Australian Studies on Storage and Packaging of Asian Leafy Vegetables, Chinese Waterchestnut, and Kabocha Pumpkin

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Abstract

Recent investment in postharvest research programs has provided substantial improvements in the quality and supply of Asian vegetables in Australia. Development of product descriptors, and optimum postharvest handling and packaging protocols, have improved quality and reduced wastage. Crops like pak choi (*Brassica rapa* var. *chinensis*) and gai lum (*Brassica oleracea* var. *alboglabra*) are now a permanent part of the vegetables on offer at mainstream supermarkets throughout Australia.

Modified atmosphere (MA) packaging has been developed for many Asian leafy vegetables and herbs in conjunction with the investigation of appropriate cool storage temperatures to maintain quality and avoid chilling injuries. Quality following storage of 11 leafy Asian vegetables was demonstrated to be better from MA packaging than from 'high humidity' packaging that maintained an air atmosphere. Atmospheres high in CO_2 and low in O_2 generally helped to reduce leaf yellowing and the proliferation of rots.

Research to optimise postharvest quality has also extended to biochemical analysis. Six varieties of 'Kabocha' pumpkins (*Cucurbita maxima* × *C. moschata*) grown for export to Japan were analysed for sugar content and carotenoid levels to help select product that best met market requirements. The colour of the flesh was also considered along with skin colour and skin blemishes.

The Australian market demands quality Chinese waterchestnuts (*Eleocharis dulcis*) with a high level of sweetness in association with plump, crisp, and turgid corms. To minimise weight loss in stored corms and to promote sweetness, different packaging materials, storage temperatures, and storage durations were investigated. Over a 5-month storage period at either 1 or 9°C, weight loss of corms was acceptably low (i.e. less than 10%) if stored in either snap-lock bags made of low density polyethylene (LDPE) film, or 'Longlife' vegetable bags (microperforated LDPE film). Higher storage temperatures were associated with a decrease in sugar content and increase in sprouting.

A wide range of Asian vegetables has been available in Asian grocery outlets in Australia for many years. In more recent times, 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 now reflected at mainstream supermarket outlets where a range of Australian-grown Asian vegetables is now available in our capital cities. However, there is still potential to increase the range and quality of Asian vegetables in supermarkets, greengrocers stores, and restaurants. Our producers of Asian vegetables are now looking to market Asian vegetables in neighbouring Asian countries where Australian produce has a reputation for quality.

However, the fragmented nature of the 'fledgling' Asian vegetable industry presents specific problems with respect to supplying markets with high quality

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produce. Primary growing areas are scattered throughout the eastern seaboard, and while this provides opportunities for diversity and extended supply, the logistics of sourcing and transport are made more complex. Many popular Asian vegetables are leafy and fragile, and therefore require careful handling and transport to ensure that consumers have access to a product in top condition.

Good postharvest management can deliver 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. By increasing the use of best postharvest practices in the Asian vegetable growing industry, profits can be increased through improved quality and reduced waste.

Modified Atmosphere Packaging for Selected Leafy Asian Vegetables and Herbs

Modified atmosphere (MA) packaging uses the plant product's natural respiration to create a high carbon dioxide, low oxygen atmosphere which extends the life of stored produce. The packages provide an improved storage environment for herbs and vegetables during distribution, thereby ensuring high product quality for consumers.

This research was started in conjunction with a commercial packaging manufacturer, but it became obvious that the relatively small needs of the Asian vegetable industry in Australia would mean low-volume manufacturing and high costs per bag. Consequently, packaging was sought that could be bought 'off-the-shelf', enabling better accessibility and pricing for growers. At manufacture, these bags were not intended for use with Asian vegetables but through testing of product types, storage temperatures, sizes, and film permeabilities, bag specifications were matched to the needs of different product types. Design of any particular MA package depends on:

- the crop for which it is intended;
- the respiration rate of that crop at the required handling/storage temperature;
- the amount of crop to be stored; and
- the properties of the film used for the package.

Respiration rates of each product were measured at a range of temperatures before selection of packaging, and again in conjunction with packaging trials.

New MA bags were tested for snake beans, hot chillies, perilla, Thai basil, coriander, spearmint, hot mint, Chinese garlic chives, pak choi (= Chinese chard), baby pak choi, kai choi (= mustard green, Chinese mustard), kangkong (= water convolvulus), and amaranth (= Chinese spinach) (Table 1). The bags were prepared for use at temperatures close to each crop's optimum storage temperature. For chilling sensitive products such as Thai basil, snake beans, and kangkong, this is approximately 12°C, while for the other crops the optimal storage temperature is typically between 0 and 4°C.

Package sizes were governed by industry requirements and constraints: perilla, 3 bunches; snake beans, 100 g; baby pak choi, 12 bunches; kai choi, 12 bunches; kangkong, 12 bunches; and hot chilli, 100 g. Five-bunch MA packages were developed for spearmint, hot mint, Thai basil, pak choi, and Chinese garlic chives.

Performance of the new MA bags was compared with that of the 'high humidity' bags currently used by some industry sectors. High humidity bags restrict some water loss but they do not restrict the movement of carbon dioxide or oxygen through the film so the atmosphere surrounding the produce is very close to normal air.

Packaging for perilla

The process of package development for perilla (*Perilla frutescens*) is documented here. Similar procedures were used in formulating the package specifications listed in Table 1. Packaging trials for perilla examined the performance of three types of plastic packaging at two storage temperatures (0°C and 4°C), followed by a simulated marketing period at 8°C. Two types of bag designed to give a modified atmosphere were compared with a control 'high humidity' bag.

Bag details (dimensions were 250 × 330 mm):

- Control, high relative humidity bag. A 50 µm thick polypropylene clipseal bag perforated with two holes of 5 mm diameter.
- MA1, 50 µm thick polypropylene bag. (Film specification: ICI propafilm, biaxially orientated polypropylene (BOPP) ML50 with an oxygen transmission rate (OTR) of 970 mL/m^2/day/atmosphere.)
- MA2, 50 µm polyethylene clipseal bag. (Film specification: Low density polyethylene with an OTR of approximately 4,250 mL/m^2/day/atmosphere.)

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Respiration rate in air was measured in conjunction with the packaging trial at each temperature. Carbon dioxide from respiration was measured from a 1 mL headspace gas sample taken from the respiration chamber upon closing and then again approximately 2 hours later. Samples were processed with an infrared gas analyser (IRGA). Respiration rate was measured as CO_2 production rate in mL/kg/hour and was calculated as follows: [$\Delta\%CO_2 \times 10 \times$ free volume (L)]/[Produce fresh weight (kg) × Δtime (hours)].

Oxygen and carbon dioxide levels in the packages were measured with a Novatech portable gas analyser. Pieces of Rehau silicone tape were stuck to the exterior of each pack to act as septa and to enable consecutive measurements without leaks.

A rating scale of 1 to 5 was used to assess turgor, colour, rots, and the general appearance (1 = excellent quality, 5 = very poor) of the produce following storage and again after 3 days of simulated marketing.

Results

Perilla was successfully stored in MA2 bags at 0°C and 4°C for up to 13 days plus an additional marketing period of 3 days at 8°C. Differences in product quality between 0°C and 4°C were minimal.

Levels of atmosphere modification in all package types are shown in Figures 1 and 2. Through the later part of the storage time in MA2 at 4°C, the oxygen level averaged around 14% and carbon dioxide was close to 6%. In comparison, at 0°C the MA2 atmosphere was about 17% oxygen and 4% carbon dioxide.

Compared with MA1 and control bags, the general appearance of perilla stored in MA2 bags was significantly better. The odour of perilla stored in MA2 packages was also superior after the marketing period. Similarly, in comparison with MA1 and control bags, produce stored in MA2 was significantly more turgid and had developed fewer rots. MA2 bags also played a significant positive role in maintaining the purple leaf colour.

MA packaging was found to provide storage benefits for Chinese garlic chives, spearmint, hot mint, Thai basil, snake beans, perilla, hot chillies, pak choi, baby pak choi, kangkong, and kai choi. The storage and packaging recommendations for these crops are summarised in Table 1. Although there are literature reports that coriander would benefit from controlled atmosphere or modified atmosphere storage, it was not evident in these trials. Similarly, the storage life of amaranth was not enhanced by MA packaging.

In general, the benefits of modified atmosphere packaging were a reduction in the incidence of rots and yellowing. For chilling-susceptible produce such as snake beans, kangkong, and Thai basil, MA also reduced chilling injury. Lower incidence of mould on the peduncles or stems, and a reduction in peduncle shrivelling were major benefits for hot chillies stored in MA bags.

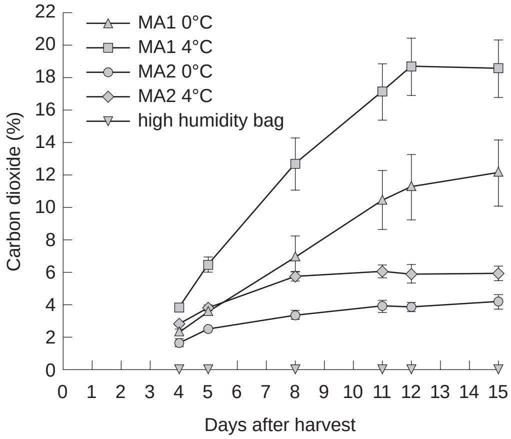

Figure 1. Carbon dioxide levels in three package types for perilla stored at two temperatures.

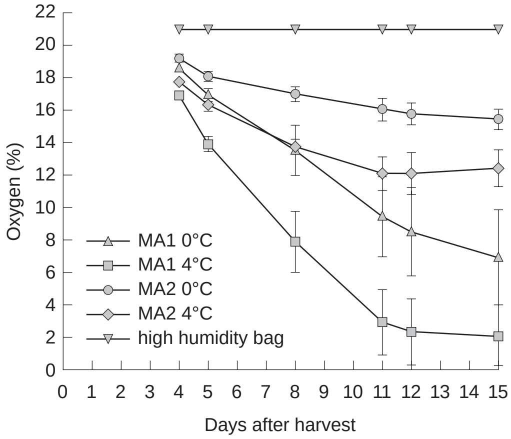

Figure 2. Oxygen levels in three package types for perilla stored at two temperatures.

Temperature is a critical factor in maintaining product quality during storage. Most of the produce types reported here are best when stored at 0°C. However, Thai basil, snake beans, and kangkong are susceptible to chilling injury if exposed to low storage

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temperatures, and Thai basil and snake beans should not be exposed to temperatures below 12°C.

Packaging trials for kangkong were conducted at 4°C and 8°C; the literature recommends storage temperatures varying from 0 to 9°C (Hirata et al. 1987). Chilling injury symptoms developed during the packaging trials reported here, suggesting that the optimum storage temperature for kangkong is higher than 8°C.

Initial high quality of produce is essential for good outturn following storage in modified atmosphere packaging. MA packaging will not improve the initial product quality. MA should always be used in con-

Table 1. Storage and packaging recommendations for Chinese garlic chives, spearmint, hot mint, Thai basil, snake beans, coriander, perilla, hot chillies, pak choi, baby pak choi, kangkong, kai choi, and amaranth.

Product	Storage temperature (°C)	Observed MA benefit	Recommended packaging	Additional requirements
Chinese garlic chives (*Allium tuberosum*) (5 bunches)	0–4	yes	50 µm polyethylene clipseal bag (355 × 400 mm)	
Spearmint (*Mentha spicata*) (5 bunches)	0	yes	50 µm polyethylene clipseal bag (355 × 400 mm)	Treatment for prevention of leaf abscission
Hot mint (*Polygonum odourata*) (5 bunches)	0	yes	50 µm polypropylene bag (Rayopp RH50) (270 × 350 mm)	Control of two-spotted mites
Thai basil (*Ocimum tenuiflorum*) (5 bunches)	12	yes	50 µm polyethylene clipseal bag (355 × 400 mm)	Storage temperature is critical for prevention of chilling injury
Snake beans (*Vigna unguiculata* subsp. *sesquipedalis*) (100 g)	12–15	yes	Rob's medium longlife bag (300 × 450 mm)	Storage temperature is critical for prevention of chilling injury
Coriander (*Coriandrum sativum*) (20 bunches)	0	no	High humidity air	
Perilla (*Perilla frutescens*) (3 bunches)	0–4	yes	50 µm polyethylene clipseal bag (250 × 330 mm)	
Hot chillies (*Capsicum annuum* var. *annuum*) (100 g)	0–4	yes	75 µm polypropylene bag (Rayopp RH50) (150 × 120 mm)	Alternative packaging: 50 µm polyethylene clipseal bag (150 × 205 mm, sealed at 120 mm)
Pak choi (*Brassica rapa* var. *chinensis*) (5 bunches)	0	yes	Fresha-pak medium or high transmission polyethylene bag (865 × 875 mm)	
Baby pak choi (*Brassica rapa* var. *chinensis*) (12 bunches)	0	yes	Fresha-pak medium transmission polyethylene bag (865 × 875 mm)	
Kangkong (*Ipomoea aquatica*) (12 bunches)	9	yes	Fresha-pak medium transmission polyethylene bag (865 × 875 mm)	Determination of optimum storage temperature
Kai choy (*Brassica juncea*) (12 bunches)	0	yes	Fresha-pak medium transmission polyethylene bag (865 × 875 mm)	
Amaranth (*Amaranthus tricolour*) (12 bunches)	0–4	no	High humidity air	

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junction with appropriate postharvest handling protocols and proper cool-chain management.

Cold Storage to Extend Shelf Life and Improve Quality of Chinese Waterchestnut

A traditional vegetable in Asia, Chinese waterchestnut (*Eleocharis dulcis*) is emerging as a new commodity in Australia with potential for export. Postharvest storage protocols have been sought by growers to extend the shelf life and thereby extend availability for domestic and, in the future, overseas markets. The effects of packaging and storage temperatures on shelf life and quality of waterchestnuts have been studied in Australia since 1997.

While some quality factors such as corm size and colour are principally determined by the growing environment and cultivation practices, other quality parameters are affected by postharvest storage practices. These parameters include weight loss, sprouting, growth of moulds on the external peel, discolouration and development of rots in internal tissues, and changes in sugar content of corms. Once one parameter falls below a critical level the shelf life of waterchestnuts is essentially ended. For example, if weight loss causes shrivelling of the corms' peels, they are considered unacceptable to consumers even though there are no signs of moulds and internal rots.

Although recommendations for postharvest storage were published as early as 1955 (Hodge and Bisset 1955), only a few systematic studies have been conducted to determine the shelf life of fresh waterchestnuts under various storage conditions. Some studies (e.g. Brecht et al. 1992) tested the effect of storage temperature on weight loss, sprouting, and sugar content of waterchestnuts. As in other tuber crops, higher storage temperatures induced sprouting and shortened shelf life by increasing weight loss through transpiration and respiration.

In tuber crops such as potato, with starch as the primary carbohydrate storage compound, low temperature storage causes unacceptable 'sweetening' of tubers. This process of sugar formation from starch in potatoes has been found to accompany four circumstances: (1) low temperatures (particularly below 10°C); (2) sprouting; (3) senescence; and (4) decay following wounding and fungal infection (Burton et al. 1992). However, 'sweetness' is appreciated in Chinese waterchestnut. Therefore, to minimise weight loss in stored waterchestnuts and to promote sweetness, different packaging materials, storage temperatures, and storage durations were tested and are reported here. Data were collected on the effect of storage temperature and storage period on the 'total soluble solids' (TSS) content which is an indicator of sugar levels in many agricultural commodities.

In assessing quality, corms that had lost more than 10% of their fresh weight were considered visually unacceptable. When stored in the open, waterchestnuts lost this proportion of their fresh weight within one week. However, when corms were packaged in low-density polyethylene (LDPE) film (i.e. 'snaplock' bags) or microperforated LDPE film (i.e. 'Longlife' vegetable bags), loss of fresh weight was within the acceptable level over a 5-month storage period regardless of the storage temperature tested (1° and 9°C). The packaging materials did not differ significantly in their efficacy in reducing fresh weight loss in stored waterchestnuts.

Compared with some other horticultural products, it was found that respiration rates in waterchestnut were low to very low (0.6–1.2 mL CO_2/kg/hour). Based on this, weight loss caused by respiration was calculated to comprise only 3% of fresh weight loss of corms stored for one month at 1°C. Therefore, weight loss of openly-stored waterchestnuts is primarily confined to transpiration, which can be successfully reduced by using packaging materials that are minimally permeable to water-vapour transfer.

Although weight loss of waterchestnuts did not differ across the two storage temperatures tested, difference in storage temperature did eventually affect development of moulds and rots. Not surprisingly, superficial fungal growth was accelerated at the higher storage temperature of 9°C but internal rots developed more rapidly at 1°C. This latter result may have been due to fluctuations in the trial's storage temperatures which could have reduced corm temperatures to below 0°C, thereby causing chilling injuries and associated rots. Moulds and rots shortened the storage life of waterchestnuts to 3–4 months at either storage temperature.

With the exception of the value for the 2-week storage period, sugar content (as indicated by TSS) increased over the first 12 weeks of storage (Figure 3). This was accelerated by the lower storage temperature, which suggests that the same (as yet incompletely understood) processes that cause 'low-temperature sweetening' in potato may also be active in Chinese waterchestnut. At present, we have no explanation for the drop in TSS after 12 weeks and then the rise at 20 weeks (Figure 3).

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Preliminary results from current research suggest that, aside from low temperature, the other processes that explain sweetening in potato have no or only limited validity in waterchestnuts. At higher storage temperatures, sprouting was accelerated but sweetening did not occur; corm senescence was hastened by higher temperatures but this inhibited sweetening; and decay after wounding and fungal infection did not enhance sugar content.

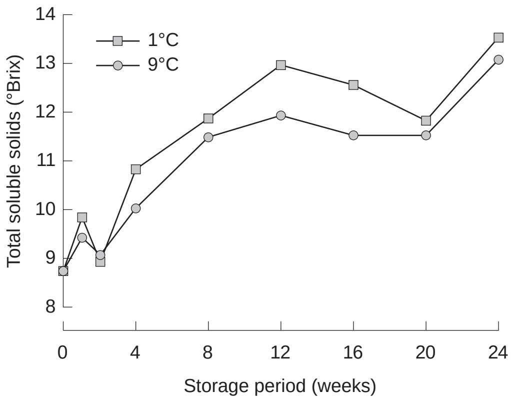

Figure 3. Effect of storage temperature and storage period on sugar content (as indicated by total soluble solids) in Chinese waterchestnut corms.

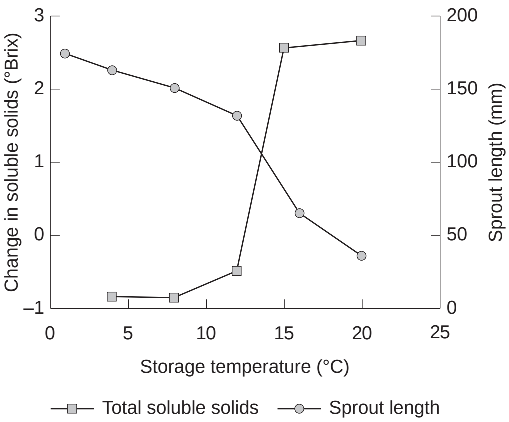

Figure 4. Relationship between storage temperature, change in total soluble solids, and sprout length in Chinese waterchestnut corms.

In our current research on storage of Chinese waterchestnut corms, a wider range of storage temperatures (4, 5, 8, 12, 15 and 20°C) has been examined to determine 'critical' temperatures below which sweetening and above which sprouting occurs.

The data presented in Figure 4 show this temperature to be 13.6°C. An attempt is also being made to calculate a 'TSS per cold unit' value (i.e. the inverse of heat units). This would make it possible to estimate the TSS content of waterchestnuts when the sum (or perhaps product) of time and temperature at which waterchestnuts were exposed to temperatures below the 'critical' temperature is known. Possibly, exposure duration is independent of whether it occurs during the growing period in the field or in postharvest cold storage. To assist in understanding this process, corms have been harvested and tested for TSS during different growth stages, and the development of their TSS is being studied under subsequent cold storage.

Quality Assessment of Kabocha Pumpkins

The word 'kabocha' in Australia refers to varieties of pumpkin preferred by Japanese consumers. Kabocha varieties are either intraspecific crosses between different lines of *Cucurbita maxima* or interspecific crosses between *C. maxima* × *C. moschata*. The name 'Japanese pumpkin' is also used.

Kabocha pumpkins are typically quite small (1–2.5 kg) and have a distinctly sweet, nutty flavour. Agronomic requirements are similar but not identical to pumpkins traditionally grown in Australia. However, Japanese consumer expectations of taste and quality are substantially different from Australian expectations.

A number of separate efforts have been made in Australia to research and develop this crop for export to Japan and to expand sales on the domestic market. Japanese consumers prefer firm pumpkins with dark green skin and dark orange flesh. A dulled (not shiny), evenly distributed green is most marketable (Jeff Hastings 1998, pers. comm.). Uniformity of colour is most affected by the earth mark (where the fruit sits on the ground) and sunburn. Warts and other blemishes can also be a problem. Warts are superficial raised corky lesions thought to be associated with maturity and excessive soil moisture. Susceptibility to both warts and sunburn varies among varieties, with sunburn being at least partially dependent on leaf coverage and time of harvest.

Japanese and Australian kabocha appear to differ more in nuttiness than sweetness and this dictates a huge difference in price (Vong Nguyen 2000, pers.

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comm.). Brix is increased by greater exposure to sunlight and diurnal temperature variation. Hence, quality tends to be better when grown inland. Desired specifications vary with the market, particularly between fresh and semiprocessed. Carotenoids are considered to have health benefits, so a market could be developed around high nutrition fruit based on carotenoid levels.

Mainland Australia is currently restricted from exporting fresh kabocha to Japan owing to the presence of fruit fly. Therefore, until disinfestation procedures have been worked out, only the island state of Tasmania can export, as it has fruit-fly-free status. Tasmanian first grade pumpkins have been exported to Asia and Japan for the last 6–10 years with current volumes at approximately 1000 t/year. About 30% of production is rejected for skin blemishes and sunburn. Australia must produce kabocha for a high quality niche market to be competitive against kabocha pumpkins exported by New Zealand.

About 28,000 t of kabocha was processed in Japan in 1991, yet there were few processed imports. Most was processed by cutting and freezing for both food service and retail markets (Pan 1995). Frozen produce is used for soup and to produce sweet cream for cakes and is also sold in supermarkets for home use (JETRO 1996). Australia could well establish a market in this product as long as the price is internationally competitive.

Trials around Australia have sought to analyse the quality of kabocha fruit from different varieties, to establish which best meet the requirements for sales in Japan. Results from Tatura (northern Victoria) and Katherine (Northern Territory) for one season are presented in detail here. There is interest at both sites in kabocha production for Japan, and both sites use greatly differing agronomic practices to suit the local environment. Some general results on carotenoid content of pumpkins conclude this section.

Materials and methods

After harvest, pumpkins were stored for 20 days at 15°C, then assessed for quality. At higher temperatures, the pumpkins dry out (Larkcom 1991) and at lower temperatures they suffer chilling injury even if the temperature is too low for only a few days (Rubatzky and Yamaguchi 1997).

Assessments

Skin colour

Ground (or background) colour lightness/darkness of the skin was evaluated. Striping (striping could be darker or lighter than the ground colour) and blotching of the skin (over the ground colour) were not considered. Five subjective categories of skin darkness were established and linked by eye to colours from the Royal Horticultural Society (RHS) Colour Chart (Table 2). Uniformity of ground colour darkness was assessed as ‘even’ or ‘uneven’.

Table 2. Evaluation categories for skin colour lightness/darkness of kabocha pumpkins.

Category	Subjective description	RHS[a] colour chart approximation
1	Pale	137C
2	Light	137B
3	Medium	136B
4	Dark	136A
5	Very dark	Darker than 136A, ranging through to black

[a] Royal Horticultural Society

Flesh colour

Flesh colour characteristics were deemed more important than skin colour and consequently these were investigated more fully. Flesh colour was assessed using the RHS colour chart and an electronic colour meter (Chroma Meter, Minolta model CR-200) calibrated using the white tile:

($L^* = 97.75$, $a^* = -0.43$, $b^* = +2.09$).

The Chroma meter CR-200 generated figures for L*, a*, and b*. Chroma (saturation) = $(a^{*2} + b^{*2})^{1/2}$. Hue angle (H°) = $\tan^{-1}(b^*/a^*)$.

Warts

The presence of warts and/or blemishes on the skin was noted as simply ‘present’ or ‘absent’. The point of ground contact was not deemed a blemish.

Sugars

Sample preparation. Peeled pumpkin (50 g) was blended with 50 mL water for 1.5 minutes. The mixture was then transferred into a 250 mL beaker. Five mL of Carrez-I solution (85 mM $K_4Fe(CN)_6 \cdot 7H_2O$) was added and the solution mixed. This was

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followed by 5 mL of Carrez-II solution (250 mM $ZnSO_4.7H_2O$). NaOH (0.1 M) was then added to adjust the pH to 7.0–7.5. This mixture was transferred into a 250 mL volumetric flask and filled to volume with water. A sample of the solution was then prepared for analysis using a 0.45 μm syringe filter.

Analysis of sample. A Boehringer Mannheim kit for the determination of sucrose/D-glucose/D-fructose in foodstuffs using an ultraviolet method was employed. The procedure followed was that outlined in the kit's instructions.

Carotenoids

Flesh samples taken at Knoxfield were frozen and held at –70°C for up to a month before delivery to the State Chemistry Laboratories (SCL) for carotenoid analysis. SCL had advised that carotene levels in frozen samples would remain stable for at least 6 weeks.

SCL procedure. Total carotenoids were determined in kabocha samples after saponification with 100% w/v potassium hydroxide under reflux for 30 minutes according to AOAC (1990). Carotenoids were than extracted with hexane. Hexane extracts were analysed for total carotenoids using UV spectrophotometry at 450 nm, according to the method of Siong and Lam (1992).

Statistical analysis

All least significant differences for the kabocha results were generated with one-way analysis of variance based on individual separate cases i.e. one case = one pumpkin.

Results and discussion

Pumpkins produced at Tatura

Thirty-six pumpkins were received from Tatura in mid-April 2000. There were 12 fruit each of the cultivars 'Pacifica', 'Delica', and 'Kurijiman'. Means for some of the quality assessments appear in Table 3. All of the Tatura fruit had uneven skin colour and warts/blemishes.

Japanese consumers prefer pumpkins with dark green skin and dark orange flesh. The skin of 'Delica' was significantly darker than that of 'Pacifica'. In comparison, skin darkness of 'Kurijiman' was intermediate but not significantly different from the other two varieties.

The more highly desirable flesh colours (e.g. Royal Horticulture Society chart 23A) have lower L* readings (represents darker) and lower hue values (represents a more yellow colour). Vivid colours have high chroma values and dull colours have low chroma values. Flesh with a 23A chart match is bright orange, the electronic colour match description being: L 77.88, hue 78.23, chroma 82.83. Some pumpkin flesh samples scored as RHS chart 22B and looked pale and dull. Their electronic description was L 83.61, hue 83.33, chroma 54.65.

Judged against the RHS colour chart, the flesh of all samples fell within the yellow–orange group (Table 3). More importantly, flesh generally matched the 'brighter/stronger' colours (as judged by the eye), within the yellow–orange group. Lower L* readings for 'Pacifica' suggest an overall darker flesh colour for this variety. The hue rating for 'Delica' was significantly higher (i.e. yellower) than that of 'Kurijiman' and 'Pacifica'. 'Delica' had a significantly higher chroma result than the other two varieties.

Average total sugars in 'Pacifica' were the lowest of the three varieties and significantly lower than the total sugar levels found in 'Delica' (Table 3). Sugar levels in 'Kurijiman' were intermediate and not significantly different from the two other varieties. The higher sugar content in 'Delica' is an observation consistent with findings in the previous year's trials.

Table 3. Comparison of quality traits for three kabocha pumpkin varieties grown at Tatura in Victoria, Australia.

Variety	Skin darkness	Flesh colour L (value)	Flesh colour hue	Flesh colour chroma	Total sugars (g/100 g)
'Delica'	3.58	67.28	79.65	74.51	1.29
'Kurijiman'	3.42	67.09	77.96	72.52	1.22
'Pacifica'	3.25	64.37	77.48	70.95	1.14
LSD (P = 0.05)	0.24	2.17	1.34	1.79	0.13

Pumpkins produced at Katherine

Fifty-nine pumpkins of varieties 'Kurijiman' (n=10), 'Tetsukabuto' (n=10), 'Pacifica' (n=10), 'Delica' (n=10), 'Sweet Mama' (n=10) and 'T110' (n=9) were received from the Northern Territory in mid-October 2000. Uniformity of skin colour varied considerably between varieties. In Japan, an evenly distributed green is most marketable. Of the six varieties supplied from Katherine, 'Tetsukabuto' and 'Sweet Mama' were rated with the most evenly coloured skins (Table 4). All samples of 'T110' had uneven skin colour.

Skin darkness varied between the varieties planted at Katherine. 'Tetsukabuto' and 'T110' skins were significantly darker than those of all other varieties. Differences between 'Kurijiman', Pacifica', 'Delica', and 'Sweet Mama' were not significant (Table 4).

In general, warts and blemishes were less prevalent on samples from Katherine than those from Tatura. Of the Katherine fruit, the best variety was 'Tetsukabuto', of which 50% were wart/blemish free. However, other than 'Sweet Mama', the 'Tetsukabuto' result was not significantly higher than that for the other cultivars. All 'Sweet Mama' samples had warts/blemishes.

As for Tatura, visual differences between the Katherine-grown varieties in flesh colour were not obvious. However, 40% of the 'Pacifica' samples matched 21B on the RHS Colour Chart and this colour is visually less 'strong/bright' than most other colour matches made for the Katherine samples.

All the varieties grown at Katherine had average readings for L that were greater than those for Tatura pumpkins. This suggests that the southern growing site produced darker and more desirable flesh. Of the Katherine samples, 'Tetsukabuto' had the darkest average flesh colour (Table 4). 'Kurijiman', 'Pacifica', 'Delica', and 'Sweet Mama' had significantly lighter flesh than 'Tetsukabuto'. 'Kurijiman' grown at Katherine had significantly lighter flesh than 'Tetsukabuto', 'T110' and Sweet Mama' from the same site.

Average hue values were lowest (i.e. more favourable) for 'T110' and highest for 'Kurijiman'. However, many of the differences between these two extremes were not significant.

'T110' flesh averaged the highest chroma values of all varieties, with a significantly higher mean than 'Kurijiman', 'Pacifica', and 'Delica' (Table 4). 'Delica' had the lowest chroma value, significantly lower (and therefore duller) than the flesh of 'Tetsukabuto' and 'T110'.

Of the Northern Territory samples, 'Delica' had the highest total sugar level (1.81g sugar/100 g flesh). However, this level was only significantly higher than the levels observed in 'Tetsukabuto' and 'T110'.

Table 4. Comparison of quality traits for six kabocha pumpkin varieties grown at Katherine in the Northern Territory, Australia.

Variety	% of sample that contained fruit with even skin colour[a]	Skin darkness	% of sample that contained fruit which were wart/ blemish free*	Flesh colour L (value)	Flesh colour hue	Flesh colour chroma	Total sugars (g/100 g)
'Kurijiman'	10bcd	1.7	40a	74.17	79.95	70.84	1.63
'Tetsukabuto'	60a	4.0	50a	67.57	77.91	75.11	1.51
'Pacifica'	40abc	2.1	30ab	72.67	79.08	71.09	1.61
'Delica'	50ab	2.3	30ab	71.35	78.32	70.70	1.81
'T-110'	0d	3.8	33a	69.10	76.91	77.24	1.50
'Sweet Mama'	60a	1.7	0b	71.02	78.80	74.23	1.64
LSD (P=0.05)	–	0.67	–	2.97	1.52	3.64	0.24

[a] Percentages (within the column) followed by a different letter are significantly different (Chi-square test, P = 0.05)

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Carotenoids

Twenty samples (unreplicated) for carotenoid analysis were received from Gatton (Queensland), Gosford (New South Wales), Swan Hill (Victoria), and Katherine (Northern Territory). There was considerable variability between the carotenoid content of the individual samples. The lowest reading was 3.0 mg/100 g for a 'Pacifica' sample grown at Swan Hill, while a 'Sweet Mama' sample from Gosford gave the highest of 13.3 mg/100 g (Figure 5). The mean for the 20 samples was 8 mg/100 g.

Based on the limited number of results available, it would appear that traditional varieties like 'Delica' and 'Pacifica' generally had lower carotenoid levels than some of the newer varieties such as 'Tetsukabuto'. An interaction with growing site is likely but small sample numbers from the different trial sites prohibit rigorous analysis. As well as possessing many of the more desirable quality traits, it is interesting to note that 'Tetsukabuto' was also a high yielding variety and therefore one that is likely to be increasingly planted.

This preliminary work shows that there may be different carotenoid levels between cultivars and production sites. More work is required to determine which cultural practices, cultivars, and growing regions result in maximal carotenoid levels. This information could then be used as a powerful marketing tool to promote the health benefits of Australian kabocha.

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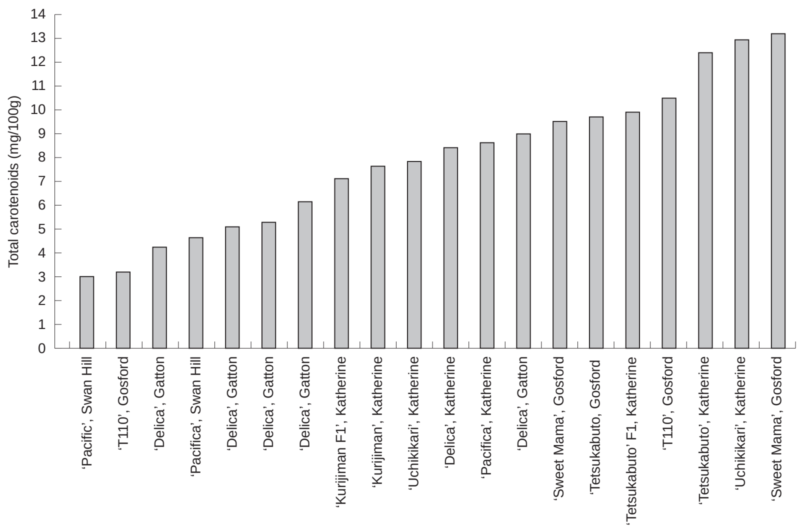

Figure 5. Total carotenoid levels in 20 kabocha pumpkin samples.

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