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Simulated sea-freight of capsicums to Japan

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

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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
Box 85, Hastings, New Zealand

Contents

1 Executive summary

This interim report describes results of a land-based trial aimed at simulating palletized sea-freight transport of capsicums to Japan. We stored two cultivars of export red capsicums from six leading growers for three weeks at 7-8°C and 90-95% RH (relative humidity) in November-December 2000. Capsicums were stored in two different types of carton in separate 'mini-pallets' in a cool-room held at low humidity (range 80-82% RH) and with considerable air movement to simulate a reefer container. Each pallet was covered in a perforated polyethylene shroud to modify humidity. The two types of carton were a Dutch 'QuaMa' box and a standard airfreight carton. After the storage period, capsicums were held in their cartons at 20°C for 3 days for shelf-life assessment. One grower's capsicums were held for 8 days before shelf-life assessment.

Capsicums generally stored well with a three day shelf-life except for shrivel symptoms on some fruit. There were no chilling injury symptoms. Shrivel symptoms were common at the end of storage suggesting excessive moisture loss, although some growers' capsicums showed no symptoms. Moisture loss rates in storage were no higher than in previous trials, suggesting that additional moisture loss had occurred after harvest and before storage (i.e. during transport to Palmerston North). We believe shrivel can be managed in practice.

Rot incidence on fruit and mould growth on stems were generally low but one grower's fruit had a high incidence of stem mould, suggesting a hygiene problem.

Our data showed that the type of carton was not important during storage, despite the different permeabilities of the cartons. We believe this indicates the usefulness of the perforated shroud in maintaining a higher humidity around the cartons. Certainly there was more water loss from fruit in conventional cartons than in QuaMa cartons during shelf-life, without the benefit of the perforated shroud. Despite the lack of difference between carton types, the cartons chosen for sea freight will need to be physically strong to cope with stacking for extended periods at high humidities.

Our simulated reefer container conditions may have been severe in terms of airflow and relative humidity. We plan to monitor capsicum quality as well as RH and water loss from fruit inside a sea-freight container during a shipment to Japan next season.

2 Recommendations

- Capsicums intended for sea freight must be of high quality and need careful attention throughout the pre- and post-harvest period.
- Attention needs to be paid to the size and variety of fruit. In our trial, cv. Special fruit of around 170 g size (approx. 30 count) performed best.
- Good hygiene is recommended before and during harvest, as is prompt cooling to 8°C after harvest, with minimal opportunity for weight loss.
- The use of a perforated pallet shroud to reduce water loss from the fruit during transport at 8°C is strongly recommended.
- The type of carton used inside the perforated shroud does not appear to be critical as long as it is physically strong enough for stacking at high humidity.
- Humidity outside the pallet shroud should preferably be kept higher than in this study.
- Pre-harvest calcium supplementation suitable for blossom end rot control may help reduce post-harvest rots.
- Storage of capsicums for three weeks is possible, with excellent retention of shelf-life and vitamin content. As a guide, water loss during three weeks storage at 8°C should be around 4%.
- Storage at 7-8°C and 92-95% RH is recommended.
- We recommend that a trial shipment to Japan be undertaken in 2001-02 season to implement and test recommendations made in this report.

3 Introduction

Successful commercial sea-freight of capsicums from New Zealand to Japan requires that fruit is kept in storage for around three weeks while still retaining 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 become too low (leading to water loss and shrivelling) or too high (leading to fruit rots).

We are aware of two companies that have trialled sea freight of capsicums from New Zealand to Japan in the last two seasons but are not privy to details of the quality of their products in the market place. We also have obtained proprietary packaging developed in Holland by Kappa Packaging and used by at least one exporter in New Zealand.

Last season's laboratory-scale research showed that:

- red capsicums (cv. Spirit) stored much better than yellow (cv. Fiesta) or orange (cv. Nairobi) capsicums,
- 7-8°C was a better storage temperature than 2°C,
- there is a narrow range of preferred humidity (90-95%), and
- storage performance of the same cultivar varied over the season and between growers.

The research gave us confidence to proceed to larger scale trials in 2000-01. We achieved satisfactory quality retention with red capsicums (cv. Spirit) in perforated packages or unlined cartons at 7°C and concluded that sea-freight of red capsicums to Japan is likely to be commercially viable.

We planned to scale up this work to pallet- and container-loads in 2001. It was, however, only possible to carry out the planned pallet trials as market conditions did not allow a commercial container trial to proceed. High domestic (NZ) prices and a heavily-supplied Japanese market meant that there were no opportunities to send a trial sea shipment in 2001. We now plan to carry out this trial in 2002. This report, an interim one, covers the pallet trial carried out at the Food Industry Science Centre, Crop & Food Research, Palmerston North.

The pallet trial used red capsicums (cvs. Spirit and Special) supplied by six growers. Conventional capsicum packaging for airfreight was compared to proprietary Dutch packaging, designed for long-term storage (i.e. sea-freight) of capsicums. To modify storage humidity we worked with Massey University (Dr D Tanner) to develop a suitable perforated polyethylene pallet shroud, based on the Israeli approach (E. Fallik, pers. comm.).

This report also covers continuing work on the impact of pre-harvest factors on post-harvest performance. Anecdotal evidence from exporters and our own data last season suggest a significant grower effect in the post-harvest performance of fruit of the same variety. In the first year of this project we reported on the effect on storage life of supplemental calcium (sprayed on fruit). The principal effect was on reducing fruit rot, which was lower in the calcium-treated fruit in three different storage trials. Confirming this result in a larger experiment this season may also address the objective of including the calcium effect on quality in a model of environmental and management influences on fruit production and storage quality.

Finally, we address a question, which is increasingly voiced, "Just because fruit and vegetables look good after storage, are we sure they are still good for us?" Last year we monitored vitamin C and carotenoid (vitamin A) contents in capsicums during the post-harvest period. This year we repeated the vitamin C measurements, as this is regarded as one of the more labile vitamins after harvest. We also measured vitamin E for the first time, completing the three major antioxidant vitamins (Stahl & Sies 1996).

4 Methods

4.1 Pallet trial: Capsicums

We worked with six growers to set up a simulated capsicum sea-freight evaluation in the cool-store at the Food Industry Science Centre, Crop & Food Research, Palmerston North. Each grower supplied up to ten 5 kg cartons of fruit for storage, sending fruit of one cultivar, either Spirit or Special. Fruit were harvested on dates to suit each grower between 12 and 15 November, 2000. Fruit were trucked or couriered without refrigeration to Palmerston North and, on arrival, placed in storage at 8°C.

4.2 Pallet trial: Packaging

We compared two types of packaging. Conventional corrugated cardboard airfreight double cartons were compared with solid cardboard Quama cartons with lids. The latter have been designed by a Dutch firm, Kappa Packaging.

We set up two 'mini-pallets' to compare packaging systems. Each mini-pallet held thirty 5 kg cartons of capsicums (plus another 6-10 empty cartons) in four layers on a 1 m x 1.2 m pallet base. The conventional cartons were set up with nine full cartons per layer for the top three layers and three full cartons and six empty cartons on the bottom layer. The QuaMa cartons were set up with ten full cartons per layer for the top three layers and empty cartons for the bottom layer. The layout of the Quama cartons created a 'chimney' (free space) in the middle of each layer. A 1.2 m x 1.4 m LDPE sheet was placed between the pallet base and the cartons.

Fresh Technologies (Massey University) provided perforated LDPE pallet shrouds for the trial. The shrouds had 0.98% perforations (diameter 2 mm) on the sides but not the top. The shrouds were sealed to the sheet covering the base using 50 mm wide adhesive tape. Under the high air flows in our store (2 m/sec over top of mini-pallet) we found the shrouds tended to 'billow' so we prevented this by weighting down the top of the pallet with collapsed cartons.

4.3 Pallet trial: Storage

The mini-pallets were placed in a cool-room held at 8°C and 80% relative humidity. Mini-pallets were stored for three weeks.

We used Tinytag Ultra electronic loggers to monitor temperature and humidity during the trial. Loggers were placed in the following positions:

1. Cool-room
2. Conventional packaging, inside carton on top layer
3. Conventional packaging, inside carton on bottom layer
4. Quama packaging, inside carton on top layer
5. Quama packaging, inside carton on bottom layer
6. Quama pallet, in central free space, sitting on pallet base sheet

Subsequent quality assessments were made during shelf-life at 20°C. Capsicum quality was assessed after 0 and 3 days shelf-life in the storage cartons loosely covered with polythene sheeting. Fruit from one grower was also assessed after a further 5 days' shelf-life. Fruit weight was recorded before and after storage and during shelf-life assessment. Cartons 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.
- Shrivel: 0 = none, 1 = slight, 2 = moderate, 3 = severe.

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 and the total number of acceptable fruit was also recorded for each carton

4.4 *Pre-harvest calcium supplementation*

The influence of pre-harvest calcium applications on storage quality and shelf life were examined in a glasshouse trial at Gerard Bennett's in Hawke's Bay. Plants of the red capsicum cv. Spirit were transplanted into sawdust-filled bags on 8 August 2000, trained to two main stems, and the first harvest of green fruit was on 10 October. Seven harvests of green fruit occurred before the calcium trial began on 17 November 2000.

Since the previous year's trial used reagent calcium nitrate plus surfactant, applied to fruit only, the focus this year was on a more commercial treatment. The product Wuxal Suspension Calcium was applied to both fruit and foliage by hand sprayer. The product has an analysis of 10% total N and 15% Ca (from calcium nitrate) plus 2% magnesium and chelated micronutrients. It has a pH of 6.5 and a density of 1.6 g/ml. The New Zealand distributor of Wuxal, Veg-Gro Supplies, usually recommends a spray concentration of 0.3% for spray intervals of 7-10 days. The primary use is to prevent blossom end rot.

Several pea sized fruit were tagged on the first application date, to follow development. Fruit were harvested weekly at full red stage. When the harvested lot contained tagged fruit (5 January 2001), the lot was taken to Palmerston North for the storage and shelf life trial. Ripening of tagged fruit continued until the next harvest,11 January 2001, so a second set of fruit was also evaluated. They were stored for three weeks in perforated polythene bags at 8°C followed by 5 days shelf-life at 20°C in open trays loosely covered with a plastic sheet. Measurements at the three times of evaluation (before storage, after storage and after shelf-life) included fruit weight loss, stem mould, fruit rot, firmness, shrivel and fruit wall thickness.

The experimental design allowed regression analysis of the results, so that the effects of the calcium treatment could be quantified and incorporated into a model of capsicum growth and storage quality. This required at least 10 rates of total applied calcium. Since capsicum fruit usually only take 6 weeks to grow and ripen in typical December temperatures, 2 sprays per week were applied in order to fit in 11 applications. The Wuxal specialist recommended a 0.2% concentration in this case. There were 48 plants used, with 12 treatments applied to an average of 4 plants each. Five plants were used for each of the mid range of calcium treatments (4, 5 and 6 sprays), to better define this range, and only 3 plants for the treatments at either end (0, 1 and 11). The experimental design involved spraying all but the three 0 rate calcium plants on date #1, all but the 0 and 1 spray plants on date #2, etc., until the last treatment had 11 applications of calcium on the last 3 plants. Plants not treated with calcium were sprayed with distilled water each time.

4.5 Vitamin retention

Four varieties of capsicums (reds: Special and Spirit; orange: Nairobi; and yellow: Fiesta) were purchased from a total of three different growers in late February and stored in perforated polythene bags at 8°C for three weeks (measured RH in cool store = 97%), followed by five days of shelf-life at 20°C in open trays loosely covered with a plastic sheet. Quality parameters and vitamins C and E (total tocopherols) were measured at each interval (before storage, after storage, after shelf-life). Vitamin analyses were carried out by AgriQuality.

5 Results

5.1 Storage assessments

5.1.1 Storage conditions

Data loggers confirmed that the cool store was maintained at 7.6-8.0°C after an initial equilibration period and the temperature inside the cartons was identical (Figs 1 and 2). The cool store humidity was in the range of 80-82% RH, but inside the cartons and the central air space in the QuaMa pallet the humidity was 90-95% RH (Figs 1 and 2).

5.1.2 Weight losses

During three weeks of storage in a shrouded pallet, capsicums lost an average of 4.8% of their weight through water loss in QuaMa boxes, and

4.4% of weight in standard boxes (not significantly different). During shelf-life at 20°C, the QuaMa boxes were significantly better at reducing water loss: capsicums lost only a further 0.8% of weight compared with 1.6% in standard boxes. These differences add up to a total weight loss on a 5 kg box of 281 g in QuaMa boxes and 301 g in standard boxes.

Fruit from some growers lost more water than from others, which may relate both to the size of the fruit and the variety. Initial fruit sizes are shown in Table 1. The small Special fruit lost most water (5.3%) and the larger Spirit fruit particularly for (growers 4 and 5) also showed a high weight loss (5.2 %). The fruit from grower 5 were noticeably softer before storage, suggesting variation in weight loss before arrival. Moderate-sized fruit (166-199 g) from growers 1 (cv. Special), 3 and 6 (cv. Spirit) lost only 4.2 - 4.3% weight. There was no significant difference between the weight losses during shelf-life of fruit from different growers; each grower's fruit lost a further 1% of weight.

Table 1. Details of fruit supplied for pallet trial on receipt in Palmerston North (i.e. before storage).

Grower	Variety	Mean Fruit weight (g)
1	Special	166
2	Special	128
3	Spirit	182
4	Spirit	219
5	Spirit	217
6	Spirit	199
	LSD 5%	9

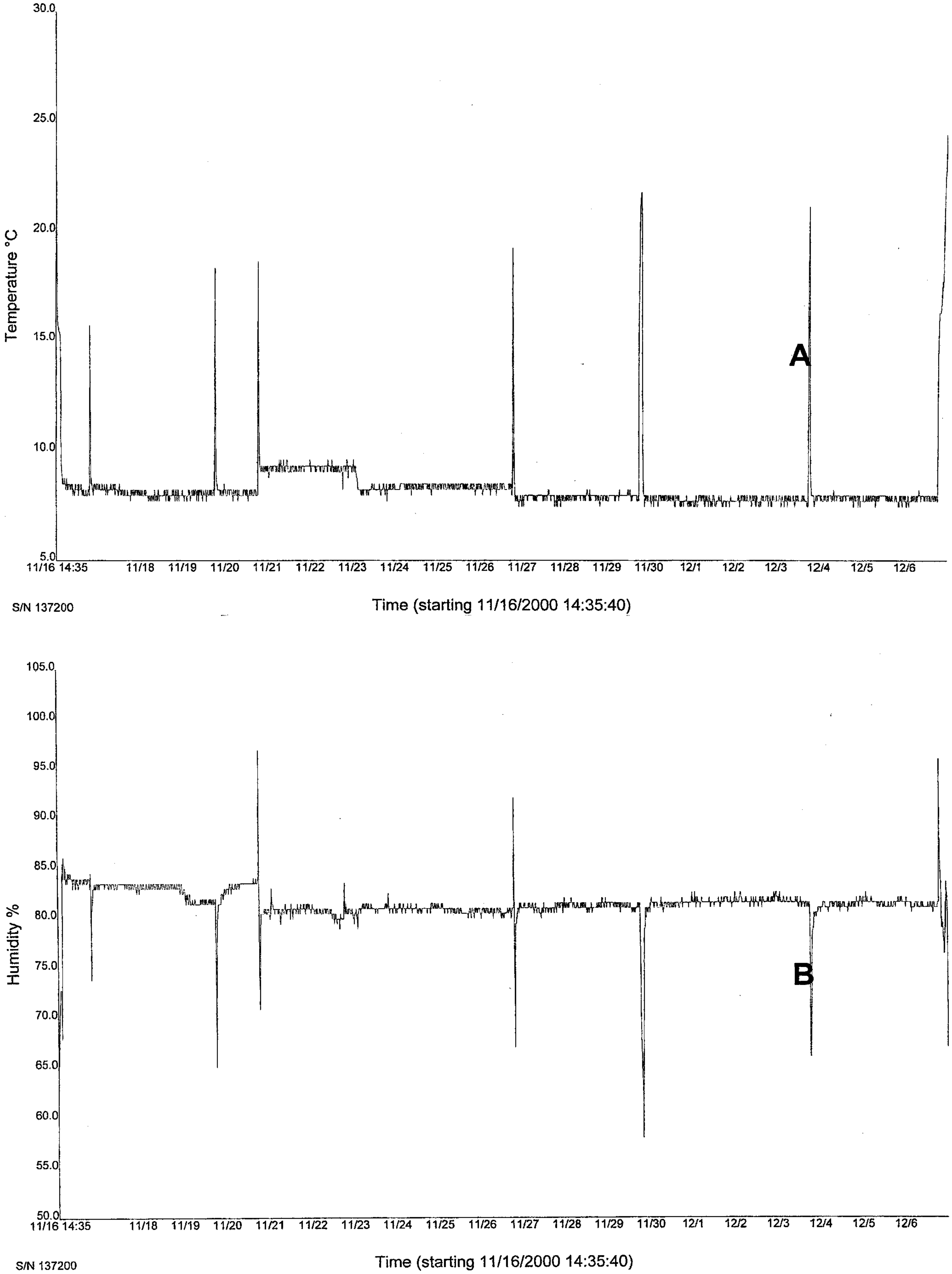
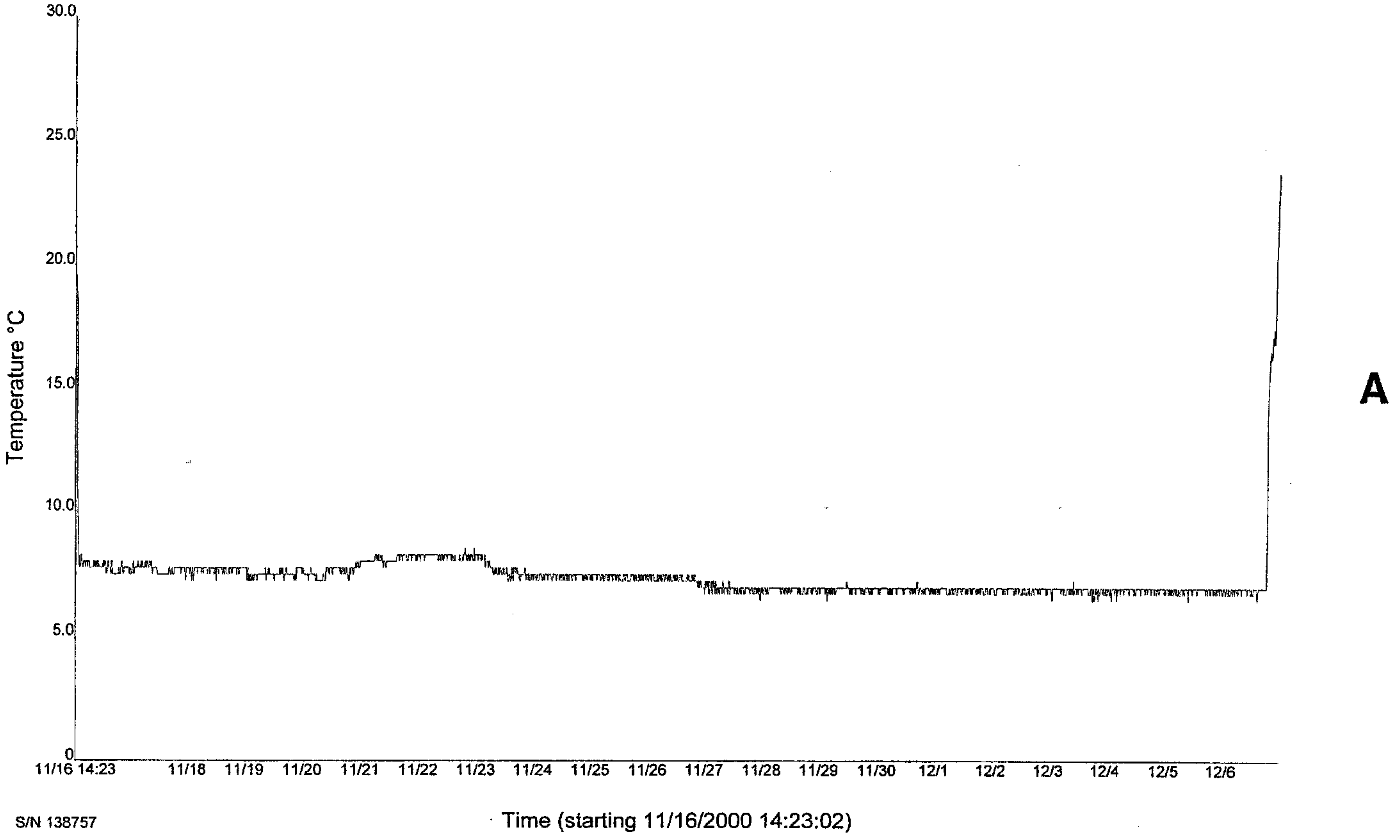


Figure 1. Temperature (A) and relative humidity (B) in storeroom for capsicum storage trial, 16/11/00 to 7/12/00.



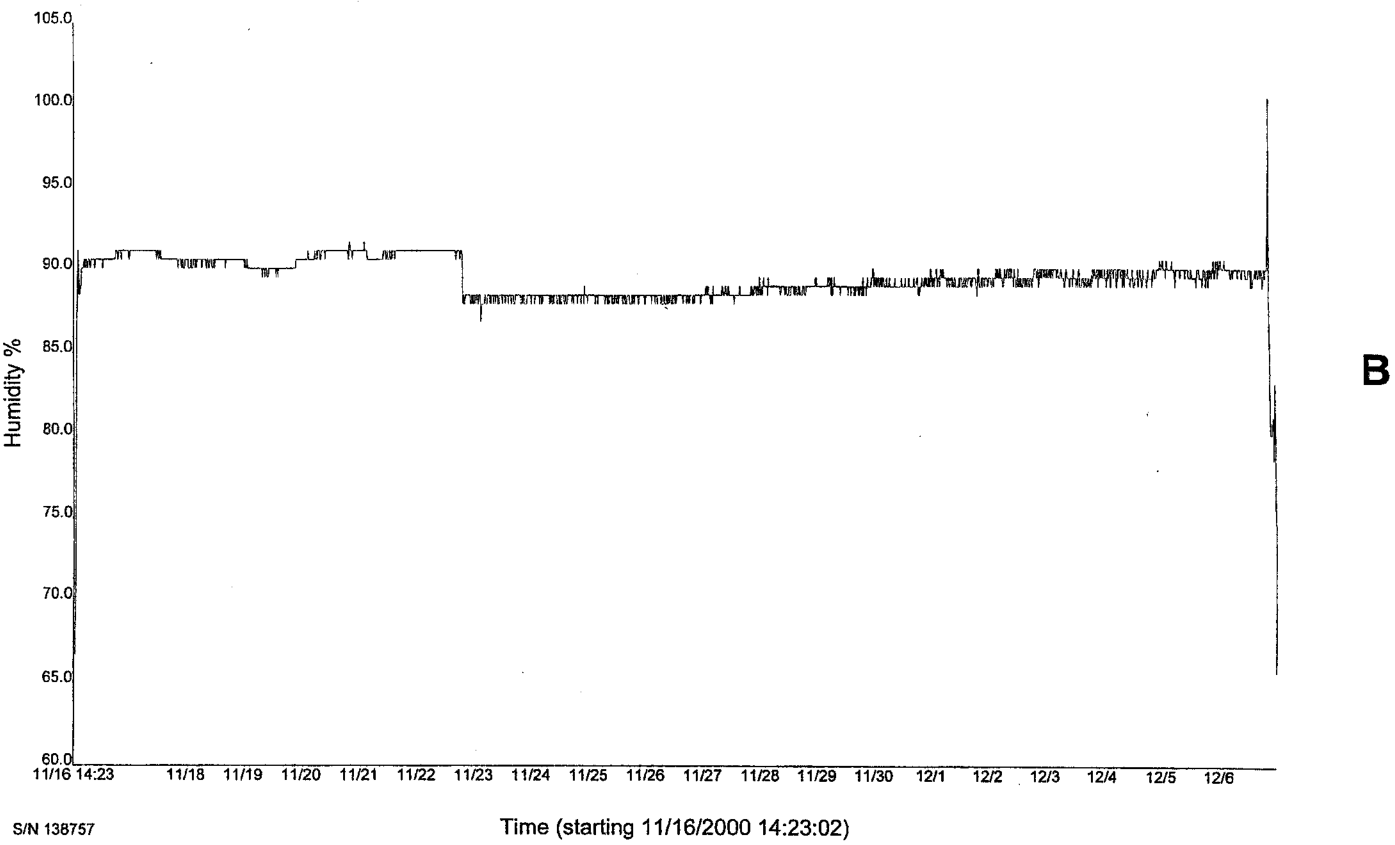


Figure 2. Temperature (A) and relative humidity (B) amongst capsicums during storage inside a QuaMa carton on the top layer of a mini-pallet covered with a perforated plastic shroud, 16/11/00 to 7/12/00.

5.1.3 *Quality losses during storage*

The overall percentage of acceptable fruit after storage did not depend on the box type; and nor did any of the individual quality parameters discussed below. However, the fruit from different growers did vary significantly. Grower no. 1 achieved 91.4% acceptable fruit after storage (cv. Special) while grower no. 5 managed only 22.9% acceptable fruit (cv. Spirit). This was not exclusively an effect of cultivar: one Spirit grower's fruit stored acceptably (76.9% acceptable fruit), and the small Special fruit from another grower did not store so well (63.3% acceptable); see Fig. 3.

- **Shrivel**

Shrivel was the major path of deterioration for almost all growers. Interestingly, only 2.6% of Grower 1's fruit showed shrivel after storage, showing that it was possible for high quality fruit to store well. Other growers' fruit had from 21-76% of fruit unacceptable because of shrivel on removal from storage (Fig. 4).

- **Stem moulds**

Stem moulds were found generally at low frequency in fruit from all growers (1-5% of fruit), with the exception of grower 4, where an average of 17% fruit showed stem moulds (Fig. 5). Because of the low and variable frequency of stem moulds, generalized linear mixed models (Genstat) were used to determine if there was any difference between the carton type during storage and shelf-life, working with data converted to a simple 'presence/absence' of stem mould per carton. There was no evidence for a carton effect (Table 2).

Table 2. Generalized linear mixed models analysis of the effect of carton type on the presence or absence of significant stem moulds or fruit rots in capsicums. Figures are percentage of boxes with any fruit rejected because of stem moulds or fruit rots. The carton type does not have a significant influence on the presence of stem moulds or fruit rots (P>0.10).

Carton type	During storage		During shelf-life	
	Stem mould	Fruit rot	Stem mould	Fruit rot
Conventional	48%	28%	30%	30%
QuaMa	42%	12%	39%	30%

- **Fruit rots**

Very few fruit showed surface rots after storage, with the exception of grower 2 who had the small cv. Special fruit. Of these fruit 6.1% showed rots after storage, compared with 1% or fewer for the other growers (Fig. 6). Although the inside of the capsicums was examined, no additional internal problems were detected that were not accompanied by external signs of deterioration. Generalized linear mixed models analysis showed no evidence for a carton effect on fruit rots in storage or during shelf-life (Table 2).

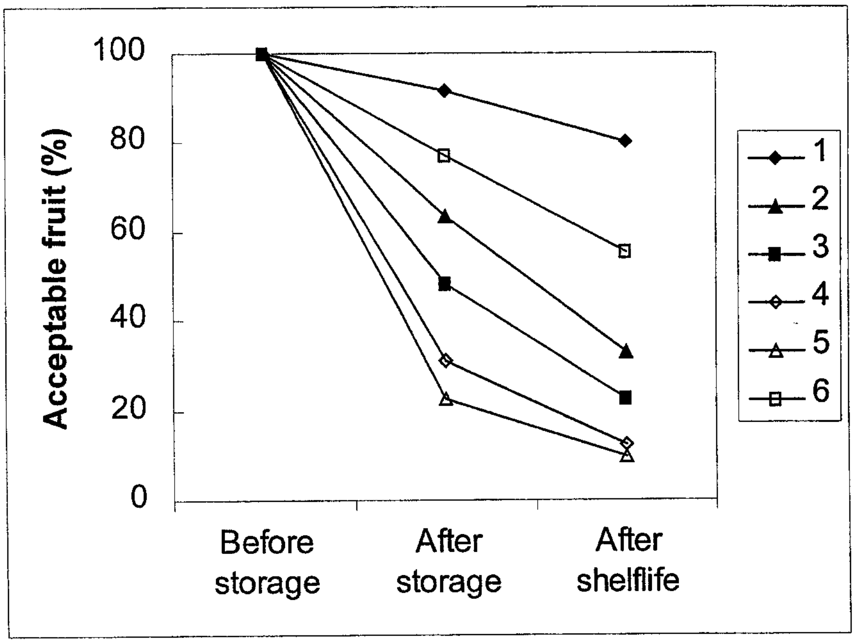


Figure 3. Overall quality loss in pallet trial during three weeks' storage at 8°C followed by three days of shelf-life at 20°C. LSD (5%) after storage = 33, after shelf-life = 23; 1-6 = Grower no.

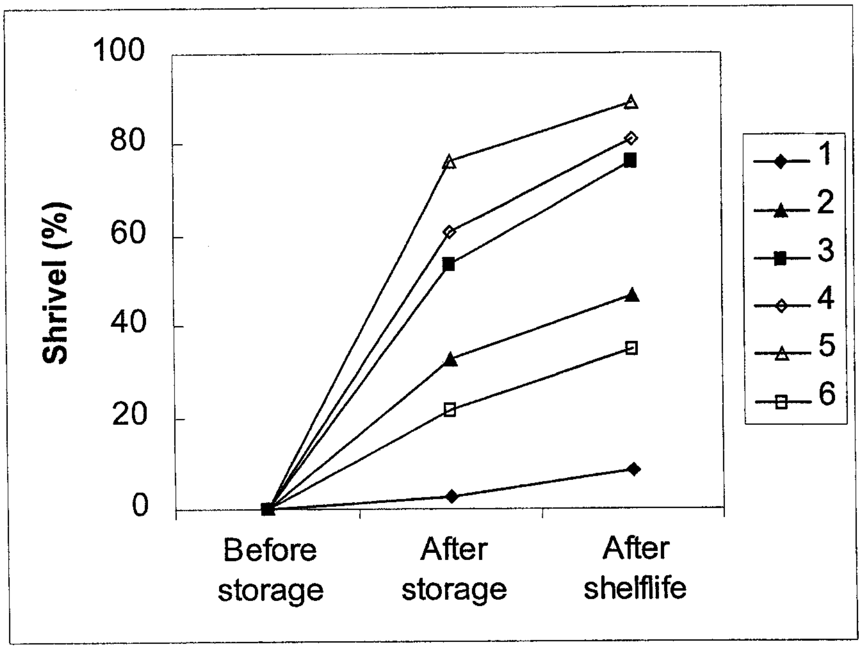


Figure 4. Percentage of fruit with moderate to severe shrivel in pallet trial during three weeks of storage at 8°C followed by three days of shelf-life at 20°C. LSD (5%) after storage = 35, after shelf-life = 22; 1-6 = Grower no.

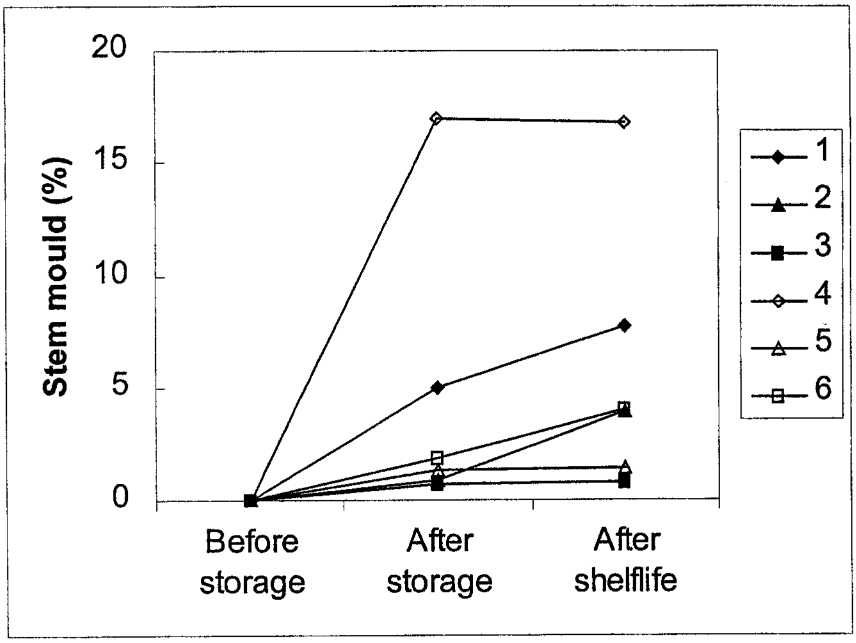


Figure 5. Percentage of fruit with moderate to severe stem mould in pallet trial during three week of storage at 8°C followed by three days of shelf-life at 20°C. 1-6 = Grower no. Data were not appropriate for analysis of variance (see text).

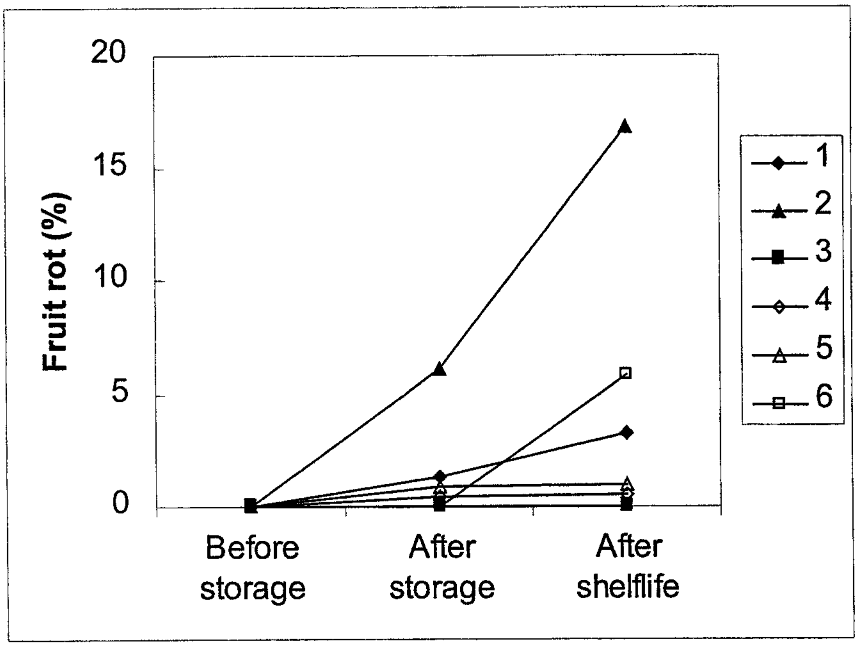


Figure 6. Percentage of fruit with moderate to severe rots in pallet trial during three weeks of storage at 8°C followed by three days shelf-life at 20°C. 1-6 = Grower no. Data were not appropriate for analysis of variance (see text).

5.1.4 Quality losses during shelf-life

As stated above, there was a significant difference between the two box types during shelf-life, with fruit in the traditional boxes losing more water than in the QuaMa boxes. Despite this, all of the quality attributes changed consistently during shelf-life. The percentage of overall acceptable fruit fell during shelf-life, but completely in line with their quality after storage (Fig. 3). The proportion of fruit showing shrivel increased for all growers (Fig. 4), from a low of 5% for grower 1 to a high of 23% for grower 3. However, stem moulds and surface rots showed some different responses. The fruit with the lowest shrivel after storage (from three growers) developed a higher incidence of stem mould and rot during shelf-life (Figs 5 and 6).

The line of fruit from grower 1 stored best and was still rated as the best after 3 days shelf-life. We continued to assess grower 1's fruit for a further 5 days of shelf-life. We believe this fruit had a shelf-life of at least a week as after 7 days 80% of capsicums were rated as acceptable.

5.2 Calcium supplementation

As in the previous year's trial with calcium nitrate, fruit in the trial maintained their quality very well through 3 weeks of storage at 8°C and 5 days at 20°C. They retained firmness, had no shrivel or chill injury pitting, and fairly low rates of fruit rot. Mild stem mould (a rating of 1) was common, but seldom bad enough to reject fruit after storage. There was also no occurrence of black spots on the stems and calyx cap, as seen in 1999-2000. This suggests that the surfactant used that year was at fault, while use of the Wuxal formulation had no such problem and did not leave any calcium residues on fruit.

The main focus of the trial was the effect on fruit rot, which was reduced by calcium in 1999-2000, and on fruit wall thickness, reportedly increased by calcium in a field trial using polyethylene tunnel culture (Toivonen & Bowen 1999). The other condition that may be improved by calcium application is pre-harvest blossom end rot. While it was quite prevalent early in the season, very few fruit were affected during this trial, so there were no calcium treatment effects on blossom end rot to report.

The effect of calcium treatments on fruit rot was similar to the previous year, i.e. a beneficial effect, but somewhat difficult to quantify. Overall fruit rot incidence was lower in this year's trial (10-20% of fruit v. 30-80% in fruit with no calcium last year). The 12 sets of plants were intended to equate with calcium treatments (0-11 applications), but on the day of spray #7 the plants intended to have 6 sprays were inadvertently given a seventh application. Therefore sets 8, 9 and 10 were also given one extra spray, so plants in the last two sets both had 11 sprays.

Due to the low overall incidence of rot, the experimental design was, in hindsight, not ideal. Since a large sample size can be needed to detect a low percentage occurrence, the approximately 200 fruit that ripened on the 2 dates of interest would have been better used for a simple comparison of 2 treatments: no calcium v. a 7 or 8 application regime. The strength of the design used is that it allows regression analysis to quantify the effect of calcium in reducing rot, but this would have required a higher overall incidence of rot.

In order to model the supplemental calcium effect on storage quality, we would prefer to express results in terms of individual fruit. However, since factors other than calcium can influence fruit quality, there was too much variability for such precise calcium treatment evaluation within the size constraints of this experiment (48 plants). Thus, another method comparing calcium treatments on a 'per plant' rather than 'per fruit' basis was used. By noting which plants the fruit with storage rot came from, the results were expressed as the percentage of plants with rot. This had the effect of smoothing the impact of, for instance, several fruit on one plant developing rot during storage or shelf life (which could occur for reasons other than the calcium treatment the plant was given).

Table 3 shows that by the final evaluation of fruit from each harvest date there was a trend for lower rot with more calcium applications (expressed as percentage of plants whose fruit suffered rot after storage). In the first trial, only one out of six calcium treatments receiving from 0 to 5 sprays was rot-free after 5 days at 20°C, while four out of six calcium treatments were rot-free among plants with 7 to 11 sprays. The difference was even greater when all plants in the Low calcium treatments were combined (36% of them had fruit with rot) v all plants in High calcium treatments (15% of plants had fruit rot). Similarly in the second trial, 50% of low calcium treated plants had fruit with rot v. 25% of high calcium treated plants had fruit with rot. The combined values for both trials (43% v. 20%) are significantly different (P = 0.02) by Fisher's exact test.

Table 3. Effects of calcium levels (0 to 11 sprays, Low and High groups) on fruit rot after storage plus 5 days at 20°C. Rot was calculated as % plants with fruit that rotted by the end of shelf-life (i.e. during or after storage). The average given is for the overall percentage of plants with rot in the low or high Ca groups.

	Treatment (no. of sprays)	Harvest 1 rot % plants	Harvest 2 rot % plants	Combined
	0	33	33	
	1	33	0	
	2	50	75	
	3	0	50	
	4	40	40	
	5	50	60	
	7	0	20	
	8	33	25	
	9	0	0	
	10	0	50	
	11	0	33	
	11	100	33	
Low Ca (all plants)		36	50	43
High Ca (all plants)		15	25	20
Significance by Fisher's exact test				*P*=0.02

The other effect of calcium that was of interest was fruit wall thickness (Table 4). This could be a mechanism of how calcium may improve storage quality. There was no trend for increased thickness with calcium sprays. Fruit wall thickness tends to increase with fruit size, so the treatment values were also compared after adjusting for fruit weight, but again there was no effect of calcium.

Stem mould was not influenced by calcium treatment. Mild mould was common, but only a few fruit were judged as rejects (a rating of 2 or 3) due to mould. Stem moulds, more so than fruit rot, was a condition associated with 8°C storage rather than shelf life at 20°C. Ratings did not change greatly from day 21 to the evaluation 5 days later (only the final data are shown in Table 4). Table 4 also lists the average values for fruit weight, which did not differ between calcium groups.

Table 4. Effect of calcium application levels (Low v. High) on fruit size and wall thickness and stem mould after 21 days of storage in perforated polythene bags plus 5 days on the shelf at 20°C. None of the Low v. High calcium comparisons were significantly different.

5 Jan 2001 harvest	Number of plants	Number of fruit	Average weight	Wall thickness	Day 21+ 5 mould rating
Treat 0-5 (Low calcium)	22	59	145.1	6.29	0.51
Treat 7-11 (High calcium)	20	49	151.5	6.22	0.53

11 Jan 2001 harvest	Number of plants	Number of fruit	Average weight	Wall thickness	Day 21+ 5 mould rating
Treat 0-5 (Low calcium)	22	77	145.1	6.27	1.10
Treat 7-11 (High calcium)	20	43	141.4	6.18	1.32

5.3 Vitamin retention

Capsicums stored in perforated bags lost on average only 1% weight during storage and a further 3% during shelf-life. The low weight loss during storage predisposed fruit to storage rots, and as usual, this was primarily a problem for yellow and orange capsicums (Table 5). Stem moulds were not significantly different between varieties (data not shown). During subsequent shelf-life, the incidence of rots continued to rise.

Table 5. Fruit rots in vitamin retention trial. Four varieties of capsicums were stored in perforated polythene bags for three weeks at 8°C, prior to five days of shelf-life assessment in open trays at 20°C (loosely covered with a plastic sheet). Values followed by differing letters are significantly different (Fisher's comparisons, analysis of variance, 5% level).

Variety	% fruit with moderate to severe rots	
Spirit – red	8	a
Special – red	21	a
Fiesta - yellow	63	b
Nairobi – orange	79	b

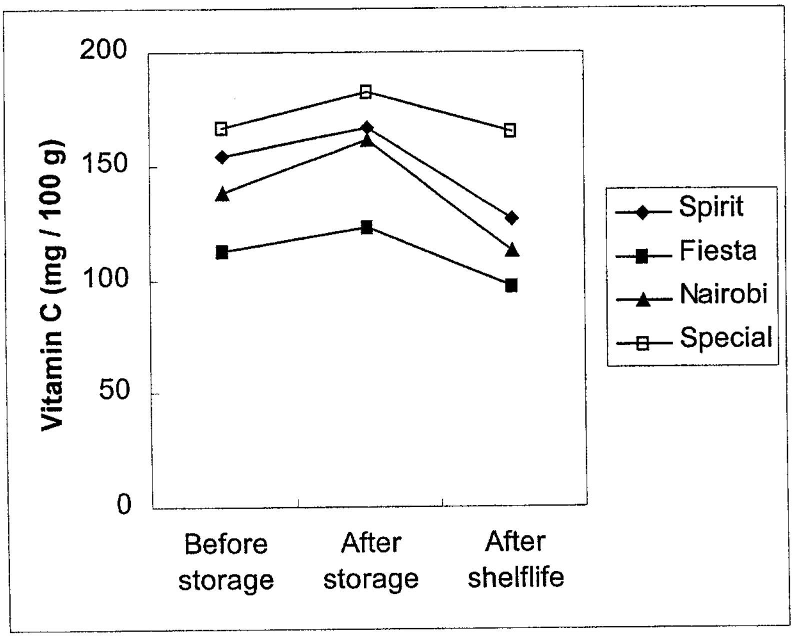


Figure 7. Vitamin C content (mg/100 g FW) in vitamin retention trial during three weeks of storage at 8°C followed by five days of shelf-life at 20°C. Experiment-wide LSD (5%) = 23.

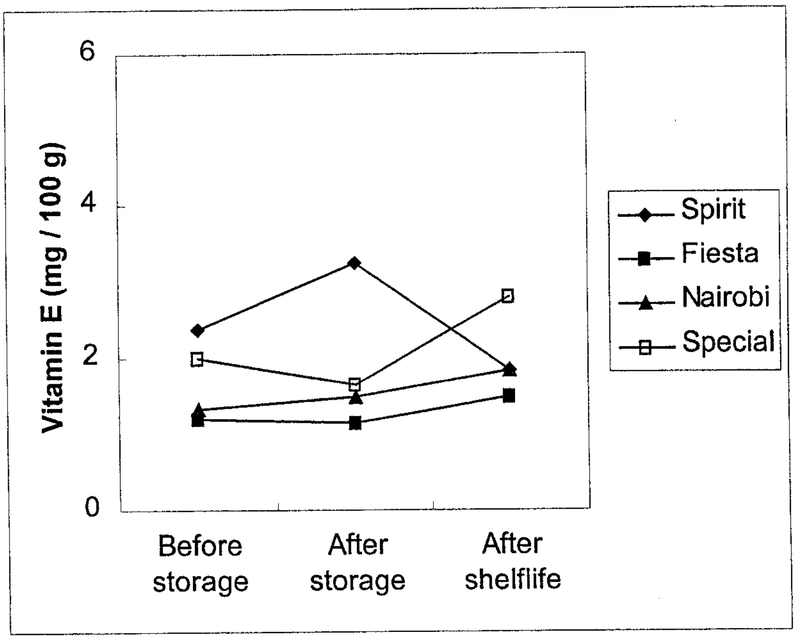


Figure 8. Vitamin E content (mg/100 g FW) in vitamin retention trial during three weeks of storage at 8°C followed by five days of shelf-life at 20°C. Experiment-wide LSD (5%) = 0.6.

We found vitamin C contents differed significantly between varieties, with red capsicums (particularly cv. Special) having a significantly higher concentration than yellow and orange capsicums. There was a small but significant reduction (about 17%) in vitamin C content across all varieties during shelf-life (Fig. 7).

Vitamin E contents were generally low and varied significantly by variety, with the lowest concentrations in yellow and orange capsicums; but there was no significant trend to a reduction during storage and shelf-life (Fig. 8).

6 Discussion and conclusions

6.1 Sea-freight potential of capsicum

Some general and some specific conclusions are possible from this second season's work. In general, we have shown that perforated shrouding of boxed capsicums can deliver high quality fruit after simulated transport to Japan, with an eight-day shelf-life.

There were large differences between fruit from the different growers, confirming last year's observations and industry reports of grower-to-grower variation in storage quality. Some of the contributing factors may be physical, relating to disease load in glasshouses and hygiene during the harvesting process; for example, the high proportion of stem mould in one grower's fruit suggests a hygiene problem. Other pre-harvest factors including calcium nutrition (see below) may also contribute to the storage potential of the fruit. It is also likely that fruit suffered differing amounts of post-harvest water loss before reaching our hands; the time taken for fruit to reach Palmerston North varied as did the method of transport (see Section 4.1). Post-harvest handling would need to be optimised if one were loading a whole container of fruit, particularly to minimise water loss after harvest.

Weight loss during storage was not affected by the type of carton, but we believe this relates to the effectiveness of the perforated pallet shrouds. Even with the shrouds, weight losses of 4-5% occurred because of the low RH and plentiful air movement. It will be interesting to see how capsicums behave in a monitored sea freight shipment next season.

Weight loss during shelf-life was affected by the packaging type and there was the usual tendency for fruit with less shrivel to show a higher proportion of moulds and rots, perhaps on account of the higher humidity maintained around the fruit surface.

Although red capsicums have a very narrow band of tolerance to storage conditions, it should be possible to achieve acceptable storage conditions for these fruit. Ideal conditions for storage are: temperature 7-8°C, 92-95% RH and CO_2 concentration <3%.

6.2 *Pre-harvest calcium supplementation*

The calcium nitrate formulation Wuxal Suspension Calcium, which also has nitrogen, magnesium and trace elements, did reduce storage rot in capsicum fruit of the red cv. Spirit. This effect showed up clearly in terms of the % of plants with fruit rot. The effect was not strong enough for statistical verification when rot was expressed as % of all fruit due to high variability among the small sets of plants. The number of fruit evaluated (228) and the extent of fruit rot (10-20% on the final evaluation) were also insufficient for a regression analysis to quantify the effect of calcium on % rot.

Based on these findings, it appears that the recommended commercial regime for the use of the calcium product for blossom end rot is likely to also have a beneficial effect on capsicum fruit storage rot, since the recommended amount of product is similar to that applied during fruit enlargement and ripening in this trial. The benefit in this trial was from 7 to 11 sprays with 0.2% calcium. Using 4 or 5 sprays with 0.3% calcium at 10 day intervals would provide a fruit with a similar amount of calcium.

6.3 *Vitamin retention*

This season's data add to last year's picture of excellent vitamin retention in capsicums, which is certainly not true for all vegetables. We have now shown that, even in fruit with symptoms of rot, the edible portions retain before-storage levels of vitamins A and E and approximately 80% of the before-storage levels of vitamin C, after five days of shelf-life. Capsicum vitamin C content is very high, on a par with oranges. There may be marketing potential in the longevity of the healthy constituents of the capsicum.

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