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Enabling sea-freight of capsicums to Japan

J Heyes[1], D Brash[1], R Renquist[2] & G Taylor[1]

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[1] New Zealand Institute for Crop & Food Research Limited
Private Bag 11 600, Palmerston North, New Zealand
[2] New Zealand Institute for Crop & Food Research Limited

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1 Executive summary

This interim report describes progress to the end of the first season of a two-year project. Sea-freight of glasshouse-grown capsicums to Japan offers significant cost savings over conventional air-freight. We are aware of two New Zealand companies who have used sea-freight for capsicums in the last two years. To achieve reliable commercial returns it is necessary to have protocols which retain adequate fruit quality after 21 days' cold storage and up to a further 5 days at room temperature. These are demanding conditions for capsicums, which are generally regarded as chilling-sensitive. Our research is designed to deliver protocols for optimum capsicum storage during sea-freight. In addition, this year's funding covered work on nutrient retention in capsicums during sea-freight and pre-harvest factors that affect post-harvest quality.

1.1 Storage conditions

Target conditions required for optimum retention of quality around glasshouse-grown capsicums are: 7-8°C, 92-95% relative humidity, less than 3% carbon dioxide. We compared several packaging materials and de-humidifying methods to achieve these target conditions in conventional or modified atmosphere packaging.

We confirmed the adverse effects of straying outside these target ranges. Water loss became excessive before the humidity fell to 90% around the fruit. Surface shrivel and fruit softening accompanied this excessive water loss. Conversely, treatments designed to lower the humidity reduced the incidence of fruit rots. This leaves a very narrow window of opportunity for long-term capsicum storage. Lower temperatures (down to 2°C) reduced fruit rots but generally led to severe chilling injury on fruit stems; this was shown by significantly greater levels of fungal growth on stems during shelf-life. The high carbon dioxide concentrations found in unperforated packaging at 7°C were associated with surface pitting in our experiments; but pitting was also bad at 2°C. Sealed modified atmosphere packaging is too risky for capsicums, carrying the risk of excessive levels of carbon dioxide or moisture around the fruit.

We achieved satisfactory quality retention with red capsicums (cv. Spirit) in perforated packages or unlined cartons at 7°C and conclude that sea-freight of red capsicums to Japan is likely to be commercially viable. There will be a significant reject rate on arrival and good liaison with an importer will be required to make this strategy effective. Scale-up of this season's work to pallet- and container-loads next season is not going to be easy as there will be significant interactions between adjacent cartons. We shall investigate perforated pallet-wrapping as this is successfully used to sea-freight capsicums from Israel to the USA.

Significantly greater quality problems were found with yellow (cv. Fiesta) and orange (cv. Nairobi) capsicums. The chilling sensitivity of the green stem of yellow capsicums was very high, leading to massive fungal attack during shelf-life. The susceptibility of orange capsicums to storage rots generally meant quality was not satisfactory after simulated sea-freight. We conclude that commercial sea-freight of yellow or orange capsicums to Japan is less likely to be viable.

1.2 Nutrient retention

There are considerable differences between the specific carotenoid profiles of red, yellow and orange capsicums, as anticipated. The carotenoid content, and hence the Vitamin A-equivalent content, of red capsicums does not decrease during simulated sea-freight to Japan. Vitamin C is generally regarded as more sensitive to degradation after harvest. In red capsicums we found excellent retention of vitamin C during simulated sea-freight. Vitamin C content remained between 125 and 135 mg/100 g from receipt in Palmerston North to the end of the storage and shelf-life period. Nutrient retention does not appear to be a problem for red capsicums under good cold-storage conditions. In addition, we were interested to find that yellow capsicums had a lower vitamin C content after cold storage (89 mg/100 g) than orange or red capsicums harvested at the same time (137 mg/100 g and 125 mg/100 g respectively).

1.3 Pre-harvest factors

The direct application of calcium nitrate by spraying onto red capsicum fruit during their growing period reduced the incidence of storage rots during standard simulated sea-freight to Japan. This effect was seen in each of three harvests during the growing season. Unfortunately we found some problems with unsightly spotting of the green stems from this treatment. Next season we propose investigating alternative calcium spray formulations, the effects of whole-plant v. fruit-only application and the effects of different timings and frequency of applications.

Preliminary tests of the effects of regulated water deficit induced by salt application to the sawdust around solution-cultured plants did not show great promise. Solution conductivity could be significantly raised with rock salt (sodium chloride) or sodium sulphate, but not with gypsum or a combination of gypsum and rock salt. Rock salt proved to be damaging to capsicum plants and significantly reduced yields. Although we found slight positive effects of sodium salts on wall thickness, we do not consider this technology to have a realistic commercial future. Because it is inherently risky we would have proposed continuing this research only if there were large benefits seen in the first season's data.

2 Introduction

Successful commercial sea-freight of capsicums from New Zealand to Japan requires that fruit be kept in storage for around three weeks and still retain four to five days shelf-life. This is only possible with refrigerated storage but capsicums are generally regarded as chilling-sensitive. Fortunately, mature capsicums are much less chilling-sensitive than immature (green) capsicums, and the Japanese market requires only mature capsicums (primarily red and yellow varieties, but some orange).

We have used the best information available internationally to direct our research into the capacity of New Zealand capsicums to withstand sea-freight to Japan. Recent overseas research into sea-freight of capsicums has been primarily conducted in Holland and Israel (Ben-Yehoshua et al. 1998; Meir et al. 1995; Polderdijk et al. 1993; Rodov et al. 1995). The consensus in the published material is that mature capsicums can be stored for two to three weeks and retain four to five days of shelf-life at ambient temperatures, providing the humidity is not allowed to go too low (leading to water loss and shrivelling) or too high (leading to fruit rots).

The optimum temperature for capsicum storage is generally regarded as 7-8°C. Some reports demonstrate effective long-term storage at temperatures as low as 2-3°C under specialised conditions (Meir et al. 1995; Serrano et al. 1997). We, therefore, compared storage at 7°C and 2°C for each variety. Humidity can be modified either within sealed cartons (e.g. by the use of salt sachets) or by using perforated packaging in an externally controlled humidity environment. In the former situation, a modified atmosphere develops around the fruit. Research into modified atmosphere packaging (MAP) of capsicums has a long history but is inherently risky: unforeseen temperature increases can lead to anaerobism during transit. Nevertheless we investigated the use of salt sachets in sealed packages in case the technology showed great promise. The use of sealed packaging would have the advantage of making each package relatively independent of its neighbours, facilitating scale-up to the pallet or container level. We are aware of two companies who have trialled sea freight of capsicums from New Zealand to Japan in the last two seasons but are not privy to details of their quality in the market place. We also investigated proprietary packaging developed in Holland by Kappa Packaging and used by at least one exporter in New Zealand.

As consumers become more discriminating it will be necessary to show that products not only look good but are still good for you after the prolonged storage and handling period required for export by sea from New Zealand. The concentration of carotenoids, and hence Vitamin A equivalents, does not generally fall significantly during cold storage. Unfortunately Vitamin C is much more labile and can be rapidly lost from perishable fresh products. Our work included gathering some baseline comparisons of the levels of these nutrients in different varieties of capsicums, and analysing how the concentrations varied during cold storage and shelf-life.

Pre-harvest factors are very likely to contribute to post-harvest storage life. Anecdotal evidence to support this comes from market information. One exporter reported that a shipping container of New Zealand capsicums had boxes of the same cultivar from two different growers. The fruit from one source had much higher losses to rot than from the other, indicating that pre-harvest factors are indeed critical. This suggests it should be possible to modify the pre-harvest environment to optimise post-harvest storage. Apart from the obvious considerations of glasshouse hygiene and careful handling, one possible means of enhancing storage life of capsicums is to thicken the fruit wall through a regulated water stress. This can be achieved for plants grown in nutrient culture by using higher salt contents to exert an osmotic effect on plants.

Two other pre-harvest avenues that could lead to greater storage life involve fruit calcium. Its application to fruit may prolong fruit firmness or improve pathogen resistance. Research to reduce blossom end rot has included applying an anti-transpirant to foliage. In conditions of high evaporative demand this slows water loss and allows more opportunity for calcium to move from the roots to the fruit, instead of mostly to the transpiring leaves. The findings most relevant to storage and shelf-life were from Toivonen & Bowen (1999) who showed a positive effect of three calcium chloride sprays on firmness retention and post-harvest decay in their research on field-grown capsicums with r ch and tunnels. We chose to compare the effects of calcium nitrate and calcium chloride sprays applied to fruit only with an antitranspirant (VaporGard) applied to upper canopy leaves.

3 Methods

3.1 Cultivars

We worked with three cultivars of capsicum, Spirit (red), Fiesta (yellow) and Nairobi (orange), from two locations, Waiuku and Kaiapoi. Export-grade capsicums were freighted to us from commercial glasshouses. Two additional projects were covered by this contract: nutrient retention in stored capsicums (Grant Taylor) and pre-harvest factors affecting post-harvest storage (Rocky Renquist). For the latter, capsicums cv. Spirit were obtained from a commercial glasshouse in Hawke's Bay. At least two harvest periods were sampled for each cultivar, (a) Nov-Dec 1999 and (b) Jan-Mar 2000.

3.2 Storage trials

All storage trials were carried out for 21 days. Fruit were stored in duplicate groups of 8, 16 or 30, in bags or capsicum cartons, as specified below. Subsequent quality assessments were made during shelf-life at 20°C. Capsicum quality was assessed after 0, 3 and 5 days in open cardboard trays loosely covered with polythene sheeting. 'Standard' storage conditions were defined as perforated LDPE packaging stored at 7°C for 21 days, followed by 5 days at 20°C. The effect of varying the following parameters was assessed:

- temperature (2, 5 and 7°C);
- humidity (number of 5 g sodium chloride sachets per pack of 8 fruit, or controlled numbers of 6 mm diameter perforations);
- package material (low-density polyethylene (LDPE, 40 μm thick, JP Packaging, Levin), PeakFresh film (Carter Holt Harvey, Auckland), hydrangea MAP film (Convex Plastics, Hamilton);
- carton type (unlined conventional, lined conventional, unlined Kappa Packaging).

For controlling humidity with salt sachets, we followed the methods of Rodov et al. (1995). Sachets (5 g) of salt were prepared using a folded and stapled Tyvek pouch. In later experiments the pouches were sealed inside an Evolution Cloth (Kimberley Clark NZ Ltd, Auckland) bag; leaking saline solution was then trapped before it could reach the fruit.

Concentrations of CO_2 and O_2 inside bags were measured by gas chromatography. Duplicate 1 ml gas samples were taken by syringe through self-sealing injection tape. Temperature and relative humidity inside packs were recorded with dataloggers. Fruit weight and '% surface area still green' were recorded before and after storage and during shelf-life assessment. Trays of fruit were labelled by randomised treatment numbers during shelf-life assessment to avoid subconscious bias.

Quality was assessed during shelf-life by several evaluators using standardised quality assessment procedures. Simple scales were used, allowing individual fruit details to be recorded quickly and accurately, as follows:

- Stem mould: 0 = none, 1 = slight, 2 = moderate, 3 = severe.
- Fruit rot: 0 = none, 1 = slight, 2 = moderate, 3 = severe.
- Pitting: 0 = none, 1 = slight, 2 = moderate, 3 = severe.
- Shrivel: 0 = none, 1 = slight, 2 = moderate, 3 = severe.
- Firmness: 0 = firm, 1 = slightly soft, 2 = soft.

In all these scales, a score of 1 was detectable by our trained assessors, but a score of 2 was necessary before fruit were regarded as 'unsaleable'. Fruit assigned a score of 2 or more were termed 'rejects' for that particular quality attribute with the exception of fruit firmness, where the mean firmness score was recorded. Significant treatment effects were found in the first batch of fruit assessed, confirming the efficacy of the assessment process.

3.3 *Nutrient retention*

Red, yellow and orange capsicums from Kaiapoi were put into standard cold storage conditions. After storage, vitamin C and carotenoid contents of the fruit were measured to compare levels in the different varieties. Vitamin C and carotenoid contents of edible portions of red capsicums were also assessed before storage and after 5 days' shelf-life to determine losses during the simulated export process. Carotenoid profiles were determined by HPLC.

3.4 Pre-harvest factors

Pre-harvest influences on storage quality and shelf-life were examined through two glasshouse trials at Gerard Bennett's in Hawke's Bay. The nutrient solution recipe was from John White in Levin. In the Preliminary Trial 8 treatments were imposed (with 4 single plant replicates of each) on 13 October 1999. Three fruit or foliar treatments (VaporGard anti-transpirant, calcium nitrate and calcium chloride) were compared to a control treatment of water and surfactant. The other 4 treatments were salts (sodium sulfate, rock salt, gypsum, and a combination of rock salt and gypsum) at rates intended to create a moderate osmotic water stress on plants. These were mixed shallowly into the sawdust in the plant bags. Use of dry salts has the advantage of having a longer lasting effect than adding dissolved salt solution, but the only practical method to create osmotic water stress is to alter the nutrient solution with salts, which was not feasible for a trial within a commercial capsicum house.

The effect of the salts was monitored for two weeks by regular measurements of CF (the Conductivity Factor; CF of 1 = 10 milliSiemens). CF was measured in leachate collected by setting the grow bags in buckets for several hours (fertigation was applied every 1.5 hours during the day). Plant growth and fruit yield were measured and fruit from two of the nine harvests (#4, #9) were taken to Palmerston North for storage trials in standard conditions.

The Main Trial was begun on 18 November 1999 in a younger planting at Bennett's. This trial focused on 3 foliar treatments with 10 single plant replicates. The Control treatment was water plus surfactant applied with a hand sprayer to fruit only. VaporGard was applied twice, and only to leaves in the upper canopy. Calcium nitrate was applied to fruit weekly with surfactant (7 times total). Fruit were harvested weekly (6 times total) and fruit from 3 harvests (#1, #3, #4) were taken to Palmerston North for storage trials in standard conditions.

4 Results

4.1 Storage assessments

4.1.1 Quality losses

It is important to note that long-term storage of capsicums at low temperatures can lead to dramatic failures. Losses of up to 100% of capsicums were recorded in some treatments. In our experiments there were several distinct modes of capsicum deterioration. Storage conditions that alleviated some of these problems exacerbated others. We rated each of the following separately:

- **Stem moulds**: a number of fungal species including *Botrytis* produced extensive fungal growth over the green stem tissues. This problem was more evident in capsicums stored at lower temperatures. We presume chilling damage rendered the stem tissue more susceptible to fungal attack. Mycelial growth was generally minimal on removal from storage and increased dramatically during shelf-life.

- **Fruit rots**: bacterial and fungal rots of capsicums were generally not detectable on removal from storage but developed dramatically during shelf-life. Infection was worse in fruit stored at higher relative humidities or with free water touching the fruit. In general, fruit rots were less serious in fruit stored at 2°C than 7°C.
- **Surface pitting**: characteristic small, often elongated, discrete depressions on the fruit surface were found, particularly on red capsicums. This symptom appeared to increase with the CO_2 concentration inside the packs at 7°C, but seemed worse at lower humidities at 2°C; more than one condition may be being called 'pitting'.
- **Shrivel**: after extensive water loss, or in immature (green) regions of capsicum fruit where presumably the waxy surface layer was not fully developed, areas of the fruit surface became shrivelled and unsightly.
- **Loss of firmness**: even moderate water loss led over the period of shelf-life to fruit softening, detectable by hand. This was always more evident in fruit stored under lower humidity conditions or higher temperatures.

Although the inside of the capsicums was examined, no additional internal problems were detected that were not accompanied by external signs of deterioration.

4.1.2 *Modified atmosphere packaging*

Since salt sachets are effective only in sealed packages we evaluated a number of different packaging materials and checked the concentration of CO_2 and O_2 as an indication of gas permeability. Table 1 shows that we did not record O_2 concentrations below 8%, so anaerobism *per se* was not a problem. However, 40 •m-thick LDPE film bags allowed the development of quite high CO_2 concentrations. Respiration would have been faster at 7°C than 2°C, and the highest concentrations were, therefore, found at this temperature. Nairobi appeared to have a significantly faster respiration rate than the other varieties. The more permeable hydrangea film supplied by Convex plastics was effective in reducing the problem of CO_2 accumulation, particularly at 2°C. Fewer measurements were made with other films, but the Peakfresh film was clearly extremely permeable, giving essentially atmospheric concentrations. Interestingly, just folding a carrot carton liner over capsicum fruit was sufficient to allow detectable CO_2 accumulation.

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Spirit capsicums; it seemed to be less common in Nairobi and rare in Fiesta capsicums. In Spirit capsicums, pitting seemed worse with more salt sachets; this may have been caused by saline solution leaking out of the sachets and damaging the fruit surface. We were careful thereafter to wrap the sachets in Evolution cloth, which minimised the passage of liquid out of the sachets. At 2°C pitting seemed worse at lower humidities even when these were produced by perforations but at 7°C any perforations almost eliminated fruit pitting in Spirit and Nairobi capsicums. This may suggest that pitting is exacerbated by either very low temperatures or concentrations of CO_2 over 2%.

In a controlled comparison of Spirit capsicum storage in conventional and Dutch cartons, better quality was retained in the Dutch cartons (Table 2). This was consistent with a higher humidity being maintained in the Dutch boxes, leading to less water loss (Table 3).

Table 2: Quality attributes of Spirit capsicums (30 per carton) after three weeks' low-temperature storage and five days' shelf-life. Figures are reject rates (percentage of fruit moderately or seriously affected), unless otherwise stated.

	Storage temperature (°C)	Stem mould (%)	Fruit rot (%)	Surface pitting (%)	Shrivel (%)	Softness (arbitrary units)[1]
Conventional	7	27	5	5	62	1.5
boxes	5	23	10	3	57	1.3
Kappa	7	15	10	0	28	1.3
Packaging	5	42	13	0	12	1.6

[1] Softness was assessed by hand on a scale from 0 = firm, 1 = slightly soft, 2 = soft.

Table 3: Water loss and final quality of Spirit capsicums after three weeks' low-temperature storage and five days' shelf-life.

	Storage temperature (°C)	Water loss (%)	Acceptable fruit (%)
Conventional	7	9.3	25
boxes	5	9.0	23
	7	8.6	63
Kappa Packaging	5	7.6	52

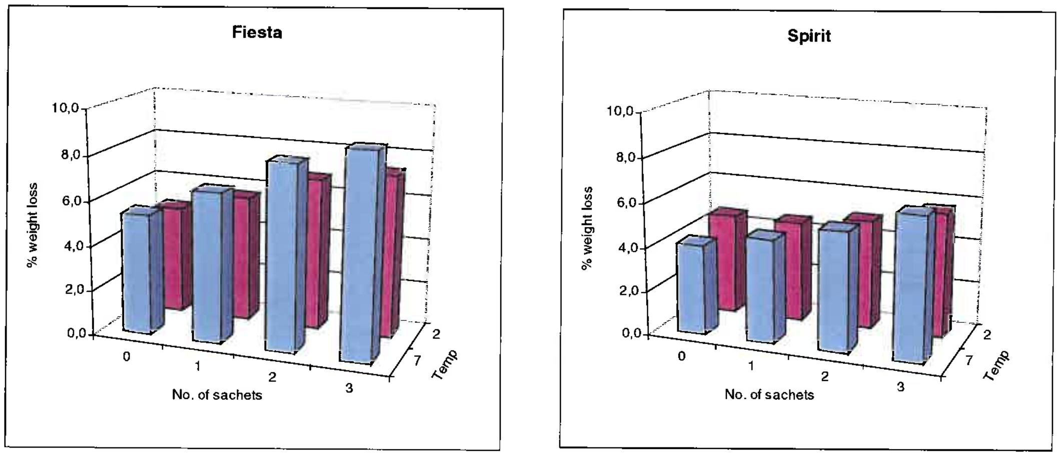


Figure 1: Effects of salt sachets and storage temperature on total weight loss of Fiesta and Spirit capsicums. Weight loss was calculated from the start of the storage period to the end of three weeks' and five days' shelf-life.

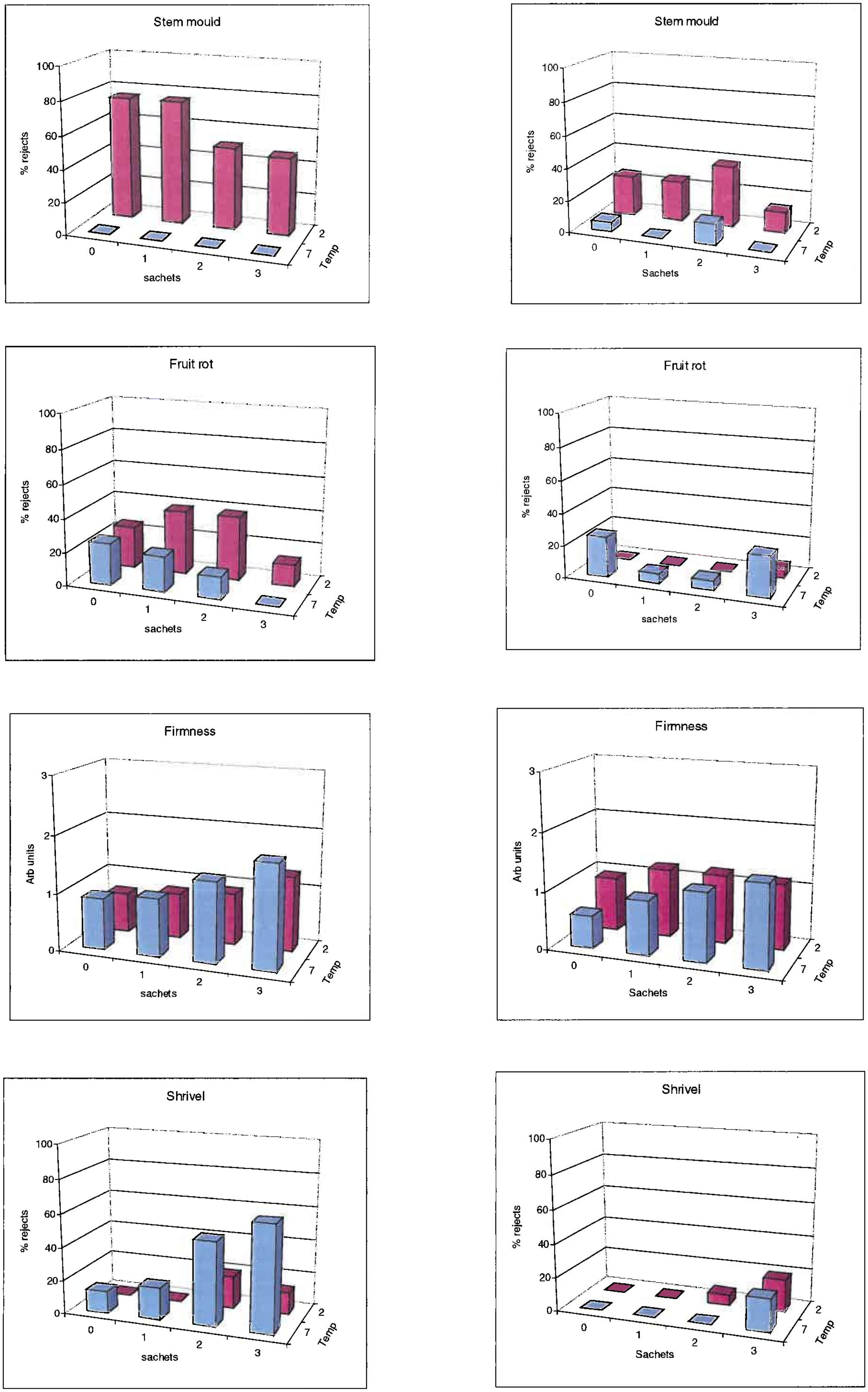
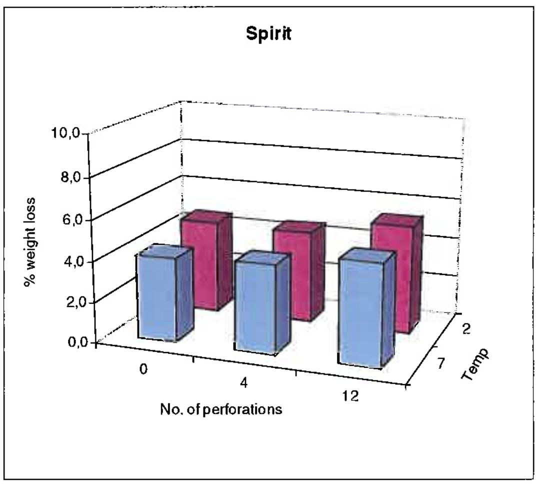


Figure 2: Effects of salt sachets and storage temperature on final quality attributes of (LH column) Fiesta and (RH column) Spirit capsicums, recorded after three weeks' storage and five days' shelf-life.



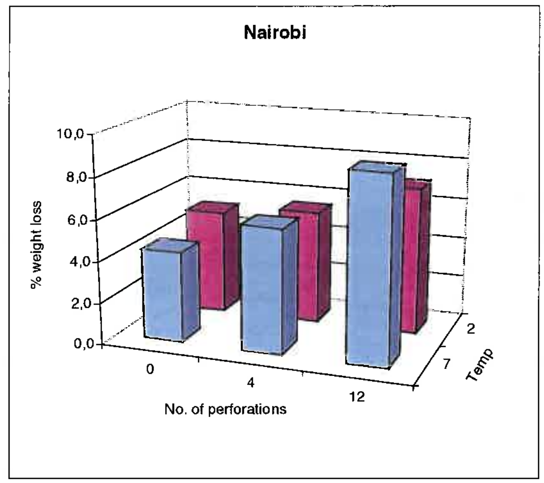


Figure 3: Effects of perforation density and storage temperature on total weight loss in Spirit and Nairobi capsicums. Weight loss was calculated from the start of the storage period to the end of three weeks' storage and five days' shelf-life.

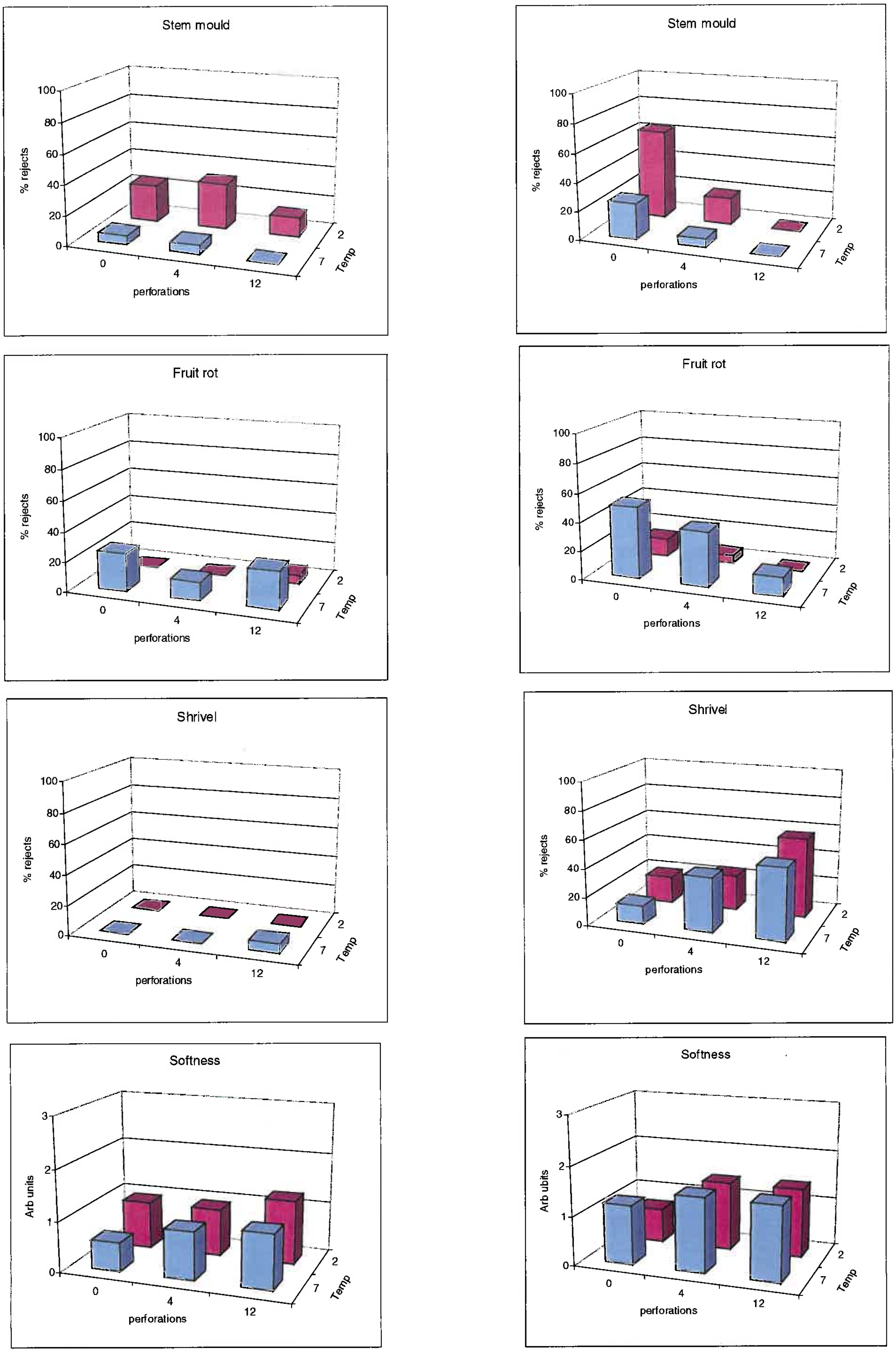


Figure 4: Effects of perforation density and storage temperature on final fruit quality attributes of (LH column) Spirit and (RH column) Nairobi capsicums, recorded after three weeks' storage and five days' shelf-life.

4.1.4 *Colour development*

Storage at 2°C slowed colour development. Fiesta capsicums were particularly affected by this since they were harvested slightly greener than the other varieties. These green areas were noticeably associated with shrivel, perhaps because they lacked the natural waxes which accumulate at maturity.

4.2 *Nutrient retention*

The storage method did not alter the carotenoid composition; both the types and amounts of carotenoids remained similar during storage. The profiles of carotenoids were different for the different varieties as expected.

After storage, there appeared to be a higher concentration of vitamin C in orange and red capsicums (137 mg/100 g and 125 mg/100 g respectively) than in yellow capsicums (89 mg/100 g).

Red capsicums retained unchanged contents of vitamin C throughout the experiment: 126 mg/100 g before storage, 125 mg/100 g after storage, 133 mg/100 g at the end of shelf-life.

4.3 *Pre-harvest factors*

4.3.1 *Preliminary trial*

The CF level in Control plants (nutrient solution only) was below 20 (see Table 4). The only salt treatments which elevated the CF noticeably were sodium sulfate and rock salt, despite periodic top watering of bags to dissolve and leach salts. Rock salt had the largest effect (CF=50 on day 1 and 30 after 2 weeks). CF was similar to the Control level after two weeks in the bags with other salts. Most salt treatments had no visual effect on plant growth, but 2 of the 4 plants with rock salt showed immediate wilting followed by badly burned foliage and they stopped growing. The salt effects on fruit number and yield were not significant for 3 of the 4 salts, but yield was reduced to 25% by the rock salt.

Foliar treatments had fairly small effects on fruit yield. Plants with both calcium nitrate and chloride had slightly larger fruit. VaporGard also appeared to increase yield, but caution should always be exercised with conclusions based on only a few replicate plants. Neither calcium nor VaporGard gave a fruiting benefit in the better replicated Main trial (see below). The effectiveness of the VaporGard was also investigated by measuring transpiration from leaves with a LICOR porometer. No reduction in transpiration was found, suggesting that the product, as used in this trial, did not have the intended effect.

The storage experiment with Preliminary Trial fruit found surprisingly few treatment effects at the end of the 5-day shelf-life test period. The sodium chloride (rock salt) negative effect on fruit number and size was confirmed. Gypsum, which was expected to be less detrimental, lowered fruit firmness and may have increased fruit rot. There was a reduction in fruit rot with calcium sprays, which supports the more definite conclusion in the Main Trial.

Fruit wall thickness was not different between treatments in the first storage experiment (SE#1 on Preliminary Trial harvest #4), but in the experiment with the final fruit harvest (#9) the Control fruit were smaller and their walls were thinner than the earlier trial. In this case, wall thickness was greater with calcium chloride sprays and with sodium sulfate, but probably only because larger fruit usually have thicker walls. If there were other effects they may have been obscured by the low number of replicate plants used.

Table 4: Effects of foliar sprays or grow-bag salt treatments on Spirit capsicums in the preliminary trial.

Treatment	Leachate conductivity CF (10 x mS)	Prelim harvests #4-8	
		No. fruit per plant	Fruit weight (g)
Water	16.2	8.3	175.6
VapGard 3x		9.5	180.5
Cal.nitrate		9.3	178.3
Cal.chloride		9.3	165.7
Sod.sulfate	29.9	8.0	175.1
Sod.chloride	50.2	3.8	85.5
VapGard 2x		12.3	170.8
NaCl+gypsum	22.2	9.0	161.3
Gypsum	20.8	10.0	164.7

4.3.2 *Main trial*

There was no effect of VaporGard or calcium nitrate treatments on fruit number or size (see Table 5). The focus will, therefore, be on the results of the three simulated sea-freight trials in Palmerston North. Fruit were rated for several conditions The evaluations were divided into storage life (after 21 days at 7°C) and shelf-life (after 5 more days at 20 °C).

Table 5: Effects of calcium or anti-transpirant sprays on Spirit fruit yield parameters.

Treatment	Main trial harvests #1-6	
	No. fruit	Avg wt
Water	13.1	188.2
Calcium	13.5	192.0
VaporGard	12.8	190.9

4.3.3 *Storage life*

1. Stem and cap black spots

One disorder that was often seen in fruit coming out of storage was the presence of black spots on the stems and caps. These had some characteristics of a cool temperature mould, since incidence was highest immediately after storage at 7°C and seemed to decrease at 20°C. In the first two storage experiments (SE1 and SE2) there were fewer black spots in the VaporGard treatment (where fruit were not wetted) than on fruit with the water/surfactant control or calcium nitrate/surfactant spray treatments.

However, in SE3 the condition also occurred in the un-wetted fruit (VaporGard).

2. Pitting

The rating for pitting may have included two visibly similar conditions with different causes. In the glasshouse it appeared that black spots or pits occurred at the low point on fruit where sprays accumulated and dripped off, suggesting a toxicity from calcium nitrate or surfactant. Only the results of SE3 (after storage, but not later) offered any support for this impression, however. Some pitting consistent with chill injury was also present in SE2, and calcium may have reduced its incidence slightly.

4.3.4 *Shelf-life*

1. Fruit rot

The results of all three storage experiments (SE1, SE2, SE3) with fruit from the well replicated Main Trial were consistent regarding post-harvest fruit rot. The percent of fruit with bad rot was reduced by weekly calcium nitrate sprays (to the fruit only). In SE1 rot was 19% v. 29-30%, in SE2 17% v. 67-90%, and in SE3 (at evaluation 2) it was 5% v. 41-42%. This supports the finding of Toivonen & Bowen (1999) using calcium chloride. For SE2 and SE3 some fruit rot and calcium benefits were already present after 7°C storage.

2. Stem mould

Stem mould evaluations showed a beneficial effect of calcium in SE1, but the two later storage experiments were quite different. In these, the effect of both calcium sprays and the water/surfactant sprays was to increase stem mould greatly over the un-wetted fruit of the VaporGard treatment.

3. Fruit firmness retention

Firmness stayed reasonably good in all treatments and no effect of calcium was apparent. There was a tendency for VaporGard to reduce firmness in SE2, as it did in the Preliminary Trial.

4. Wall thickness

Wall thickness was not increased by treatments in these well replicated trials, even though calcium chloride sprays have recently been reported to do so in field capsicums in Canada (Toivonen & Bowen 1999). Calcium nitrate was used in this trial and was not applied to foliage, so it is possible that the benefit reported in Canada was due to a combination of the positive effect of calcium and the stress effect of chloride on foliage.

5 Discussion and conclusions

5.1 Sea-freight potential of capsicum

Some general and some specific conclusions are possible from this first season's work. In general, we have shown that yellow (Fiesta) capsicums are very prone to stem mould and moderately sensitive to fruit rots. They lose more water than the other varieties tested and are liable to shrivel. Fruit losses were generally severe under all conditions tested.

Orange (Nairobi) capsicums are also very prone to stem mould and fruit rots. They show a high respiration rate and can suffer from pitting. The fruit are generally softer than the other varieties tested. Fruit losses were generally severe under all conditions tested.

Red (Spirit) capsicums can suffer from stem mould and fruit rots and also surface pitting. They generally lose less water in storage, retain firmness and show very little shrivel. They have the best potential for sea-freight of the varieties we tested.

There were large differences between fruit from the different districts and harvest times, but we cannot draw definite conclusions yet about the overriding reasons for this. We propose examining seasonal effects carefully next year; indications are that capsicums harvested before Christmas may be more suited to long-term storage, which is in line with anecdotal comments received during the project.

It should be possible to achieve acceptable storage conditions for red capsicums, although these fruit have a very narrow band of tolerance to storage conditions. Ideal conditions described in the literature are: storage temperature 7-8°C, 92-95% RH, CO_2 concentration <3%. Our data confirm that these should be achievable in perforated packaging.

We did not find a suitable range of environmental conditions to permit adequate retention of shelf-life in yellow or orange capsicums and do not currently recommend commercial sea-freight of these varieties.

Theoretically, achieving these environmental parameters in refrigerated storage is possible with either the use of perforated plastic liners or highly gas-permeable modified atmosphere packaging containing desiccant salts. The benefit of the latter would have been that each carton could have been treated more or less as an individual entity, relatively protected from the external environment and with its internal humidity modified by salt. In practice we found this was too demanding for routine use and we recommend unsealed packaging and the maintenance of a high external humidity.

Securing adequate storage in small, carefully controlled packs is one thing, but scale-up to carton-, pallet- and container-loads brings a further set of issues. We have evaluated some Dutch packaging, Kappa Packaging, kindly provided by Pacific Harvest for research purposes. This packaging has been promoted in the trade media. There is some scepticism in the international research community as the packaging has only minor modifications over conventional boxes: better aeration, much stronger corners, slightly smaller volume. These structural changes would make the boxes perform well under cold, humidified conditions. However, capsicums did store better in these boxes than in regular capsicum boxes during low-temperature storage. Optimum storage requires an optimised environment around the boxes and the second season's work will focus on carton-, pallet- and container-scale tests, which we hope will be carried out with the collaboration of commercial partners to enable the costs to be minimised. Julian Heyes was in Israel in April and spoke to Elazar Fallik, who is an experienced researcher in this field. Whole-pallet perforated plastic wrapping is used to send red capsicums from Israel to USA by sea at 7-8°C. During the course of the discussions, Elazar strongly recommended his own specialised technology, hot water brushing, as a means of reducing disease load on capsicum fruit and improving their survival during storage (possibly by smearing the natural fruit surface waxes over minute cracks in the fruit surface). He finds that the storage temperature can be safely reduced to 6°C after this treatment, which reduces water loss and storage rots. The situation is slightly complicated as he has been in discussion with another New Zealand researcher about licensing this technology in New Zealand. We are in contact with this New Zealand collaborator and it does not seem that they will proceed with an application. Crop & Food Research can make further enquiries about this technology if VegFed is interested. It is unlikely to be of practical value immediately as the equipment would come at a considerable capital cost, but it is important to look to the future.

5.2 *Nutrient retention*

The carotenoid profiles seen were characteristic for the different varieties. We were not surprised to find little change in these during storage and shelf-life. What was more striking was the excellent retention of Vitamin C during storage and shelf-life. This is in marked contrast to our own earlier work with (highly perishable) fresh peas. The lower Vitamin C content in yellow capsicums was interesting.

5.3 *Pre-harvest factors*

Findings with the use of salts in the Preliminary Trial, even though not highly replicated, do not offer great promise for improving storage or shelf-life of capsicums by inducing plant water stress with salts in the root medium. Since the commercial scale logistics of such a practice were known to be tricky at the outset, treatments would have to look very positive to warrant further research investment.

In contrast, there are some promising results with calcium sprays which are well worth pursuing. Comparisons should include: the calcium formulations; the effect of spraying the whole plant v. just the fruit; and spray timing and frequency.

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