

# **Identify process improvements for preserving peak freshness of Broccoli**

Dr Jenny Ekman  
Applied Horticultural Research Pty Ltd

Project Number: VG13086

## **VG13086**

This report is published by Horticulture Innovation Australia Ltd to pass on information concerning horticultural research and development undertaken for the vegetables industry.

The research contained in this report was funded by Horticulture Innovation Australia Ltd with the financial support of the vegetables industry.

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ISBN 0 7341 3456 8

Published and distributed by:  
Horticulture Innovation Australia Ltd  
Level 8  
1 Chifley Square  
Sydney NSW 2000  
Telephone: (02) 8295 2300  
Fax: (02) 8295 2399

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**Horticulture  
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Identify process improvements for preserving  
peak freshness of broccoli

Final Report

VG13O86



Horticulture Australia

Project Number: VG13086

May 2014

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**Funding, purpose and disclaimer**

This project has been funded by HAL using levy funds from the Australian vegetable industry and matched funds from the Australian Government.

The purpose of this project was to examine supply chain factors that could affect broccoli quality, evaluate retail display conditions and determine whether consumer expectations of broccoli are likely to be met.

Although temperature management in broccoli supply chains generally appeared to be good—at least until delivery to distribution centres—quality at retail was extremely variable. While many retail displays were not refrigerated, neither cooling, display method or price were any guarantee of quality and shelf life. The results suggest that consumers will be disappointed with the quality of broccoli offered at retail on at least one in five occasions.

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*Horticulture Australia*



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# 1. Media summary

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Previous consumer research conducted in VG12045 found that purchases of broccoli were significantly reduced by inconsistent quality and freshness at retail. This study has sought to find whether there is any basis to this perception, and why such inconsistency might be occurring.

Randomly selected retail stores in Sydney, Melbourne, Brisbane and Perth were visited to assess the type of displays used and quality of broccoli being sold.

The range of display quality was huge, including both beautifully arranged, multilayered and hand-misted displays and yellowing, physically damaged or excessively large broccoli heads thrown randomly onto a grubby shelf. Many of the best displays were not refrigerated, but were constructed with evident care for the product.

Broccoli temperatures averaged 10-15°C when displayed in an open environment and around 5°C in a refrigerated unit. However, such averages concealed a huge range of variation. Moreover, cold temperatures were no guarantee of quality.

The results suggest that consumers expecting to purchase broccoli that was of 'excellent' or at least 'good' quality would be disappointed in quality at least one trip in five.

Samples purchased from 56 Sydney retailers were stored at 5°C or 22°C to measure storage and shelf life. Average life was two days at 22°C and two weeks at 5°C. However, this concealed huge variation, with some samples essentially unacceptable at purchase while others lasted more than four weeks under normal fridge conditions. Sixteen of the samples (28%) would not have met consumer expectations of both good initial quality and at least seven days storage life.

Harvest, packing and transport were studied to see if these were likely to be the source of variable quality at retail. However, growers were found to be highly conscious of the need to cool broccoli quickly after harvest. Broccoli is packed when fully chilled and transported under well refrigerated conditions.

Broccoli is still usually packed in Styrofoam containers and top-iced. This keeps it cold even if the cold chain is broken. It does, however, increase energy and transport costs as well as the industry's environmental footprint. If the ice melts it can also damage the broccoli. Plasticised cardboard cartons designed for top icing offer some improvement, but become difficult to handle if the ice melts.

Broccoli is now supplied to some retailers without ice, packed in lined plastic crates. While many remain reluctant to move to ice-free broccoli, no negative quality effects were seen during this trial.

Broccoli freshness at retail is highly variable. Quality does not correlate to display method or price, and storage life cannot be easily predicted from quality at purchase. It is entirely possible that consumers do indeed purchase broccoli less often because of quality issues. While the source of variability was not clear in this study, it appears unlikely to be due to poor temperature management by growers and packers.

## 2. Technical summary

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Previous consumer research conducted in VG12045 found that purchases of broccoli were significantly reduced by inconsistent quality and freshness at retail. This study has sought to find whether there is any basis to this perceived issue, and if so why such inconsistency might be occurring.

Randomly selected retail stores in Sydney, Melbourne, Brisbane and Perth were audited anonymously to assess the type and quality of broccoli displays as well as the quality and temperature of product being sold.

Independent grocers were more likely to display broccoli without refrigeration. The range of display quality was huge, including both beautifully arranged, multilayered and hand-misted displays, and yellowing, physically damaged or excessively large broccoli heads placed directly on a shelf or even left in the box along with the meltwater they were supplied in. Displays at supermarkets and mini-marts (such as IGA) were more uniform, with most using refrigerated or iced displays. Many of the best displays were not refrigerated, but were constructed with evident care for the product.

Broccoli temperatures averaged 10-15°C when displayed in an open environment and around 5°C in a refrigerated unit. However, these averages concealed a huge range of variation and overlap between the methods. Cold temperatures were no guarantee of quality, with some of the highest quality broccoli purchased from open displays and some of the worst from refrigerated units. Around 20% of broccoli at retail was graded as 2 or less, indicating it was marginally acceptable or poorer quality.

Purchased samples from 56 Sydney retailers including supermarkets, minimarts and independent grocers were stored at 5°C or 22°C to measure storage and shelf life. Average life was two days at 22°C and fifteen days at 5°C. However, there was huge variability between and even within samples. While some broccoli remained acceptable for up to 30 days, around 23% of samples would not meet consumer expectations of a minimum seven days storage life at 5°C. Little relationship was evident between display conditions, temperature at purchase or initial quality and subsequent storage or shelf life of broccoli.

Supply chain studies indicated that broccoli is cooled reasonably quickly after harvest, packed cold and transported under well refrigerated conditions. Top icing is still widely used with broccoli packed in Styrofoam cartons. This has some advantages but also many disadvantages, particularly industry environmental footprint, potential product damage and cost. Broccoli packed in Styrofoam without ice stays warm after packing. Top icing in plasticised cardboard cartons can only be effective if the cold chain is well maintained.

Broccoli has more recently been supplied to some retailers without ice, packed in lined plastic crates. While many in the industry remain reluctant to move to ice-free packing, this appears to be working well with no apparent ill effects on retail quality.

The research concluded that broccoli freshness at retail stores is highly variable. Quality does not relate to display method or price, and storage life cannot be easily predicted from quality at purchase. The source of variability was not clear from the current study, but appears unlikely to be due to poor temperature management in the early part of the supply chain.

### 3. Introduction

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Broccoli is widely regarded by consumers as a healthy, tasty vegetable that can add variety to a wide range of meals<sup>1</sup>. Although cultivated in some form since Roman times, broccoli is still a relatively new addition to the standard vegetable purchases. Popularised by Italians in the USA and Australia during the 1920s, production has increased greatly over the last 30 years. This is partly due to the development of new varieties, with large compact heads, efficient growth habits and mild flavour. It is also likely due to better understanding of how to cook the vegetable. Whereas it was once common to serve broccoli boiled until it was grey and bland, most consumers understand that it is best cooked lightly by microwaving, steaming or stir-frying. This results in better flavour and texture, and has boosted its popularity.

Broccoli has a strongly healthy image, with many consumers aware that it has potential health benefits—even if they are not sure exactly how or why these occur. For example, a French study refers to broccoli's 'negative image' of being a healthy product rather than a tasty one!<sup>2</sup>. Broccoli is not only widely recognised as being high in vitamin C, but also a source of potent anti-carcinogens. Like other brassicas, broccoli contains a range of glucosinolate compounds. These are broken down into their active forms by the enzyme myrosinase, a reaction catalysed by cutting or chewing. New varieties have been selected for their content of bioactive compounds<sup>3</sup>, with an Australian example being the high glucosinolate 'Booster' variety. Along with broccoli's vitamin and flavonoid content, these health promoting compounds have resulted in broccoli being commonly referred to as a 'Superfood', along with products such as berries, garlic and walnuts ([www.health.com](http://www.health.com)).

Despite the importance of such health benefits, there is much evidence that taste and liking are the main determinants of food choice. As stated in the 2013 International Food Information Council report, while the majority of consumers say they want to make nutritious choices, when it comes to actual purchases healthiness and quality are often less important than taste and price<sup>4</sup>. This includes purchase and consumption of vegetables<sup>5</sup>. New varieties have improved consumer acceptance of broccoli flavour, with cooked broccoli scoring high on sensory attributes such as fresh flavour and crispness, moderate on sweetness and low on bitterness<sup>6</sup>.

A study of consumer preferences based on sensory evaluation of a range of brassica vegetables found that broccoli and cauliflower were the most preferred, with 'intention to purchase' higher for broccoli than for any of the other vegetables tested (Brussels sprouts were the lowest!). Interestingly, this study also found that providing specific health

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<sup>1</sup> Hamblin D. et al. Project Harvest monthly report W14 2014. Broccoli, chillies, lettuce and sweetcorn. Colmar Brunton. VG12078 Horticulture Australia Ltd. report.

<sup>2</sup> Baros C. 2003. Broccoli: one more cabbage? Image, purchases and consumption. Centre Technique Interprofessionnel des Fruits et Legumes. Paris, France.

<sup>3</sup> Dominguez-Perles R et al. 2011. Novel varieties of broccoli for optimal bioactive components under saline stress. *J. Science Food Agric.* 91:1638-1647.

<sup>4</sup> International Food Information Council. 2013. 2013 Food and health survey: Consumer attitudes to food safety, nutrition and health.

<sup>5</sup> Schatzer M, Rust P, Elmadfa I. 2010. Fruit and vegetable intake in Austrian adults: intake frequency, serving sizes, reasons for and barriers to consumption and potential for increasing consumption. *Public Health Nutr.* 13:480-487.

<sup>6</sup> Jacobsson A *et al.* 2004. Influence of packaging material and storage condition on the sensory quality broccoli. *Food Quality and Preference* 15:301-310.



information about the benefits of brassica vegetables, including potential protection against cancer, did not override taste aversion in consumers who did not like these products, or increase intention to purchase<sup>7</sup>.

While flavour is certainly important, appearance is the most important factor affecting selection of specific vegetables at retail. For broccoli, quality is mainly judged by colour, which is associated with chlorophyll content<sup>8</sup>. Greenness determines consumers' acceptance of broccoli more than either aroma or flavour<sup>9</sup>. Misting helps retain chlorophyll and, therefore, green colour of broccoli during retail display, increasing consumer purchases<sup>10</sup>.

Recent research has found that key quality measures for Australian consumers include:

- Hollow, split or browned stem
- Excess stem length (considered a waste of money)
- Open florets or yellowing
- Insect contamination

Based on a series of focus groups, this study found that poor and inconsistent quality, notably across the major supermarket chains, was a significant barrier to increased broccoli consumption. Some participants also saw limited shelf life after purchase and high prices as issues<sup>11</sup>.

The influence of price on demand for broccoli is unclear. A study by Piccone<sup>12</sup> found that although reducing price could increase demand for broccoli in certain markets, the effect was not consistent across all stores and prices. Other studies have found that price was not a barrier to vegetable consumption<sup>4</sup>.

This project has sought to determine whether broccoli does indeed have poor and inconsistent quality at retail. This has involved assessing broccoli quality on display and after purchase. In addition, we have surveyed packaging, transport and handling for a range of different broccoli supply chains. Results will be used to determine whether interventions have the potential to improve broccoli retail sales.

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<sup>7</sup> Cox DN *et al.* 2012. Acceptance of health promoting brassica vegetables: the influence of taste perception, information and attitudes. *Public Health Nutr.* 15:1474-1482.

<sup>8</sup> Francis FJ, Clydesdale FM. 1975. Green Vegetables. In 'Food Colorimetry: Theory and applications'. P214-226. AVI Westport CT.

<sup>9</sup> Garitta L, Hough G, Chaves A. 2013. Sensory analysis of broccoli over time: Consumer defined critical attributes and evaluation of digital photographs in comparison to real product appearance. *Food Quality and Pref.* 29:48-52.

<sup>10</sup> Barth MM *et al.* 1992. Misting affects market quality and enzyme activity of broccoli during retail storage. *J. Food Sci.* 57:954-957.

<sup>11</sup> Hamblin D, Todd S. 2013. Project Hurdle. Understanding the attributes that inhibit the purchase and consumption of vegetables: broccoli. Final Report VG12045 Horticulture Australia Ltd.

<sup>12</sup> Piccone M. 2009. Understanding the retail performance of broccoli using a tool for determining in store performance and consumer demand. Final report VG05100, Horticulture Australia Ltd.

## 4. Retail display evaluations

### 4.1. Introduction

The objective of this part of the project was to examine:

- Retail prices for broccoli
- The range of display types used for broccoli at retail
- Display method, in terms of type of container and quantity of product displayed
- The quality and appeal of the display itself
- Maximum and minimum temperatures of the broccoli

### 4.2. Method

To more readily conduct assessments in stores, an auditing 'app' was developed using i-auditor as a base. This allowed the store surveyor to easily key information into a phone while in the store. A photograph could also be taken of the display for inclusion in the report without disturbing store staff. A series of screen shots from the app are shown in Figure 1.

Temperatures were measured using an infrared thermometer, recording broccoli temperatures at what appeared to be the coldest, warmest and average points within the display.

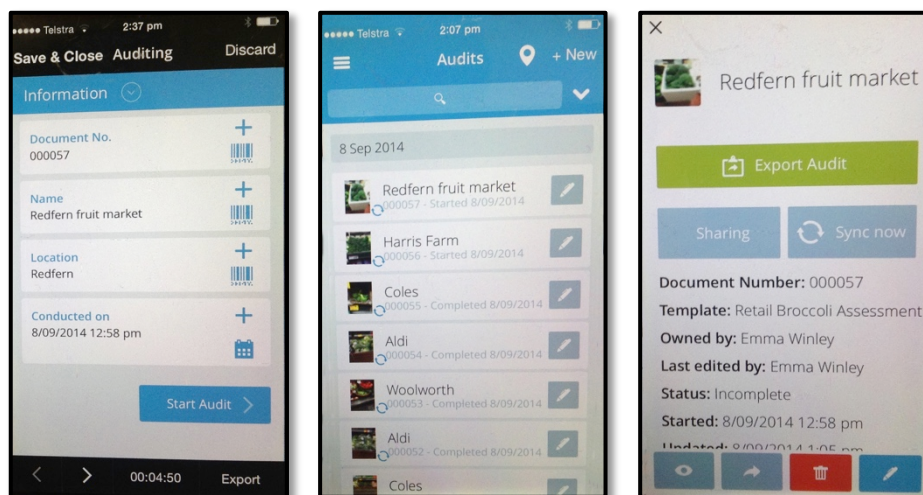


Figure 1 Screen shots from the i-Auditor 'app' used to conduct assessments of retail store displays

Retail store assessments were conducted in Sydney, Melbourne, Perth (and surrounds) and Brisbane.

Retailers were selected to include a range of different demographics, and included independent grocers as well as major supermarkets and convenience stores. The locations of the stores sampled are indicated in Figure 2.

At each store a sample of either six (Sydney stores) or three (all other locations) heads of broccoli was randomly selected and purchased for closer examination and evaluation of retail quality. Assessment was done in comparison with a standard scale, included in the Appendices of this report.

Samples in Sydney, as well as some samples from other locations, were used to assess storage and shelf life after purchase. The results of these assessments are detailed in Section 5 on storage trials.

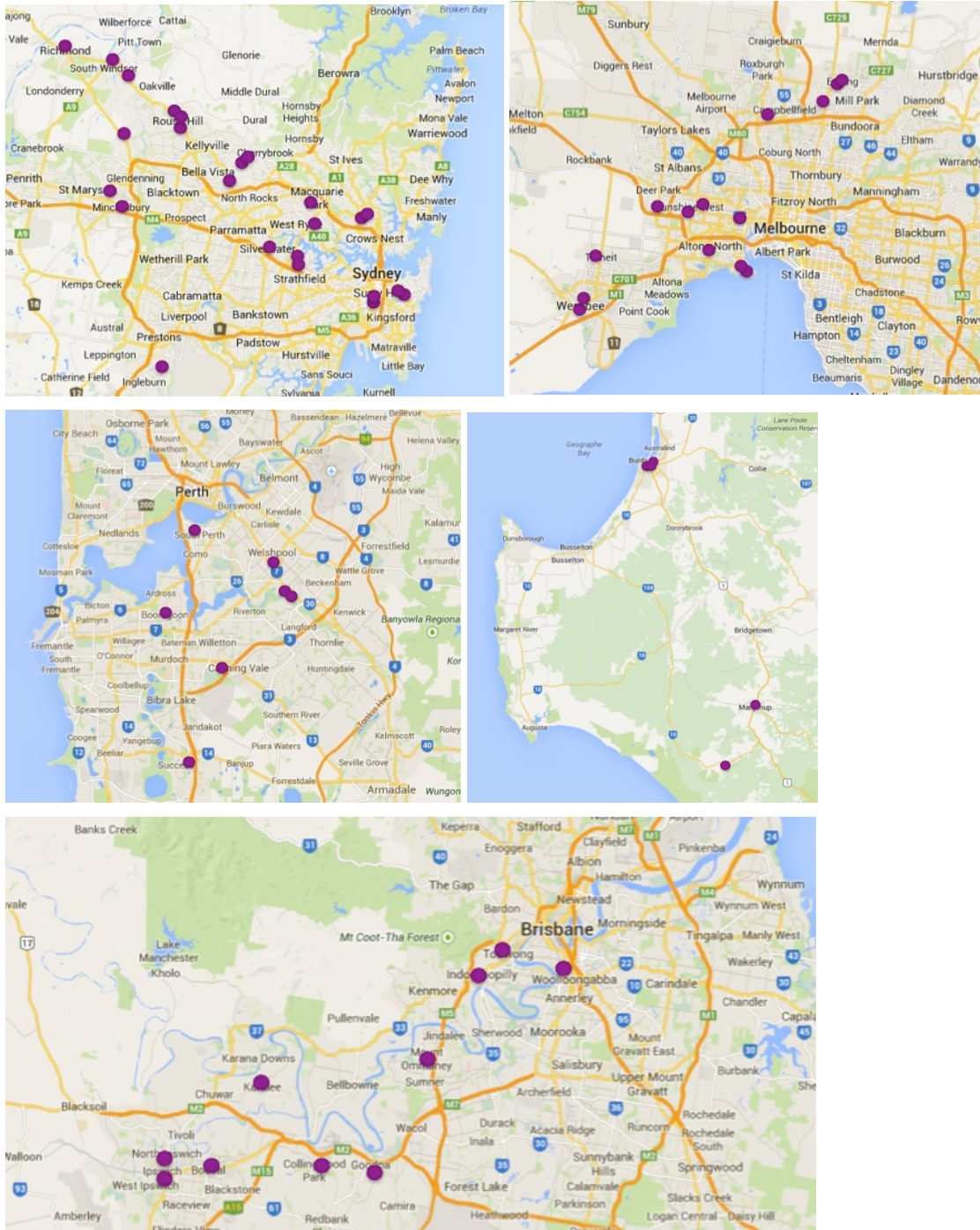


Figure 2 Sampling locations in Sydney, Melbourne, Perth plus surrounds and Brisbane

Table 1 Locations and types of retailers evaluated including mean, maximum and minimum price paid for broccoli sample.

Location and sampling dates	Retailer type	No. samples	Price (\$/kg)		
			Average	Max	Min
Sydney 4/8/14 – 8/9/14	Greengrocer	23	\$4.42	\$15.98 (organic)	\$1.20
	Coles	11	\$4.90	\$8.00	\$1.20
	Woolworths	9	\$5.10	\$8.00	\$2.00
	Aldi	9	\$3.50	\$6.00	\$1.20
	Other s' market	4	\$7.67	\$9.00	\$6.68
Melbourne 16/9/14 – 17/9/14	Greengrocer	6	\$2.21	\$2.99	\$1.15
	Coles	6	\$3.99	\$3.99	\$3.99
	Woolworths	6	\$1.78	\$2.98	\$1.18
	Aldi	3	\$1.82	\$2.49	\$1.15
	FoodWorks	1	\$3.59	\$3.59	\$3.59
Perth / WA 23/9/14 – 26/9/14	Greengrocer	5	\$2.31	\$3.70	\$1.49
	Coles	6	\$5.98	\$5.99	\$5.95
	Woolworths	7	\$5.62	\$5.99	\$3.48
	IGA	5	\$4.79	\$7.99	\$1.99
Brisbane 27/10/14 – 29/10/14	Greengrocer	7	\$4.27	\$5.99	\$2.99
	Coles	5	\$3.98	\$3.98	\$3.98
	Woolworths	8	\$3.98	\$3.98	\$3.98
	Aldi	2	\$2.69	\$2.69	\$2.69

The average price paid for broccoli over the entire survey was \$4.18/kg.

### 4.3. Results

#### 4.3.1. Display type

##### *Independent greengrocers*

Most independent fruit and vegetable stores displayed broccoli on open shelves or benches without refrigeration. Only two of the 41 stores surveyed in Sydney, Perth and Melbourne were using a refrigerated cabinet. Queensland stores were a notable exception, with five of the seven stores visited displaying broccoli under refrigeration.

The quality of display at certain independent stores was extremely high. In some cases broccoli was displayed in an elaborate pyramid, carefully arranged and hand misted by the store staff. In others, it was neatly arranged on a box or display cabinet.

However, just as some of the *best* displays were observed at independent greengrocers, so were some of the *worst*. In some stores the broccoli had been simply emptied out on the shelf, or just placed on a bench still in its Styrofoam box complete with melted ice. Product was sometimes displayed under warm conditions without refrigeration or even a liner, in conditions less than optimally hygienic. In Perth, some stores were selling gigantic heads around 1kg weight, with and without leaves attached.



Figure 3 Appealing (top) and less appealing displays at independent fruit and vegetable shops

While the lack of refrigeration would normally be considered a negative, many of the best quality displays were on an open shelf or bench. Average display quality at independent greengrocers with refrigeration was 2.3 (OK to good) while those without refrigeration averaged 1.3 (good to excellent).

Consistent with this, virtually no yellowing was observed in any of the purchased samples which had come from non-refrigerated displays (average score = 1.1, fully green), whereas the six samples from refrigerated displays averaged 1.5 (approx. 5% yellow). Perhaps surprisingly, broccoli purchased from non-refrigerated displays was generally firmer, had fewer rots and higher overall quality than broccoli from refrigerated cabinets (Figure 4).

### **Supermarkets and minimarts**

In contrast to greengrocer shops, most supermarkets use cooled displays for broccoli. This includes both refrigerated cabinets and the new Coles displays where product is displayed on a layer of flaked ice protected by a clear plastic sheet. The main exception is when broccoli is advertised as on special, when it may be placed on a more prominent, central display. During the survey period broccoli was advertised as a special in NSW, with the result that around 40% of supermarket displays were under ambient conditions. Similar results were found for Victoria. However, non-refrigerated displays were rare in WA and non-existent in the stores surveyed in Queensland.

Unlike the results observed for independent grocers, there were few differences in average initial quality of purchased samples from supermarkets in relation to display type. Stock turnover rate, supply chain continuity and many other factors are very different for Coles and Woolworths compared to an independent greengrocer.

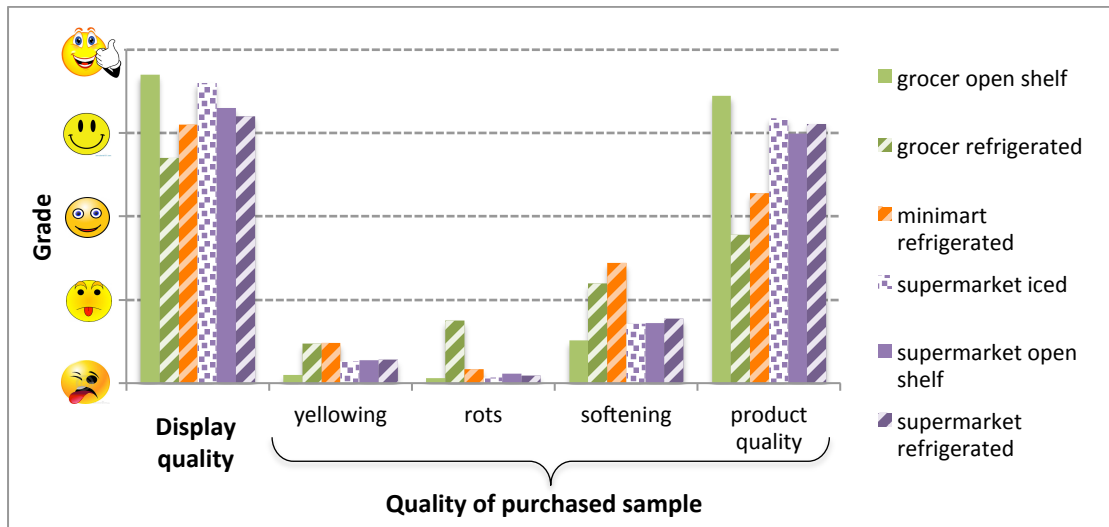


Figure 4 Quality of purchased samples divided by type of retailer and store display. High values are good for display and product quality; high values indicate increased yellowing, rots or softening for those criteria.



Figure 5 A selection of iced, refrigerated and non-refrigerated displays observed in the major retailers

Unlike other supermarkets, Aldi stores in NSW and Victoria do not refrigerate their displays, but instead package broccoli to preserve condition and reduce weight loss. In Queensland, Aldi still sells broccoli loose in lined crates in refrigerated shelving. Aldi displays were

generally scored lower than those of other retailers, as packed product does not present well. However, Aldi was reliably cheaper than other retailers and broccoli quality was consistently high. A shopper was observed in one store who had clearly been to a major supermarket for her other groceries, but had chosen to come to Aldi to buy fresh produce, including broccoli.

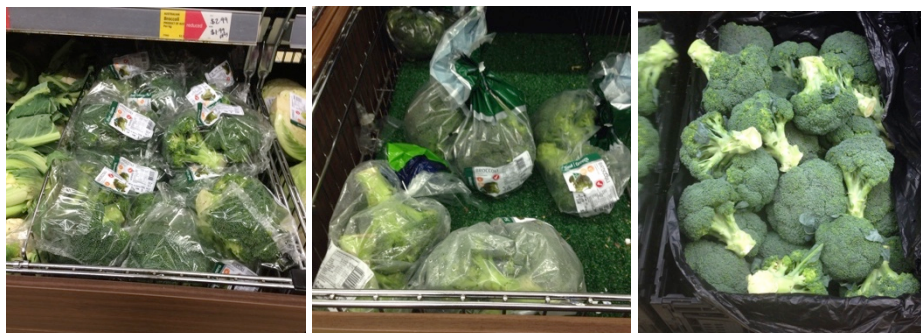


Figure 6 Broccoli displays at Aldi in NSW, Victoria and Qld (L – R)

All ‘minimarts’ surveyed, such as IGA and Foodworks stores, used refrigerated displays. These stores could be expected to have lower turnover of fresh vegetables, perhaps making refrigeration more important. Although average quality of purchased samples was similar to that from grocers using the same display type, variation was extremely high. While some of the larger stores such as Supa-IGAs had good quality broccoli, a number of other samples were very poor, with extensive yellowing or rots already present in the displayed product.

Some minimarts and greengrocers also sold broccoli in packages, but in this case it was usually simply cling-wrapped in store in an attempt to stop dehydration. Organic broccoli may also be sold packaged to differentiate it from the regular product.



Figure 7 Broccoli displays in ‘minimarts’; local supermarkets such as IGA and Foodworks

#### 4.3.2. Display quantity and containers

Around 70% of the displays at independent grocers and 50% of displays at supermarkets and minimarts involved placing the broccoli directly onto a shelf or bench rather than inside a protective box, tub or carton. Displays which put product directly onto open shelves as well as those using cartons often failed to include a liner or underlay to protect the broccoli and maintain cleanliness. Refrigerated displays in particular can have relatively high airflow, against which an unlined plastic crate offers little protection, and an open shelf none at all. This suggests that simply including a liner could significantly reduce moisture loss.

The new Woolworths displays, which use ceramic bowls inside the refrigerated cabinet, are not lined. However, they appear reasonably easy to clean after use. As they have shallow walls and a solid base they may also offer better protection against dehydration than more

open systems. They only contain a relatively small amount of product, providing the additional benefit of ensuring regular stock rotation.

Liners can also have down sides. A number of instances were observed where the crate liner was filled with meltwater and fragments of broken florets, suggesting it had not been changed recently. This reduced the quality of the display and could potentially increase stem splitting and disease.

Over 60% of displays were one layer only or a single layer with a few heads on top. Multiple layer displays were mainly observed in Sydney stores, and were more frequent in independent grocers than in supermarket type outlets (Table 2). The number of layers helps to indicate the volume of product displayed at the one time. Contrary to expectations, supermarkets are more likely to put smaller volumes on display, whereas independent grocers often construct a large, perhaps more eye-catching display—a ‘cornucopia’ of broccoli. However, if this product is not sold quickly, quality is likely to deteriorate.

*Table 2 Number of layers of broccoli displayed.  
Values are percentages of all stores surveyed (greengrocer n=41, supermarket + minimart n=82)*

	Percentage of displays	
	Greengrocer	Supermarket or minimart
1 layer	20	24
1 layer + a few on top	15	52
2 - 3 layers	34	20
Multiple layers or pyramid	32	4

Displays were split fairly evenly between the broccoli being put directly onto the display shelf and it being placed inside a plastic crate or tub. As with independent grocers, liners were not always used, even though this is an easy way to protect the product from excess moisture loss.



### 4.3.3. Display temperatures

The researchers expected that display temperatures would fall roughly into two groups: refrigerated displays, which are usually set to around 4 – 8°C, and non-refrigerated displays, where the broccoli could be expected to be close to the ambient temperature of around 22°C in an air-conditioned store.

However, temperatures were spread fairly evenly across a wide range. As shown in Figure 8, there were as many readings >15°C as there were at the optimum temperature of 2.5–5°C. Most broccoli was displayed cool, but not cold, at temperatures where it remains sensitive to ethylene in the store environment and deterioration is relatively rapid.

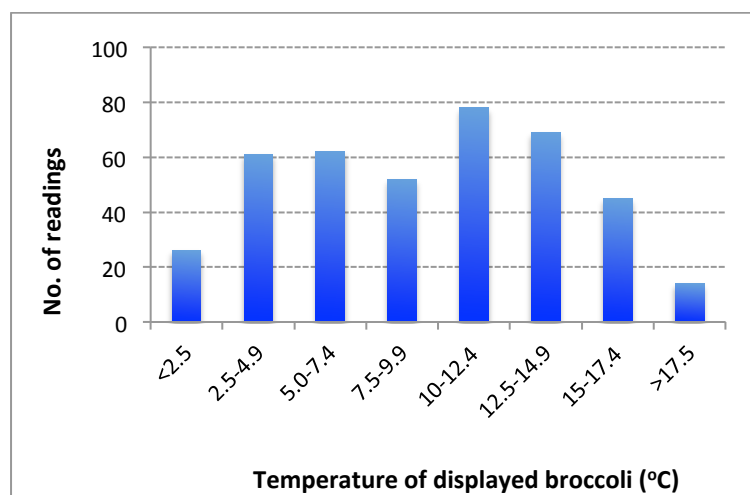


Figure 8 Number of temperature readings taken at all stores and of all display types in 2.5°C increments. Bar height indicates the total number of readings, 3-6 readings per retailer, 123 stores.

To analyse these results further, the data was broken down by display type and by state. Although temperatures inside supermarket and minimart refrigerated cabinets averaged around 5°C, values ranged from over 10°C to below 0°C. Refrigerated cabinet displays in greengrocers—which were only observed in significant numbers in Queensland—had an even wider range, with broccoli temperatures from 1.9°C to over 23°C recorded (Figure 9).

The ambient temperatures recorded on open shelves averaged between 10°C and 15°C (Figure 9). This was significantly colder than the store itself. Broccoli had evidently been transferred fairly recently from the cold store, while evaporative cooling due to moisture loss would also have contributed to the reasonably low temperatures observed. The lowest open shelf temperatures were recorded in Victoria, where it was still quite cool weather at the time of the survey. In contrast, the Qld survey was carried out when daytime temperatures were hitting 40°C, undoubtedly a factor in why only two stores out of the 22 visited were not using cooled displays.

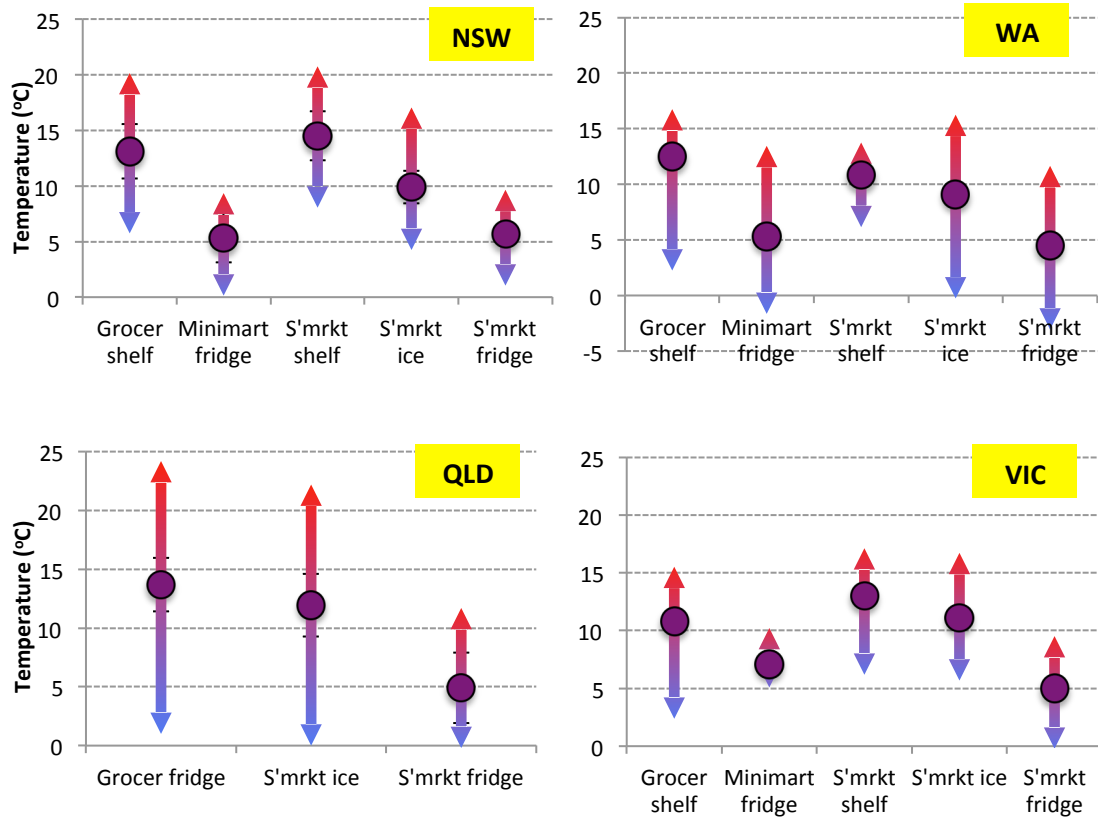


Figure 9 Average (●), maximum and minimum temperatures recorded in different states by retailer category and display type. Bar height indicates the range of values recorded, from maximum to minimum.

### 4.3.4. Product quality

None of the quality attributes recorded on purchased samples of broccoli varied significantly between supermarkets and greengrocers. Some attributes—particularly softening and leaf scar discolouration—tended to be more severe in product purchased from minimarts, presumably because of lower stock turnover. However, the most striking aspect of the quality data presented in Figure 10 is the high degree of variability within each sample.

In some cases, variability was high within a single display, indicating that new stock had been placed on top of older product. For example, a single sample could easily include heads that were completely softened and wilted as well as ones that were fresh and firm. Yellowing heads were found alongside ones that were still full green; and the ethylene produced by senescent heads can potentially increase deterioration of their sound neighbours.

Moreover, mixed product displays encourage rummaging by customers searching for firm, dark green broccoli heads. This behaviour increases breakage, reduces the appeal of the display overall, and makes it impossible for store staff to practice proper stock rotation.

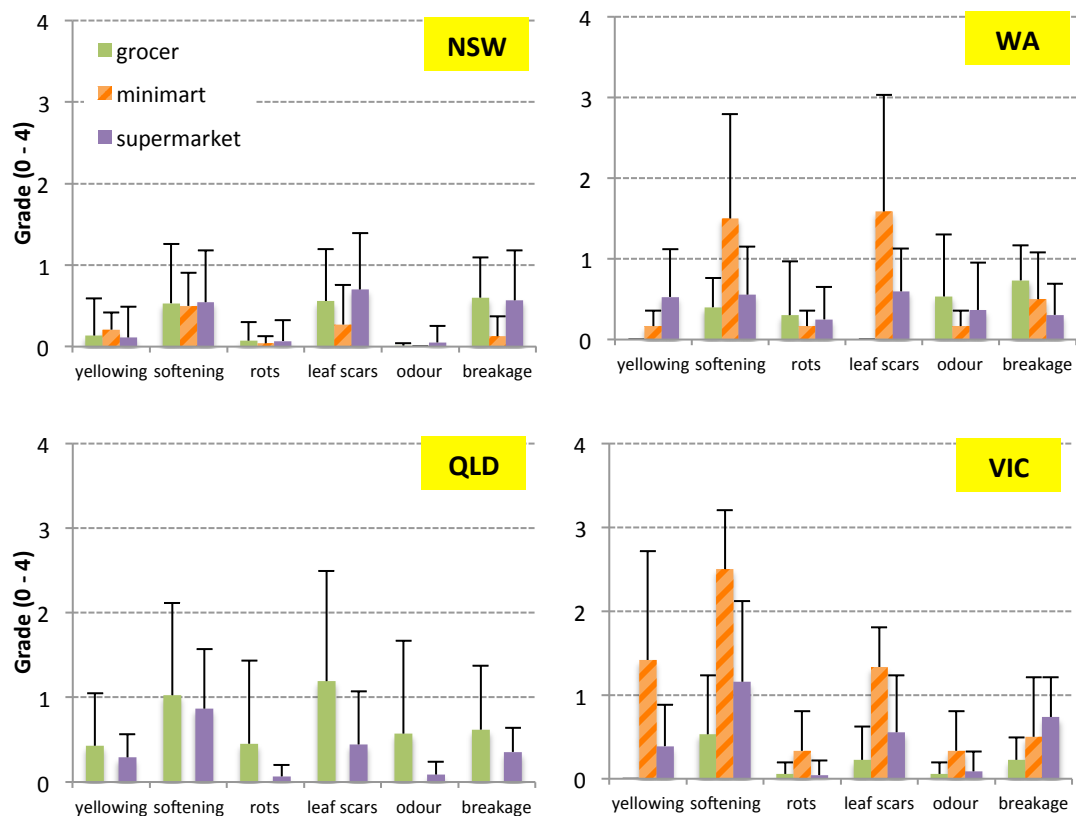


Figure 10 Quality of purchased broccoli samples by store type and state. Height of column indicates the mean degree of yellowing, softening, development of rots, discolouration of leaf scars, odour and breakage, evaluated by comparison with a standardised scale where 0 = none and 4 = severe. Error bars show the standard deviation of each mean value.

Overall saleability and acceptability of purchased samples also did not differ significantly between supermarkets and grocers, although there was again a trend to minimarts having poorer quality product (Figure 11). Broccoli purchases in WA and Queensland averaged 'OK' to 'good' quality, while those in NSW and Victorian greengrocer shops tended to be 'good' to 'excellent'. Because the surveys were conducted at different times, this does not necessarily suggest that NSW retail quality is generally any higher than other states. Again, the most significant finding from this data is the high level of variability between stores and, indeed, within stores.

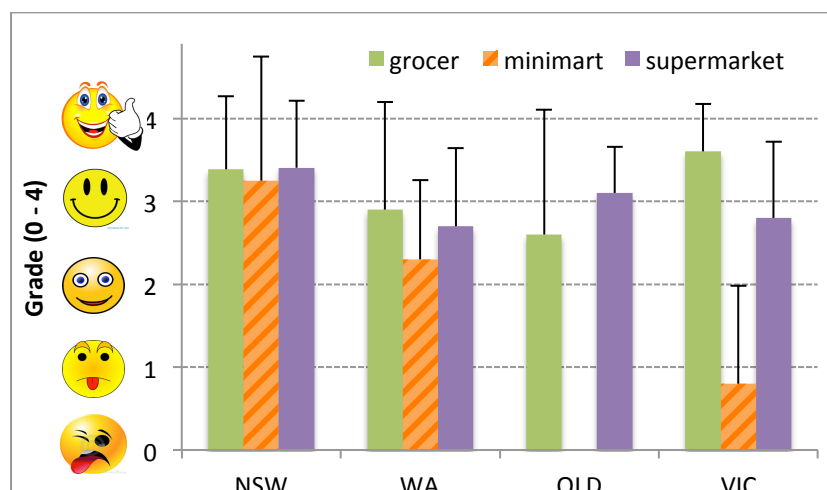


Figure 11 Overall quality of purchased broccoli samples by store type and state. Height of column indicates mean acceptability where 4=excellent and 0=disgusting. Error bars show the standard deviation of each mean value.

A total of 530 heads of broccoli were purchased from the various retail outlets surveyed. More than three quarters of all purchases were graded as either 'Excellent, fresh' or 'Good to very good'. A further 13% were considered barely saleable, and just under 10% were graded unacceptable.

**This suggests that if a consumer shops for broccoli in random retail outlets—including supermarkets, specialty greengrocers and convenience minimarts—then they will be disappointed with the quality available on at least one trip in five.**

Table 3 Proportion of all randomly purchased broccoli samples (n=530) rated as excellent, good, OK, poor or disgusting.

	Proportion of samples (%)
Excellent	57.4
Good	19.8
OK	13.4
Poor	8.1
Disgusting	1.3

## 4.4. Conclusions

At the start of this study it was hypothesised that there was really no significant problem with broccoli quality at retail. The only time quality could be less than acceptable would be if the product was displayed for extended periods without refrigeration—as could occur at some greengrocer stores or on central display units in supermarkets.

In fact, this study has indicated that broccoli is actually **less** likely to be good quality when it is displayed under refrigerated conditions. While this seems counter-intuitive, it may indicate that refrigerated displays have slower turnover. Also, whereas products in open displays are often returned to cold rooms at night, refrigerated displays are not, even though cooling may be less efficient.

Loss of firmness was a major cause of quality loss, and the cold air produced by refrigerated displays can be very low in absolute moisture content. If product remains warm but is exposed to cold, dry air then it can lose moisture rapidly, especially given the relatively high rate of air movement in such displays. It would be interesting to compare rates of water loss in commercial refrigerated displays compared to that in the air-conditioned store.

Although **average** broccoli quality was generally acceptable, variability in quality is a significant issue. Product ranged from firm to soft, green to yellow and appealing to malodorous and inedible. While this was by no means a comprehensive survey, and quality will inevitably vary by season and location, the study has demonstrated the range of quality that may be offered not just at different stores, but even within the one display at a store.

While it appears a positive result that 77% of broccoli samples purchased were excellent or very good standard, this means that 23% of samples were of limited saleability, or even completely inedible. For the vegetable shopper, this represents a significant proportion of trips where they may be reluctant to purchase broccoli. In some cases, this may just mean they purchase a different green vegetable. But in others it may mean avoidance of fresh produce altogether.

Price also varied widely during the survey, ranging from \$9.00/kg to only \$1.15/kg. There was no relationship between price and broccoli quality. Samples purchased for less than \$1.50/kg were scored as excellent while others costing \$7.98/kg were scored as OK to poor. While this is by no means unusual in fresh produce—the best quality often coincides with the lowest prices—this is likely to further reduce consumer confidence in broccoli as a regularly purchased vegetable.

In summary, while many suppliers and retailers are doing a good job with storing and displaying broccoli, there remains room for improvement, especially among outlets which may have relatively low rates of turnover for fresh produce.

## 5. Storage trials

### 5.1. Introduction

While much work has examined storage life of broccoli under optimum conditions, less has examined storage life under the type of conditions that might be used by consumers.

Recently published work by Colmar Brunton (Monthly report W14, *Project Harvest*) indicates that consumers expect broccoli to stay fresh in the fridge for at least seven days after purchase. We were interested in whether randomly purchased broccoli samples would meet this expectation, and whether good initial quality necessarily reflected longer subsequent storage and shelf life. Additionally, if storage and shelf life appeared to be influenced by the display conditions, then that could provide a way to reduce variability in broccoli freshness.

### 5.2. Methods

Samples of six heads of broccoli were purchased from the retail outlets surveyed in NSW, as noted in Section 4 of this report. Each sample was randomly selected from different parts of the display, if possible, so as to include the full range of product available to the consumer.

The heads were placed in cooler bags or bins and immediately transported to the AHR laboratory. Initial quality was assessed by comparison with the subjective grading scale, as included in the Appendices of this report.

Attributes recorded included colour, firmness, odour, floret rots, leaf base scar discolouration, breakages on the head, presence of any blisters and overall appeal.

Digital photographs were taken of the heads on a black background with standard white tile included. This could be used to assess head colour objectively if necessary.

The broccoli was allocated either to storage at 5°C, simulating a domestic refrigerator, or to ambient storage at 22°C. Quality attributes were assessed daily during storage at 22°C or twice weekly during storage at 5°C. Heads were individually assessed on each occasion, and a photograph used to record colour of the three broccoli heads in standard locations.

The number of days of storage or shelf life of each sample was calculated by plotting each quality characteristic over time. A polynomial equation was fitted to the data and used to estimate the exact time at which any attribute increased to a value of 2. The broccoli was considered no longer acceptable once any attribute (yellowing, softening, rots, and overall acceptability) equalled 2.

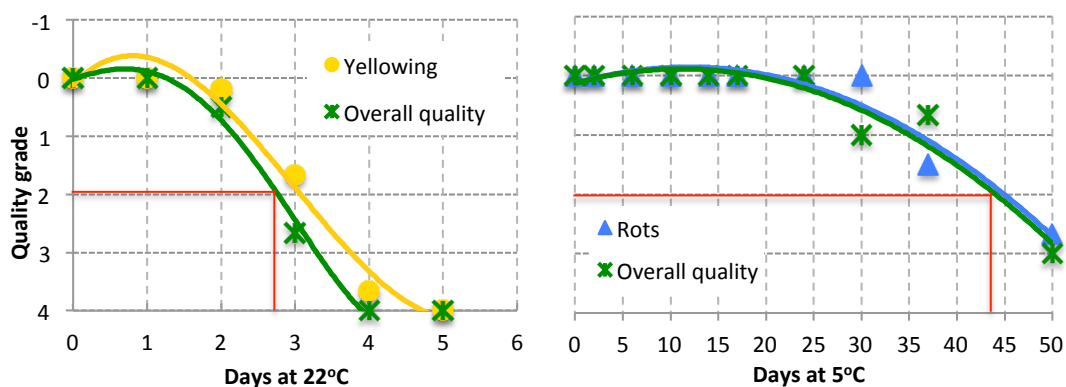


Figure 12 Method used to calculate shelf life at 22°C and storage life at 5°C. Polynomial trendlines have been fitted to the data and gridlines used to estimate the exact number of days until any quality attribute fell to grade 2. In the example shown shelf life was 2.7 days and storage life was 44 days.

### 5.3. Results

Yellowing and softening were major causes of deterioration at 22°C. At 5°C the appearance of rots became a more significant issue, with yellowing or browning occurring later. However, at both 22°C and 5°C the major factor limiting shelf life was overall acceptability. This effectively integrates all the individual characteristics of the head, so perhaps is a more sensitive measure than specific quality attributes such as leaf base scar blackening.

**A total of 56 samples of six heads of broccoli were obtained from a range of different retail stores. Of these, 13 remained acceptable for less than 7 days at 5°C.**

**This suggests that 23% of the broccoli samples purchased at retail would not meet consumer expectations in terms of storage life.**

A very large degree of variation was observed among the samples. While average shelf life was 2 days at 22°C and 14 days at 5°C, maximum values were 5.5 days at 22°C and 30 days at 5°C. Other samples were essentially unacceptable at purchase, giving them a life of effectively zero.

Neither shelf life at 22°C or storage life at 5°C varied significantly between display types or by type of retailer (Figure 13). While there appeared to be a slight extension of life in broccoli that had been purchased from iced displays in supermarkets, it should be noted this is based on only 4 samples, compared to 11 or 14 from refrigerated cabinets or open displays respectively. Given the large variability overall, this cannot be considered a significant effect.

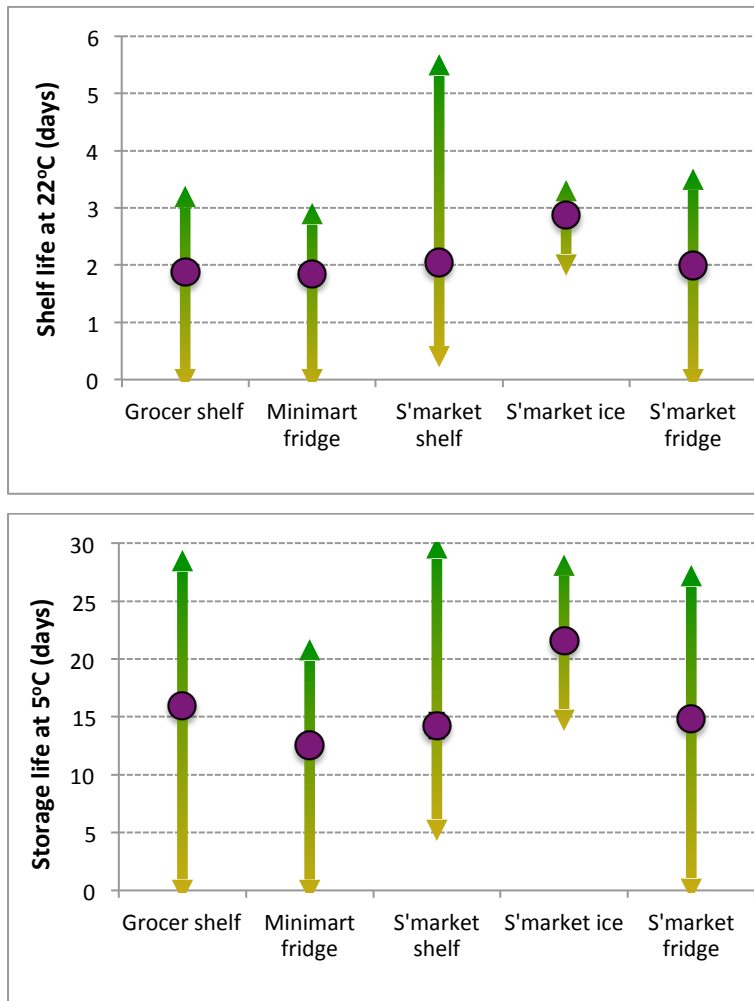


Figure 13 Shelf life at 22°C and storage life at 5°C of broccoli purchased from different retail outlets and display types. Average value indicated by ●, maximum and minimum recorded values indicated by height of each bar

A trend was noted that broccoli which was purchased while warm (over 15°C) tended to have a shorter storage life at 5°C than other samples purchased at lower temperatures. However, samples that were more thoroughly chilled at purchase also tended to have shorter storage life than those at moderate temperatures, making it risky to draw excessive inference from this result.

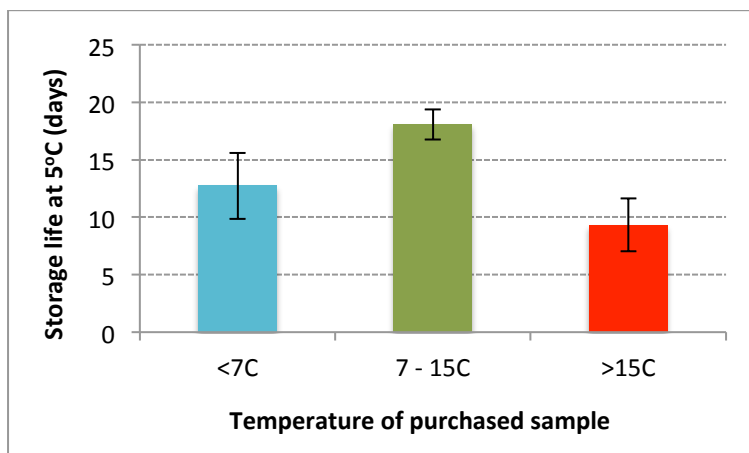


Figure 14 Storage life of randomly purchased samples of broccoli in relation to temperature of the sample at purchase.



Initial quality also appeared not to relate significantly to storage or shelf life. Some broccoli samples that were graded 4; 'Excellent', at purchase proved to have relatively little remaining life, while others ranked similarly lasted a long time. Similarly, some samples considered to be only marginally acceptable at purchase were slow to deteriorate further, equalling the storage and shelf lives of samples that were initially much better quality.

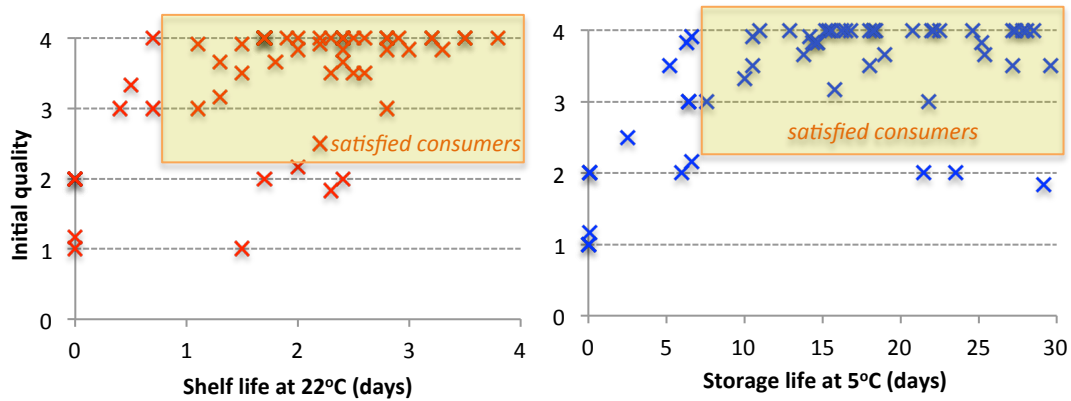


Figure 15 Relationship between initial quality at purchase and storage and shelf life of broccoli samples. Box indicates the samples which fully met consumer expectations. That is, initial quality was >2 and storage life was >1 day at ambient temperature or >7 days at 5°C.

For a broccoli purchase to be fully satisfactory to the consumer, it may be assumed that initial quality should be good to excellent (grade >2) and storage life at 5°C should be >7 days.

**Using these criteria, consumers would be dissatisfied with 16 of the 56 samples, or around 28% of purchased broccoli**

## 5.4. Conclusions

The results are not clear in terms of any relationship between broccoli display type, or even broccoli display temperature, and subsequent storage and shelf life. While the retail conditions are likely to have an effect, this does not take into account the time broccoli spends on display, the amount of time it was previously held in storage, or its management within the supply chain.

What the results do clearly indicate is that retail quality of broccoli is extremely variable. Even samples that appear to be good quality at purchase can prematurely turn yellow, develop rots, or become generally unacceptable.

It was previously noted that consumers wishing to purchase broccoli would be disappointed in quality on around one in five trips. Given that an additional percentage of apparently good quality broccoli lacks the expected seven days storage life in the refrigerator, this suggests that consumers may be dissatisfied on as much as one in four occasions. This is reasonably consistent with the 2014 Colmar-Brunton *Project Harvest* report, which suggested that consumers were 'usually' or 'always' satisfied with broccoli around 80% of the time.

This project was based on the assertion made in Project VG12045 that inconsistency in quality and freshness was a major inhibitor of consumer purchase of broccoli. The information collected as part of this project supports that conclusion.

Broccoli quality at retail has indeed been found to be highly variable, while storability of broccoli ranged from essentially zero to over four weeks at normal refrigerator temperatures. Price is an additional variable, ranging from only just over \$1/kg to as much as \$8 or even \$9/kg. Given that price is no indicator of quality (in fact often the opposite is true) this may be an additional disincentive to some consumers.

While questions remain as to the effect of these factors on actual purchases, it is clear that variability in broccoli freshness certainly has the **potential** to impact sales. The final question therefore relates the sources of this variability and whether there is anything that industry can do to address this issue.

## 6. Supply chain studies

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### 6.1. Introduction

The results from the retail survey and storage trials indicate that quality of broccoli offered to consumers is highly variable. Even broccoli that appears good when purchased can prove unsatisfactory in terms of its storage life.

This raises the question of why such variability occurs. Broccoli is harvested as an immature flower head. Its metabolic processes continue after harvest, including maturation of the florets, respiration and transpiration. The best way to slow senescence is through cooling, although reducing the effects of ethylene may also have an effect.

Examining what happens to broccoli once it has been harvested could provide more clues as to sources of variability in retail quality. The speed at which it is cooled after harvest, the integrity of the cold chain and the length of time needed for transport, wholesale and retail may all influence end quality.

### 6.2. Method

#### 6.2.1. Supply chains and treatments

Temperature monitoring has been conducted in four different supply chains:

1. Harvest in Werribee → cooled → packing → Aldi Distribution Centre → 3 x local Melbourne stores
2. Harvest in Werribee → cooled → packing → local wholesaler → Coles distribution centre (air temperature only)
3. Packing in Manjimup → transport to Perth → retail at Perth wholesale market
4. Harvest in Gatton → packing → Brisbane wholesale market → independent greengrocers in Mt Tambourine and Murwillumbah

Broccoli in **supply chain 1** was packed into twin head pre-packs, as per Aldi specifications. These were then placed inside returnable plastic crates for delivery to Aldi stores. Each of the Aldi stores surveyed received a single crate of broccoli, along with other fresh products, as part of its overnight stock delivery. The broccoli was initially placed in the cool room before transfer to open shelf display units when the store opens. Aldi is different to other retailers in that it does not keep stock in hand. A store gets a delivery of a specific amount of product, which is generally sold that day. This minimises the need for cold room space at the store but does mean that stock can, and does run out.





Figure 16 Broccoli in Werribee is picked (top L) and transported back to the packinghouse (top R). The next day it was packed for Aldi (bottom L), including some packaged heads with loggers attached (bottom R)

**Supply chain 2** broccoli was packed in 8kg Styrofoam cartons with approximately 4kg top icing. Unfortunately it was not possible to insert loggers into the broccoli stems for this chain due to food safety concerns; only air loggers were used. It was not possible to track a certain container of broccoli into a Coles store, as delivered broccoli is pooled at the distribution centre (DC) then picked for individual store orders on a first in first out basis. For this reason temperatures were only monitored until broccoli reached the distribution centre.

In **Supply chain 3** broccoli was not being harvested on the days of the study. However, pre-cooled broccoli was being packed and this was used. In this case standard Styrofoam containers with top icing were compared to packing in Styrofoam without ice. The effect of iced vs non-iced packing was tested because the elimination of icing has the potential to significantly reduce costs and environmental footprint of the industry. Styrofoam containers are not ideal for a non-iced system as they lack ventilation. However, it was thought this could still provide some valuable information.



Figure 17 Packing broccoli into Styrofoam containers in Manjimup

Harvest and packing conditions for supply chains 1, 2 and 3 were cool (<math><15^{\circ}\text{C}</math>) and relatively humid. The conditions during harvest for **supply chain 4** were extremely different. This harvest was near the end of the Gattton season and temperatures had soared into the low 40s. At the time of harvest it was relatively early morning (around 9:00am) but the temperature was already well over



Figure 18 Broccoli harvest during a heatwave in Gatton

The broccoli harvested in Gatton was packed into either a standard Styrofoam container and top iced, or into a new packaging type developed specifically for top iced broccoli. This is a plasticised cardboard box, manufactured so as to provide a completely sealed container. Unlike the waxed cartons still used for top iced broccoli in the USA, this carton will not leak water if the ice melts, making it acceptable from an OH&S and logistical point of view.

The plasticised cartons are cheaper than Styrofoam, at least in some broccoli growing locations. It also requires less storage space and poses fewer disposal issues. Space saving due to the thinner walls of the package means that 10kg can be packed into a carton compared to 8kg in Styrofoam, so more broccoli can be loaded onto a single pallet. This represents a significant saving in transport costs. However, it has not yet had a strong uptake due to concerns regarding how well it would perform in a standard supply chain.

### 6.2.2. Temperature monitoring

Two different types of loggers were used:

1. i-button thermochrons (resolution 0.5°C, accuracy  $\pm 0.5^\circ\text{C}$ )
2. Logtag temperature recorders with external probes (resolution 0.1°C, accuracy  $\pm 0.5^\circ\text{C}$ )



Although thermochrons have a lower resolution than the Logtags, they are significantly cheaper, so were used when there was a reasonably high probability that the logger might not be retrieved. The thermochrons were inserted into hollowed out cavities inside the broccoli stems. The stem was then wrapped with duct tape and marked with flagging tape (Figure 19).

Logtag probes were inserted into the centre of each broccoli stem. The Logtags themselves were kept dry during hydrocooling and transport by sealing in plastic ziplock bags (Figure 19).



Figure 19 Broccoli with i-button Thermochron (L) or Logtag probe inserted into the stem.

Loggers were downloaded immediately after retrieval using the appropriate software. All data was analysed using Excel.

### 6.3. Results

#### 6.3.1. Supply chains 1 and 2

As shown in Figure 20, broccoli was cooled rapidly, with core temperatures reduced to less than 5°C within two hours of cutting from the plant. Temperatures were maintained at around 2°C overnight before packing, ensuring that all heads in the bin were thoroughly cooled. Packing itself resulted in only a transitory temperature increase, and heads were cooling again before loading onto the truck for transport to the Aldi DC.

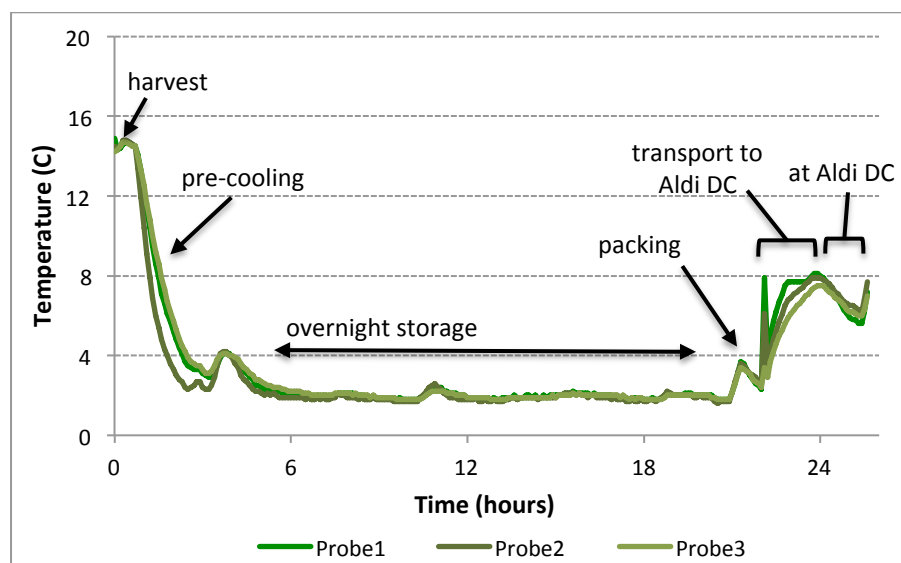


Figure 20 Temperature during harvest, cooling, packing and delivery to Aldi DC, recorded using Logtag probes

During several hours storage at the Aldi DC and transport to individual stores, broccoli generally stayed below 6°C (Figure 21). After delivery and placement in the back-of-store cold room it quickly reduced to 3.5°C. Unfortunately, loggers were retrieved from only two of the three stores that the marked broccoli samples were sent to. However, both of the loggers sent to each of the Altona and Maribyrnong stores were recovered.

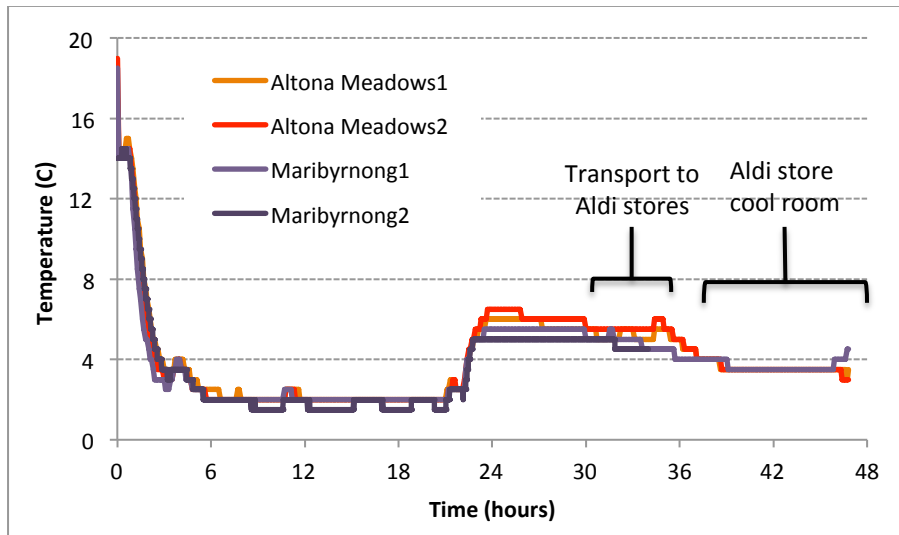


Figure 21 Temperature during harvest, cooling, packing, delivery to the Aldi DC and distribution to individual Aldi stores, recorded using i-buttons

The relatively rapid cooling observed in the packed broccoli is one advantage of the open crates system. Although the broccoli warmed relatively easily, it was quick to cool down after placement in a cooler environment. It is also encouraging that both of the back-of-store cool rooms appeared to be operating well.

The cooling and packing temperature logs for the container sent to the Coles Distribution Centre (supply chain 2) were the same as those shown in Figure 20. As previously, broccoli that was top iced maintained a temperature of around 2°C through the supply chain.

In this case, it could have been beneficial to keep the broccoli well insulated and with ice, as the carton was delivered to the DC at around 20°C (Figure 22).

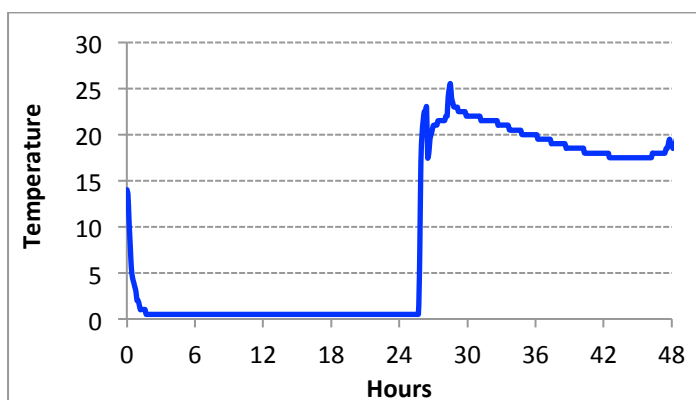


Figure 22 Air temperatures recorded for broccoli shipped to the Coles Distribution Centre

### 6.3.2. Supply chain 3

Six Styrofoam containers —three iced and three non-iced—were monitored from packing through to sale at wholesale for the broccoli samples in WA. It is immediately clear from the results (Figure 23) that, unless broccoli is packed while fully chilled, Styrofoam containers cannot be used without adding ice. Just as Styrofoam prevents the packed broccoli from heating during breaks in the supply chain, it also prevents it cooling.

The results also demonstrate that some ice must melt after packing in order to re-chill broccoli close to zero. This free water inside the carton has the potential to increase stem splits and disease. Nevertheless, it is a good result that containers 1 and 2 remained at virtually 0°C during storage and transport, only increasing to around 0.5°C after reaching the wholesale market. The clear exception was container 3. It is unclear whether this reading was due to a faulty sensor or actually reflects the temperature of the broccoli. Subsequent calibration of the probe indicated it was working correctly (Figure 23). However, it may have been affected by the presence of free water inside the container.

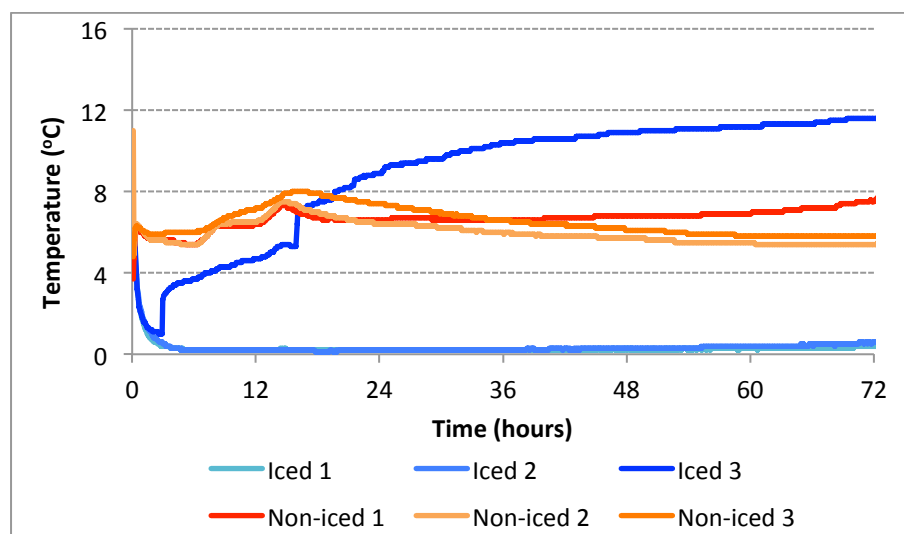


Figure 23 Broccoli core temperatures between packing in Manjimup and retail at Perth wholesale market



### 6.3.3. Supply chain 4

This was the most challenging supply chain examined due to the high temperatures experienced at harvest. In this case, two different bins were monitored during harvest and cooling. Bin 2 cooled more quickly than bin 1, presumably due to location in the cool store. While the broccoli core temperature came down quickly initially, it took at least 13.5 (bin 2) to 15 hours (bin 1) for temperature to be reduced to 7°C, the point where yellowing would be significantly slowed down (Figure 24).

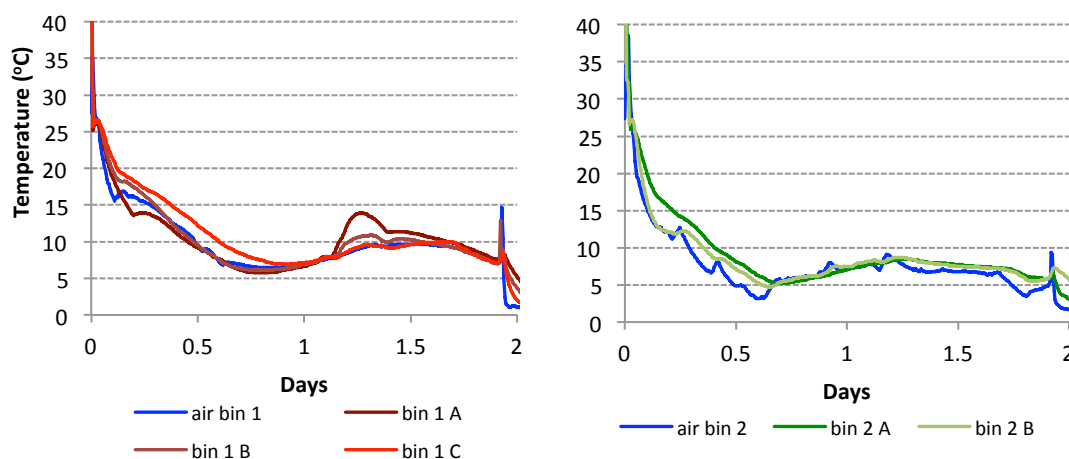


Figure 24 Air temperatures and broccoli core temperatures during postharvest cooling and storage

After a transient spike in temperature during packing and top icing, air temperatures inside the cartons fell rapidly. Broccoli core temperatures took considerably longer to chill down close to the desired setpoint of around 2°C. As previously noted, some melting of ice is inevitable during this stage, and it is the melting of the ice that cools the broccoli.

All broccoli was well under 2°C by the time it was dispatched to the wholesale market (2.5 days). At this stage one of the loggers in the cardboard carton stopped working, presumably due to the amount of melted ice inside the box.

After delivery to the wholesale markets clear differences started to emerge between the Styrofoam and cardboard cartons (Figure 25). This break in the cold chain increased melting of the ice, particularly in the cardboard, which is less well insulated from temperature fluctuations. The boxes were then loaded into non-refrigerated (but air-conditioned) vans for delivery to the retail stores. Again, the Styrofoam container held temperature better than the cardboard, as would be expected.

Despite this, it is evident that none of the broccoli exceeded 4°C, so temperatures remained well below those that would increase senescence. Given the short transport period, it would be expected that such temperatures would still result in acceptable quality.

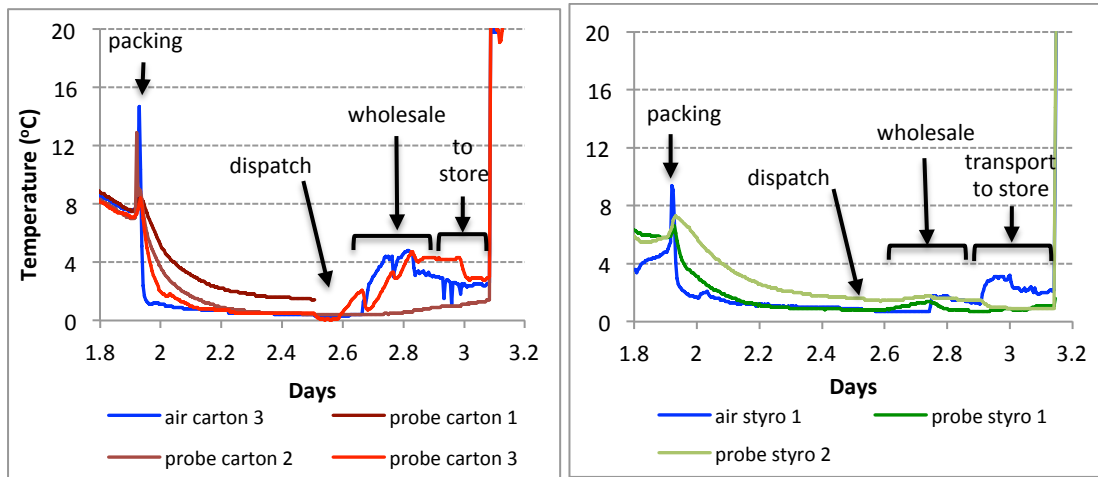


Figure 25 Air temperatures and broccoli core temperatures during packing, storage, transport to wholesale market and then transport to independent grocers. Broccoli was packed in plasticised cartons and sold through a Murwillumbah retailer (L), or Styrofoam cartons and sold through a Mt Tambourine retailer (R)

What was more of an issue with the cardboard cartons was the large amount of meltwater inside, which significantly reduced their structural integrity. Although they did not leak, they were soft and difficult to handle by the time they arrived at the retail store.

It appears that the top iced cardboard boxes function satisfactorily so long as the cold chain is maintained. This includes packing the broccoli when it is thoroughly chilled to avoid initial melting of the ice and weakening of the carton structure.

## 6.4. Conclusions

### 6.4.1. Cooling effectiveness

All of the supply chains traced in this trial appeared to be functioning well. Broccoli was immediately removed from the field and cooled reasonably rapidly after harvest. It was chilled thoroughly at least overnight before packing and then dispatch to the distribution centre or wholesale market by refrigerated truck.

Although the cooling rate of broccoli was not measured in Manjimup, the intention had been to compare standard forced air cooling with the new hydro-vacuum cooler the grower had recently installed. Unfortunately the machine was still not working at the time of the trial, so this could not be done. The grower had purchased this machine to speed cooling and make more efficient use of existing cold room facilities. The anticipated cooling time using the hydro-vac machine was estimated to be 30 minutes. This is a major investment, and demonstrates the importance attached to cooling the harvested broccoli as quickly and efficiently as possible.

While this study is by no means comprehensive, it does appear that most growers are conscious of the need to cool broccoli quickly after harvest. Lack of postharvest cooling therefore does not appear likely to be the major issue affecting subsequent storage life and quality.

## 6.4.2. Top icing

Top icing remains a somewhat controversial practice, with both positive and negative effects. With the exception of Brussels sprouts, no other product is top iced. The reasons for this practice often appear to be historical, rather than based on a specific need. The issue has been discussed with a number of growers and packers, with points for and against summarised as follows:

FOR	AGAINST
Ice protects the broccoli against temperature fluctuations during storage and transport.	Ice only cools broccoli as it melts; the phase change of solid into liquid absorbs heat energy from the surroundings.  If broccoli sits in water it is more likely to develop rots, stem splits and discoloured leaf base scars.
Ice looks good in the box and customers expect to see it. Non-iced broccoli will not be acceptable to many customers.	If customers see melted ice they may reject broccoli consignments.
Broccoli which is top iced stays hydrated and fresh. Without it, heads quickly become soft and limp.	Other products which wilt easily, such as leafy greens, asparagus and fresh cut salad mixes, are not top iced – <i>why is this necessary for broccoli?</i>
Top icing after packing quickly brings the broccoli back down close to ideal temperatures.	Top icing of warm broccoli results in the ice melting. Free water encourages rots, stem splits and discolouration.
Ice is relatively cheap insurance against damaging temperatures.	Producing ice uses a lot of energy and is a significant production cost.
Styrofoam cartons are strong and easy to handle. Recycling / re-use facilities are available.	Styrofoam cartons are expensive (>\$3 each). They are unsustainable, environmentally unfriendly and cannot be readily disposed of.
Although ice is heavy, broccoli is light, so it makes no difference to road transport cost /pallet	Styrofoam cartons with ice are heavy and take up more room on the pallet than non-iced cardboard cartons. Eliminating ice would reduce transport cost /kg broccoli.

### 6.4.3. Packaging

While a range of packaging options are available, there is little doubt that 8kg Styrofoam boxes with top icing remains dominant.

- All wholesale markets expect broccoli to be supplied packed in 8kg Styrofoam cartons with up to 4kg ice added on top.
- Coles requires broccoli to be delivered in Styrofoam cartons with top icing. There is some interest in changing over to plasticised cardboard cartons, still with top icing, to reduce transport costs.
- Woolworths accepts broccoli in plastic lined returnable plastic crates. It also at times accepts broccoli top iced in Styrofoam cartons.
- Aldi receives broccoli loose in lined black crates (Queensland) or as pre-packed heads also in returnable plastic crates (Victoria and NSW).

Export markets such as Singapore and Dubai require broccoli to be in Styrofoam cartons and top iced. However, some agents will accept a reduced amount of ice, one to two kg, added to each carton to save on airfreight costs. In this case cartons may have extra ice added after arrival. Broccoli without ice is not considered saleable in these markets.

## 7. Recommendations

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This project was originally proposed by the Design Team to find ways to improve broccoli freshness at retail. However, after some consideration of the issues, it was decided that the first step should be to find out;

- Whether there is a real, as opposed to a perceived, issue with quality and freshness of broccoli offered for retail sale
- The degree of variability in broccoli quality at various retail outlets and in different states
- Possible sources of variability, including management of broccoli within current supply chains.

This study has shown that quality and shelf life of broccoli at retail is indeed highly variable. Displays ranged from excellent to having very low appeal, and there was little consistency in how or where broccoli was displayed.

The results suggest consumers are likely to be disappointed with broccoli quality at least one trip in five. Should they choose to store their purchase before use, this increases to one disappointing experience in four. It is perfectly conceivable that such “hit-and-miss” success could well be affecting broccoli sales.

Recommendations as to possible solutions / mitigation include;

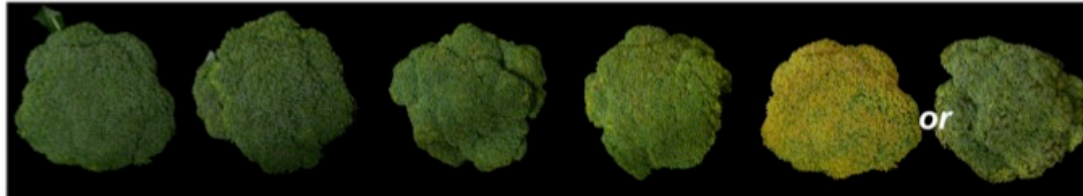
- Evaluate the cost and effectiveness of different current cooling practices used on-farms. These include hydro-vacuum coolers, hydrocooling, forced air systems with / without misting and simple room cooling in bins. This study should include assessment of the effect of different cooling rates on postharvest storage and shelf life as well as the relative cost of such systems.
- Training materials or information targeted at retailers to improve temperature management, handling and display of broccoli.
- Evaluate other supply chains, particularly focussing on iced vs non-iced systems. While eliminating ice has major environmental and cost benefits, change will not occur unless the effects on retail quality and shelf life are clearly demonstrated within a normal supply chain.
- Test the effectiveness of 1-MCP / Smartfresh (particularly the new ‘In-box’ treatment sachets) as an alternative to top icing, under conditions that could occur during supply and marketing of broccoli. This could include testing on closely related crops including broccolini, gai lan and Brussels sprouts.

It is therefore recommended that the Design Team consider funding a “Phase 2” to this project, as originally conceived.

## 8. Appendices

### Broccoli grading scales

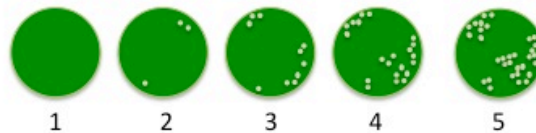
#### Broccoli colour



- |             |              |               |               |                           |
|-------------|--------------|---------------|---------------|---------------------------|
| <b>1</b>    | <b>2</b>     | <b>3</b>      | <b>4</b>      | <b>5</b>                  |
| Fully green | 5-10% yellow | 10-20% yellow | 30-50% yellow | Very yellow and/or rotten |

#### Blistering

1. Even, well formed, no blisters
2. 1-2 blisters, very minor
3. Immature blistering over 5-10% surface
4. Blistered florets over >10% surface
5. Enlarged & open florets affecting >10% surface area



#### Breakages

1. None or <1cm<sup>2</sup> crushed area
2. Minor crushing of a few florets 1-3cm<sup>2</sup>
3. Broken stemlet or 3-5cm<sup>2</sup> crush injury
4. 2-3 broken stemlets or 6-10cm<sup>2</sup> crush injury
5. Major physical damage



#### Firmness

1. Solid head, very firm
2. Very slight 'give' but less than 1cm flex across head
3. Slightly softened, still firm, approx 1-2cm flex
4. Moderately soft, approx 3-4cm flex
5. Soft, floppy, rubbery, >4cm flex

#### Odour

1. No off odours, fresh broccoli smell
2. Very slight odour, inoffensive
3. Slight off odour, noticeable only when held to nose
4. Moderate off odour, offensive
5. Extremely stinky

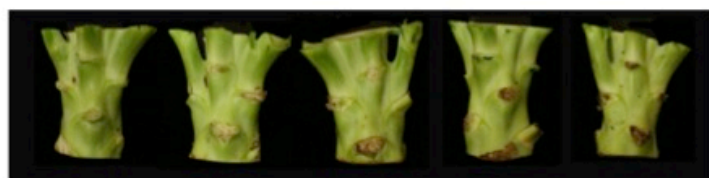
#### Floret Rots

1. No rots in florets
2. Very slight, a few dark florets
3. Slight, <5% florets with rots
4. Moderate, 5-10% florets rotten
5. Severe, >10% florets rotten, obvious slimy lesions



#### Stem scars

1. Freshly cut
2. Slightly discoloured
3. 50% brown or grey
4. Brown or grey
5. Dark brown to black



#### Overall appeal

1. Excellent, fresh, looks like just harvested
2. Very good, would definitely buy
3. Good, would probably buy
4. Poor, wouldn't buy but would still eat
5. Very poor, compost quality

