

Carrots : Ice Bank Storage
and Shelf Life trial

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CARROTS - ICE BANK STORAGE AND SHELF LIFE TRIAL

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Status of work: first year work completed

Year of experiment: 1

Report Number: 1

Period covered: November 1987 to June 1988.

Summary

Carrots were grown on two sites with very different soil types, sandy or fen peat, and overwintered either in bulk bins in a high humidity cool store or in the field covered with straw or straw and black polythene.

Carrots were lifted for cool storage in both November and March and assessed for quality out of store in April and May. The carrots were also assessed for shelf life quality following lifting for storage and at later assessments in April and May. Sugar content was analysed and sensory appraisal undertaken to determine differences in flavour between storage treatments.

Carrots grown in a sandy soil, lifted in November and overwintered in a cool store produced a higher percentage of marketable roots during April and May. In contrast, carrots grown on the fen peat were better overwintered in the field.

The skin quality of cool stored carrots was worse than that of field stored roots, especially on carrots from the sandy site. No differences in taste were detected until May when carrots from the peat site were less sweet and more bitter following field storage than when cool stored through the winter.

Objective

To provide good quality carrots from UK sources in the period from March to June using the best field and cool storage techniques. To provide quality carrots not only as lifted or out of store but also after a period of shelf life.

Introduction

Growers store carrots from November onwards in two ways. Crops grown on deep peat can be insulated against extreme cold weather by ridging up the soil. This method holds the crop in reasonable condition until April at the latest, but is an unreliable system. The peat covering may not provide sufficient insulation in cold weather especially where the sides of the ridge have eroded, and secondly the black soil absorbs heat in the spring encouraging the crop to grow again, which leads to loss of root sugars and to development of woodiness. Those crops grown on mineral soils are covered with straw - a system which potentially can keep carrots frost free but light and heat may still penetrate the cover and encourage the crop to regrow and thus reduce quality.

Since 1982 ADAS has encouraged growers to improve their field storage system. Trials at Arthur Rickwood Experimental Husbandry Farm have determined the best varieties, sowing dates, covering materials and covering dates which give a reliable field storage system. Now the system is being evaluated against the standard commercial practice and against high quality cool storage. This will determine which system offers the best economic alternative for each month from March to June to ensure a supply of excellent quality carrots.

In addition to assessing the quality of carrots out of store or as lifted, the condition during subsequent shelf life is of increasing importance to many market outlets. The storage technique used can have a marked effect on this shelf life quality but requires detailed assessment to determine these effects.

Materials and methods

The following storage comparisons were included in the trial:

1. Cool stored from November onwards
2. Field stored until March, cool stored March onwards
3. Field stored throughout (straw covering)
4. Field stored throughout (straw + polythene covering).

Store environment: 95% RH, 0-1°C.

Store and field assessments: Pre-storage - November

March

April

May.

Three crops of carrots grown according to good husbandry practices were selected in October 1987. Samples were lifted from each site and loaded into bulk bins for high humidity cold storage on 29 October. Bins were drenched with Benlate (a.i. 50% benomyl) before storage.

Sites

- A. Lakenheath, sandy silt soil, variety Nantes Ideal
- B. Chatteris, fen peat, variety unknown
- C. Arthur Rickwood EHF, fen peat, variety Rondino.

In March only two of the sites were selected and a further sample lifted from straw covered areas on each site for cold storage on 1 March. Bulk bins were drenched with Benlate as for the November lift. Following this lift a sample of the remaining crop in the field was covered with black polythene and straw whilst the rest of the crop remained only straw covered). Samples were assessed from both field and cool stored treatments in March, April and May. An assessment in June was not feasible due to the rapid deterioration of quality in all treatments.

Storage records

Three nets (10 kg) of randomly selected carrots were weighed and loaded into each of two bins for each site in November and March. At each store assessment the nets were re-weighed and replaced. In addition a random sample of carrots was graded to record the weights of marketable and unmarketable. Roots were also classified according to the cause of unmarketability.

Shelf life records

For shelf life assessments three replicate sets of 5 x 1 lb bags of Class I carrots were taken from each treatment and placed into self life conditions of 20°C and 50% RH. Disease, skin finish and shoot regrowth were recorded at 0, 24, 48, 72 hours and 6 days using a scoring system of 9-0, where 9 = excellent, 6 = just unmarketable. Weight loss was also recorded over this period.

Sensory and sugar analysis

A sample of carrots from each of the three sites was sent to CFDR for an initial assessment in early November. Samples out of the cool store, or from field storages from one site only (A) were assessed in March and April. A field sample from site (B) only was available for analysis in May. Full details of the methods used for the analyses are given in Appendix I.

Statistical analysis

The statistical analysis for this trial has been undertaken by Andrew Mead, IHR Wellesbourne. Six replicates (three from each of two bins) were used for storage assessments with three replications of each treatment in shelf life. Data has been subjected to analysis of variance with angular transformation of those results expressed as percentages.

Results and discussion

Three sites were selected for this trial in the early autumn of 1987 as an insurance should one, at least, not be available (frost, market forces etc) the

following spring. The two sites retained in the spring represent two very different soil types, a sandy silt (A) and a fen peat (B).

The storage assessments indicate some marked differences not only between the different cool stored treatments but also between the two sites.

EFFECT ON MARKETABLE QUALITY

The effect of different overwintering storage treatments on the percentage of marketable carrots will be manifest in the level of disease and rotting which may develop.

Results indicate that the percentage of rotten/diseased carrots out of cool store increased with the increasing duration of storage and that on the sandy site (A) cool storage during the winter (until March) led to less rots out of store in April and May than field storage during the same period (Table 1). No differences were evident in March. Results from the fen peat site (B) were less distinct.

Table 1 Percentage rotten/diseased carrots (by weight) of total

Assessment	Site A (sandy)		Site B (peat)	
	Cool stored Nov	Cool stored March	Cool stored Nov	Cool stored March
November (as lifted)	0		0	
March	0.6 (1.8)	0.1 (0.8)	11.7 (18.7)	0.6 (3.1)
April	13.7 (19.3)	29.9 (33.1)	41.7 (40.2)	37.4 (37.6)
May	33.1 (34.9)	37.8 (37.8)	42.2 (40.4)	37.8 (44.4)
SED (Site x storage x removal)	3.38* (65 df)			

Bracketed figures have been angularly transformed. Statistical analysis refers to these figures.

If the total percentage of marketable carrots out of cool store is assessed a similar picture emerges. Tables of total percentage marketable exclude carrots outgraded for shape. Shape defects were actually fairly high from the sandy site (A) so percentage marketable figures appear low.

In March neither field nor cool stored treatments showed a significant reduction in quality from November assessments. However, by April and May the percentage of marketable roots had reduced substantially (Table 2).

Table 2 Percentage marketable (by weight) of total

Time of assessment	Site A (sandy)	Site B (peat)	Mean
November	44.3 (41.7)	82.0 (64.9)	63.2 (53.3)
March	56.9 (49.2)	73.0 (59.0)	65.0 (54.1)
April	29.9 (32.6)	36.5 (37.1)	33.2 (34.9)
May	20.8 (26.4)	28.2 (31.6)	24.9 (29.0)
Mean	38.0 (36.9)	54.9 (45.7)	
SED (between site means)			1.367*** (65 df)
SED (between mean of March + Nov. removals)			2.214 ns
SED (between mean of April/May/March removals)			1.808*** (65 df)

Carrots from the fen peat site (B) showed no difference in April and May between a November lift with subsequent cool storage and a March lift with subsequent cool storage (Table 3). In contrast, carrots from the sandy site (A) fared better when overwintered in a cool store than when overwintered in the field (Table 3).

Table 3 Percentage marketable (by weight) of total (mean of 3 removal dates)

Storage treatment	Site A sandy	Site B peat
Cold stored overwinter	40.4 (39.1)	44.2 (41.4)
Field stored overwinter	31.3 (33.1)	47.6 (43.7)
SED (between site and store methods)	2.087** (65 df)	

EFFECT ON SHELF LIFE

Sensory appraisal and sugar analysis were able to compare the different field stored treatments in April and May in addition to the cool storage treatments.

Pre-storage quality

Pre-storage shelf life analysis indicated no difference between the crops at each site excepting that carrots from the sandy site (A) suffered greater weight loss. Sensory appraisal of these crops in November indicated quality from both sites was good. Carrots were medium orange in colour, moderately bright and had moderately prominent cambial layers. The other characteristics are listed in Table 1.2 found in the Appendix. Carrots from the peat site (B) were deeper orange than the sandy site (A) and had a slightly stronger flavour flavour. Total sugar levels of around 4.5 per cent were recorded from both sites (Table 4).

Table 4 Sugar analysis of carrot tissue (total % sugar)

Storage treatment	Site	Date of sampling			
		Nov.	March	April	May
As lifted	A	4.42			
	B	4.40			
Nov. lifted + cold store	A		5.71	5.99	
	B				3.22
March lifted + cold store	A			4.77	
	B				1.89
Field stored (straw only)	A		5.05	5.82	
	B				2.41
Field stored (straw + polythene)	A		4.55	4.61	
	B				2.64

Post storage quality

Shelf life assessments in March showed November lifted, cool stored carrots lost less weight in shelf life than field stored carrots. These carrots must already have desiccated to some extent in store particularly losing moisture from their surface cells.

The levels of disease were higher from the November lifted, cool stored carrots and the extent of silvering on the skin surface worse, especially on the crop from site (A), the sandy silt soil, (Tables 5 and 6). Grazes and abrasions on the skin surface made at lifting had suberised and gave the carrots a rather 'dirty' appearance. In general disease was worse on carrots from site (B).

Table 5 March shelf life assessment - Disease scores after 72 hours
Scored 9-0 where 9 = excellent

Treatment	Site A (sandy)	Site B (peat)	Mean
Nov. lift into store	8.27	7.73	8.00
Field stored (straw only)	8.87	8.27	8.57
Field stored (straw + polythene)	8.33	8.07	8.20
Mean	8.49	8.02	
SED : site	0.125*	(10 df)	
storage	0.153*	(10 df)	
site x storage	0.216 ns	(10 df)	

Table 6 March shelf life assessment - Silvering scores after 72 hours
Scored 9-0 where 9 = excellent

Treatment	Site A (sandy)	Site B (peat)	Mean
Nov. lift into store	5.40	6.73	6.07
Field stored (straw only)	7.47	7.60	7.53
Field stored (straw + polythene)	7.20	7.73	7.47
Mean	6.69	7.36	
SED : site	0.128*** (10 df)		
storage	0.157*** (10 df)		
site x storage	0.222* (10 df)		

Shoot growth in pre-packed carrots is undesirable since it will lead to a reduction in the sugar levels in the roots. Shoot growth appeared slightly worse from sandy site (A) carrots and on this site worse on the overwintered, cold stored samples (Table 7).

Table 7 March shelf life assessment - Shoot growth after 72 hours
Scored 9-0, where 9 = excellent

Treatment	Site A (sandy)	Site B (peat)	Mean
Nov. lift into store	7.87	8.07	7.97
Field stored (straw only)	8.93	7.80	8.37
Field stored (straw + polythene)	8.93	8.07	8.50
Mean	8.58	7.98	
SED : site	0.119*** (10 df)		
storage	0.146* (10 df)		
site x storage	0.206** (10 df)		

In March, sugar levels from the cool stored, field stored, straw only and field stored straw + polythene treatments were all slightly lower than the November control (Table 4). (Site A carrots only were assessed). Sensory appraisal indicated all treatments were of good quality with a slight to moderate strong carrot flavour and a slight to moderate sweetness and bitterness.

By April all treatments showed a similar desiccation during shelf life. Disease was again worse on the site (B) samples in comparison to site (A). Differences were also evident between the treatments with the November lifted, cool stored carrots and field straw and polythene stored carrots showing the least disease in shelf life after 72 hours and March lifted, cool stored carrots showing the most disease (Table 8).

Table 8 April shelf life assessments - Disease scores after 72 hours
Scored 9-0, where 9 = excellent

Treatment	Site A	Site B	Mean
Nov. lift, cold store	8.40	7.53	7.97
March lift, cold store	7.00	6.33	6.67
Field stored (straw only)	8.00	6.63	7.32
Field stored (straw + polythene)	8.53	7.87	8.20
Mean	7.98	7.09	
SED : site	0.118***	(14 df)	
storage	0.167***	(14 df)	
site x storage	0.237 ns	(14 df)	

The skin finish was, as expected from the March assessments, generally worse on carrots from the sandy site (A). Within the treatments both November lifted, cool stored carrots were more silvered than the March lifted sample. Both of these were more silvered than the field stored treatments, especially during the earlier part of the shelf life period (Table 9).

Table 9 April shelf life assessments - Silvering scores after 72 hours
Scored 9-0, where 9 = excellent

Treatment	Site A (sandy)	Site B (peat)	Mean
Nov. lift, cool store	2.13	4.33	3.23
March lift, cool store	4.33	5.67	5.00
Field stored (straw only)	6.20	6.57	6.38
Field stored (straw + polythene)	6.80	7.33	7.07
Mean	4.87	5.98	
SED : site	0.189***	(14 df)	
storage	0.268***	(14 df)	
site x storage	0.379*	(14 df)	

In April there were no differences between the sites in the extent to which tops grew during shelf life. November lifted carrots from site A produced significantly more top growth than other treatments on this site (Table 10).

Table 10 April shelf life assessment - Shoot growth score after 72 hours
 Scored 9-0 where 9 = excellent

Treatment	Site A	Site B	Mean
Nov. lift, cool store	6.60	7.47	7.03
March lift, cool store	7.87	7.60	7.73
Field stored (straw only)	7.87	7.90	7.88
Field stored (straw + polythene)	8.27	7.40	7.83
Mean	7.65	7.59	
SED : site	0.104 ns (14 df)		
storage	0.148*** (14 df)		
site x storage	0.209*** (14 df)		

The eating quality of all the carrots was still good in April. There were slight differences between treatments in colour with the straw + polythene field stored carrots slightly paler than other treatments (Table 13). No significant difference in flavour or texture attributes were scored. Slight off-flavours were recorded in the cool stored carrots. Sugar levels were similar to those in March.

Unfortunately the commercial sandy soil site (A) was harvested in late April so comparisons between treatments in May are limited to the cold stored treatments from each site and the field stored treatments from site (B) only.

Carrots field stored at the peat site (B) under straw only had the least disease of all treatments during most of the shelf life period. March lifted, cool stored carrots showed most disease (Table 11). Silvering was worse on all the cool stored treatments in comparison to the field stored carrots (Table 12). As in previous assessments the sandy site (A) carrots were more silvered than those carrots originally from the peat site (B) and on site A at least the November lifted treatment was the worst.

Table 11 May shelf life assessment - Disease scores after 72 hours
 Scored 9-0, where 9 = excellent

Treatment	Site A	Site B
Nov. lift, cool store	7.73	7.73
March lift, cool store	7.47	7.20
Field stored (straw only)	N/A	8.33
Field stored (straw + polythene)	N/A	7.80
SED (between all treatments)	0.168***	(10 df)

Table 12 May shelf life assessment - Silvering scores after 72 hours
 Scored 9-0 where 9 = excellent

Treatment	Site A	Site B
Nov. lift, cool store	1.67	4.93
March lift, cool store	2.87	4.73
Field stored (straw only)	N/A	7.33
Field stored (field + polythene)	N/A	7.33
SED (between all treatments)	0.222***	(10 df)

Shoot growth inside the packed bags was less on the field stored treatments, perhaps because any growth had been trimmed off at lifting. The November lifted cold stored carrots from site A gave most top growth in the shelf life packs (Table 13).

Table 13 May shelf life assessments - Shoot growth scores after 72 hours
Scored 9-0 where 9 = excellent

Treatment	Site A	Site B
Nov. lift, cool store	6.67	7.27
March lift, cool store	6.93	7.20
Field stored (straw only)	N/A	8.33
Field stored (straw + polythene)	N/A	8.20
SED (between all treatments)	0.191*** (10 df)	

Sensory and sugar analyses in May were carried out on all treatments from site B. Sensory appraisal revealed significant differences between treatments (Table 14). Carrots cool stored since November had the highest scores for depth of orange, strength of flavour and sweetness but the lowest scores for fibrousness of texture (Table 1:2). The field stored carrots were the most bitter (a soapy flavour was also recorded). Sugar analysis indicated the sugar level in the November cool stored carrots was also higher than the other treatments (Table 7). Sugar levels in general were lower in May than at any other time in the trial.

Conclusions

1. The site and soil type in which carrots are grown has a marked effect on the shelf life quality of the crop.
2. In terms of marketable quality, carrots grown on a fen peat site overwintered equally well whether in the field or in a cool store. Carrots from a sandy site overwintered best when lifted and cool stored.
3. Silvering and overall skin finish was always worse on cool stored carrots in comparison to direct lifted field stored carrots. On sandy site carrots, the length of period in cool store had an accumulative effect on the extent of silvering.
4. Silvering and overall skin finish was worse on carrots grown on a sandy site.
5. Only in May did sensory appraisal and sugar analysis show any differences between cool stored and field stored samples.

Recommendations for future action

- 1 The trial should continue into its second year with greater emphasis to be given to obtaining economic comparisons between field and cool storage techniques and between different sites.
2. Assessments of shelf life quality should be repeated to verify these results.
3. Sensory appraisal and sugar analysis should be extended to ensure a full comparison of both storage method and site differences.

SENSORY APPRAISAL AND SUGAR ANALYSIS OF STORED CARROTS FOR LUDDINGTON EHS 1987/88

Methods

A sample of carrots from each of the three sites was sent for an initial assessment to the Campden Food and Drink Research Association in November 1987. Samples out of ice bank store, and from field storage were assessed at intervals in 1988. Treatments from site 1 were assessed in March and April and from site 3 in May.

Sensory appraisal

Carrot samples were hand peeled, cut into 5 mm slices and cooked for 10 minutes in boiling salted water. Three samples of each treatment were tasted (three replicates) by a trained panel of five or six people. Colour, flavour and texture of the samples was rated using the QAV method of sensory appraisal and the scoring system in Table 1. Results for each assessment date were analysed using the Mann Whitney 'U' test for non-parametric comparisons. Carrots tasted on different dates cannot be compared.

Analysis of sugars

High performance liquid chromatography (HPLC) was used to determine sugar composition of the samples.

Table 1.1 Scoring systems for quality appraisal of processed carrots

Attribute		Score				
		1	2	3	4	5
Colour	Tint	Very pale	Slightly pale	Medium orange	Slightly dark	Very dark
	Brightness	Dull	Slightly dull	Moderately bright	Bright	Very bright
	Uniformity	Extremely non-uniform	Very non-uniform	Moderately non-uniform	Slightly non-uniform	Very uniform
	Prominence of cambium	Not at all	Slightly	Moderately	Very	Extremely
Flavour	Sweetness	Not at all	Slightly	Moderately	Very	Extremely
	Bitterness	Not at all	Slightly	Moderately	Very	Extremely
	Strength of carrot	Moderately weak	Fairly weak	Slightly weak	Slightly strong	Moderately strong
Texture	Softness	Not at all	Slightly	Moderately	Very	Extremely
	Firmness	Not at all	Slightly	Moderately	Very	Extremely
	Fibrous cores	Not at all	Slightly	Moderately	Very	Extremely

Table 1.2 Quality appraisal control samples November 1987

Site	Orange	Bright	Unif	Prom	Soft	Firm	Fibro	Sweet	Bitter	Strength
Site 1	3.1B*	2.9	3.1	2.9	2.2	2.7	1.1	2.6	1.9	3.2
Site 2	3.0B*	3.2	3.4	3.1	2.1	2.6	1.0	2.5	2.1	3.0A
Site 3	3.5A	2.9	3.3	2.9	2.2	2.4	0.9	2.7	1.8	3.5B
Overall mean	3.2	3.0	3.3	3.0	2.2	2.6	1.0	2.6	1.9	3.2

Tasters comments site 1 - Soapy/perfumery (3 tasters)

Table 1.3 Quality appraisal site 1 April 1988

Treatment	Orange	Uniform	Tasters comments
November to store	3.3B**	3.2	Soapy/musty/earthy/??? (2 tasters)
March to store	3.5B**	2.9A	Doughnuts/disinfectant (2 reps, 2 tasters)
Field (straw + poly)	2.7A	3.4	
Field (straw)	3.1B*	3.5B*	
Overall mean	3.2	3.3	

	Range	Mean
Brightness	3.0 - 3.4	3.2
Prominence of Ca	2.0 - 2.5	2.3
Softness/firmness	3.0 - 3.3	3.1
Cores	1.2 - 1.5	1.4
Sweetness	1.9 - 2.2	2.0
Bitterness	2.1 - 2.6	2.3
Strength of flavour	2.4 - 2.8	2.7

Treatments marked A are significantly different from those marked B.

Confidences of differences from Control.

(Confidences are per column of 4 treatments based on Fisher's Modified LSD procedure)

- * 95%
- ** 99%
- *** 99.9%

Table 1.4 Quality appraisal site 3 May 1988

Treatment	Orange	Bright	Unif	Soft	Fibro	Sweet	Bitter	Strength
Nov to store	3.6A	2.9	3.3	2.7A	1.2A	2.8A	1.9A	3.2A
Mar to store	3.1B**	3.1	3.4A	3.2B*	1.5	2.2B*	2.3	2.8
Straw + poly	2.9B**	2.9B*	3.1B*	3.1	1.7B*	1.8B***	2.5B**	2.5B*
Field (straw)	2.7B***	3.3A	3.1B*	2.8	1.5	1.9B***	2.5B**	2.7
Overall mean	3.1	3.0	3.2	3.0	1.5	2.2	2.3	2.8

Tasters comments: November lifted - Earthy (2 reps)
 Field (straw) - Soapy
 Field (straw + poly) - ?/Soapy

	Range	Mean
Prominence of Ca	2.4 - 2.9	2.8

Varieties marked A are significantly different from those marked B.

Confidence of differences from Control.

(Confidences are per column of 4 treatments based on Fisher's Modified LSD procedure).

* 95%
 ** 99%
 *** 99.9%

Shelf life diary

Pre-storage assessments 3/11/87

Site A

0 HOURS - The carrots were long, thin to medium thickness of root. The colour was light orange though a little dullish.

24 HOURS - No disease, the roots had a mottled, silvered appearance.

48 HOURS - No disease, the skins were drying out with 75 per cent of the surface area silvering, some roots had a very dry appearance.

72 HOURS - The silvering was quite noticeable on all roots, some very dry but no loss of turgidity. One bag was cut open and the roots were assessed internally. 12 per cent showed some very minor pithiness occurring in the core and there was some paling of colour around the core outline. The colour was a bright orange.

6 DAYS - The roots had a dry, quite silvery skin finish and lateral root growth was visible on 13 per cent of the carrots. The crowns were sprouting and the tails were browning.

Site B

0 HOURS - The carrots were short and stubby with a dirty appearance even after washing.

24 HOURS - No disease, a few tail roots were browning.

48 HOURS - No disease, the skin was very dry with a scored appearance on some roots and silvering on about 5 per cent of the surface area. The tails were brown.

72 HOURS - The skins were slightly dry with a scored appearance to some roots. Mould growth had started to develop around the crown. One bag was cut open and the roots were assessed internally. 24 per cent showed slight pithiness in the core with some whitening around the core. The colour was bright orange.

6 DAYS - The skins were dry with a little silvering, 11 per cent showed lateral root growth. There was some slight mould growth around the crown and there was some sprouting. The tails were brown and rotting.

1. Site A, November lift, cold store

0 HOURS - The carrots were dull orange in colour, with silvering apparent, the surface appeared grazed and brown in places. Very little disease present, a small amount of white mycelium on one carrot.

24 HOURS - The carrots looked 'dirty' in appearance. The skin surface was abraded, silvering was very evident and had turned brown in places. Generally unattractive. Slight rotting present but not extensive.

48 HOURS - Skin surface still silvered, brown and with abrasion. Carrots looking 'tired' and quite badly discoloured. Some tops started to sprout.

72 HOURS - Tops continue to sprout, adventitious roots starting to grow and the tails turning brown. General appearance unattractive and tired. Very little disease.

6 DAYS - Adventitious roots and sprouts continued to develop, with some rotting of the tops. The carrots felt slightly limp and looked desiccated.

2. Site B, November lift, cold store

0 HOURS - The carrots were dull orange in colour, with a 'dirty' appearance and grazed skin surface but with very little silvering. The tops were green but not sprouting. Carrot fly damage was present on some carrots with a small amount of associated fungal growth.

24 HOURS - The carrots look unattractive, due to the skin abrasions and 'dirty' appearance. Disease had not spread.

48 HOURS - Little further deterioration, silvering a little more extensive and tops had started to sprout. Condensation building up inside bags.

72 HOURS - Carrots looking unattractive with browning and desiccation of the skin surface. Small adventitious roots had developed on some carrots and some tops sprouting.

6 DAYS - Sprouting of tops more developed and silvering of skin surface quite extensive at this stage. Tails of carrots had turned brown and a few roots developed.

3. Site A, March lift, field storage (straw only)

0 HOURS - Carrots bright orange in colour, very attractive and fresh looking. Tails paler in colour. Virtually no silvering or disease present. Skins clean.

24 HOURS - Attractive, bright colour is still apparent with carrots looking fresh. A small amount of silvering on the skin surface with condensation developing on the inside of the bags.

48 HOURS - Appearance is very similar to 24 hours. Carrots fresh with a little more silvering but no disease or sprout growth. Condensation present inside bags.

72 HOURS - A very small amount of top growth and a few adventitious roots present. Carrots still bright, clean and attractive. Virtually no disease.

6 DAYS - Silvering was more extensive on the skin surface and a little more sprouting of the tops had developed. Skin finish was otherwise very good. Carrots firm and fresh. One carrot only had started to rot.

4. Site B, March lift, field storage (straw only)

0 HOURS - The carrots were fairly clean, palish orange in colour with a slightly uneven colour distribution on some. The skin surface showed some silvering and was slightly grazed. A few carrots had been damaged by carrot root fly.

24 HOURS - Very little deterioration in quality. Silvering was marginally more extensive than on entry into SLR. Condensation had started to build up inside bags.

48 HOURS - A slight development of silvering and a small amount of rotting. Carrot tops had started to sprout.

72 HOURS - Little further deterioration save sprouting of the tops and a few adventitious roots developing.

6 DAYS - The carrots were still fairly turgid and of good appearance with some silvering on the skin surface and sprouts from the tops. The colour was still palish orange. Adventitious roots were developing and detracted from the overall appearance.

5. Site A March lift, field storage (straw + polythene)

0 HOURS - Carrots fairly bright orange in colour with very little disease or silvering present. The carrots looked clean and attractive.

24 HOURS - No deterioration of carrots with respect to disease although silvering was more extensive and skin surface drying out in places.

Condensation building up inside bags.

48 HOURS - Similarly very little further deterioration except the slight increase in silvering.

72 HOURS - A lot of condensation present in bags and tops of a few carrots starting to sprout. Adventitious roots were also developing.

6 DAYS - The carrots were still bright orange in colour and looked fresh and clean. Silvering had developed fairly extensively over the skin surface although carrots did not look 'dried' out. A small amount of rotting in carrot tops.

6. Site B, March lift, field storage (straw + polythene)

0 HOURS - Carrots were fresh and palish in colour, although difficult to clean and retained traces of peat on skin surface. The appearance was therefore slightly 'dirty'. Some silvering was present and some carrot fly damage.

24 HOURS - Carrots looking fairly pale with a slightly mottled appearance. Very little deterioration since entry into SLR.

48 HOURS - A little rotting coming into the carrot tops which were already looking ready to sprout. Silvering was slightly more extensive although condensation in the bag reduced the visible signs.

72 HOURS - Several carrot tops had started to sprout and a few adventitious roots were apparent. Carrots were otherwise turgid and fresh.

6 DAYS - A lot of condensation inside bags with carrots showing considerable sprouting and adventitious roots. Several carrot tops had started to rot. Appearance was otherwise acceptable.

APRIL REMOVAL 19/4/88

1. Site A, November lift, cold store

0 HOURS - Some small areas of rot on a few roots. The skin was badly silvered and had a dry appearance. Minor yellow regrowth visible. Roots firm.

24 HOURS - Dull, pale coloration, very badly silvered. Minor disease. Regrowth greening. Roots solid.

48 HOURS - Very dull dry appearance, very silvered. Slight rots on tips of roots. Regrowth green. Roots solid.

72 HOURS - Very dry, dull appearance, very silvered. Small rots around crown and tips of carrots. Lot of regrowth, lush and green. Roots solid.

6 DAYS - Very dull and dry due to badly silvered skin. Brown rots on tips of roots. Lot of green regrowth and small lateral roots developing. Very slight loss of turgidity.

Internal - Dark orange coloration. Very minor pithiness visible in central core of a few roots.

2 Site B, November lift, cold store

0 HOURS - Root fly damage and small rots. Minor silvering, skins still quite dirty. Green coloration around a few crowns. Slight yellow regrowth visible. Roots solid.

24 HOURS - Dull, palish coloration, quite silvered. Root fly and rots on a few roots. Regrowth yellow. Roots solid.

48 HOURS - Very dull, silvered appearance. Skin abraded and dirty. Disease minor though all roots infected. Regrowth green. Roots solid.

72 HOURS - Dry, dull appearance. Skin very abraded and silvered. Small rots with some black rots developing on a few roots. Small amount regrowth. Roots solid.

6 DAYS - Dull, dry appearance. Very abraded and silvered skin. Regrowth sprouted. Roots quite solid.

Internal - Mid to dark orange coloration. A few roots had some minor pithiness but quite a lot showed signs of white cells around the core, which appeared woody. A couple of roots had green coloration radiating from the crown into the core.

3. Site A, March lift, cold store

0 HOURS - Brown rots on roots and around crown. Minor silvering. Slight regrowth visible. Roots solid.

24 HOURS - Root tips rotting, few roots have minor disease. Quite a lot of silvering and slight abrasions on the skin. Dull, darkish coloration.

Sprouting regrowth yellow. Roots solid

48 HOURS - Dullish appearance, skins quite silvered. Rots on quite a few roots, some black rots developing. Minor sprout regrowth. Roots solid.

72 HOURS - Very dry, dull appearance. Skin abraded and quite silvered. Rots on roots and around crowns. Minor sprout regrowth. Roots fairly solid.

6 DAYS - Dull, dry appearance. Roots quite silvered. Rots around crown and on roots, some black rots developing. More sprout regrowth, green and leafy.

Fairly solid roots.

Internal - Darkish orange coloration. Quite a few roots had minor pithiness visible in the core and some appeared slightly woody.

4. Site B, March lift, cold store

0 HOURS - Quite a few roots have black rots on them. The skins are dirty with minor abrasions and silvering. Yellow sprout growth, slight signs. Roots solid.

24 HOURS - Dullish, mid coloration. The roots are showing quite a lot of black rots. The skins are slightly abraded and dirty with minor silvering. Little sprout regrowth. Roots solid.

48 HOURS - Dullish, dry appearance. The black rots are spreading and softening. The skin is abraded and slightly silvered. The tops are blackening and soft. Roots solid.

72 HOURS - Dull, dry appearance. Skin abraded and silvered. Black rots on roots numerous and large areas. Tops also rotting on some roots. Minor sprout regrowth. Roots solid.

6 DAYS - Dull, abraded and silvered skin. Large, numerous black rots on the roots, tops rotting on some carrots. Regrowth green. Fairly solid roots.

Internal - Mid orange coloration. Quite a few roots had minor pithiness visible in the core. A few roots had a woody core and a couple of roots were hollowing due to crown rots.

5. Site A, April lift, field (straw)

0 HOURS - Slight root fly. No silvering visible. Some growth not removed before packing. Roots solid.

24 HOURS - Brightish coloration, slight silvering on skin. Growth left blackening and decaying. minor root fly damage. Roots solid.

48 HOURS - Dullish, slightly silvered skin appearance. Tops rotting off and black. No disease development. Minor regrowth.

72 HOURS - Dry, dull appearance, skin silvering. Tops rotted and black though some minor regrowth sprouting. Few small rots developing. Roots solid.

6 DAYS - Dull appearance, silvering on skin. Crown rots and some brown rots. Some regrowth of tops and lateral roots, very slight softening of roots.

Internal - Mid orange coloration. About half the roots had slight pithiness in the core.

6. Site B, April lift, field (straw)

0 HOURS - Root fly damage. No silvering visible. Long growths left on when packed. White bulbous growths on ends of a few roots. Roots solid.

24 HOURS - Mid orange, slightly dull coloration, very little silvering. Root fly and rots on quite a few roots. Tops blackening and rotting. Roots solid.

48 HOURS - Dry, dull appearance. Minor silvering on skin. Tops black and rotting. Soft rots on quite a few roots. minor regrowth.

72 HOURS - Dry, dull, silvering skins. Tops black and rotting. Some regrowth sprouting. Crown rots and soft rots. Solid roots.

6 DAYS - Dry, slightly abraded, silvered appearance. Blackened tops. Crown rots, mould spores. Soft rots on roots. Slight regrowth sprouting and lateral roots. Very slight softening of most roots.

Internal - Pale mid orange coloration. Some roots had minor pithiness in the cores, a few were woody. A number of roots were black around the crown and down a short way into the shoulder.

7. Site A, April lift, field (straw + polythene)

0 HOURS - Very little disease. No silvering. Longish growths left on when packed. Roots solid.

24 HOURS - Brightish orange coloration, minor silvering. Small amount of root fly. Roots solid.

48 HOURS - Slight dullness and silvering of skin. Tops blackening and softening. Minor disease on a few roots.

72 HOURS - Slightly dry and dull with some silvering. Few rots, tops rotted and black. Minor regrowth. Roots solid.

6 DAYS - Dull, slightly silvered appearance. Crown and root rots, a few roots had totally broken down making a slimy package. Slight regrowth was sprouting. Some slight loss of turgidity.

Internal - Mid orange coloration. Some roots had slight pithiness in the core. A few roots were rotting causing a hollowing of the root.

8. Site B, April lift, field (straw + polythene)

0 HOURS - Minor soft spots and root fly. No silvering. Long growths left on when packed. Roots solid.

24 HOURS - Slightly dull, mid orange coloration. minor silvering. Growth left turning black and decaying. Few rots and root fly damage. Some regrowth sprouting. Roots solid.

48 HOURS - Slightly dull, minor silvering on skin. Tops black and rotting. Rots softening. Regrowth green.

72 HOURS - Dry, dullish appearance, slight silvering on skin. Top black and rotting, some green regrowth sprouting. No disease development. Roots solid.

6 DAYS - Dry and dullish appearance, slight silvering. Tops black and rotted, some into crown. Minor disease. Regrowth green, very slight softening of roots.

Internal - Mid orange coloration. Quite a few rots had slight pithiness in the core.

MAY REMOVAL - 10/5/88

1. Site A, November lift, cold store

0 HOURS - Small amount of disease, minor cavity spot. Very abraded and silvered skin. Tops trimmed, no growth.

24 HOURS - Few brown rots developing. Skin finish very abraded and very silvered, giving carrots a dry, dull appearance. Minor yellow regrowth of tops.

48 HOURS - Few brown rots. Skin very abraded and silvered. Carrots have a dry, dull appearance, some look old and shrivelled. Regrowth of tops green.

72 HOURS - Small amount of rotting. Skin very abraded and extreme silvering.

Very dry, dull appearance, all look old. Fair amount of green top regrowth

6 DAYS - Small amount of rots. Very abraded and extremely silvered skin. Very dry, dull appearance. Old sample with some shrivelling of the roots. Lots of top regrowth plus lateral roots.

Internal - Mid orange coloration. Slight to moderate incidence of pithiness.

Core had woody appearance.

2. Site B, November lift, cold store

0 HOURS - Small amount of disease, mainly cavity spot. Slight abrasions and silvering of skin. Tops trimmed.

24 HOURS - Slight cavity spot and other rots. Skins badly abraded and starting to silver. Dryish, dull appearance. Minor top regrowth.

48 HOURS - Rots spreading, very abraded skin, some silvering. Dryish, dull appearance. Slight top regrowth.

72 HOURS - Brown and other fungal rots, some mould spores. Very abraded skin, silvering. Dry, dull, rather dirty appearance. Top regrowth green, some lateral roots.

6 DAYS - Numerous patches of myceliar growth and rots, mould spores. Very abraded skin, some silvering. Very old, dry dull appearance. Skins dirty. Some top regrowth. Very poor sample.

Internal - Pale mid orange coloration. White around core. Woody opaque core.

Dry appearance with some hollowing. Moderate incidence of pithiness.

3. Site A, March lift, cold store

0 HOURS - Small amount of disease, cavity spot and brown rots. Skins slightly abraded with quite a lot of silvering. Tops trimmed.

24 HOURS - Minor spots of fungal rots developing. Skins abraded and quite silvered giving a slightly dryish, dull appearance. Very little top regrowth.

48 HOURS - Slight rots. Abraded and quite silvered skin. Dry, dull appearance. Some top regrowth.

72 HOURS - Quite bad infections of fungi and brown rots on some roots. Skin abraded and badly silvered. Dry and dull, some had a shrivelled appearance. Longish green regrowth.

6 DAYS - Rots. Abraded and quite badly silvered. Dry, dull, oldish appearance to roots. Lots of top regrowth, few lateral roots.

Internal - Mid orange coloration with a slight whiteness to the outer core. Slight incidence of pithiness. Few cores appear slightly opaque and woody.

4. Site B, March lift, cold store

0 HOURS - Small amount of disease, cavity spot and carrot fly. Quite abraded but only slight silvering. Tops trimmed.

24 HOURS - Minor cavity spot and other fungi. Skins badly abraded, some silvering. Dryish, slightly dull appearance. Minor regrowth of tops.

48 HOURS - Fungal rots increasing, brown rots. Badly abraded skins silvering. Dryish, dull appearance. Slight top regrowth.

72 HOURS - Numerous areas of rots developing. Very abraded and silvered skins. Dry, dull appearance, some dirty. Top regrowth.

6 DAYS - Quite badly diseased with rots. Skins very abraded and silvered. Dry, dull, dirty appearance. Lot of top regrowth. Very poor sample.

Internal - Pale to mid orange coloration with white around the core. Moderate incidence of pithiness. The cores are slightly opaque and woody. Some hollowing in a few roots.

5. Site B, May lift, field (straw)

0 HOURS - Very little disease. Minor abrasions on skin, no silvering. Tops trimmed.

24 HOURS - Very little disease. Minor abrasions and slight silvering. Bright appearance to carrots. No regrowth.

48 HOURS - Minor spots of disease. Few abrasions with minor silvering of the skins. Bright appearance. No regrowth.

72 HOURS - Small areas of brown rot and few crown rots. Minor silvering of skins. Appearance still bright. Very little top regrowth.

6 DAYS - Few rots on ends of roots and crowns. Some silvering of the skins. Appearance slightly dull. Very little top regrowth, some small lateral roots.

Internal - Mid orange coloration. Slight opaque, woody appearance to some cores. Slight to moderate incidence of pithiness.

6. Site B, May lift, field (straw + polythene)

0 HOURS - Small amount of cavity spot. Slight abrasions, no silvering. Tops trimmed.

24 HOURS - Minor cavity spot. Slight abrasions with minor silvering of the skins. Brightish appearance. No regrowth.

48 HOURS - Slight cavity spot. Minor abrasions and silvering of the skins. Brightish appearance. Very little regrowth.

72 HOURS - Carrot fly damage deteriorating with rots developing. Minor silvering. Brightish appearance still. Very little regrowth.

6 DAYS - Rots quite numerous. Some silvering of the skins. Fairly bright appearance though some roots were looking slightly old. Slight top regrowth.

Internal - Mid orange coloration. Opaque, slightly woody appearance to the cores. Slight to moderate incidence of pithiness.