Improving competitiveness of Australian vegetable exports: Augmenting existing vegetable export opportunities

Final report

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Media summary

Improving competitiveness of Australian vegetable exports

Australian vegetable export supply chains need to become more efficient to remain competitive. Due to high air freight costs, sea freight is being considered as an alternative, but its technical feasibility needs to be assessed. We report here on a pilot project with commercial businesses that evaluated options to assess and improve sea freight performance for selected high value vegetables.

Improving sea freight broccoli to Japan and Taiwan

Broccoli sea freight exports to Asia have sometimes arrived with inconsistent quality. Monitoring of sea freight shipments have highlighted that container temperatures can fluctuate above and below the set point. This can cause the ice that is packed around the broccoli to melt and refreeze or result in chilling or freezing injury. We investigated the impact of time and temperature and packaging options on quality and shelf life under simulated conditions. Key learnings included:

- Optimal shelf life was achieved by combining top ice with Modified Atmosphere Packaging (MAP).
- The next best options were the traditional top icing treatment or the MAP liners (no ice) alone.
- The ideal shipping temperature was close to 0°C.
- Increasing temperatures to 4°C reduced shelf life by up to 7 days, particularly for longer storage.

Developing sea freight best practice for sweet corn and green beans

Fresh sweet corn is a relatively new product to Japanese consumers who prefer green fully husked cobs or semi-husked pre-pack cobettes. We simulated sea freight to Japan by storing both loose fully husked corn in perforated liners and semi-husked prepack cobettes at 1°C (optimum temperature) for 15 days, with or without Controlled Atmosphere (CA - 3% O_2, 15% CO_2). We found that shipping under a CA treatment doubled shelf life on arrival in market to 7-10 days.

With short shipping times to the relatively small New Zealand market of around 6 days, there is an opportunity to send product more frequently and as mixed shipments. We examined the possibility of shipping sweet corn and green beans together despite their different optimum storage temperatures. Working with cultivars previously identified as possessing improved shelf life, we found that sweet corn and green beans could be shipped at 5°C to provide a shelf life of 10 days for both products.

Identifying Iceberg lettuce cultivars with export potential

Iceberg lettuce has become an increasingly popular product in the Japanese food service sector. We identified that a new series of cultivars with the Knox™ delayed browning trait, developed by Rijk Zwaan, displayed improved quality after simulated sea freight than current commercial standards.

Conclusions/recommendations

Developing efficient sea freight supply chains that deliver consistent and predictable quality vegetables to export markets should consider the following:

- Select cultivars with characteristics that meet consumer expectations and with sufficient robustness to handle sea freight conditions.
- Evaluate packaging and controlled atmosphere treatments to further extend storage life and reduce risks associated with sea freight.
- Examine time and temperature impacts on quality and shelf life of specific vegetable commodities to provide exporters with knowledge and confidence to pursue sea freight.

Background

The newly released 2025 Vegetable Industry Export Strategy (VIES) has been developed after wide consultation with the Australian vegetable industry and its stakeholders. It has established targets under a two-pronged approach to 1) Recover and sustain trade ($300 million by 2023) and 2) Drive growth ($400 million by 2025).

Activities under this pilot project demonstrates some of the approaches required by the industry to deliver on the strategic pillars such as “value proposition” (strategic pillar 2, Horizon 1) and more importantly “delivering the promise” (strategic pillar 4, Horizon 2). This pilot project aimed to demonstrate a range of collaborative activities that can assist in building the export capability and competitiveness of the Australian vegetable industry through:

- Understanding target market/s competitive environment and windows of supply opportunity, product requirements and supply chain conditions.
- Analysing existing and new supply chains to recommend improvements and efficiencies.
- Conducting simulation experiments to enrich monitoring data and decision aid tool development.
- Facilitating improved knowledge and decision making along the supply chain by participation in supply chain analysis and making recommendations for future development of information resources and decision aid tools.

Recent work through the Growing Queensland’s Food Exports (GQFE) grant program have highlighted that our major vegetable competitors (such as the US) in Asian markets are predominantly delivering vegetables to these markets via sea freight. This global competitive environment coupled with our current air freight shortage and associated increases in costs highlights that there is a need to develop efficient and effective seafreight vegetable supply chains from Australia. To achieve this there is a need to:

- Understand which cultivars are robust enough to endure long timeframe supply chains but still meet the product requirements of the target market.
- Understand production systems to maximise robustness and quality (pre-harvest).
- Evaluate cultivar performance throughout the supply chain through monitoring (and simulation) of varying supply chain conditions.

DAF’s Supply Chain Innovation’s (SCI) team has demonstrated the importance of partnering with key commercial businesses involved in exports to maximise adoption and build model demonstration supply chains (e.g. AM15002 Serviced Supply Chains project; SSC). DAF also partners closely with Trade and Investment Queensland (TIQ) in Australia and overseas to assist with market knowledge and identification of suitable supply chain businesses to partner with. Key learnings and resources are then implemented for the wider industry benefit.

Engaging with commercial export businesses this pilot study looked at three case studies to investigate solutions to issues or opportunities to improve vegetable export chains to Asia and New Zealand. The three case studies are summarised in the following sections and described in detailed reports in Appendices A, B and C. The three studies were:

Project 1: Improving performance and consistency of sea freight broccoli to Japan and Taiwan.

Project 2: Understanding and developing seafreight best practice for pre-packed and loose green beans and sweet corn.

Project 3: Identifying Iceberg lettuce cultivars to maximise quality in export seafreight supply chains.

Project 1: Improving performance and consistency of sea freight broccoli to Japan and Taiwan

Introduction

Sea freight is increasingly becoming an important commercial option for vegetable export businesses to be competitive in target export markets. More recently the advent of the Covid 19 Pandemic, necessitating travel restrictions, has seen reduced airfreight capacity and subsequent increases in airfreight costs. However, to be a commercially viable alternative, the longer sea freight supply chain requires produce arriving at the importing country with adequate quality and remaining shelf life.

Australian broccoli production continues to increase with 76,631 tonnes of broccoli produced in 2020 (Australian Horticulture Statistics Handbook 2019/20, Hort Innovation) with a farm gate value of $288 million. Broccoli is predominantly produced in Queensland and Victoria with 7% of the crop exported in 2020. Broccoli and cauliflower exports have fluctuated over the last 7 years between $6-27 million dollars in value. Queensland is Australia's largest exporter of broccoli and cauliflowers. Singapore is the largest export market destinations for Australian broccoli with growing interest from markets such as Japan and Taiwan.

Limited feedback from customers in Japan and Taiwan have highlighted inconsistency in sea freight broccoli quality (e.g. yellowing of florets, stem breakdown) when it reaches the market. The lack of knowledge of time and conditions in the supply chain is preventing the consistency of supply.

The objective of this study was to simulate supply chain conditions for sea freight export shipments of broccoli to Japan and Taiwan by means of optimising storage temperatures, control atmosphere (CA) and packaging techniques to maximise the shelf life of headed broccoli.

Methodology

Broccoli cultivar 'Overland' was harvested on 16th Sep 2020 as per commercial practice from Qualipac's Inglewood farm in South East Queensland. They were then transported to the Gatton packing shed within 24 hours in a refrigerated truck. The journey from Inglewood to Gatton takes approximately 2 hours. Broccoli were then placed in the cool room on arrival until packing. Broccoli was subjected to normal packing processes including trimming of leaves and stems and then packed into waxed cartons (approximately 30 heads per carton). Experiment 1 conducted a sea freight simulation (15 days at 0^{o}C) with three cartons of each packaging option i) waxed cartons (no CA); ii) waxed cartons (to be placed in CA, 2% O_2 and 5% CO_2), iii) with MAP liner, iv) with top ice, v) with liquid ice and vi) with MAP liner and top ice. An additional three cartons of broccoli were received to be used in experiment 2 a shelf life study to examine broccoli quality responses to a range of temperatures (0, 1, 2, 3, 4°C) by a range of storage times (5, 10, 15, 20, 25 days). Previous monitoring of commercial sea freight shipments showed temperature reached as high as 3°C.

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1. Carton + NCA (no controlled atmosphere)
2. Carton + CA (controlled atmosphere at 2% O_2 and 5% CO_2)
3. Carton + MAP liner (modified atmosphere packaging liner)

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4. Carton + top ice (standard packing for export)
5. Carton + liquid ice (slurry ice fully surrounding broccoli heads)
6. Carton + MAP liner + top ice

Plate 1. *Six packaging treatments applied to broccoli at the packing shed and stored at and stored at 0°C for 15 days.*

The broccoli cartons were transported from Qualipac's packing shed at Gatton to DAF's postharvest research facility at the Maroochy Research Facility (MRF), Nambour in a refrigerated van at 2.5°C on 17/9/20.

On arrival at MRF a quality assessment (weight, colour, firmness and visual quality) was conducted at intake (17/9/20) for all treatments for experiment 1 and experiment 2. Assessment was conducted on 3 randomly selected broccoli heads per treatment. For the time by temperature trials 3 randomly selected broccoli heads were place in perforated bags and put into cardboard cartons for each treatment. Broccoli were then placed in the allocated temperature chambers +/- CA at 90% RH.

Temperature monitoring and supply chain mapping and analysis was also conducted to understand the harvesting, transport and packing processes that export broccoli are subjected to. This analysis was conducted as a separate activity at a later date than the simulation trials to understand the typical handling conditions and time frames from harvest to packing.

Key results

Key results – Broccoli monitoring and supply chain analysis

Supply chain analysis of harvesting and packing practices identified some areas of risk for improvement. These include:

- Broccoli stalks were being trimmed up to 3 times between harvesting and packing procedures. This creates inefficiencies in labour use but also exposes the broccoli heads to potential disease inoculum entry points. Breakdown of stalks during sea shipments of broccoli has been identified as a quality issue.
- Cleaning and sanitising of knives for harvest or trimming was not observed. This may lead to microbial contamination or disease development in broccoli.
- The practice of 'wetting down' broccoli in field bins to reduce field heat needs to be examined. Could an overhead sprinkle system, built into farm holding sheds, using sanitised water, be considered?
- Water quality was not ideal for making ice for packing as when the ice melted it left a white residue on the broccoli. Water quality for ice making and the in-field bin wetting down procedure should be tested for microbes, pH and salinity regularly.
- Temperature fluctuations or broccoli exposure to sub-optimal high temperatures for long periods of time during harvesting to packing needs to be addressed to improve shelf life in the export market destination.
- Field bins are often exposed to sun and dust increasing temperature and potentially causing abrasion damage to broccoli during field transport to holding shed or to packing shed. Covering/shading (top) bins would assist in minimising heating up of broccoli.

Additional information collected from previous shipments to Taiwan and Japan show:

- Temperatures in sea containers to Taiwan show variation throughout the container and the journey. Temperatures were recorded as low as -0.7^{o}C probably near the vent. Broccoli freezes at -0.6^{o}C. Temperatures were also recorded up to 4.9^{o}C in the latter part of the sea freight journey to Taiwan.

- Fluctuations of temperature in the container are like to be causing melting and refreezing of ice used for packing in turn causing freezing damage to the broccoli.
- The length of time broccoli is in the container seems to vary with irregular shipping timetables. It is common for the length to be 19 days but as short as 9 days. More export shipment monitoring is required to understand the real timeframes to target markets.

Key results – Packaging options for seafreight simulation to Japan

- End of shelf life was determined if broccoli had a firmness score of 4, yellowing score of 3, presence of any decay, visual quality of 3 or combination of these factors. In this study, most of broccoli reached end of shelf life (ESL) due to softness.
- Broccoli packed in waxed cartons and MAP liner plus top ice had the longest shelf life (18.7 days shelf life and 34.7 days after harvest), followed by those packed with MAP liner or top ice (15.8 days to ESL or 31.8 days after harvest). Broccoli packed in cartons only had a shorter shelf life (7.5 days RSL, 23.5 days after harvest). Those packed in cartons and stored under CA had a 6-day longer shelf life compared with those stored at air.
- Insects were identified in 10% of broccoli heads used in the study

Key results – Identifying impacts of time and temperature on broccoli shelf life

- In the time by temperature trial, most of broccoli reached ESL due to firmness of 4 and a small number of head with yellowing of 3.
- In most treatments broccoli stored at 0°C had the longest shelf life irrespective of removal time (29-36 days). The result from this study suggested that broccoli could be kept at 4 or 5°C (retail) for 27 days or longer if the storage temperature is 0°C.
- Residual shelf life reduces with an increase in storage temperature which becomes more obvious the longer the broccoli is stored as seen in the figure below.

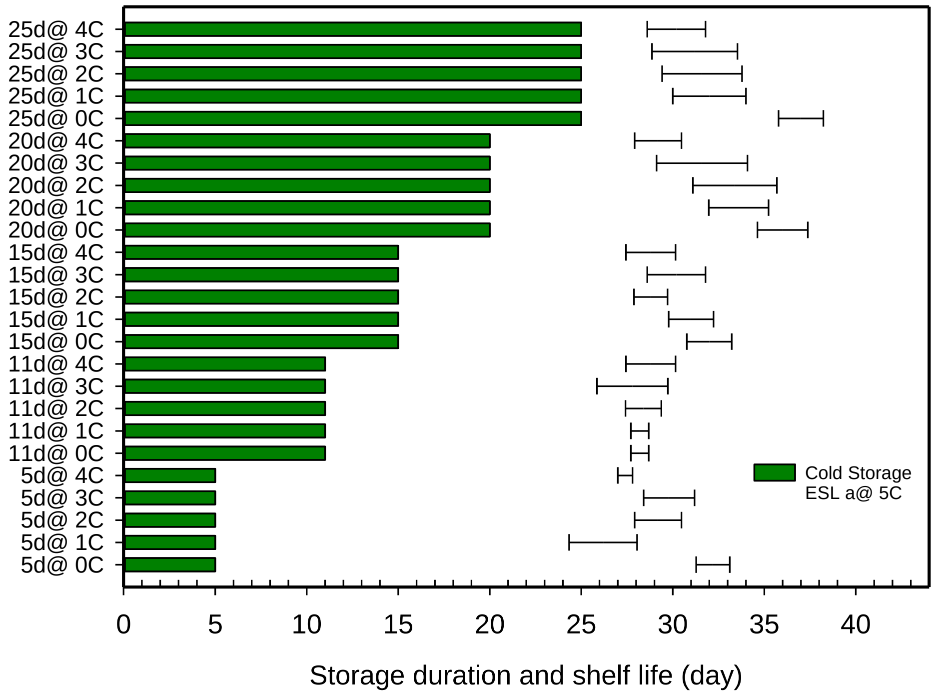

Figure 1. *Shelf life of broccoli stored at different temperatures and duration, then held at 5°C until end of shelf life. Blue colour is time broccoli at cold storage and pink colour is time at 5°C. Bars is standard error of means (n=5)*

Conclusions and recommendations

Based on the results from two experiments, it can be concluded that shipping broccoli in a carton with a MAP liner and covered with ice on top reduced weight loss, increased the firmness, maintained overall quality and increased the shelf-life by more than 10 days compared to samples in a carton only and more than 3 days for those in a carton with top ice. Broccoli packed with top ice had the same shelf life as those in a MAP liner. Therefore, for export broccoli, a MAP liner is recommended to maximise the shelf life. The MAP liner advantages will reduce shipping cost due to the extra amount of ice added to the carton and to avoid quality problems associated with direct contact of water on broccoli heads (e.g. yellowing of florets, freezing or breakdown of stems). In addition, keeping broccoli at or close to 0°C can prolong the shelf life.

It is recommended to test broccoli using MAP liners and stored under CA to investigate the synergistic effect of these on the shelf life.

The quality issues, such as stem breakdown or yellowing florets, identified as out-turn quality issues of commercial shipments on arrival in market were not replicated in these trials. Wilting of broccoli heads was the main cause for determining ESL. This suggests that commercial shipments are being subjected to freezing temperatures (below -0.6°C). The breakdown of broccoli heads likely to be caused by the packing ice melting and refreezing in some locations throughout the container.

Insect disinfestation needs to be resolved to comply with strict phytosanitary quarantine requirements for some export destinations such as Japan. This is a particular issue if recommending MAP bags as an alternative to top ice. If live insects are found in a shipment on arrival in Japan the entire shipment will need to be methyl bromide fumigated. As MAP bags are relatively impermeable the methyl bromide fumigation cannot be applied to the packaged broccoli.

Temperature monitoring and supply chain analysis of harvesting to packing procedures have identified some fluctuations in temperature mainly from harvesting to the packing shed. The time broccoli spends out of cooling (eg delivery to the packing shed before being stored in a cool room) will reduce shelf life or create inconsistent quality and shelf life at the market destination. It was also identified that broccoli stems generally may be cut up to 3 times during harvesting and packing. This increases labour costs and risks of disease inoculum entry particularly if cutting knives are not regularly cleaned and sanitised.

Collection of temperature by time monitoring data from Moonrocks broccoli export shipments to Taiwan was useful in understanding the variability of sea freight times and temperature fluctuations. It would be beneficial to conduct full shipment export monitoring from harvest to export retail examining time by temperature and associated quality response to these conditions. The accumulation of data (over a number of shipments) could lead to the potential development of decision models to predict residual shelf life in market.

The industry would benefit from an investigation into broccoli cultivar suitability for export markets and shelf life for long term storage sea freight.

It would also be beneficial to understand nutritional and irrigation impacts on broccoli shelf life.

Best practice principles for sea freight of Broccoli to Asia

- Supply chain handling
    - At harvest minimise exposure of field bins to direct sun by covering with shade cloth or shade structures.
    - Cool quickly after harvest to remove field heat prior to packing.
    - Ensure packed broccoli is cooled to transport temperature (0-4^{o}C) before loading into the sea container.
    - Ensure the refrigerated sea container is pre-cooled before loading. The recommended temperature set point is 0^{o}C. Higher temperatures will compromise shelf life.
    - Minimise time from harvest to packing of the refrigerated sea container (3-4 days).

- Packaging

- It is recommended that ice in packaging is avoided where possible because of the risk of freezing broccoli heads or water contacting florets causing yellowing.
- Where ice has to be used ensure cartons are designed to allow melted ice to drain freely from carton to avoid pooling of water which can refreeze.
- MAP liners provide the same shelf life response to top ice but provide less quality risks and decreased moisture loss.

The detailed report can be found in Appendix A.

Project 2: Understanding and developing seafreight best practice for pre-packed and loose green beans and sweet corn

Introduction

Sea freight is increasingly becoming an important commercial option for vegetable export businesses to be competitive in target export markets. More recently the advent of the Covid 19 Pandemic, necessitating travel restrictions, has seen reduced airfreight capacity and subsequent increases in airfreight costs. To identify viable options for desirable outcomes at the importing country, we investigated the impact of selected packaging and storage conditions on quality and shelf life of fresh sweetcorn and green beans under typical sea freight and retail conditions encountered during export to Japan and New Zealand.

A preliminary study conducted in September 2020, for the Mulgowie Farming Company (MFC), identified that selected cultivars of green beans and sweet corn performed better than others under longer sea freight storage times than others. The study also identified better packaging options for sea freight. This study selected similar cultivars to the previous study and also used the best or improved packaging options to test for the New Zealand market.

Previous market insights into growing a fresh sweet corn market into Japan identified the need to supply fully husked or semi-husked corn to differentiate it from the traditionally sold retort (dried) corn. If the product is sold with a green husk it equates to fresh sweet corn.

Methodology

Sweetcorn cv. 'Astronaut' harvested in North Queensland was transported to Mulgowie Farming Company (MFC)'s packing facility in the Lockyer Valley, then commercially processed and packed as: (i) fully husked whole cobs packed in bulk cartons with a perforated liner ('fully husked'), (ii) semi husked cut cobs wrapped in cling film around a plastic tray ('cling film), and (iii) fully de-husked cut cobs sealed in flow wrap at both ends of a plastic tray ('flow wrap'). Three cobs were packed per liner (~1.0 Kg) or tray (~0.67 Kg).

Green beans cv. 'Mulgowie Green' were harvested in the Lockyer Valley, commercially processed and packed into mod-6 cardboard trays as: (i) pods cut at both ends, re-sanitised and packed into 'ready to cook' 200 g sealed plastic bags ('pre-packed'), with 30 bags per tray (~6 kg), and (ii) loose pods (~10 kg) fully wrapped in polyethylene perforated carton liners ('loose').

Harvesting and packing procedures for green beans were observed and recorded and temperature monitored throughout the process.

Both commodities were transported by refrigerated truck at 6.2°C to DAF's research facility at Nambour on 12/11/20. The times between harvest and arrival at the laboratory were four days (sweetcorn) and one day (green beans). On arrival at the lab, quality was initially assessed, including external appearance, kernel/pod quality (i.e. texture, defects and diseases), off-odour, Brix and weight.

To simulate expected maximum sea freight time from Brisbane to Japan, ‘fully husked’ and ‘cling film’ sweetcorn cobs were held at 1°C (optimal storage temperature) under either air or controlled atmosphere (CA) at 3% O_2 and 15% CO_2, recommended to retain the greenness of the husk, for 15 days.

Plate 2*. Sweetcorn packaging types tested in experiment 1: fully husked cobs wrapped in perforated bag (left) and semi husked cobs wrapped in cling film around a plastic tray (middle). Samples were placed into experimental chambers (right) for storage under either CA (top three chambers) or air conditions (bottom three chambers).*

To simulate sea freight from Brisbane to New Zealand, including in potentially mixed consignments, both commodities were air-stored for 6 days under the following conditions: (i) for sweetcorn, ‘cling film’ and ‘flow wrap’ cobs were held at 1, 3, 4 or 5°C, (ii) for green beans, the loose pods together with the ‘pre-packed’ bags, held at 3, 4, 5 or 6°C. Optimal storage temperature is 1^{o}C for sweet corn and 6^{o}C for green beans to avoid chilling injury.

After removal from storage the loose pods had the ends manually cut before being packed in sealed 200 g plastic bags (‘post-packed’) with all pack types and commodities held at 5°C to simulate retail display and domestic storage. Quality was assessed at removal as above, then every 2–4 days until the end of shelf life based on the overall visual appearance.

***Plate 3**. Green beans packaging types tested in experiment 3: loose pods packed in in mod-6 cardboard trays (~10 kg) and fully wrapped in a polyethylene perforated liner (left), commercially pre-packed 'ready to cook' 200 g sealed plastic bags (middle), and manually cut and packed into 200 g sealed plastic bags after the samples had been stored for six days at 3, 4, 5 or 6°C (right)*

***Plate 4**. Cutting and packing of loose green beans into 200 g sealed plastic bags in the laboratory after the samples had been stored for six days at 3, 4, 5 or 6°C*

Key results

Key results – Monitoring from farm, packing and transport to MRF

Temperature monitoring and supply chain analysis of sweet corn from North Queensland was not conducted for this trial however the sweet corn had been adequately cooled prior to loggers being inserted at MFC the day before transporting to MRF. It is important to note the need to minimise time from harvest to potential loading of a sea container bound for Japan. Simulation results below show that residual shelf life (in market) is limited after a long sea voyage particularly if CA is not applied during shipping.

Monitoring the green bean harvest at the Mulgowie farm demonstrated that the green beans could be harvested, processed/packed and cooled to 6-7°C within 24 hours. Shortening the supply chain like this will result in longer residual shelf life in the New Zealand market (see simulation experiment results below) and potentially allow for mixed shipments with sweet corn products.

Key results – Sweetcorn to Japan

- Both storage condition and packaging type significantly affected sweetcorn quality and shelf life following 15 days storage at 1°C:
  - Maximum residual shelf life of sweetcorn held at 5°C was 12 days after storage (DAS) or 31 days after harvest (DAH) for 'fully husked' CA-stored cobs, followed by ~8 DAS (~27 DAH) for 'cling film' CA-stored cobs, and only ~4–5 DAS (~23–24 DAH) for air-stored cobs regardless of the packaging type
  - Rating scores for kernel overall appearance were generally higher in sweetcorn cobs stored under CA than under air at 3, 7, 10 and 12 DAS
  - For CA-stored sweetcorn, scores for kernel visual appearance at 10 and 12 DAS were higher for 'fully husked' than for 'cling film' cobs
  - Regardless of the storage condition, 'fully husked' cobs had higher scores for husk overall appearance at 3, 7, 10 and 12 DAS than 'cling film' cobs, with the latter reaching scores below 3 ~8 DAS
  - For 'cling film' cobs, scores for husk appearance where higher for storage under CA than air at 5 and 7 DAS, with little significant differences at 10 or 12 DAS
- Texture decline (i.e. dimpled/shrivelled kernels) and pink yeast at the cut ends were the main causes end of shelf life (ESL)
- Regardless of the packaging type, cobs stored under CA had a lower number of dimpled kernels up to 12 DAS, whereas 'fully husked' cobs stored under air had the highest
- Regardless of the storage condition, incidence of diseases was low in 'fully husked' uncut cobs at 7, 10 and 12 DAS, whereas 'cling film' cobs had severe pink yeast at the cut ends at 7, 10 and 12 DAS (air-stored) or at 10 and 12 DAS (CA-stored)
- 'Cling film' cobs had severe off-odour at 10 and 12 DAS (CA-stored) or at 12 DAS (air-stored) upon unwrapping of the prepacks, whereas there was generally light off-odour in fully husked cobs at any time, especially when stored under CA

Key results – Sweetcorn to New Zealand

- The maximum residual SL of sweetcorn held was 14 DAS (24 DAH) for 'flow wrap' cobs that had been stored at 1°C, and 10 days (20 DAH) for those that had been stored at 3, 4 or 5°C
- Testing of 'cling film' cobs done at 7 and 14 DAH only (due to insufficient samples) suggest that their maximum shelf life would be 10 DAH even at 1°C, with low (1–2) rating scores for kernel overall appearance at 14 DAH for all storage temperatures

- Differences for kernel overall appearance scores between packaging types and among temperatures were not significant at 7 DAS
- ‘Flow wrap’ cobs stored at 1°C had higher rating scores for kernel overall appearance at 9, 12 and 14 DAS than cobs stored at 3, 4 or 5°C, with little differences among the latter three
- Texture decline (i.e. dimpled and shrivelled kernels) was the main cause of ESL, with generally more severe symptoms in ‘cling film’ compared to ‘flow wrap’ cobs at 14 DAH
- In ‘cling film’ cobs, the second major quality issue was pink and white yeast at the cut ends, whereas no yeast symptoms were observed in ‘flow wrap’ cobs at 14 DAS
- Off-odour became more pronounced at 9 DAS onwards, with ‘flow wrap’ cobs that had been stored at 1°C having a slight off-odour (score of 3) compared to a moderate off-odour (score of 2) for those stored at 3, 4, or 5°C at 12 and 14 DAS, or for ‘cling film’ cobs at 14 DAS at any temperature

Key results – Green beans to New Zealand

- After removal from storage for 6 days at 3, 4, 5, or 6°C, overall appearance and shelf life of pods held at 5° was significantly affected by packaging type and storage temperature:
    - Residual SL of ‘pre-packed’ pods was only 5 or 7 DAS (12 or 14 DAH) when bags had been stored at 3–5°C or at 6°C, respectively
    - Residual SL of ‘post-packed’ pods was around 14–16 DAS (21–23 DAH), with a trend of longer SL with the higher storage temperatures (5–6°C) than the lower ones (3–4°C)
- The main causes of quality loss of ‘pre-packed’ pods after storage were spoilage at the cut ends and, to a lesser extent, rusting marks (due to chilling injury) after 9 DAS, with less severity in pods that had been stored at 6°C than those stored at 3, 4 or 5°C
- The main cause of quality loss of ‘post-packed’ bags after storage was rusting marks, which increased gradually from 5 DAS onwards, with a higher percentage of affected pods at 12 and 14 DAS for pods stored 3–4°C than at 5–6°C
- A slight to moderate off-odour of a fermented type was detected upon opening of ‘pre-packed’ bags at 5, 7 and 9 DAS, with no off-odour in ‘post-packed’ bags

Conclusions and recommendations

- The use of CA seems critical for export of sweetcorn to Japan to ensure enough residual SL after arrival both for ‘fully husked’ and ‘cling film’ cobs
- All treatments (CA or air) demonstrated that the husk remained green throughout the seafreight simulation.
- Given the higher overall quality of ‘flow wrap’ compared to ‘cling film’ sweetcorn air-stored for 6 days at 1, 3, 4, or 5°C at 14 DAS shown in experiment 2, it appears warranted to test ‘flow wrap’ sweetcorn stored under CA for 15 days as a potential option to increase the relatively short SL of 8 days shown by ‘firm wrap’ in experiment 1

- The shipping of sweetcorn in temperatures above the optimum 1°C (e.g. 3–5°C in mixed shipments with green beans) should be carefully weighed against the potential SL reduction of ~4 days and associated quality loss
- Time between harvest and sea freight dispatch should be reduced where possible (4 days in this trial for sweetcorn), especially if shipped at temperatures higher than the optimum
- If mixed shipments are used to New Zealand, there may be an advantage in using 5°C as opposed to 3–4°C to reduce the risks of chilling damage to green beans as there appears to be generally little differences in sweetcorn quality stored at 3–5°C

Table 1. *Saleable life matrix for green beans and sweet corn for mixed load sea freight to New Zealand*

Product	Saleable life - Days after storage (shipping)/days after harvest @				
	6°C	5°C	4°C	3°C	1°C
GB* pre-pack	7/14	5/12	5/12	5/12	N/A
GB* post-pack	16/23	16/23	14/21	14/21	N/A
SC** flow wrap	N/A	10/20	10/20	10/20	14/24
SC** cling film	N/A	10/20	10/20	10/20	10/20

GB* = green beans; SC** = sweet corn

Ideal mixed shipping temperature to avoid chilling injury of beans

- The export of loose green beans in bulk cartons with perforated liners, for later processing into 'ready to cook' plastic bags upon arrival at New Zealand, appears to be a viable and safer option, but further testing is required under real commercial conditions on arrival
- The longer SL and better quality of 'post-packed' green beans compared to 'pre-packed' raises the question if the processing (e.g. mechanical cutting) at the commercial packing facility could be improved to reduce spoilage at the cut ends of the pods
- The above results should be interpreted cautiously given the limitation of the work, i.e. trials were based on only one cultivar for each commodity, harvested from one growing location at one time, so further research is warranted to allow more robust recommendations to be made

Best practice principles for sea freight of sweet corn to Japan

- Production

- Sweet corn crops should be grown for export production (not just grading the best from domestic production)
- Production practices and cultivar selection need to meet export market quality specifications and have superior shelf life for long term storage (see freight).
- Suitable cultivars with superior shelf life for sea freight include Astronaut and Garrison.

- Supply chain handling
  - At harvest minimise exposure of field bins to direct sun by covering with shade cloth or shade structures.
  - Cool quickly after harvest to remove field heat prior to packing.
  - Ensure packed sweet corn is cooled to transport temperature (1^{o}C) before loading into the sea container.
  - Ensure the refrigerated sea container is pre-cooled before loading. The recommended temperature set point is 1^{o}C. Higher temperatures will compromise shelf life.
  - It is recommended that controlled atmosphere (CA) is used for sea voyages longer than 10 days. Set point should be 3% O_2 and 15%CO_2.
  - Minimise time from harvest to packing of the refrigerated sea container (3-4 days).
- Packaging
  - It is recommended that whole cobs of corn are packed in bulk (10kg) cartons with perforated liners to allow for CA permeation.
  - Where prepacks are used, flow wrap appeared to work better than cling film and allows permeation of the CA.

Best practice principles for mixed load sea freight of sweet corn and green beans to New Zealand

- Production
  - Green bean and sweet corn crops should be grown for export production (not just grading the best from domestic production)
  - Production practices and cultivar selection need to meet export market quality specifications and have superior shelf life for long term storage (see freight).
  - Suitable cultivars with superior shelf life for sea freight include Astronaut and Garrison for sweet corn and Venice and Mulgowie Green for green beans.
- Supply chain handling

- At harvest minimise exposure of field bins to direct sun by covering with shade cloth or shade structures.
- Cool quickly after harvest to remove field heat prior to packing.
- Minimise time from harvest to packing of the refrigerated sea container (2-3 days).
- For mixed loads of green beans and sweet corn sea freight to New Zealand (6 days in a refrigerated container) aim for 5°C to avoid chilling injury in green beans.
- Ensure packed sweet corn and green beans are cooled to transport temperature (5°C) before loading into the sea container.
- Ensure the refrigerated sea container is pre-cooled before loading. The recommended temperature set point is 5°C. Higher temperatures will compromise shelf life of the sweet corn.
- Controlled atmosphere (CA) is not required for sea voyages less than 10 days.

- Packaging
    - Flow wrapped prepacked corn works well in this supply chain.
    - If shipping bulk (10kg) packs of green beans use a perforated liner to allow for ventilation to minimise in transit rots.
    - Prepacked (200g) green bean bags work well in this supply chain provided pods are not damaged during the packing process. That is ensure that equipment used to top and tip beans is sharp and does not “smash” pod ends causing entry points for disease.

The detailed report can be found in Appendix B.

Project 3: Identifying Iceberg lettuce cultivars to maximise quality in export seafreight supply chains

Introduction

Export development activities under the Growing Queensland's Food Exports (GQFE) program identified that there is an opportunity to supply whole crisphead (iceberg) lettuce to Japan in supply windows that compliment and supplement existing supply from the United States and Taiwan. There is potential to expand the export development learnings from Japan into other Asian markets.

This study investigated cultivar, planting date and postharvest storage with the aim of producing premium quality 'fluffy' crisphead lettuce for the Japanese export market by sea freight.

Engaging with Rijk Zwaan seeds, two cultivars in the study possessed the Knox™ delayed browning trait developed by Rijk Zwaan.

The objectives of the study were:

1. To quantify the effects of cultivar and planting date on plant growth, yield and postharvest quality of crisphead lettuce grown in the Lockyer Valley.
2. To quantify the effect of a simulated sea freight period on shelf life and postharvest quality of crisphead lettuce grown in the Lockyer Valley.

Methodology

The experiment was planted at DAF's Gatton Research Facility over two planting dates on the 7 and 21 July 2020. Eight cultivars were selected: Corvinas (Knox), Larsunas (Knox), 45-144 RZ, Jalonas, Kong, Carabine, Titanic and Roundhouse.

Field assessments were conducted at planting (8 week old seedlings) and 3 and 6 weeks prior to harvest measuring phenology stage and canopy area. Air temperature, relative humidity, soil temperature and moisture (10, 20, 30 and 40 cm) and leaf wetness were monitored every 30 minutes.

On 9 September 2020 commercial growers and agronomists met with the research team to examine the trial. It was determined that the first planted lettuce was at a density and maturity suitable for the Japanese market. Harvest for the first planting date lettuce commenced on 10 September (65 days after planting). The second planted date lettuce was harvested on 15 September 2020 (55 days after planting).

 

Plate 5. *Field inspection on 9 September 2020 and harvest on 10 September 2020*

After harvest the lettuce was subjected to two storage regimes:

1. Retail simulation – 5°C until end of shelf life (ESL)
2. Sea freight simulation – 4 weeks at 1°C then 5°C until ESL

Postharvest assessments were conducted at harvest and every 4 days (post storage for treatment 2). Lettuce were assessed for visual quality, defects, trimmed head mass, leaf colour, internal quality (density, bolting, tip burn). Storage conditions (carton air temperature and relative humidity) were monitored every 60 minutes.

Key results

The second planting was exposed to higher air and soil temperatures than first planting resulting in generally more rapid growth.

Second planted lettuce had lower trimmed head mass than first planted across all cultivars demonstrating the impact of planting dates by environmental conditions. Heads from the first planting were more dense, with cvs. 'Titanic', 'Kong' and 'Jalonas' exhibiting the highest head density.

Under the retail simulation postharvest quality was influenced by cultivar and planting date. Shelf life was not significantly affected by cultivar or planting date (mean shelf life at 5°C was 17.4 days).

Knox™ cultivars exhibited less severe browning of butt/midrib than other cultivars at 5°C. No difference in brown stain severity was detected between lettuce cultivars. The second planting generally produced better visual quality than first planting.

Under the sea freight simulation most (86%) lettuce heads were non-marketable at the end of 4 weeks at 1°C.

Conclusions and recommendations

Plant growth is more strongly influenced by environmental factors than cultivar.

Knox™ cultivars are capable of delaying butt/midrib browning in whole crisphead lettuce stored at 5°C.

The sea freight simulation period was too long at 4 weeks. It is recommended that a shorter period of 15-19 days is used.

This pilot study demonstrated that selection of cultivars, production practices and postharvest handling factors, affecting whole crisphead lettuce shelf life, requires further investigation and development. Further studies on environmental impacts at different sites on lettuce postharvest quality would also be of benefit.

Further trials and data collection could assist the development of shelf life prediction models to guide environment (site) selection, planting dates and benchmarking of cultivar selection.

The detailed report can be found in Appendix C.

Recommendations

The pilot export vegetable project was able to demonstrate the range of R,D and E activities that can be applied to export vegetable chain analysis and improvement. The three case studies show the importance of collaborating with commercial businesses to analyse their commercial chains, assess the risks/issues and develop improvements to individual chains and develop recommendations on best practice to the wider industry.

While the three case studies were able to develop some new recommendations, they clearly show that there is a lot more work required to assist in improving export vegetable supply chains. Each case study outlines the recommendations in each report as an example of what can be achieved. Specifically, these recommendations include:

- Project 1: Broccoli sea freight
    - Monitor conditions and quality of commercial sea freight shipments to Japan and Taiwan from farm to retail.
    - Conduct further simulations with more temperature options, particularly to replicate quality issues (stem breakdown, yellowing of florets) experienced on out-turn in market destinations.
    - Test recommended packaging options (MAP liners, MAP + Ice) in commercial shipments.
    - Examine further packaging combinations and options (eg. MAP + CA)
    - Investigate more suitable cultivar options for sea freight and impacts of nutrition, irrigation and other production inputs to broccoli quality.
- Project 2: Sweet corn and green beans
    - Commercially test and monitor mixed shipments of green beans and sweet corn to New Zealand at 5^{o}C
    - Develop shelf life predictive tools (calculator) to assist in making decisions on storage temperature and impacts on residual shelf life at the market destination.
    - Test and identify cultivars of both commodities that have superior shelf life and quality characteristics to make the markets expectation.
    - Commercially test sweet corn sea freight to Japan using recommended storage conditions (CA at 3% O_2, 15% CO_2 @ 1^{o}C) and packaging including perforated liners for bulk fully husked cobs and flow wrap for semi-husked prepacks.
- Project 3: Iceberg (crisphead) lettuce
    - Need to further test cultivar comparisons in a range of environments (locations) and planting timings to develop a list of recommended cultivars that are more robust with better shelf life and deliver the quality characteristics (eg density, head size, blemish free) for the target market.

    - Further investigate sea freight simulations at various lengths of time. Use the data to develop predictive models for decisions aide management tools.

Supporting the newly released 2025 Vegetable Industry Export Strategy (VIES), there is a responsibility to deliver R,D&E programs that can assist in delivering on the strategic pillars around the Australian vegetable “value proposition” (strategic pillar 2, Horizon 1) and more importantly “delivering the promise” (strategic pillar 4, Horizon 2) through a reputation of value and consistency.

Therefore it is more broadly recommended that there needs to be further vegetable export R,D&E in:

- Establishing a clear understanding of market opportunities (supply windows, market segments, product types and specifications) for Australian vegetables.
- Developing whole of chain approaches to improvement from production to export market destination retail. This includes identifying suitable cultivars that are robust enough for long sea freight supply chains and deliver the quality expectations of the market.
- Monitoring and analysis of commercial vegetable export sea freight chains to identify areas of risk or improvement.
- Conducting sea freight simulations to test potential improvement options in storage/transport conditions, new technologies and packaging.
- Applying learnings from simulations to commercial chains and monitoring improvements and impacts.
- Develop best practice resources and decision aide tools for the wider industry to improve efficiency and consistency of export vegetables in target markets.

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Appendix A – Project 1: Improving performance and consistency of sea freight broccoli to Japan and Taiwan full report

Appendix B - Project 2: Understanding and developing seafreight best practice for pre-packed and loose green beans and sweet corn full report

Appendix C - Project 3: Identifying Iceberg lettuce cultivars to maximise quality in export seafreight supply chains full report