



# Diversifying Asian Vegetable Markets

**A report for the Rural Industries Research  
and Development Corporation**

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# Foreword

A wide range of Asian vegetables has been available in Asian grocery outlets for many years. Recently, Australian horticulture has seen an increased focus on the growing of vegetables that are Asian in their origins. The increase in popularity of these vegetables is reflected at mainstream supermarket outlets where a range of Australian grown Asian vegetables is now available in our capital cities. However, there is potential to increase the range and quality of Asian vegetables in supermarkets, greengrocers stores and restaurants. In addition, our Asian vegetable producers are now looking beyond domestic shores to neighbouring Asian countries where Australian produce has a reputation for quality.

To better exploit these new market opportunities, RIRDC's Asian Foods Program has funded the research described in this publication together with Agriculture Victoria and Oriental Merchant Pty Ltd, a major wholesaler of Asian foods.

Preliminary economics of growing particular crops have been considered along with quality issues for major retail lines. Research focussed on postharvest packaging technologies for whole produce to deliver a quality product through local and export distribution networks.

The value adding activities of salting and minimal processing have also been examined to diversify the product range that Australian producers might deliver to overseas markets.

While Australian rural industries are typically based more on a competitive spirit than on active cooperation and coordination, there are a number of instances where a particular industry or section of an industry has adopted a successful collaborative approach to the export or domestic marketing of their produce.

Collaborative marketing groups have the potential to be an effective alternative to other marketing arrangements.

This publication considers some of the features of group marketing together with general features of membership groups and how they influence the effectiveness of collaborative marketing groups. It analyses data from case studies and surveys collected from representatives of 13 primary industry groups and other industry representatives in Western Australia.

This project was funded from RIRDC Core Funds which are provided by the Federal Government.

This report, a new addition to RIRDC's diverse range of over 600 research publications, forms part of our Asian Foods R&D program, which aims to provide an R&D program that supports industry in its drive to develop new products and markets and to gain competitive advantage through improving productivity in, and achieving price premiums for, Australian production.

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# Executive Summary

This project aimed to diversify markets for Asian vegetables through a combination of new and improved field practices and postharvest procedures. There is a real opportunity to increase exports and add value on both domestic and export markets if the correct postharvest handling, processing and packaging protocols are developed for targeted crops and products.

The project investigated production costs for Chinese cabbage, baby Shanghai buk choy, Chinese chives, choy sum, daikon radish, Chinese spinach, garland chrysanthemum, water convolvulus and Japanese pumpkin. A review was undertaken of Sydney and Melbourne market prices. Quality descriptor language manuals were prepared for Chinese cabbage, choy sum, gai lum, buk choy and Shanghai buk choy. Postharvest research focussed on the development of modified atmosphere packaging for whole produce, including Shanghai buk choy, choy sum, gai lum, hot mint and Chinese chives. Protocols were developed for preparing salted Chinese cabbage (varieties Harusakari and Matilda) for the Japanese market. Minimally processed stir-fry mixes, and associated modified atmosphere packaging, were developed using fresh and canned Asian vegetables.

## Challenges

The project management committee (Wendy Morgan, IHD; Sam Yiu, Oriental Merchants Pty Ltd; Graeme Thomson, IHD) met on a monthly basis to discuss project objectives and progress. Research components of the project, especially those of a postharvest nature, were undertaken to address field issues and commercial problems encountered by Oriental Merchants in the process of supplying quality vegetables to major supermarket chains.

The fragmented nature of the 'fledgling' Asian vegetable industry presented specific problems to Oriental Merchant. Primary growing areas are diversely located through the Eastern seaboard and while this presents opportunities for vegetable diversity, the logistics of sourcing and transport are made more complex. Asian vegetables are alive, many are leafy and fragile, and therefore require careful handling and transport to ensure that consumers have access to a product in top condition.

Asian vegetable growers often have a non-English speaking background and consequently transfer of technology needs special attention. The infrastructure for optimum postharvest handling of crops is often not currently available for use in communities growing Asian vegetables. The future should see improved vegetable quality as a consequence of correct handling awareness, and investment in equipment (e.g. cooling).

Oriental Merchant now supply 25 Safeway & Franklins stores with around 20 different types of Asian vegetables: Chinese buk choy, baby Chinese buk choy, Shanghai buk choy, Chinese cabbage, Chinese mustard green, choy sum, green choy sum, Chinese celery, Chinese chives, Chinese flowering chives, Chinese lettuce, Chinese spinach, hot mint, kan kong, taro shoot, perilla leaves, penny wort, snowpea shoot, spearmint and watercress. These vegetables are considered 'leafy' and are particularly prone to wilting, yellowing etc. after harvest.

## Postharvest requirements

Good postharvest management delivers horticultural produce to the end consumer in a condition which is virtually unchanged from harvest time. Handling should avoid mechanical injuries, preserve the product's food reserves and storage life, restrict water loss and avoid proliferation of microorganisms.

To develop new modified atmosphere packaging applications for Asian vegetable crops their rates of respiration needed determination. Storage trials have been completed for Shanghai buk choy, gai lum,

choy sum, Chinese chives and hot mint. These vegetables generally stored better at 1°C than at higher temperatures. However, domestic distribution chains cannot currently guarantee optimal temperatures and with this constraint in mind, 4°C was used for package development in some instances.

Modified atmosphere packaging was tested for each of the 5 vegetables and trial results have been comprehensively documented. For buk choy, choy sum and gai lum, initial trials focussed on liners for 10kg cartons but later work shifted to 5kg (approx.) to meet new Oriental Merchant supply requirements. Compared to air storage, product held in MA generally had superior appearance at out-turn, was greener and less affected by storage rots. MA carton liners made from polyethylene film were developed in conjunction with a commercial packaging company.

If stored at 0° to 1°C in MAP, Shanghai buk choy would have sufficient storage life to survive sea export to SE Asia if initial quality was of a very high standard.

For the herbs, Chinese chives and hot mint, consumers are believed to prefer to purchase small amounts. It is recommended that samples of 50g be stored in MA bags made from 50µm thick ICI BOPP propafilm. At 4°C, storage life in these bags is expected to be 16 days for the hot-mint and 14 days for Chinese chives.

### **Fresh-cut stir-fry mixes**

Minimal processing is an innovative way of adding value to fruit and vegetables. The perception by consumers of fresh, nutritious, convenient, ready to use products is making these commodities increasingly popular.

There are many different types of fruit and vegetable preparations available in the market place. These include freshly squeezed fruit juices, frozen products, lettuce and mixed vegetable salads, fruit slices and salads, peeled products and ready to cook vegetable mixes. This last group includes stir-fry mixes which generally contain cabbage, carrot, broccoli and cauliflower florets and snow peas. To date none have contained any traditional Asian vegetables.

There is very little information available on the response of Asian vegetables to minimal processing and how they should be packaged and handled. Experiments in this project tested post-processing behaviour and determined packaging requirements for a range of novel Asian stir-fry mixes. One mix was developed which included buk choy, broccoli, carrot, bamboo shoots, baby corn, snow peas, water chestnuts and red cabbage.

### **Salting of Chinese cabbage**

A consistent aim throughout the work undertaken for Project DAV-128A was improvement of postharvest practices to deliver fresh Asian vegetables in optimum condition to consumers. For export markets this can be difficult to achieve because long journeys by sea often necessitate the use of complex packaging and storage requirements for live, fresh product. The value of whole, fresh vegetables often does not justify the use of quicker, but far more expensive, air transit.

The project developed processing procedures for salted Chinese cabbage, a product which is physiologically dead and therefore simpler than fresh produce to store and handle for export. Salted cabbage is produced by 'value-adding' activities and this brings additional benefits to the Australian economy. RIRDC's Research Paper No 95/14 determined that Australia was in a good position to supply the Japanese market with salted vegetables, and salted Chinese cabbage is Japan's second most popular pickled vegetable.

Australia currently produces Chinese cabbage of high quality but the procedures required for processing into salted product were not previously fully elucidated. Salting trials undertaken in this project were in conjunction with a consultant from the Australian pickling industry (GeeVee Pickles Pty Ltd) and have been fully documented. Through GeeVee, an approximate protocol for salting was initially obtained from a Hiroshima food company. However, trials were needed to determine use of appropriate temperature and physical pressure. Quality assessment (including comment on product sent to Japan) considered appearance, taste and texture.

Temperature and pressure treatments during preparation were found to have important effects on both appearance and taste. The cultivar 'Matilda' was preferred because of its yellow coloured heart.

The salting protocol developed in this project puts the Australian food processing industry in a position to capitalise on recognised export opportunities to Asia for minimally-processed, salted product. The salted Chinese cabbage produced by this protocol conforms to Japanese market requirements and trial export shipments were well received. The salted cabbage produced in our trials was assessed at the stage where it could be used immediately, or further processed and fermented to produce a product such as kimchi. Future work could examine the cost effectiveness of various shipping methods, and the procedures required to prepare other products such as salted daikon. Air freight is probably not an economic option.

# Introduction

## Why Asian vegetables?

Vegetable varieties of Asian origin have been grown in Australia since the gold-rush days but until recently their consumption was largely restricted to ethnic Asian communities. However, the appeal of these vegetables has now been recognised more widely and mainstream supermarkets like Safeway, Franklins and Coles have identified Asian vegetables as a new growth area.

Although Victorian production of Asian vegetables has increased dramatically in recent years, exporters are keen that local production increases to meet heavy demands and interest from overseas markets. To date, our most successful export has been fresh Chinese cabbage from East Gippsland. However, recent orders for fresh Chinese broccoli, Chinese flowering cabbage and Shanghai buk choy confirm opportunities for export of other Australian grown Asian vegetables. In order that the full potential of these opportunities is realised, considerable research and development is required.

## Background - modified atmosphere packaging

Fresh plant products use oxygen and their own food reserves during respiration to produce the energy required to keep them alive. Temperature is one of the most important factors effecting rate of respiration. Lower storage temperatures help to reduce respiration and lower consumption of finite food reserves, thereby preserving the product's life.

In addition, the gaseous atmosphere around the harvested plant produce can also be used to regulate respiration rates. If oxygen levels are lowered and carbon dioxide increased, the rate of respiration can be reduced.

Modified atmosphere packaging (MAP) uses the product's natural production of CO<sub>2</sub> and consumption of O<sub>2</sub> to help create a gaseous environment wherein the respiration rate is lowered. In combination with low temperatures and high humidity, MAP has been demonstrated to improve storage of various crops.

## Background - Japanese pickling/salting

In Japan, pickled vegetables (or 'tsukemono') are consumed with nearly every meal. Even snack packs of rice products, or cooked food sold in convenience stores, contain a small serving of pickled vegetable. Tsukemono can be divided into seven basic varieties based on the major pickling ingredients used. However, dry salt is common to all seven varieties as its primary functions are to draw water from the vegetables, impart a salty taste, inhibit or kill some of the micro-organisms on the vegetables, and permit the survival of useful micro-organisms. Useful micro-organisms produce acids and flavours by fermentation of sugars in the vegetables.

'Shiozuke' is the traditional method of pickling vegetables using heavy salting and slow natural fermentation to produce typical salty and sour flavours. Chinese cabbage (hakusai) pickled in this way is consumed as a salad or vegetable dish with traditional Japanese food. Only daikon is more popular than Chinese cabbage for Japanese tsukemono. In 1991, some 177,000 tonnes of fresh Chinese cabbage from Japanese domestic sources were used for pickling.

Japanese tsukemono manufacturers began seeking raw vegetable materials from overseas during the 1960s, and imports of semi-processed vegetables have been increasing steadily in the last few years. In 1991, imports of fresh vegetables and provisionally processed vegetables for tsukemono manufacture amounted to 165,840 tonnes. The main reasons for importing raw materials were: unavailability of Japanese grown material, low purchase price, security of stable supply and good material quality.

In the early days, tsukemono companies provided technical knowledge to overseas farmers contracted to grow and brine the vegetables. The semi-processed or brined vegetables were then imported for final processing in Japan. After desalting, the vegetables could be processed into finished products of the same quality as those made with Japanese grown materials.

### **Background – minimal processing**

Minimal processing of horticultural produce causes cellular damage, elevated respiration rates and exposure of cut surfaces to possible pathogen invasion. All of these processes lead to a shorter shelf-life for the product. Processing involves many handling steps to achieve the final fresh-cut product. These include harvesting, grading, sorting, pre-cooling, trimming, peeling, cutting/chopping/shredding/dicing, washing, drying, mixing, packing, storage, transportation, distribution and marketing. Each step in the procedure relies on every other step being properly performed to ensure a valuable, marketable product.

Fresh product quality at harvest must be at a premium with preference for first pick harvests and little mechanical injury. Physical damage can reduce the shelf-life of the vegetable and the end, processed product. All fresh vegetables need to be pre-cooled as soon as possible after harvest. Pre-cooling benefits shelf-life and also reduces the adverse effects of wounding during processing. Lowered temperature also reduces the vegetable's rate of respiration, which in turn decreases the rate at which nutrients are lost leading to a reduction in senescence rate. Good temperature management of the raw product is essential to ensure a good quality fresh-cut product. The raw product must be transported under refrigeration to the processing line where all processing steps should be performed at 4°C.

The normal processing steps are as follows. Initial manual trimming and sorting is generally necessary. This is normally followed by automatic / machine peeling, cutting, chopping, shredding or dicing, depending on the end use of the product. In all of these procedures blades need to be kept very sharp. Dull blades cause bruising and damage which lead to a reduced shelf-life. Double washing is normally undertaken in agitated chilled water baths with a sanitiser present in the first wash. This process removes exudates from ruptured cells and reduces the microbial load. After washing, it is necessary to remove excess water to reduce the risk of rots. This is normally performed using centrifugation or spin drying and is essential for leafy vegetables. Any brined components must be used within 23 months of manufacture and should be sourced from undamaged cans.

All processed products must be at 4°C at time of packing. Once the bags are sealed the elevated respiration rate caused by processing will take 2-3 days to equilibrate at 4°C and longer at higher temperatures. For this reason, the chosen packaging film needs to be carefully matched to each individual fresh-cut product. This enables development of an atmosphere inside the package which is not detrimental to the product. Modified atmosphere packaging (MAP) uses the product's respiration and the permeability of the packaging film, to create a beneficial gaseous environment within the package that aids product longevity. MAP requires carbon dioxide accumulation and oxygen depletion which slows quality loss substantially compared to conventional storage in air.

After packing it is vital for the product's shelf-life that it remain chilled at 4°C. Temperature abuse of these products leads to rapid quality loss and unsaleable packs. Increased respiration at elevated temperatures leads to excessive oxygen depletion and a possible switch to anaerobic respiration with associated off-odours, off-flavours and tissue death. It is advised that just as much care be given to fresh-cut vegetable products as that received by dairy products during handling, distribution and marketing.

# Objectives

- Investigate and develop domestic and export market opportunities for fresh whole, minimally processed and processed Asian vegetable products.
- Develop packaging systems to facilitate distribution of fresh Asian vegetables for a major commercial Asian food distributor.
- Ensure the quality of fresh Asian vegetables by developing Quality Descriptor Language Manuals for use by growers, harvesting and packing teams, wholesalers, retailers and exporters.
- Develop new stir-fry mixes which are predominantly traditional Asian vegetables. Determine the post-processing behaviour, particularly with respect to respiration rates, and develop modified atmosphere packaging systems to minimise quality loss and maximise shelf-life.
- Verify the suitability of Australian grown Chinese cabbage for use as a salted product for sale in Japan.

# Methodology

**Note** - Detailed methods for each experiment appear in the RIRDC publication “*Postharvest studies of selected Asian vegetables – Part 1*”. The following described methods are representative of those employed.

## A. Measurement of respiration rates – WHOLE PRODUCT

Respiration rates were determined in air for bunches of produce at 1°C, 5°C and 8°C. Each temperature was replicated in 2 rooms each containing 3 respiration chambers of 15 litre capacity, into which known weights of produce were sealed. From each respiration chamber, a 1ml sample of the gaseous head-space was sampled immediately after closure and again after 2 hours. Gas samples were analysed using an IRGA series 225 gas analyser.

Respiration rate is presented as CO<sub>2</sub> production rate in ml/kg/hr and was calculated as follows:  

$$\left[ \Delta\% \text{CO}_2 \times 10 \times \text{Free volume (L)} \right] / \left[ \text{Produce weight (kg)} \times \Delta t \text{ (hr)} \right]$$

After measurement of each respiration rate, produce was stored at approximately 92% relative humidity in the respiration chambers with lids partially open to allow gaseous exchange. Respiration rates were measured for at least 10 days after harvest to fully cover the handling period through to supermarket and consumer.

## B. Quality assessment – WHOLE PRODUCT

Quality assessments were undertaken using a 5 point rating scale (Table 1). Assessments continued at regular intervals until the product was unsaleable.

**Table 1: Rating scale for quality assessment of whole, fresh Asian vegetables**

RATING	Colour of leaves	Inflorescence (i.e. flowering shoot)	Turgor	Unsavory odours, rots & disease	General appearance
1	Bright green, 95-100% of leaf surface area	Excellent	Turgid	None	Excellent
2	85 to 95% green	Good	Less turgid	Trace	Good
3	70 to 85% green	Fair	Trace limp	Slight	Fair
4	50 to 70% green	Poor	Limp	Moderate	Poor
5	less than 50% of surface area (i.e. mostly yellow)	Very poor	Dried	Severe	Very poor

### **Description of quality characteristics**

- *Leaf colour.* At harvest, leaf-blades should be bright green. However, the breakdown of chlorophyll that commonly occurs with increasing storage time is associated with progressive and increased yellowing of leaves. Older leaves were used as primary indicators.
- *Inflorescence.* Condition of the flowering shoot, including flower buds and flowers, especially sepals and petals. Flowering branches should be structurally firm, upright and green. Unacceptable quality associated with advancing senescence is often indicated by softening, wilting, loss of petal colour and shedding of petals.
- *Turgor.* Leaves, petioles (i.e. leaf-stalks) and stems should appear fresh and crisp with whole bunches upright and free of limpness. Lost water causes reduction in turgor and is linked to storage humidity. Stems and petioles that are initially smooth and very fleshy may retain their structural rigidity but become shrivelled and wrinkled with prolonged storage.
- *Unsavory odours.* Objectionable odours can occur with advancing senescence and biochemical changes. 'Off-odours' can also be due to rotting of produce.
- *Visible Rots.* Breakdown of host tissues caused by micro-organisms. May occur where the bases of stems have been cut during harvest, and on leaf parts, inflorescences and stems that have been mechanically damaged during handling
- *General appearance* is the overall perception of produce with respect to saleability and consumer appeal.

### **C. Measurement of weight loss**

Vegetable samples were weighed and stored in a refrigerated display cabinet cooled to between 6°C and 8°C. Although a commercially produced unit for display of fruit and vegetables, the humidity control was poor and varied between 70%RH & 100%RH. Individual bunches were weighed at intervals over approximately 5 days to determine percentage weight loss. Crop dry weights were calculated after storage at 70°C for 5 days.

### **D. Modified atmosphere packaging**

Product used in package testing was typically transported to Oriental Merchant's warehouse at Laverton North in a refrigerated truck. Produce was stored at between 1° and 3°C at OM facilities until delivery next morning to IHD, Knoxfield in a refrigerated truck. At Knoxfield produce was immediately placed at appropriate cool storage temperatures.

Quality of the produce was assessed before and after storage using a rating scale (Table 1). Often bunches were mechanically injured and leaves were spotted by *Pseudocercospora capsellae*. Produce invariably arrived wet, some excess water was removed by shaking before packing.

Packaging development took place in conjunction with a commercial company with extensive experience in MA use in horticulture. Modified atmosphere bag size varied with the crop and application. Herbaceous materials was contained in bags with sealed dimensions of 400mm x 150mm whereas 5kg packs for e.g. Shanghai buk choy used carton liners 45cm x 83cm. Films were generally polyethylene and 30µm to 60µm thick. Macro-perforations (roughly 'pin-size') varied in number

between 0 and 16, depending on requirements. OTR (oxygen transmission rate) ranged between approximately 1,000 and 18,000 ml/bag/day/atmosphere depending on hole numbers per bag.

For each film type, generally six replicate packages were stored at one temperature in two rooms (i.e. 3 reps per room). MA bags were sealed by twisting the top and fastening with a plastic, cable tie. A control comparison used high humidity liners for air storage.

## **E. Salting methodology**

Chinese cabbage (*Brassica rapa* var. *pekinensis*) varieties 'Harusakari' and 'Matilda' were sourced in mid-September from Victoria and Queensland respectively. Matilda has an intense yellow heart which is a preferred trait in Japan.

Cabbages were cooled overnight at 5°C prior to use. In a 5°C working environment, wrapper leaves (4 to 6 per head) were removed and cabbages halved longitudinally by cutting with a hand-held knife through the stem and basal parts of leaves (i.e. not the majority of leaf blade material). Halves were then torn apart to give leaf-blade edges a natural, rather than cleanly cut appearance.

Trimmed cabbage was then immersed in a 200 to 300ppm sodium hypochlorite solution at 4° (to 5°C) for approximately 5 minutes. Following disinfestation, the halves were rinsed in 5°C tap water and hand-shaken to remove excess water before transfer to tubs. Tub dimensions (all inner): Length- upper 56.0 cm, base 52.0 cm; Width- upper 36.5 cm, base 32.5 cm; Depth 20.0 cm.

Halved cabbages were packed approximately 18 per tub. Each of the preparation treatments was represented by at least 6 tubs (i.e. 108 halves). During the packing and layering into tubs, salt was sprinkled onto the stem/leaf-petiole area, at the rate of 5% by weight i.e. approximately 30 to 35g per half cabbage. Salt works as a preservative and germicide.

Chilled (4° to 5°C) salt solution (5%) was then added to the tubs at the rate of 15% cabbage weight. Cabbages were placed under pressure by positioning weighted tubs over them, and weight was obtained with water or concrete blocks. Pressure is used to extrude water from the cabbage and facilitate salt absorption. The standard weight employed was 170 to 180% of total cabbage weight/per tub, and this gave approximately 1.2kPa pressure. Additional treatments used a heavier weight which was 220 to 230% of the cabbage weight, or approximately 1.6kPa.

Weighted Harusakari cabbages were then held overnight at one of three air temperatures (4°, 15° or 25°C), whereas Matilda was examined only at 15°C. Rooms were duplicated at each temperature and replicates stored evenly across rooms. After 16 hours, brine and cabbage temperature had equilibrated to room air temperature. At this stage, 25% of surface weight was removed, an additional 1.0 to 1.5 litres of salt solution was added to each tub and all tubs were transferred to 4°C. After 4 days with weighted pressure at 4°C, cabbages were roughly drained and vacuum-sealed in plastic bags made from a barrier film.

Salted cabbage halves were assessed for appearance, flavour and texture using the rating scale in Table 2. Analysis of variance was used to determine the least significant difference (LSD) between the mean values.

**Table 2 : Score sheet for salted cabbage assessment**

<b>SAMPLE</b>			
<b>APPEARANCE</b>		<b>FLAVOUR</b>	<b>TEXTURE</b>
Excellent	9a	9d	9f
	8	8	8
Very good	7	7	7
	6	6	6
Good	5b	5	5
	4	4	4
Fair	3	3	3
	2	2	2
Poor	1c	1e	1g

**RATINGS AS INTERPRETED BY TASTE TESTER**

- a **yellow/green, strong contrast**
- b **slight colour fading**
- c **faded/grey**
- d **mustard-like**
- e **just salt**
- f **crisp**
- g **soft**

Salted cabbage was assessed after 5 to 6 weeks stored at 4°C in vacuum-packaging. At this stage the product still has additional shelf-life, although colour had faded slightly. Nevertheless, there are several weeks available for flexibility in shipping and product distribution. In theory, the cabbage is ready for consumption after the initial few days of salting under pressure. The Japanese prefer a 'fresh' salted product.

**F. Fresh-cut stir-fry mix (animal processing)**

**Processing and packaging**

All components, including canned, brined products and washing solutions were pre-cooled to and held at 4°C. The Shanghai buk choy, gai lum, broccoli, snow peas and red cabbage were trimmed and chopped by hand. Carrots and broccoli stems were trimmed by hand and processed using a robot-coupe® CL60 with an 8mm x 8mm julienne blade. All fresh products were washed in water containing 70-100ppm chlorine (calcium hypochlorite 650g/kg active ingredient) and rinsed in potable water. Leafy material (buk choy and gai lum) was spun dry to remove excess moisture. Mixes were prepared on a percentage weight per component basis. Pack size measured 230mm x 250mm at the seal. All processing (including washing and storage before and after packing) was undertaken at 4°C.

**Storage temperature**

After packing, the bags were sorted into randomised complete block designs and moved to relevant temperature regimes (4°C or 8°C) to simulate storage, distribution and retail display. Temperatures reflected the usual range encountered in supermarket display cases. Two replicate coolrooms were used for each temperature and packaging treatments were replicated between 4 and 8 times.

## Packaging

Seven different packaging films were tested in six packaging trials (Table 3).

**Table 3 : Packaging films tested**

Film	Formulation	Thickness	Oxygen transmission rate (OTR) ml/m <sup>2</sup> /day
1. Cryovac	RC001	38 gauge	na
2. Barrier film Corp.	BF635	2.0ml/L	10000
3. Propafilm MG	BOPP	25µm	1900
4. High Relative Humidity (HRH) air control	Perforated BOPP	25µm	very high
5. U.S. film	na	na	6000
6. Cryovac	RY208	na	5000
7. Lifespan	na	na	8000

*na: not available*

Control bags, which maintain a high relative humidity but do not alter carbon dioxide and oxygen levels substantially from air were manufactured using Propafilm MG (Orica Films, Australia) perforated with eight, 0.5mm diameter holes per bag.

## Atmosphere measurements

Oxygen and carbon dioxide measurements were conducted for the duration of storage time using a Novatech 2000 portable gas analyser. Pieces of Rehau silicon tape were stuck to the exterior of all packs to act as septa and to enable consecutive measurements without leaks. Gas analysis data were analysed using ANOVA.

## Quality measurements

All packs were assessed at the conclusion of storage for weight loss (%), visual market quality and off-odour using the rating scale shown in Table 4. All data were analysed using ANOVA or REML (Residual Maximum Likelihood).

**Table 4 : Rating scale for assessment of market quality and off-odours**

Score	Market quality	Off-odour
1	very good	none
2	good (slight defects)	trace
3	fair but saleable	slight
4	poor and unsaleable	moderate
5	very poor and unusable	severe

## **Microbiological measurements**

Product was tested for total plate count (aerobic bacteria), presumptive coliform count and the presence of *Escherichia coli*. Tests were conducted using a 50g (or 100g) sample of product from each pack, ensuring it accurately reflected the proportions of components in the mix. Samples were blended with 225ml of peptone buffer (0.1%) using a Stomacher 400 laboratory blender. A 1ml sample of the resulting solution was withdrawn and serial dilutions were performed with peptone buffer. Appropriate dilutions were plated onto 3M petrifilm plates (aerobic count and coliform/*E.coli*) according to their required specifications. Aerobic plates were incubated at 25°C for 48 hours. Coliform plates were incubated at 35°C for 24 hours then moved to 42°C for 24 hours to enable the detection of *E.coli*. Total yeast and mould plates were incubated at 25°C for 72 hours and the yeasts counted. Moulds were counted after an additional 48 hours of incubation.

# Results

Summaries presented here derive from the reports listed in each sub-section. These reports comprehensively document materials and methods, results (including statistical analysis) and discussion.

## A. Modified atmosphere packaging

### 1. Shanghai buk choy (also called Shanghai Chinese chard, Shanghai pak choy)

Shanghai buk choy (*Brassica rapa* var. *chinensis*) is a versatile vegetable with old origins. It is one of the more popular Asian vegetables found in the Australian marketplace. Trials were conducted to improve the postharvest life of Shanghai buk choy in order to expand flexibility in marketing and to ensure better postharvest quality for consumers.

A range of modified atmosphere (MA) packages was investigated for both export (10kg) and domestic (5kg) distribution. MA liners/bags were designed for use in conjunction with appropriately sized fibre-board cartons. Package atmospheres were modified by reducing oxygen levels and increasing carbon dioxide, thereby reducing respiration rate and conserving food reserves. General out-turn appearance from MA packaging was superior to air packaging, and in particular less leaf yellowing was observed in MA.

For 10kg export packs of Shanghai buk choy, recommendations are a storage atmosphere of approximately 5% O<sub>2</sub> and 10% CO<sub>2</sub> achieved in a 60µm thick polyethylene bag with oxygen transmission rate of approximately 5,500 ml/bag/day.atmosphere. Storage life is estimated to be 21 days at 0°C.

For 5kg domestic packs, use of a 60µm thick, polyethylene bag with OTR of approximately 4,500 ml/bag/day.atm. is recommended. Storage life is estimated at 10 to 12 days in a 4°C environment. After this period, the product should still have approximately 4 days life during transport and marketing.

General protocol for handling of buk choy: avoid damaged or wilted produce; MA packaging will not improve the quality of produce, initial quality must be high. At the initial stage of packaging, buk choy should be free of rots, disease, soil and excess surface water.

*[For more details on this research topic refer to the RIRDC publication “Postharvest studies of selected Asian vegetables – Part 1”]*

### 2. Gai lum (also called Chinese broccoli, kailan)

The storage life of gai lum (*Brassica oleracea* var. *alboglabra*) can be increased with the use of MAP and good postharvest handling practices. Benefits include delayed senescence, reduced chlorophyll degradation and yellowing, reduced water loss, and decreased microbial spoilage.

As plants use oxygen and consume their food reserves during respiration, it is preferable to reduce the respiration rate to increase storage life. The respiration rate of gai lum decreased with decreasing temperature and therefore lower storage temperatures (1°C to 5°C) are desirable.

Gai lum is moderately susceptible to water/weight loss. After 30 hours, gai lum showed visible signs of wilting (5-10% weight loss) and it is recommended that this produce type is handled in a manner that will avoid water loss.

Modified atmosphere carton liners, suitable for 10kg of produce and storage at 0°C, were developed and tested for the export of gai lum. The MAP 20 carton liner, a polyethylene film (30µm thick) with an oxygen transmission rate of 16700 ml/bag/day/atmosphere, was found to give the best result with respect to general appearance and colour after 23 days storage. However, the general appearance of gai lum after 23 days storage in the MAP 20 carton liner was fair to poor. Therefore, further improvements in the MAP specifications are required to obtain 3 weeks storage and this requires further work.

Bags suitable for 5kg of produce and storage at 4°C were trialed for the distribution of gai lum on the domestic market. The A2 carton liner, a polyethylene film (30µm thick) with an oxygen transmission rate of 6400 ml/bag/day/atmosphere, is the preferred package for the storage of gai lum. However, the produce was of poor to very poor appearance after 14 days storage due to the occurrence of disease.

*[For more details on this research topic refer to the RIRDC publication “Postharvest studies of selected Asian vegetables – Part 1”]*

### **3. Chinese chives**

Respiration studies on Chinese chives (*Allium tuberosum*) over 10 days indicated a beneficial effect on respiration as the storage temperature decreased from 8°C to 1°C. Respiration rates observed at 1°C were approximately one third of those observed at 8°C.

Shelf life trials showed that Chinese chives could be stored successfully for 14 days at 4°C using MAP. This allows post-storage distribution, handling and marketing, at slightly elevated temperatures, before the product becomes unsaleable. The major factors limiting storage were loss of turgor and the occurrence of rots, however, these were controlled satisfactorily using a polypropylene bag (50µm thick with sealed dimensions of 400mm x 150mm) with an oxygen transmission rate of 970 ml /m<sup>2</sup> /day /atmosphere for 50 grams of produce.

To lessen the occurrence of storage rots chives should be free of surface moisture, soil and disease. It is also beneficial for the chives to be packaged and handled at 4°C to reduce rapid respiration elevation inside the package once sealed.

*[For more details on this research topic refer to the RIRDC publication “Postharvest studies of selected Asian vegetables – Part 1”]*

### **4. Choy sum (or Chinese flowering cabbage)**

MAP in conjunction with good postharvest handling practices, is beneficial in increasing the storage life of choy sum (*Brassica rapa* var. *parachinensis*). The benefits of MAP storage of choy sum include delayed senescence, reduced chlorophyll degradation and yellowing, reduced water loss, and decreased microbial spoilage.

Temperature had a significant effect on the respiration rate and shelf life of choy sum. Storage benefits increased as temperature decreased from 8°C to 1°C and respiration rate decreased as temperature decreased from 8°C to 1°C. The increase in shelf life at lower temperatures can be attributed to the reduced rate of respiration.

Shelf life trials showed that choy sum could be successfully stored for 9 days at 1°C in high humidity bags. Whilst 9 days at 1°C would be an adequate storage period for the domestic market, it is unlikely that this temperature could be maintained throughout distribution. At 5 and 8°C, the shelf life of choy

sum was 6 and 5 days, respectively. The major limitations to storage were rots on the stems and leaves, loss of leaf colour and inflorescence. These results indicated that an additional postharvest treatment such as MAP was required to increase the storage life of choy sum.

Water/weight loss was identified as a major limitation to the storage life of choy sum. After just 24 hours choy sum appeared wilted (7-12% weight loss) and it is therefore recommended that this product receives handling to avoid water loss.

Prototype modified atmosphere carton liners were developed for export of choy sum. The bags were designed to hold 10kg of produce and are suitable for use at 0°C. MAP 4, a polyethylene film (30µm thick) with an oxygen transmission rate of 10,500 ml/bag/day/atmosphere, was found to be the most suitable of the bags trialed. The general appearance of choy sum stored in MAP 4 was better than produce stored in all of the other bags. In addition there were no off-odours detected in this bag which is attributable to the higher oxygen levels. Yellowing was the limiting factor for air stored choy sum whereas choy sum stored in MAP was affected by the occurrence of rots and a general water-soaked appearance. To overcome the occurrence of rots, choy sum should only be packaged in MAP when there is no excess surface moisture.

[For more details on this research topic refer to the RIRDC publication “Postharvest studies of selected Asian vegetables – Part 1”]

## 5. Mint

Shelf life trials showed that hot mint (*Polygonium minus*) and spearmint (*Mentha spicata*) could be successfully stored in high humidity bags for 17 and 18 days at 0°C, respectively. The shelf life of the produce decreased with increasing temperatures. The major limitations to storage were loss of leaf colour and turgor. The occurrence of rots was also a limiting factor during storage at 8°C.

Temperature had a significant effect on the respiration rate of hot mint and spearmint. Increasing temperatures resulted in a higher rate of respiration.

Loss of turgor was quantified by measuring the water loss of both hot mint and spearmint during display in a refrigerated display cabinet at 68°C. After 30 hours, weight loss for the hot mint averaged 22% and 16% for spearmint.

MAP was developed for hot mint only. The higher wholesale value and demand for hot mint justified the consideration of a more costly packaging approach.

The benefits of MAP for hot mint include: reduced water loss, reduced yellowing and decreased occurrence of rots. Pack D, a polypropylene film (50µm thick) with an oxygen transmission rate of 970 ml/m<sup>2</sup>/day/atm, was the most suitable of the bags trialed. Hot mint stored in Pack D remained saleable throughout 16 days storage at 4°C followed by 6 days simulated transport and marketing at 8°C.

[For more details on this research topic refer to the RIRDC publication “Postharvest studies of selected Asian vegetables – Part 1”]

## B. Salting

The final appearance of salted Harusakari was affected by both overnight holding temperature and compression used during the initial salting phase of preparation. With the standard applied pressure of

1.2kPa, the coldest preparation temperature (i.e. 4°C) produced a significantly better appearance than that achieved with over-night holding at 15°C or 25°C.

Increasing the pressure to 1.6kPa significantly improved the appearance of cabbage that had been prepared at 15°C and 25°C but brought no additional benefit to the 4°C material.

Flavour of the salted Harusakari was affected by holding temperature and pressure in the same manner as 'appearance'. The lesser pressure produced good/ 'mustard-like' flavour if the overnight preparation temperature was 4°C, but flavour of 15° and 25°C derived product was more salty, and therefore inferior. (While the presence of salt is necessary to impart some savoury taste, the balance is delicate).

Increasing the pressure to 1.6kPa improved flavour of the 15°C and 25°C derived material to 4°C standards. Consequently, with use of the higher pressure during initial salting, temperature at this time had no significant effect on flavour.

Lower temperatures probably play a role in restricting loss of volatile chemical compounds that contribute to flavour.

Temperature effects on texture were not significantly different for product prepared at the lower pressure. Texture of 15°C and 25°C derived material improved (i.e. became crisper) with additional pressure. Overall, the tested variables for preparation had less effect on texture than on the other quality parameters.

Extra pressure may have improved the quality of salted-cabbage by increasing both the rate at which water was drawn out of the cabbage, and rate of salt uptake. These are the primary reasons for use of pressure during preparation. Nevertheless, because the cabbage halves were not totally submerged initially in brine, the extra weight may have simply forced more cabbage into the brine. In turn, this would have reduced the amount of cabbage exposed to air. Pressure effect was most evident for product stored at 15°C and 25°C. Greater submersion through pressure may have increased the amount of cabbage in the initially colder (4°C) brine and lessened the cabbage in contact with higher air temperatures.

Variety 'Matilda' was better suited to production of 'tsukemono'. Matilda's appearance, flavour and texture were all superior to that of Harusakari. However, it should be noted that the Matilda cabbages had better initial quality and Matilda was only tested at one over-night preparation temperature i.e. 15°C.

Ten assemblymen from Hachioji City, Japan tasted the salted Matilda and enthusiastically proclaimed its excellence.

### **Recommended procedure for commercial salted Chinese cabbage production**

- cool cabbages to 5°C, and in a working environment at this temperature remove overly mature and damaged wrapper-leaves
- halve cabbages longitudinally by cutting through the stem and leaf-petioles, but not the majority of leaf-blade material
- tear halves apart and immerse for 5 minutes in a 200 to 300ppm sodium hypochlorite solution at 5°C

- following disinfestation, rinse the halves in 5°C tap water and shake to remove excess water before transfer to salting tubs (inner tub dimensions- Length- upper 56.0 cm, base 52.0 cm; Width- upper 36.5 cm, base 32.5 cm; Depth 20.0 cm)
- during packing and layering into tubs, sprinkle salt onto the stem/leaf-petiole area at the rate of 5% by cabbage weight
- 5% salt solution at 5°C is then added to tubs at the rate of 15% cabbage weight
- cabbages are placed under pressure with surface weight for 16 hours at an air temperature of either 4°C or room (i.e. 15° to 25°C)
- the pressure employed at 4°C is 175% of total cabbage weight/per tub, or approximately 1.2kPa pressure
- if higher room temperatures are used pressure should be higher, approximately 1.6kPa (producers can determine if low temperature or high pressure is easier to achieve in their factory)
- remove 25% of surface weight and add approximately 10% (by cabbage weight) additional volume of salt solution and store at 4°C
- after 4 days, roughly drain cabbage halves and vacuum-seal in barrier-film bags
- product is now ready for either immediate consumption or additional processing
- continued storage should be at 4°C

*[For more details on this research topic refer to the RIRDC publication “Postharvest studies of selected Asian vegetables – Part 1”]*

### **C. Packaging systems for fresh-cut Asian vegetable mixes**

This component of the research examined the preparation of minimally processed Asian stir-fry mixes and the available packaging and handling required to deliver these products in optimal condition to the consumer.

In studies to identify a suitable 350g Asian stir-fry package several films were tested in six trials. All packed bags were held for a minimum of 8 days at 4°C and/or 8°C, with a maximum of 11 days. Of these, two package types were deemed adequate for the conditions in which they were held. Vegetables within each of these films were still saleable at the end of the storage time. Off-odours were not present or were slight and dissipated quickly after opening. Both films, Barrier Film Corporation’s BF635 and Cryovac’s RC001, are commercially available and are recommended for commercial trials on the minimally processed products tested here.

After 10 days storage at 8°C, high levels of aerobic bacteria were recorded. Microbial growth was reduced by maintaining the packages at 4°C throughout storage. The brined products contained in the mix were identified as a potential source of nutrients for the microflora. Washing them in a sanitiser before packing should alleviate this problem.

Two trials were conducted to develop a suitable packaging film for the storage of 5kg lots of Asian stir-fry mix for use in the food service industry. The developmental package MA6500 performed best

under the conditions of this trial with visual market quality and the microbial loads of the mix remaining acceptable following 7 days storage at 4°C. It is recommended that commercial trials are conducted to test this packaging system under actual storage and distribution temperatures.

*[For more details on this research topic refer to the RIRDC publication “Postharvest studies of selected Asian vegetables – Part 1”]*

## **D. Quality descriptor language manuals**

Issues of Asian vegetable quality are not well documented. Quality descriptor language manuals for five Asian vegetables (Chinese broccoli, Chinese cabbage, Chinese flowering cabbage, buk choy and Shanghai buk choy) were prepared to clarify aspects of desired quality for customers and consumers at all stages of the handling and sales chain. These documents were based on the Australian Horticulture Corporation's Apple Product Descriptor Language. The five Asian vegetables selected for manual preparation were identified as the top five Asian vegetables for supermarket requirements.

Quality is achieved when customer requirements are consistently met. This is only possible when the requirements are understood and agreed upon by both suppliers and customers. The documents prepared for this project clearly describe physical traits, product disorders and handling issues which can be used to define the customer's requirements.

Each vegetable displays many variations in quality characteristics. Quality descriptor language provides the basis for the development of product specifications that are understood and accepted by everyone within the product marketing chain.

Quality traits vary within regions, seasons and varieties. Cultivar selection, production practices, pest and disease management, storage, postharvest handling and transportation are other factors influencing product characteristics.

Adoption of the quality descriptor language manuals will bring the following benefits:

### **Vegetable grower**

- Enables growers to accurately define product quality and receive appropriate value for it.
- Provides a framework for enabling sale by description.
- Provides a framework for maintaining accurate, on-farm records of crop variation.

### **Harvesting and packing teams**

- Provides a basis for selection or grading of harvested produce.
- A simple yet effective resource for training and updating of harvesting team skills.
- Increases efficiency of packing and grading-out of unsuitable produce for quality endorsed sale.

### **Wholesalers, retailers and exporters**

- Provides a full and accurate set of visual standards by which ordering and dispatching of consignments takes place.

Specifications can be reassessed at different points within the marketing chain and quality changes can be monitored throughout the distribution system.

These quality descriptor manuals will be marketed by the Australian Horticulture Corporation throughout Australia and it is envisaged they would be used by both growers/suppliers and customers.

## **E. Market surveys & costs of production**

Retail surveys of Asian vegetables were conducted in Melbourne resulting in the publication of *Melbourne Retail Asian Vegetable Survey Part 2 (March 1995-March 1997)*. The aims of the report were to:

- identify what Asian vegetables were available in Melbourne retail outlets during the period of the study.
- document their availability over the twenty-five months from March 1995 to March 1997.
- record their retail prices over the same period.
- estimate the total quantity for sale.

This information was needed to facilitate the expansion of domestic and export market opportunities.

Five growers were interviewed to determine the gross margins for six Asian vegetables. The Asian vegetables were baby Shanghai bok choy, Chinese cabbage, choy sum, daikon radish, garland chrysanthemum and Japanese pumpkin. Asian vegetable growers are reluctant to give details about costs and probably don't have a good understanding of costs of production.

# Recommendations

## Outcomes and deliverables of proposed new research

Increased production and consumption and reduced waste of Australian grown Asian vegetables by:

- Optimal post harvest handling, packaging and processing protocols for whole and minimally processed Asian vegetable products.
- Quality assurance of on-farm production and packaging processes.

This new proposed project builds on the success of this report's findings. Oriental Merchant's commitment to proceed with further investment in new work shows that the objectives are real and will be implemented immediately. It offers an important opportunity to fast track development of a number of whole and minimally processed products for domestic (supermarket and food service) and export markets.

The large (previous and present) financial commitment of a major Asian food distributor, Oriental Merchant, is indicative of the relevance and importance of this project to the Asian vegetable industry. Oriental Merchant will continue to supply Australian supermarkets. Potential benefit would include increased value of the Asian vegetable industry including both production and value-added elements.

The project will continue to focus on improving quality of production and on-farm postharvest handling procedures. Ethnic growers will be assisted in agronomy, chemical application, harvesting and best practices for storage with increased emphasis on productivity, reduced waste and scaling up production.

Postharvest handling protocols will be developed for a further 5 vegetables (snake beans, perilla, Thai basil, coriander & hot chilli) including correct post field storage and transport temperature and development of bulk pack modified atmosphere liners. All packaging development for minimally processed products will include microbial spoilage testing as part of shelf-life assessment.

As this project will address priorities of an industry partner (and their suppliers) with whom the team meet formally on a monthly basis, communication and adoption will occur throughout the project. Much of the information (cool chain management, agronomic practices, chemical use etc.) will be extended to other growers concurrently to improve quality and availability of Asian vegetable products in the domestic market.

The new stage of the project (outlined above) commenced in September 1998 and is jointly funded by RIRDC and HRDC (Horticultural Research and Development Corporation).

On completion, its findings will be published along with those from other RIRDC funded Asian vegetable projects.