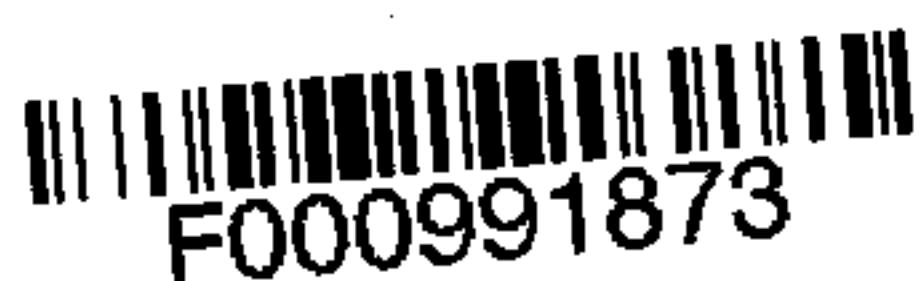


Improved postharvest handling of fresh carrots for export



Crown Records
Management

A report prepared for
**Fresh Vegetable Research and
Development Grants Committee
Vegfed
Wellington**

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& J F Potter
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Mana Kai Rangahau

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1 EXECUTIVE SUMMARY

This report covers the second year of research into improving the out-turn of fresh carrots exported to Asian markets, particularly Japan. Our research focused on three areas:

1. Measuring the storage potential of traditional Nantes-type cultivars compared to the preferred new cultivar, Koyo II;
2. Improving disease control;
3. Measuring the influence of mechanical harvesting and washing on development of rots in storage.

Carrots stored well at 0-1°C for no longer than 4 weeks. We did not obtain an improvement in disease control from the chlorine and fungicide treatments used in the experiment. Koyo II stored as well as Nantes. Carrots harvested in August 1996 did not store as well as carrots harvested in May and July 1996.

We were unable to measure differences in storage rot development related to mechanical damage caused by harvesting and washing.

Black root rot (caused by *Thielaviopsis basicola*) was the most important storage rot recorded, followed by bacterial soft rot (caused by *Erwinia carotovora*).

Although our experiments did not produce significant results, we believe attention to better sanitation and more gentle mechanical handling systems will bring improved disease control in storage. New approaches to sanitation and avoiding free water in packed cartons are suggested.

2 RECOMMENDATIONS

1. Koyo II carrots, although requiring more careful handling, should be stored in the same way as Nantes-type cultivars, i.e. they require cooling to below 5°C within 24 hours of harvest and storage at 0-1°C with high humidity.
2. Black root rot and bacterial soft rot are the most important storage rots in carrots. Incidence of these rots can be minimised by gentle handling systems, a sanitation dip treatment just prior to packing and avoiding free water in packed cartons. Future research should focus on best methods of achieving these requirements.
3. Late winter shipments of carrots are more likely to develop storage rots. Shipments at this time are more prone to storage rot and require extra attention to disease control.

3 INTRODUCTION

Exports of fresh carrots have grown rapidly in recent years from \$0.45 million in 1991 to \$6.34 million in 1996. The demand is primarily from Japan, but other markets in Asia are also being developed. A number of purpose-built packhouses and coolstores have been set up and awareness of the importance of rapid pre-cooling after harvest and of storing carrots at 0-1°C has grown following publication of the results of last year's research (Brash 1996).

A trade mission to Japan (Cooke 1996) reviewed New Zealand's carrot export performance in the Japanese market. The mission highlighted the Japanese market requirement of the Koyo II variety for fresh consumption and a high standard of visual appearance. Storage rots were evident on out-turn, pointing to the need to reduce incipient disease through better management of diseases in the field and in the packhouse.

This project is in the second year of investigating postharvest handling practices for export carrots and aims to better define the storage potential of export carrots, including the new cultivar, Koyo II. The effects of harvest date and of postharvest disease control on storage potential were measured as well as the influence of mechanical harvesting and washing on losses in storage.

4 METHODS

We carried out two experiments, one assessing the storage potential of carrots given various postharvest dip treatments, and the other examining the effects of mechanical harvesting and washing on development of storage rots. We also examined a subsample of export carrots held in a New Zealand coolstore and submitted some carrot samples for disease diagnosis.

4.1 Storage potential experiment

The objective of this experiment was to measure the storage potential, over the harvest season, of export carrots given dipping treatments to improve disease control. Koyo II and Nantes cultivars were examined.

We obtained freshly harvested and washed carrots from Ohakune on four occasions (15/5/96, 31/5/96, 22/7/96 and 13/8/96). Nantes carrots were collected from the same property (Kim Young and Son Ltd) at each harvest (120 kg each harvest). Koyo II is prone to splitting in winter and was only available for the first two harvests (15/5/96 and 31/5/96). Koyo II was obtained from the same property (Mr F Taylor) at both harvests (120 kg each harvest). The carrots were transported back to Levin at 10-15°C and cooled overnight to 1-3°C in a coolstore set at 0-1°C. They were not allowed to dry out.

The carrots were then given one of the following dip treatments:

1. Control - water, dip for 5 minutes
2. Chlorine - 150 µg/ml chlorine (using Janola), dip for 5 minutes.
3. Fungicide - 500 µg a.i./ml iprodione (Rovral) plus Agral LN wetting agent (0.5 ml/litre), dip for two minutes.

Chlorine rates were increased from 50 ppm (used last year) to 150 ppm to improve disease control. The fungicide treatment, although not commercially acceptable, was introduced to maximise disease control in storage.

The carrots were agitated in the dip after each minute of the dipping period. After dipping, the carrots were allowed to drain and then packed into 10 kg boxes with plastic liners. Twelve boxes of carrots were put into storage at 0-1°C for each cultivar at each harvest - four boxes of the three dip treatments. The four boxes were randomly allocated to examination after 0, 4, 8 and 12 weeks storage.

The assessments were for disease and visual appearance. Samples were submitted for disease identification as required.

4.2 Harvest damage experiment

The objective of this experiment was to measure the effect of mechanical harvesting and washing on development of storage diseases on carrots.

We obtained freshly harvested and washed Nantes carrots from Ohakune on two occasions (22/7/96 and 13/8/96). The carrots were collected from the same property (Kim Young and Son Ltd) at each harvest. At each harvest three separate samples (20 kg) of carrots were collected from three locations:

1. From the field - hand-dug.
2. Bins after harvest, prior to washing.
3. In the packhouse, after washing.

All carrots were from the same field. The carrots were transported back to Levin at 10-15°C and cooled overnight to 1-3°C in a coolstore set at 0-1°C. They were not allowed to dry out. Tops and excess soil were removed from each sample. Half the sample was left untreated (10 kg) and the other half (10 kg) was washed gently in cold running tap water and dipped in 150 ppm chlorine for 5 minutes (as outlined in 4.1). Each sub-sample (18 from each harvest, 36 in total) was packed into 10 kg boxes with plastic liners and put into storage for 4 weeks at 0-1°C. At the end of storage the carrots in each carton were assessed for disease development. The carrots were repacked after assessment and incubated at 20°C for 10 days. Disease development was re-assessed.

4.3 Carrots in storage, Perry's Berries

On 6 and 7 June 1996 we examined thirteen cartons of carrots held in Perry's Berries (Mangere, Auckland) coolstore. (Perry's Berries grade and pack Kim Young and Son's carrots for export.) The carrots were subsamples of export consignments sent to Japan during the period 1/4/96 to 7/5/96. The purpose of the examination was to find out how well early season carrots store. We examined 50 carrots/carton and assessed them for disease and visual appearance.

4.4 Disease diagnosis

Diseased carrots were collected at intervals from the storage experiments and from the export carrots from Perry's Berries and symptoms recorded. Sections of infected tissues were cut, surface sterilised, then plated onto potato dextrose agar (PDA). Fungal and bacterial isolation and identification were made using appropriate media incubated at room temperature (about 20°C). Pathogenicity tests were also carried out using washed and wounded carrots, inoculated with spores or mycelium of the fungus.

5 RESULTS AND DISCUSSION

5.1 Storage potential experiment

Results of the storage potential experiment, expressed as % acceptable carrots, are summarised in Figure 1. Statistical analysis was carried out using two ANOVA, one comparing Nantes and Koyo II at the first two harvest dates and the other comparing Nantes at all four harvest dates. Arcsin transformation was required. In both analyses, there was a marked effect of weeks in storage ($P < 0.001$). Although there was no difference between 0 and 4 weeks storage, there was a difference between 4 and 8 weeks and between 8 and 12 weeks.

Carrots stored for 4 weeks yielded over 95% acceptable carrots. We believe the markets require at least 95% acceptable carrots. While 4 weeks may be just adequate for seafreight to Japan, mature, topped carrots should be able to be stored for longer than this period. A storage life of 4-5 months is normally expected at 0°C and 95% relative humidity (AUF 1989). We need to continue to seek improved storage and handling methods. Storage life of export carrots will be further shortened if the carrots are not held close to 0°C; e.g. there may be inadequate pre-cooling prior to loading in refrigerated containers, or shipping at higher temperatures than used in this experiment.

There was no difference in storage potential between Nantes and Koyo II (Figure 1). Providing that suitable methods of growing and harvesting Koyo II are developed, this cultivar could be exported in the same way as the Nantes-type cultivars. Koyo II is not as well suited to the mechanical harvesting, washing and grading systems already used for Nantes-type cultivars because the surface tissue is more easily damaged and the root itself is very prone to splitting. More gentle harvesting, washing and grading systems are required for Koyo II.

When the four Nantes harvests were compared, the date of harvest became important ($P = 0.003$). Figure 1 shows the final harvest of 13/8/96 was different from the others. Carrots harvested late in winter had lower storage potential than earlier harvested carrots.

The dipping treatments had only a small effect on carrot quality (Figure 2). When the four Nantes harvests were compared there were no differences between dipping treatments ($P = 0.113$), but when Koyo and Nantes were compared dipping effects became significant ($P = 0.013$). Chlorine-dipped carrots were of lower quality than the other two treatments. This result was unexpected. We expected the chlorine

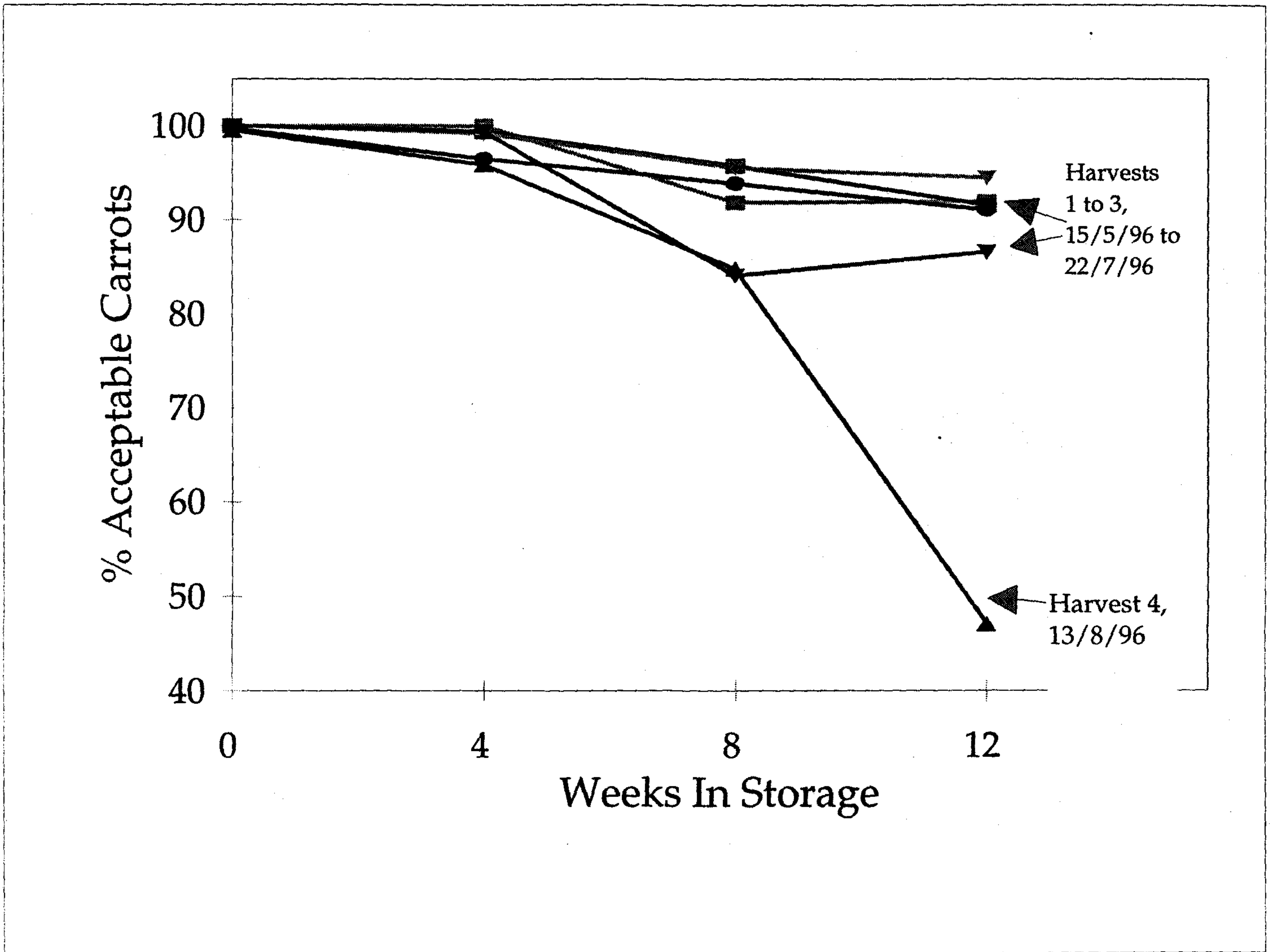


Figure 1: Storage potential of Nantes (dark lines) and Koyo II (grey lines) carrots from four harvests (Harvest 1 on 15/5/96 ■, Harvest 2 on 31/5./96 ▼, Harvest 3 on 22/7/96 ●, Harvest 4 on 13/8/96 ▲).

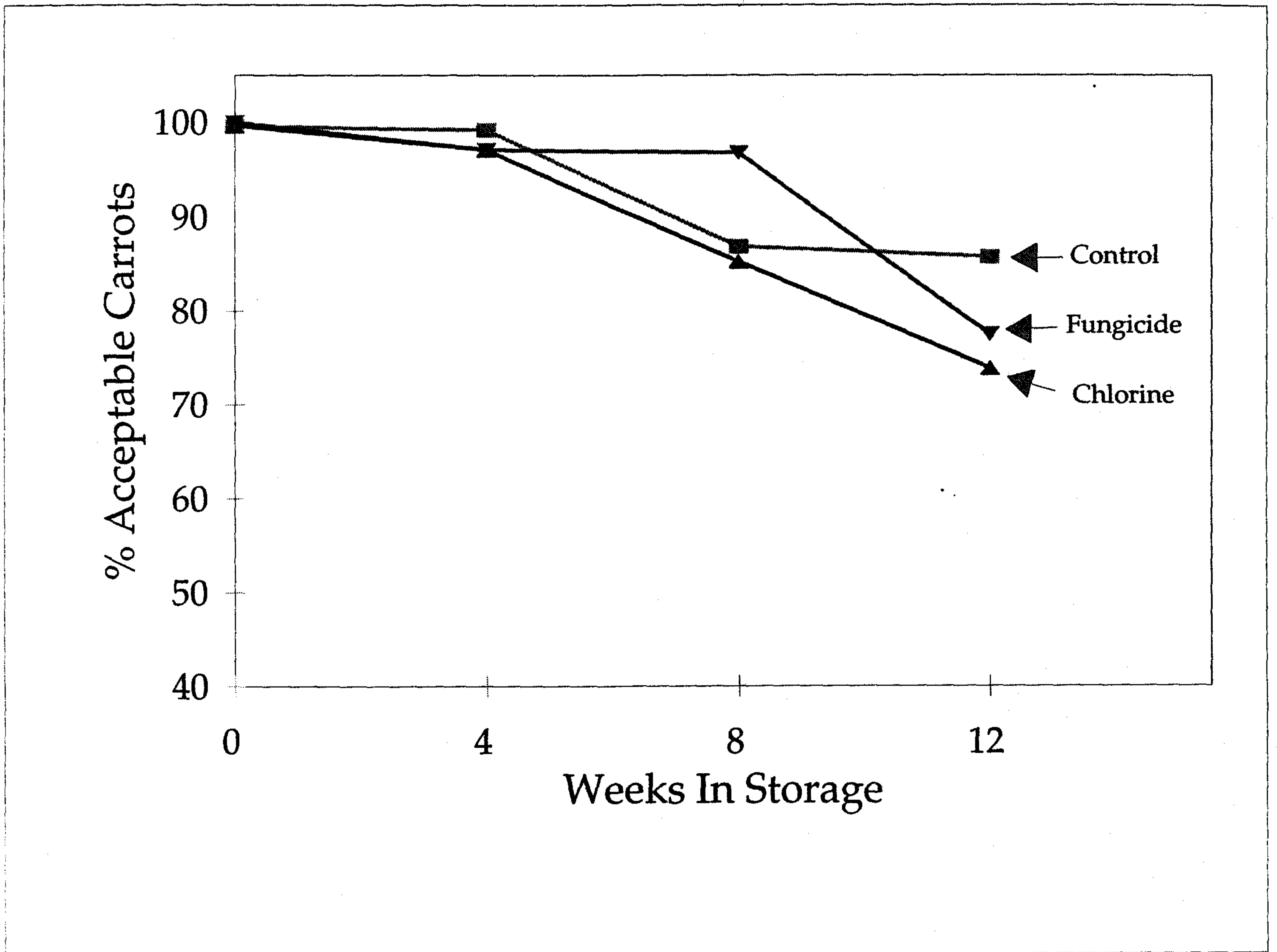


Figure 2: Effect of dipping treatments on storage potential of carrots (means of four harvest dates and two cultivars, Nantes and Koyo II).

treatment to give some benefit over the control treatment and expected the fungicide to maximise storage potential. Although the carrots did not benefit from the dipping treatments, careful attention to sanitation is still recommended for minimising the impact of disease development in storage (Snowdon, 1991).

Chlorine would probably be more effective at higher rates and after lowering solution pH. Punja and Gaye (1993) found rates of 50-80 $\mu\text{g}/\text{ml}$ of chlorine, typical of carrot hydrocoolers in British Columbia, Canada, were ineffective in reducing black root rot development. (Black root rot (*Thielaviopsis basicola*) was the most important storage disease we identified from export carrots.) Punja and Gaye (1993) recommend 200 $\mu\text{g}/\text{ml}$ of chlorine in a dip treatment after grading. Adjusting pH of the dip solution also gave benefit. The pH of our unadjusted solution was 10.2. A pH of 6.8-7.0 is recommended. Punja and Gaye (1993) also found a Ca-propionate dip was more effective than chlorine-based dips. This chemical is already used in the preservation of some baked goods in New Zealand although regulations do not allow its use on carrots here at present.

We expected that the fungicide dip treatment, although not able to be used commercially in New Zealand, would control diseases in storage and provide a useful guide to the maximum storage potential of export carrots. The fungicide treatment gave high levels of disease control for 8 weeks. This effect was not a significant improvement over the other dip treatments. Iprodione is a widely used postharvest fungicide but its use for black root rot control has not been tested previously. It is possible that it is not effective for control of black root rot at the rates used. Bacterial root rot development is not likely to be influenced by the use of a fungicide.

Table 1 summarises the pattern of rot development in storage. Symptoms of black root rot were most common, showing either as a lens-shaped black lesion on the root or covering the root tip. The bacterial soft rot was caused by *Erwinia carotovora*.

Table 1: Percentage of carrots developing storage rot during 12 weeks at 0-1°C

Storage rot	Weeks in storage			
	0	4	8	12
Black root rot - on root	0.0	0.9	2.6	6.4
Black root rot - root tip	0.1	0.1	3.3	5.6
Bacterial soft rot	0.2	0.5	3.0	4.1
Total % carrots developing storage rots	0.3	1.5	8.9	16.1

We identified the presence of licorice rot (caused by *Mycocentrospora acerina*) in one sample collected late in storage. The symptoms were not typical of licorice rot and showed as pink-coloured, dry flesh in the core of the carrot below the crown. Licorice rot is a serious storage rot of carrots in northern Europe.

Most of the cartons (14 out of 18) yielded over 95% content of acceptable carrots after 4 weeks in storage. Some of the cartons (5 out of 18) yielded over 95% acceptable carrots after 12 weeks in storage. A few cartons, where storage rots had become severe, had a marked effect on treatment means. We are not sure of the reason for this but believe the amount of free water inside the plastic liner may have had an influence on rot development. Carrots which were not drained for long enough after dipping and small variations in the way the plastic liners were sealed may have caused carton-to-carton variation independent of the dipping treatment. We believe controlled drying after washing (probably during a period of forced air cooling) could be combined with use of perforations in the plastic liner to help eliminate free water around the carrots. Careful surface drying is recommended for control of bacterial diseases of carrots (Snowdon 1991) and should be further tested.

Variations in storage temperature may lead to disease problems caused by condensation. Temperature fluctuations during storage will cause water vapour to move from the carrots into the air inside the liner. The moisture condenses on the plastic and can drip onto the carrots. Loading patterns and temperature settings of shipping containers should be checked to ensure temperature variations are minimised.

5.2 Harvest damage experiment

There were no detectable differences in rot development between sampling locations in this experiment. Results are shown in Table 2. We have been unable to demonstrate a link between mechanical damage and rot development in storage although other researchers have shown this link. Differences may have been better highlighted with more replication and the use of artificial wounding and disease inoculation. Punja et al. (1992) found black root rot was initiated only after harvest and resulted predominantly from fungal colonisation of tissues that were wounded during harvesting and grading. They found carrots were most susceptible to colonisation by fungi in the first 40 hours after harvest. Snowdon (1991) indicates that the incidence of the following carrot diseases is reduced by minimising mechanical damage - black root rot, Licorice rot and sour rot. The first two are diseases we have identified from export carrots. We believe minimising wounds and abrasions is desirable to not only minimise rots that develop in storage but also to minimise the number of carrots that are broken and damaged. Packouts will increase with a more gentle handling system.

Table 2: Effect of mechanical digging and washing on storage rot development (expressed as % acceptable carrots).

Carrots from	After 4 weeks storage	After incubation
Field	96	56
Bins after harvest	93	50
Grader, after washing	93	56
LSD 5%	4	11

5.3 Carrots in storage, Perry's Berries

The coolstore was running at 3-4°C when we visited, a setting that had been unchanged during the previous 3 months. Carrots should be stored at 0-1°C for maximum storage life. We noted sprouting of roots and tops in carrots that had been stored for more than 6 weeks. The sprouting is related to the high storage temperature. Disease levels were low to moderate with lesions on 6% (0-10% range) of carrots (examined after 4-8 weeks in storage) with no difference between Nantes (cv. Explorer) and Koyo II. The primary pathogen identified was black root rot (caused by *Thielaviopsis basicola*). This microorganism occurred most frequently and was the most pathogenic in tests. Symptoms were often noted on root tips. Other microorganisms detected were *Erwinia carotovora* and *Fusarium oxysporum*. *Sclerotinia* (*Sclerotinia sclerotiorum*) was not detected. *Cladosporium* spp. and *Botrytis cinerea* were noted on remnants of decayed foliage.

5.4 Disease biology and control

Black root rot survives in plant debris or as resting spores in the soil. Bacterial soft rot survives on plant debris in the soil. Carrot roots are likely to be surface-contaminated at harvest time with these diseases. The likelihood of postharvest infection and decay is governed by handling practices and the storage environment (Snowdon 1991).

Buildup of bacteria and fungal spores can occur in wash water and on machinery in the grading system. Maintaining wash water quality and scrubbing and cleaning of the conveyor system is essential to minimise buildup of organic matter and inoculum (Punja and Gay 1993).

Minimising wounding and abrasion is essential. Black root rot infects carrots at sites of injury and abrasion occurring during harvesting, washing, sorting and grading.

Black root rot is unable to establish through the outer periderm layer of the carrot. Control treatments, such as chlorination, work best when placed after potentially wounding treatments such as washing and grading (Punja and Gaye 1993).

Crop rotations to reduce disease inoculum levels in the field may be useful. *Erwinia* bacteria are very sensitive to desiccation (Snowdon 1991). Drying treatments are likely to be beneficial as long as carrot quality is not affected.

6 CONCLUSION

1. Export grade carrots given good temperature management were able to be stored for more than 4 weeks. Levels of rots were unacceptably high after 8 weeks in storage.
2. There was no difference in the storage life of Koyo II and Nantes-type cultivars.
3. Chlorine and fungicide treatments did not extend storage life, although potential improvements to the sanitation treatments have been suggested.
4. We were unable to detect differences in storage rot development related to mechanical damage caused by harvesting and washing operations.
5. Black root rot was the most important storage rot, followed by bacterial soft rot.

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