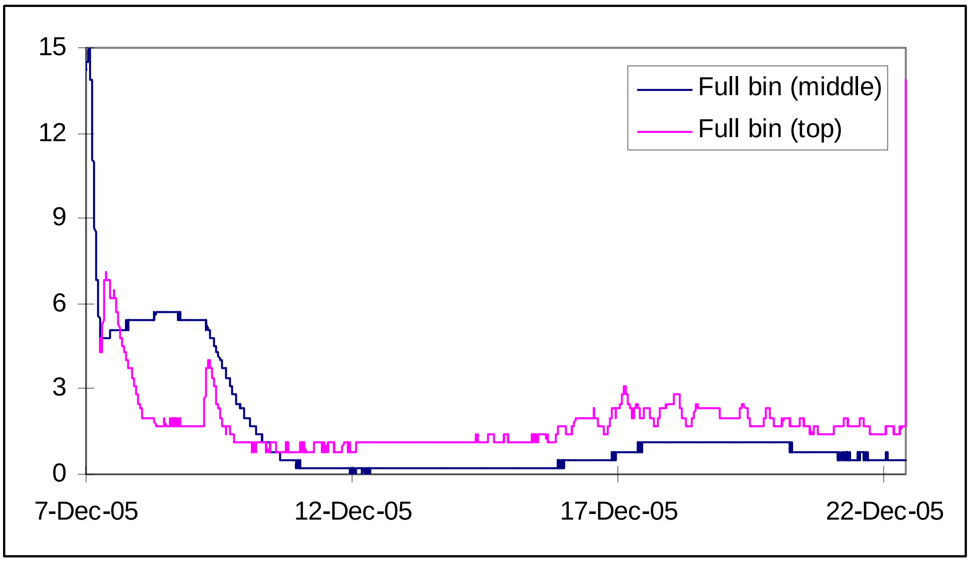


Figure 7.4.1. Storage temperature of iceberg lettuce in the centre and top layers of the full bin during transport to Malaysia.

The pre-cooling trend of iceberg lettuce was as expected, however during the road trip, the temperature in the centre of the bin rose 1°C, where it remained until loaded into the sea container. The cooling unit in the sea container was then able to decrease the temperature at the centre of the bin to 0.2°C. On 16 December there was a fluctuation in temperature, but the core only reached 1.1°C.

Lettuce at the top of the bin reacted swiftly to fluctuations in temperature. For example when placed in the exporter's cool room on 7 December the temperature decreased rapidly, whilst at the same time the middle core temperature rose. The core temperature at the top of the bin when in transit remained steadily higher and fluctuated more rapidly than that in the middle of the bin. This is similar to the trend seen in the broccoli test shipment. The most likely cause is the exposure of this layer to air moving across the produce and impacting rapidly on the head temperature.

Figure 7.4.2. Produce on top of the full bin post transport. Cox® logger in view at bottom edge.

Figure 7.4.3. Produce on top of the half bin post transport.

Figure 7.4.4. Dehydration of lettuce head on the top of the full bin post transport.

Figure 7.4.5. Example of dehydrated wrapper leaf post transport.

Figure 7.4.6. Example of good quality produce post transport.

The out turn of produce in the full and half bins (Figures 7.4.2 and 7.4.3) to Malaysia was described by the exporter as “good”. The photo’s show a consistent quality of produce across the two bulk bin treatments, with neither bin type out-turning iceberg lettuce of superior quality.

The importer commented that “Only the top layer had wilted wrapper leaves and these could be easily peeled off” (Figures 7.4.4 and 7.4.5). The air moving across this layer in transit was able to remove excess moisture, causing the wrapper leaf to dehydrate and wilt, unlike produce further down the bin (Figure 7.4.6). Future research needs to identify cost effective methods to reduce the problems associated with this air movement across the top layer of bin produce, in particular dehydration.

7.5 Test shipment 5 – Cos lettuce to Malaysia

On 16 December 2005 Cos lettuce was harvested from a field trial completed at Manjimup Horticultural Research Institute. A full bin and a half bin were harvested early in the day to decrease the field temperature of the lettuce heads prior to pre-cooling. During harvest one probe of a Cox® logger was inserted into a lettuce core at the centre of the full bin, and then remainder of the bin was filled. A second probe was then inserted into the core of a lettuce at the top of the full bin.

Pre cooling began immediately after harvesting in a high humidity cool room, where produce was cooled to 2°C. Following pre-cooling, produce remained in the cool room. Soon after pre-cooling the temperature of the produce increased, coinciding with the icing up of the cool room’s generators. Once generators were defrosted the produce was again pre-cooled. Produce was then collected and transferred to Perth (a 300 km road trip) on 19 December and placed in an exporter’s cool room until loading on 23 December. Prior to loading the half bin top was sealed with a solid cardboard sheet.

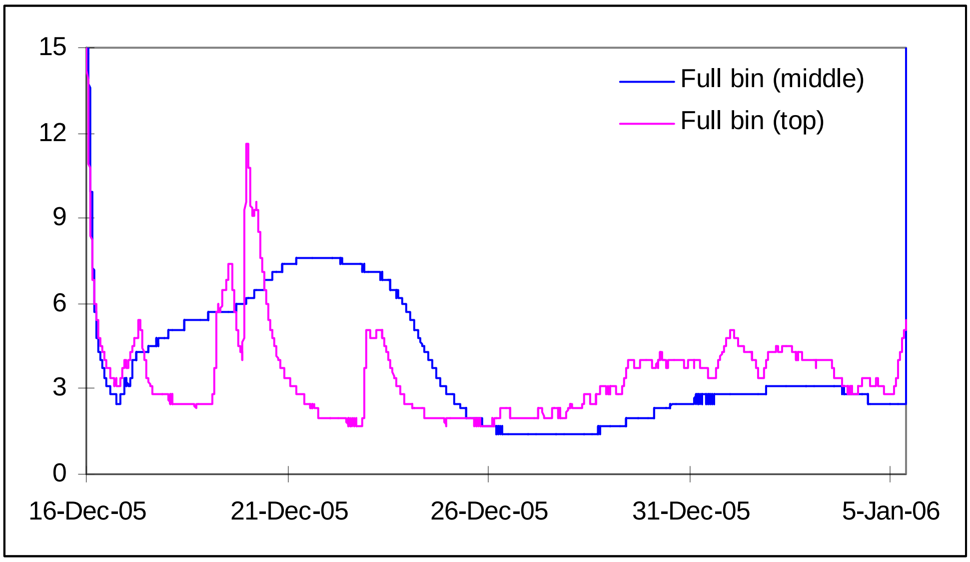


Figure 7.5.1. Storage temperature of cos lettuce in the centre and top layers of the full bin during transport to Malaysia.

The original pre-cooling of the bulk bins was as expected. However, the overall cooling history of the cos lettuce prior to, and during transport was unsatisfactory. Temperatures prior to and during road transport were not maintained below 2°C. Once loaded into the sea container, the temperature of the produce at the centre of the full bin decreased rapidly, but still fluctuated up to a temperature of 3.1°C. The produce at the top of the bin fluctuated in a similar manner as noted for the iceberg lettuce trial with more rapid fluctuations and an average temperature greater than produce at the centre of the bin.

Figure 7.5.2. Bulk bins unloaded in Malaysia.

Figure 7.5.3. Sealed plastic top of half bin post transport, note upward bulging of plastic.

Figure 7.5.4. Produce on top of the full bin post transport.

Figure 7.5.5. Minor rot developed during transport.

Figure 7.5.6. Severe rot developed during transport.

The test shipment of cos lettuce to Malaysia out turned unmarketable produce at the destination. The majority of produce developed rots with varying degrees of severity between Figures 7.5.5 and 7.5.6. Poor produce out-turned at the destination is the combination of four factors. These include the maturity of the crop, the inability to keep produce cool directly after pre–cooling, the time between harvest and shipping and the leaf matter of cos lettuce.

Initially this consignment of cos lettuce was grown for a test shipment to Dubai to leave the week ending 16 December. However the shipment was cancelled and produce was held in field a week longer than optimum to allow it to be shipped to Malaysia. After harvesting, the produce was then held in a coolroom for five days before transport to Perth for shipping. The combined effects of the delayed harvest and subsequent storage in a coolroom experiencing temperature control problems resulted in a poor quality produce being shipped and ultimately a poor out-turn.

A week elapsed between harvest and loading allowing more time for the integrity of the cool chain to be comprimised.

Cos lettuce is a very leafy product, which tends to flatten and compact when loaded more than a few layers deep in a bulk bin. This compression would reduce air movement in and around individual heads. This reduced air movement would probably encourage rot development and reduce the ability of a refrigeration system to maintain a stable core temperature during transport.

Overall the conclusion from this work is that other products such as broccoli, cabbage and iceberg lettuce offer more potential as candidates for bulk shipping than cos lettuce, However, good out-turns of cos lettuce are possible with strict adherence to maintaining the cool chain, optimum timing of harvest, packing in shallow bins and minimising transport time. Further research work is required on these aspects to prove a satisfactory method for shipping cos lettuce in bulk.

7.6 Test shipment 6 – Iceberg lettuce to Dubai

Lettuce was harvested from field trials at Medina Research Station on 23 October 2006. At harvest two full bins were packed with a total of 774 heads with a gross bin weight of 287 kg each. During packing a Cox® temperature probe was inserted into the core of a lettuce head at the centre of one full bin. Lettuce from the second bin was repacked into cardboard cartons immediately after pre-cooling as a commercial control treatment to compare against produce packed in bulk bins. At this time, a second temperature probe was inserted into the core of a lettuce in one of the cartons.

Pre cooling commenced immediately after harvesting. It took 13.5 hours to decrease the core temperature of all the lettuce below 2°C. Once completed a moistened waxed cardboard sheet was secured to the top of the bulk bin to decrease air flow through the bin while in transit. Cartons were then packed with pre-cooled lettuce from the other bin and stacked into an unlined bulk bin for ease of transport. On 24 October 2006, the bin of cardboard cartons was stacked on top of the bulk lettuce bin (Figure 7.6.3) and transported to a local exporter for storage until loading into a sea container. The produce remained in these cool rooms until exporting on 28 October 2006 in a 40 foot sea container together with a consignment of carrots in cartons. Produce was unloaded in Jebel Ali (Dubai) on 18 November at 9:17 p.m.

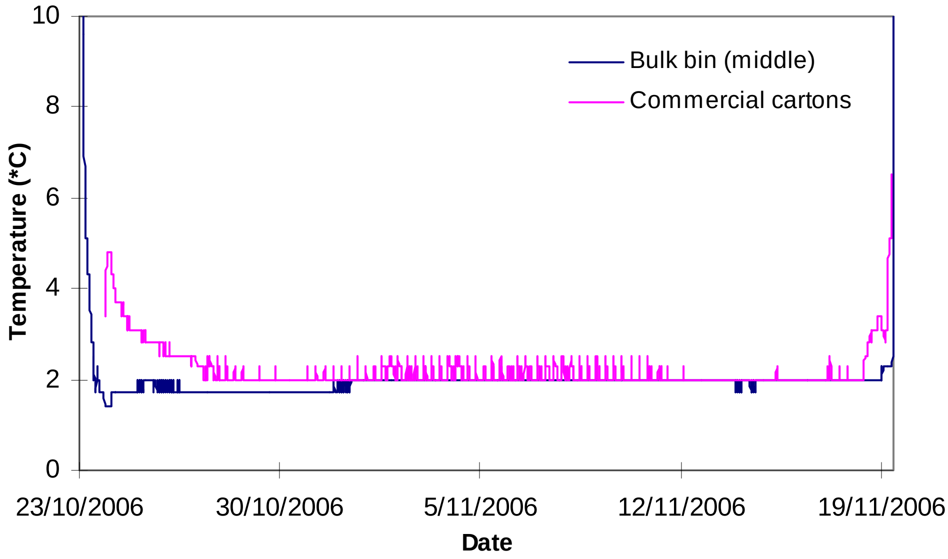


Figure 7.6.1. Storage temperature of iceberg lettuce at the centre of the Bulk bin and in commercial cartons during transport to Dubai.

The original pre-cooling of the bulk bins was as expected in that it reduced the temperature of the lettuce in the bulk bin to 1.7˚C at the time of loading. Repacking of the lettuce into cartons resulted in an increase in the core temperature above 4˚C at loading. The temperature in the container appeared to be set at 2˚C with the bulk bin increasing to this temperature 24 hours after loading. The cartons required three days after loading for the produce temperature to equilibrate with the container at 2˚C. Cartons continued to fluctuate between 2˚C and 2.5˚C until unloading at Jebel Ali, 21 days later. It is possible that the temperature probe may have become dislodged from the core of a lettuce inside the carton and this probe recorded air temperature for the duration of the voyage.

Figure 7.6.2. Lettuce prior to shipping.

Figure 7.6.3. Bulk bins unloaded in Dubai. Cartons stacked in the top bin.

Figure 7.6.4. Produce on top of the full bin post transport.

Figure 7.6.5. Rot developed in bulk bins during transport.

Figure 7.6.. Rot developed in cartons during transport.

Figure 7.6.7. Rot developed in cartons during transport.

Previous static trials (Chapter 6.1.2) investigating the duration of storage for iceberg lettuce packed in bulk bins showed a significant increase in rot development after 28 days storage at 1°C in a sea container. Considering the time of transport (26 days) and sea container set temperature of 2°C, it is encouraging that relatively few rots occurred in the full bin (Figure 7.6.5). Also encouraging was the crispness of lettuce in the top layer of the full bin (Figure 7.6.4).

Despite lettuce remaining at a lower transport temperature with minimal temperature fluctuation in the full bin when compared to cartons, the importers in Dubai believed that the produce quality in cartons was superior. However, photographs returned suggest that rots were not discriminatory, also occurring in cartons (Figures 7.6.6 and 7.6.7).

The test shipment to Dubai was a good test of bulk handling methods and marketable quality following a 'long haul' journey. Results suggest that this method of shipping lettuce may be more practical for markets that do not require repacking eg processing and that are closer to Western Australia, therefore not requiring such a long shipping time. At the same, time, if success can be achieved with sea shipments in cartons to this market on a repeatable basis, bulk shipping is equally possible and potentially more cost effective. This is particularly so if attention is paid to ensuring optimum temperature set points for sea containers destined to this market.

7.7 Test shipment 7 – Broccoli to Dubai

Mature broccoli was harvested selectively from field trials at Medina Research Station on 3 and 6 November 2006. At harvest, a full bin was packed with 1200 broccoli heads weighing approximately 300 grams each. During packing, one probe of a Cox® temperature logger was inserted into the core of a head at the centre of the full bin, and a second probe into the core of a head at the top of the bin. For comparison, eight polystyrene cartons were packed according to standard commercial practise with 8 kg of broccoli heads and 8 kg of ice.

Pre cooling commenced immediately after harvest and 7.5 hours was required to decrease the temperature of the produce from 25.6°C to 1.1°C. Once cooled, a waxed cardboard sheet with 56, 40 mm holes was secured to the top of the bulk bin to reduce air flow through the bin during shipping. On 7 November 2006, the bulk bin and cartons were transported to a local exporter and stored in his cool room. The produce remained in these cool rooms until exporting on 12 November 2006 in a 40 foot sea container together with a consignment of carrots in cartons. Produce was unloaded in Jebel Ali on 4 December 2006.

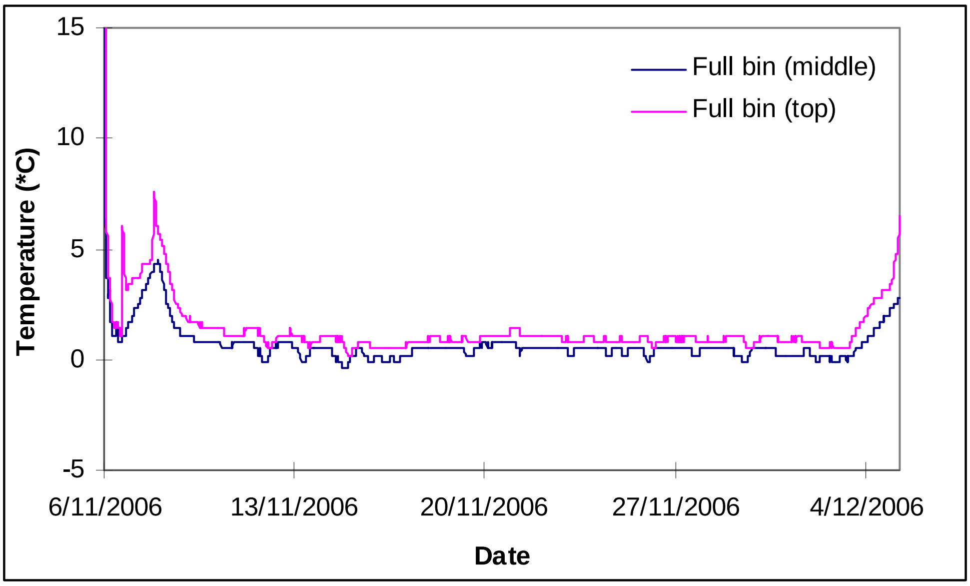


Figure 7.7.1. Storage temperature of broccoli at the centre and top layers of the full bin during transport to Dubai.

The original pre-cooling of the bulk bins was as expected. However the transport of the bin to the exporter and storage in the coolroom, allowed an increase in produce temperature throughout the bin. Temperatures reached 4.3°C in the centre and 7.6°C at the top of the bin. Once loaded into the sea container the produce at the centre of the full bin decreased rapidly, but still fluctuated up to a temperature of 3.1°C. The produce at the top of the bin fluctuated in a similar manner as noted for previous trials, with more rapid fluctuations and an average temperature higher than produce at the centre of the bin. Once loaded into the sea container, produce temperature decreased, to remain between -0.1°C and 0.8°C until the consignment was unloaded in Dubai on 4 December 2006.

Figure 7.7.2. Bulk bins unloaded in Dubai.

Figure 7.7.3. Broccoli at top of bin post transport. Compaction of the load below the top of the bin was noticeable.

Figure 7.7.4. Produce on top of the full bin post. transport.

Figure 7.7.5. Minimal yellowing occurred during transport.

The test shipment of broccoli to Dubai out turned a high percentage of marketable produce at the destination. Although compaction of broccoli in the bulk bin occurred in transit (Figures 7.7.2 and 7.7.3) very little damage to broccoli heads was noted by the importer. Minor yellowing was noted on a few heads (Figure 7.7.5), but had little impact on the overall marketability of the produce. Overall, the importer reported the produce to have “not so much damage, out turn was good and they managed to sell everything”.

The trial shipment was a good test for the bulk handling method and a commendation for the high quality of cooling system in this sea container. This result contrasted with the relatively high temperature that prevailed throughout the preceding lettuce shipment, and may have disadvantaged the out-turn of lettuce compared to broccoli.

The results showed that broccoli can be transported by sea for up to 32 days without ice and expensive polystyrene cartons as long as the cool chain is good. Broccoli has excellent potential for being shipped in bulk by this method with the major benefit being a significant reduction in the cost of shipping. Bulk shipping allows up to 8 tonne (versus 3.6 tonne by traditional methods) of fresh broccoli to be shipped in a sea container to export markets as far as Dubai and out turn marketable produce.

Future R&D work should focus on refining the bulk shipping process and commercialising broccoli as a first priority target crop for this method.

8. TECHNOLOGY TRANSFER

On Friday, 17 June a field day was held at Medina Research Station. The program for the day was developed in conjunction with David Ellement, the WA IDO and it was attended by 22 growers and trade representatives. The objectives of this project were outlined to the audience together with a progress report on work done to date. David did the advertising for the field day and was an invited speaker. Other current HAL funded projects were topics also covered at the field day.

A poster produced to publicise the project was presented at the 3rd Lettuce Industry Conference at Werribee in May 2005. This poster together with Powerpoint presentations from the 17 June field day were sent to Karen Hellwig for the AUSVEG 'vegetable levy payers website'. A story outlining the successes of the project was published in the December 2005 edition of *WA Grower* magazine.

A verbal presentation on the project and results was presented to the executive of Vegetables WA on 3 May 2006. A more comprehensive presentation was delivered to a national vegetable industry audience at the Australian Vegetable Industry Conference on 11 May 2006. A paper submitted for inclusion in the conference proceedings is available, together with the Powerpoint presentation.

9. RECOMMENDATIONS

Broccoli offers the best prospect for successful shipping in bulk bins by sea to export markets with expected out-turns up to 25 days after harvesting the product in Australia. This can be achieved using conventional refrigerated sea containers with 'no frills' packing techniques as long as the cool chain is good and sea container refrigeration units are set to achieve optimum storage temperature for the product. Careful attention to harvesting broccoli at optimum maturity and cutting heads with short stems to minimise damage to heads in the bulk package are also essential to a good out-turn. Deep bins that stack 'two high' in a standard sea container are recommended to maximise transport efficiencies, and these bins should have a ventilated waxed cardboard floor and lid fitted to minimise product dehydration.

Cabbage, Chinese cabbage and celery are the next best prospects for bulk shipping after broccoli. The packing and shipping methods for cabbage and Chinese cabbage are the same as those for broccoli, but the potential savings in freight costs for cabbage from bulk shipping will not be comparable to broccoli. Chinese cabbage out-turned better with a pre-wet perforated or solid cardboard lid on the bin, but this result needs confirmation before a firm recommendation could be made.

A test shipment of celery was not completed in this project, but the prospects for success are good if the product is pre-cooled and packed dry and un-sleeved in deep bins to maximise the freight advantage. The savings possible from bulk shipping celery are likely to be second only to broccoli.

Iceberg lettuce is more difficult to ship in bulk than the three products mentioned above, but with attention to detail in the field, and in transport it could be perfected, particularly for markets that are accessible within 15 days of harvesting. The economics of lettuce will be more favourable if shipped in deep bins covered with a loosely fitted solid pre wet un-waxed cardboard lid during sea freight. Lettuce maturity is critical to good out-turn and heads need to be firm but not over-mature. Indicative average head weights around 700 to 800 grams are considered best. The best destination market for iceberg lettuce is processing because wrapper leaves will need to be stripped from the heads at the destination to remove dehydrated leaves.

Cauliflower offers potential for bulk shipping, but more work is required to identify the optimum handling procedure. Indications are that shallow bins may be better suited to cauliflower, reducing the potential freight advantages from shipping in bulk. A waxed cardboard lid perforated with 20 mm holes offers the best potential to minimise dehydration damage in cauliflowers during shipping.

Cos lettuce proved to be not well suited to bulk shipping because it compressed and flattened while in transit. There was very little crushing noted in shallow bins and it may still have potential for a processing end destination if shipped in bulk. Further work would be required to test this opportunity.

Sweetcorn offers potential for shipping in deep bins, but vacuum cooling is essential and more work needs to be done to perfect the technique. A stronger bin design may be needed for sweetcorn than that used in this project, because the rails on the bins bulged significantly under the weight of this product.

10. ACKNOWLEDGMENTS

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