ATO-DLO

Sprout suppression of ware potatoes by means of carvone

Semi-practical (15 tons stores) storage experiments with the cv. Bintje conducted on the ATO-DLO experimental farm " de Eest" (NOP) during the storage season 1992-1993

CONFIDENTIAL

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and coördinated by dr.ir. P. Diepenhorst

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Summary

Various carvone containing formulations properly suppressed sprout growth of potatoes (cv. Bintje), when stored on a semi-practical scale (15 tons stores) for a long period (± 270 days). The quality of both fresh and processed potatoes was well preserved during this storage period.
The best results were obtained when a small amount of IPC/CIPC (Gro Stop) powder was applied at loading time followed by regular applications during storage of the carvone containing formulation L 91105 D, or when regular L 91105 D applications were combined with mechanical cooling.
An important side-effect of application of carvone containing formulations, was a striking growth inhibiting effect of silver scurf (*Helminthosporium solani*) infection.

1. Introduction

Sprouting control is very important when potato tubers must be stored for a long period. Good storage practice is in particular important, when tubers have to be stored for processing into crisps and French fries later in the season.
When, after the curing period, the temperature is lowered to 2-4°C, followed by storage at constant temperature, sprouting will be kept within acceptable limits. However, in this temperature range the so-called low temperature sweetening will develop, leading to a high reducing sugar content which, depending on cultivar and growth circumstances will in turn cause a brownish, bitter product when processed (Maillard reaction).
In this case storage at higher temperatures (6-8 °C) combined with a sprout inhibiting treatment is necessary. Worldwide isopropyl N-phenylcarbamate (IPC or propham) and isopropyl N- (3-chlorophenyl) carbamate (CIPC or chlorpropham) are most used as sprout inhibitors for potatoes.

Since long there is a demand for other sprout inhibiting components, instead of both carbamates.
There are now several plant essential oils used in the food and cosmetic industry as fragrancing and flavouring substances, which have promising inhibiting properties on potato sprouts (Meigh, 1969; Beveridge et al., 1981).
Small scale as well as semi-practical scale experiments within 15 tons stores cooled with outside air, has shown that sprout growth can be inhibited by the monoterpene carvone (l-methyl-4-isopropenyl-Δ6-cyclohexen-2-one) from the essential oil of caraway seed (*Carum carvi* L.) or dill seed (*Anethum graveolens* L.). (Hartmans & van Es, 1988; Buitelaar & Hartmans 1991; Hartmans & Buitelaar, 1992 a and b; Hartmans & Buitelaar 1993).
During the storage season 1992\1993 different carvone formulation, dosages and application methods were tested in 15 tons stores at the ATO-DLO experimental farm "de Eest" .
Reported here is the comparison between different carvone treatments and a standard IPC/CIPC treatment, on sprout suppression and quality aspects of the potatoes during the whole storage season (1992\1993)

An interesting side-effect of carvone application under laboratory conditions was the inhibition of silver-scurf growth. *Helminthosporium solani* is the causal agent of silver scurf of potato tubers. Silver-scurf is considered a storage disease of potatoes, although infection often takes place before harvest. Unsightly blemishes are readily observed on washed, infected tubers. The fungal hyphae penetrate the cork cells of the periderm and be confined mainly within the periderm. Infected and disrupted periderm is no longer fully effective as a barrier against water loss and seriously affected tubers can shrivel sufficiently to become unsaleable, specially for the potato processing industry. Adequate control of the disease can be very useful, and this was a reason for determining the silver-scurf index at unloading time.

2 Materials and methods

2.1 Materials

2.1.1 Potatoes

The research was conducted on the cultivar Bintje. The required potatoes were cultivated on clay soil, 38% elutriation, on the ATO-DLO experimental farm "de Eest" at Nagele (NOP).

The following plant protection treatments were carried out during cultivation:

	Type	number of treatments	Name	dosage.ha^{-1}
-	herbicide	1 x	Mirabo	7.6 l
-	fungicide (phytophthora)	13 x	Topper	3 kg
-	,,	3 x	Pirimor	0.4 kg

The haulm was killed at the end of August by using 2.5 l Reglone/ha. The potatoes were lifted on September 14th and 15th. Harvesting was done under dry soil conditions (nearly no soil remained on the potatoes) which caused some damage due to handling.

2.1.2 Sprout inhibitors

The sprout inhibitors involved in the research were:

* **IPC**, Propham, O-isopropyl N-phenyl carbamate; MW: 179.21
* **CIPC**, Chlorpropham, isopropyl N-(3-chlorophenyl) carbamate; MW: 213.68

Formulations:
- a liquid sprout inhibitor used for fogging of ware potatoes, containing the active ingredients IPC (40 g/l) + CIPC (260 g/l). This product is available on the market, as Gro Stop SC (charge no. 5501-30-02).
- a powder sprout inhibitor used for ware potatoes, containing the active ingredients 0,5% IPC and 0,5% CIPC. This product is available on the market as Gro-Stop powder (charge no. 3107-202).

* **Carvone**, 1-methyl-4-isopropenyl-Ø6-cyclohexen-2-one; MW:150.21

* **Menthol**, 5-methyl-2-(1-methylethyl)-cyclohexanol; MW: 156.26

Formulations:(code)	Composition
L 91105D	d-carvone 95 HN (liquid with 95% d-carvone)
D 4066	l-carvone 97 HN (liquid with 97% l-carvone)
D 4046	d-carvone 20 GR (granules with 18.4% d-carvone)
D 4047	dl-menthol 6 GR (granules with 5.6% dl-menthol)

2.1.3 Sampling for quality control

During the entire storage season, all stores were sampled every six weeks in order to make various quality and chemical analyses. To that end, representative potato samples of about 12 kg were taken each time from the top of every store. Subsequently, the potatoes were divided up at random to asses sprouting and external damages, internal sprouting, sensory quality after steam cooking, French fry quality, residue and sugars contents.
At unloading times, one representative sample was taken from the entire store and three from different stack heights at 0.5, 1.5 and 2.5 m. For that purpose a sufficient number of potatoes of the desired size was collected from the conveyor belt and divided up in order to make various analyses.

2.2 Methods

2.2.1 Storage conditions

The potatoes (cv. Bintje) to be put in the stores no.1 to 10, 25 and 26 were harvested and stored in bulk on September 14th and 15th. The unloading time of the stores was partly determined by the sprout suppression effects of the agents and varied from the 26 th of May till the 10 th of June (254 to 269 days).

The storage research was conducted on the ATO-DLO experimental farm "de Eest". Use was made of ten 15 tons stores cooled with outside air and two mechanical cooled stores. With exception of the curing and drying period and the period required for heating the potatoes prior to delivery, the ventilation system was controlled by microprocessors. After the liquid sprout inhibitors had been applied as "fog", a ventilation-free period of $\pm$ 40 hours was inserted.
During the drying and curing period, a storage temperature of 12 - 15°C was kept. After this period, the true storage period followed, starting on September 30th.

The research programme also stated that in periods in which ventilation with outside air was not possible for a long time, a number of hours of internal air circulation would automatically be supplied, to level the temperature in the stacked potatoes. Each ventilation-free period of 4 x 24 hours was followed by one hour of internal air circulation.

Prior to delivery, the temperature of the potatoes was increased to about 20°C, by internal ventilation combined with artificial heating or by outside air ventilation.

Within store no. 8 L 91105D was dosed automatically after every outside air ventilation period. The short L 91105D dosage period was combined with an internal ventilation period of 30 minutes.
Furthermore in the two stores no. 7 and 8, internal ventilation was started at a temperature difference of $\geq$ 2°C between two temperature sensors; one at a stack height of 0,5 m and one at 2,5 m.

In each store an electronic temperature sensor was installed 50 cm below the

surface of the potatoes. In all stores, temperatures and number of internal and external ventilation hours were registered daily.

2.2.2 Dose rates of sprout inhibitors

During this investigation, the products, number of treatments and dosing time varied. A survey of the test variants is given Table 2.2.2.

Use was made of a swingfog apparatus (nozzle 0,9 for Gro Stop SC and nozzle 1.2 for the carvone formulations) to apply the liquid agents. The internal air circulation system was used during and continued another 15 min. after application.

Within store no. 8 L 91105D was automatically applied (Table 2.2.2), 5 min after every outside air ventilation period, by the use of a compressed air fogging equipment (Dofra - The Netherlands). Within store no. 7 L 91105D was applied automatically every six weeks with the same compressed air equipment. This fogging was also combined with internal air ventilation, which continued another 15 min. after the application.
The Gro Stop powder was spread by hand during loading.

Table 2.2.2. A survey of the experimental applications used to investigate the sprout suppressant activity of carvon during storage of ware potatoes of the cv. Bintje (storage season 1992/1993).

store no.	Sprout inhibitors	Application per 1000 kg potatoes			Application times
		number of applications	dosage per application	total amount	
1	Gro Stop SC (30%)	4	20 ml	80 ml	30-09, 22-12, 24-02 and 28-03.
2	L 91105D	6	75 ml	450 ml	30-09, 11-11, 22-12, 05-02, 17-03 and 28-04.
3	L 91105D + L 91105D	1 6	100 ml 75 ml	100 ml 450 ml	15-09 equal to store 2
4	D 4046 (granules) + L 91105D	1 6	0,6 kg 75 ml	0,6 kg 450 ml	14-09 (during loading) equal to store 2
5	D 4047 (granules) + L 91105D	1 6	0,5 kg 75 ml	0,5 kg 450 ml	14-09 (during loading) equal to store 2
6	D 4066	6	75 ml	450 ml	equal to store 2
7	L 91105D	6	75 ml	450 ml	equal to store 2 (automatically)
8	L 91105D	39 28 1	*)4,3 ml *)5,2 ml 100 ml	163 ml 149 ml 100 ml	from 2 Oct. (automatically) average 2.0x per week 17-02
9	Gro Stop powder (1%) + L 91105D	1 6	0,5 kg 75 ml	0,5 kg 450 ml	15-09 (during loading) equal to store 2
10	Gro Stop powder (1%) + Gro Stop SC (30%)	1 6	0,5 kg 13 ml	0,5 kg 78 ml	15-09 (during loading) equal to store 2
25	L 91105D	6	75 ml	450 ml	5-10, 11-11, 22-12, 05-02, 17-03, and 28-04
26	L 91105D	4	75 ml	300 ml	22-12, 05-02, 17-03, and 28-04

*) average values

2.2.3 *Carvone determination in the storage atmosphere (headspace)*

The carvone content in the storage atmosphere (head space) was determined by means of absorption of carvone onto a Tenax absorbent, followed by thermal desorption cold trap injection on GC.
During the storage season, air samples were taken in the stores at regular intervals. An amount of air was sucked trough glass tubes filled with 100 mg of Tenax TA (20-35 mesh) for 15-60 seconds (flow: 1 ml.sec.$^{-1}$), depending on the carvone concentration to be expected.
The air samples were taken from the upper part of the stores. The first samples were take one hour after treatment. Carvone was analyses with GC, as described by Hartmans and Buitelaar 1993.

2.2.4 *Quality aspects of potatoes during storage*

2.2.2.1 *Sprout suppression, tuber defects and silver-scurf infection*

Sprout suppression

Sprout suppression during storage

During the whole storage period, a regular assessment was made of the degree of sprouting. This could only be done in the upper part of the stores.
In order to simulate the effect of short storage at higher temperatures on small quantities (super market situation), samples were taken from the bulk stores at regular intervals of six weeks and stored for an additional period of three weeks in perforated plastic bags at 15°C. For that purpose, two representative samples of 20 tubers each (size ± 40 - 60 mm; weight ± 100 g) taken from the upper part of the stores, were used. After one and three weeks all sprouts of one sample were removed, counted and weighed.

Sprout suppression at unloading time

When unloading the stores, the degree of sprouting in the entire lot was visually assessed and the mean sprout suppression effect was determined and expressed as follows:

1 = bad
2 = insufficient
3 = almost sufficient
4 = sufficient
5 = amply sufficient
6 = good
7 = excellent

If the sprout suppression effect is considered to be "excellent", this means that no or

hardly any sprouts were found in the lot. If the sprout suppression effect is regarded as "bad", this means that a lot of potatoes were heavily sprouted. A sprout suppression effect which is "sufficient" (4), is just effective enough to create no problems with the customer.
Furthermore a representative sample of 30 to 40 kg was collected form the entire store, sprouts and tubers weighed separately and the number of tubers per sample counted.
Four small samples of 20 tubers from the entire store were collected and stored in plastic bags for an additional period of three weeks at 15°C. The number of sprouts and the sprout weight was determined from two samples after one and three weeks respectively.

Tuber defects

Internal and external defects

In order to determine internal sprouting and any damage to the potatoes as a result of agents used, two representative samples of 100 tubers were collected from each store during unloading. The samples were washed and an assessment was made of any external damage due to the agent used; subsequently, the samples were cut and the degree of internal sprouting and any other defects were determined.

Blackspot susceptibility

Blackspot susceptibility was determined on two representative samples of 100 tubers (size ± 40 - 70 mm) collected at unloading time. After two extra days of conditioning at 15°C, the samples were shaken for 30 sec. on an approximately 1 m^2 shaker plate (at a rotational speed of 290 $rev.min^{-1}$). Next, the tubers were kept 48 hours storage at 15°C, then the blackspot index of the tubers was determined after peeling as follows: peeled tubers were visually inspected and divided into four classes, based on the area of tuber surface with blackspots.

susceptibility class	blackspot area of the tuber surface in %
no	0
light (L)	0 - 2%
moderate (M)	2 - 10%
severe (S)	> 10%

The blackspot index was calculated by using the formula:

$$\text{Blackspot index} = \frac{(L + 2M + 3S)}{6}$$

Silver-scurf (Helminthosporium solani) index

The silver-scurf infection was determined at unloading time by collecting two representative samples of 25 tubers each (tuber size between 40 and 70 mm) from the entire store. After washing, one side of each tuber was visually inspected and the % infected silvery surface of each tuber estimated. The affected tubers were classified, the number of affected tubers within each class multiplied with a certain factor (Table 2.2.4.1.) and the silver-scurf index (SSI)calculated (Buitelaar 1990) by using the formula:

$$SSI = \frac{[(na)\ 2.5 + (nb)\ 8.75 + ...(nf)87.50]}{25}$$

Table 2.2.4.1 Classification of potatoes on % of silver-scurf infection of the tuber suface.

class	% infected surface	multiplication factor
	0 %	0
a	0 - 5 %	2.5
b	5 - 12.5 %	8.75
c	12.5 - 25 %	18.75
d	25 - 50 %	37.5
e	50 - 75 %	62.5
f	75 - 100 %	87.5

2.2.4.2 Residue Analyses

Residue content of IPC/CIPC

IPC/CIPC was extracted from fresh potatoes by means of an organic solvent, prepurified with aluminium oxide and analysed by means of a GC fitted with a nitrogen phosphorus detector (NPD) (Hartmans & Buitelaar 1992a). For the determination of IPC and CIPC, the NPD type of detector is more sensitive than the FID type.

Residue content of carvone and menthol

Carvone and menthol were extracted from fresh potatoes by means of an organic solvent, suitable for lipid extraction (Bligh & Dyer, 1959). An internal standard was added to the extract, which was than injected straight onto a sampling tube filled with the absorbens Tenax. Subsequently analysis was carried out by means of a GC fitted with a thermodesorption cold trap injection system (Hartmans, 1992; Hartmans & Buitelaar, 1993).

2.2.4.3 Sensory quality of steam cooked potatoes

The sensory qaulity of steam cooked potatoes was assessed three times during storage, n.l. in October, March and at unloading time. Potatoes of four carvone treated stores (no.'s 2, 5, 6 and 25) were used for this purpose. Potato samples of the Gro Stop SC treated store (no. 1) were used as reference.
Sensory research of steam cooked potatoes was carried out by a panel.
The method chosen was that of an ordinal comparison in pairs of potatoes with a number of relevant characteristics.
The method was described by Hartmans & Buitelaar (1992b).

2.2.4.4 Processing quality (sugar content and French fry colour)

Determination of sugars (glucose, fructose and sucrose)

Sugars were extracted from representative freeze-dried potato samples by means of water. The extract was filtrated several times and subsequently 'cleaned up' by means of a small Sep-pack column. The solutionis now ready for injection into the HPLC (Hartmans & Buitelaar, 1992a).
Separation on the SUGAR pack column is based on a combination of mechanisms, such as hydrophillic and hydrophobic adsorption and separation based of particle size. Detection takes place by means of a refractometer (Anon., 1980; Brons & Olieman, 1983).

French fry colour index

The French fry colour was determined, according to the standard procedure used by the Dutch processing industry and developed by Ludwig (1989).

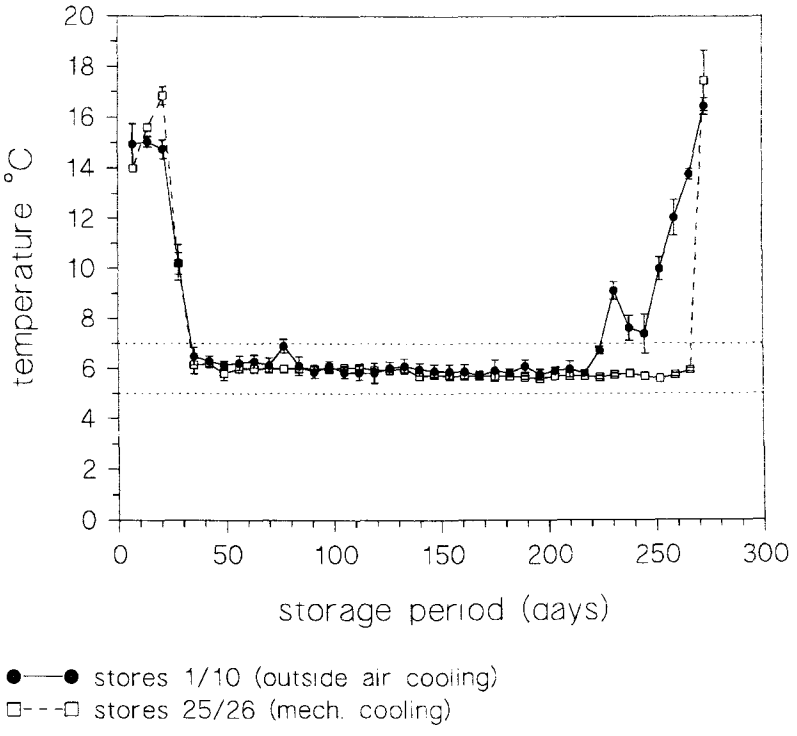
3 Results and discussion

3.1 Storage conditions

3.1.1 Temperature

From the daily registered temperatures, the average weekly values were calculated per store. The average weekly temperatures from the 10 outside air cooled stores and from the 2 mechanical cooled stores over the whole storage season are shown in Fig. 3.1.1.
With exception of the beginning of the storage season (cooling period) and the end (too high outside air temperature), the storage temperature could be kept rather constant within the 5-7°C range.

Fig. 3.1.1
Average storage temperature per week of 12 experimental stores
("De Eest" storage season 1992/1993, stores 1/10 and 25/26)



3.1.2 Ventilation

From the daily registered external and internal number of ventilation hours, the average weekly values were calculated per store and shown in Fig. 3.1.2. A and B for all 10 outside air cooled stores and in Fig. 3.1.2. C for the 2 mechanical cooled stores.

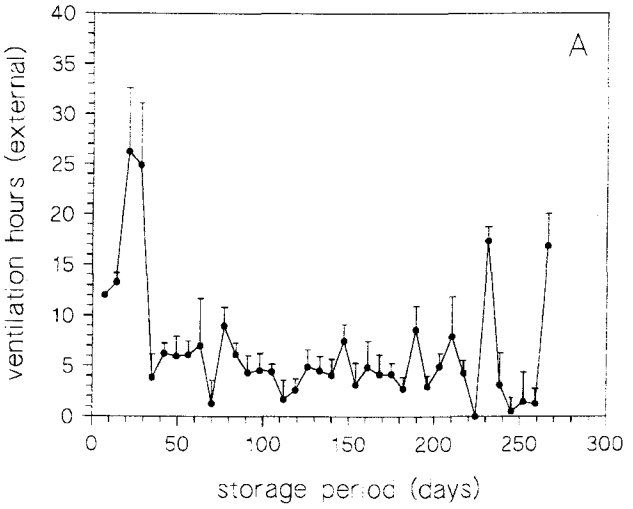
Table 3.1.2. A survey of the number of ventilation hours during the storage season 1992/1993.

Store no.	External ventilation hours during			Internal ventilation hours during	
	curing period after loading	storage period	heating period prior unloading	storage period	heating period prior unloading
1	21	154	22	46	0
2	21	193	20	45	0
3	21	198	20	45	0
4	21	195	16	46	0
5	21	203	16	48	0
6	21	190	16	44	0
7	21	322	12	27	0
8	21	215	9	28	14
9	21	230	15	51	0
10	21	202	15	43	0
25	22	0	21	404 *)	0
26	22	0	21	390**)	0

*) of which 401 hours during mechanical refrigeration.
**) of which 388 hours during mechanical refrigeration.

The total number of ventilation hours during curing, storage and heating periods are summarized in Table 3.1.2. The variation in internal ventilation hours was rather constant over the whole season (Fig.3.1.2.B). The number of external ventilation hours varied more at the beginning and end of the storage season, due to the higher outside air temperatures and more frequent cooling periods (Fig.3.1.2.A & Fig.3.1.2.C).

Fig. 3.1.2 A
Average number of ventilation hours per week of 10 experimental stores ("De Eest" 1992/1993, stores 1/10)



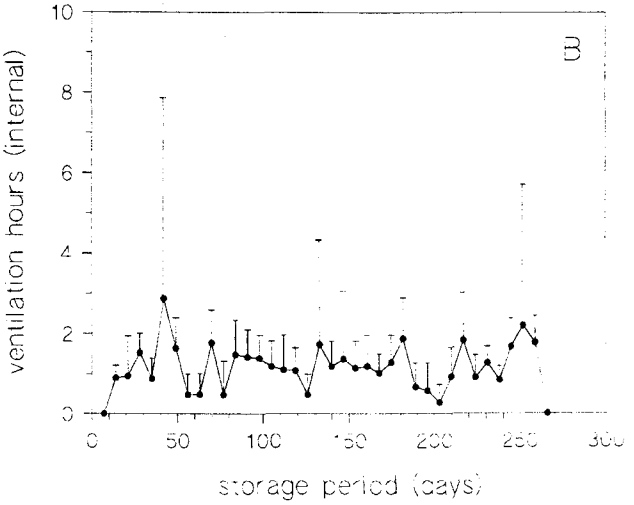
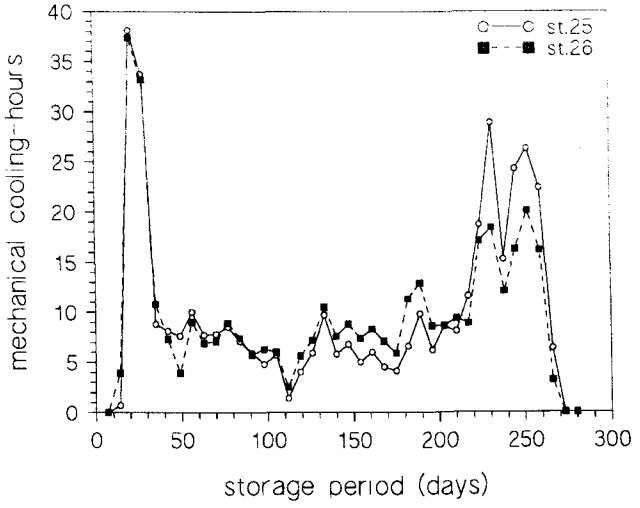


Fig. 3.1.2 C
Average number of mechanical cooling hours per week
(" De Eest" , season 1992/1993 stores 25 and 26)



3.1.3 Carvone concentration in the atmosphere (head space) during storage

Fig. 3.1.3 en Table 3.1.3 (Appendix) show the changes in carvone concentration in the headspace of the stores during the storage. The carvone measurements were carried out once a week (three times a week for store no.8)

- Periodical treatments every 6 weeks with high dosages (all stores except store no. 8) showed high carvone concentrations just after application. These high concentrations decreased within a few weeks to low levels.
- Automatical treatments with low dosages (store no.8) showed a more or less constant low level of carvone in the head space during storage. Because of inadequate sprout inhibition an extra amount of L 91105D was applied (100 ml. ton^{-1}) after about 160 days in store no.8. This caused somewhat higher values in the head space.
- The decrease of carvone in most cases was less between about 75 and 200 days. This was probably due to the fact that there was less external ventilation (Fig. 3.1.2.) during this period, which means less carvone losses.
- An additional treatment at loading time (store no's 3 and 4) did not cause higher carvone contents afterwards.
- An additional treatment at loading time with menthol (D 4047 - store no.5) did not show a detectable menthol concentration in the atmosphere.
- Although the stores 25 and 26 were mechanical cooled, which means there was no ventilation with outside air, the changes in carvone content within these stores nevertheless were more or less the same as within the store's with comperable applications (store no.s 2 and 6) but cooled with outside air ventilation.

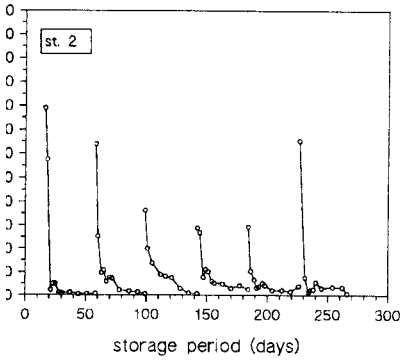
  This unexpected phenomenon was not understood, but different explanations were possible, as for instance:

  * beside losses due to forced air ventilation, there could be other air losses caused by leakage of the store.
  * absorption of carvone to isolation material. In contrast with the store no.'s 1 to 10, the stores 25 and 26 were at the inside isolated with polyurethane foam.

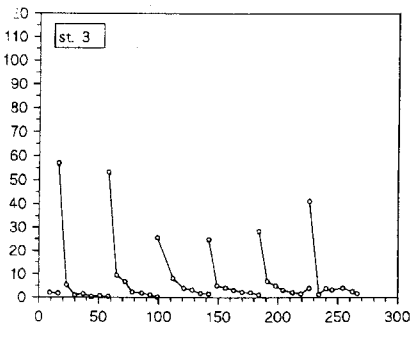
The concentration of carvone in the storage atmosphere depends in general on:

. the administered dose
. the time after dosing
. amount of ventilation between dosing times.

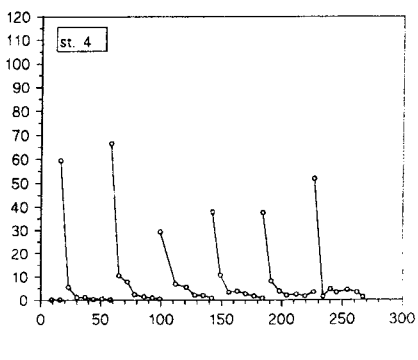
g. 3.1.3
luence of different carvone treatments during storage
the carvone concentration of the storage atmosphere.



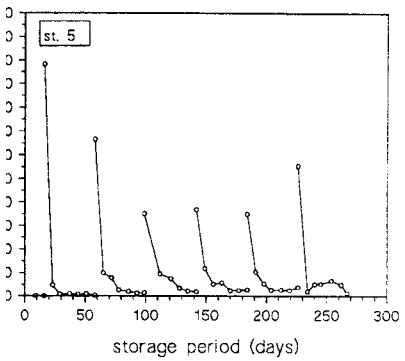
6x75 ml/t/6 weeks L91105D



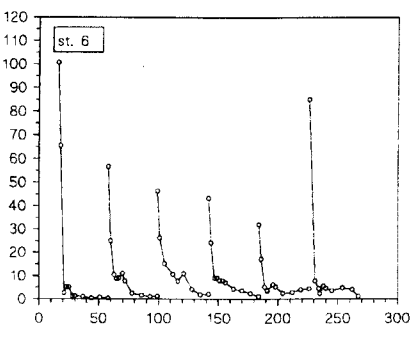
100 ml/t at loading time + 6x75 ml/t/6 weeks L91105D



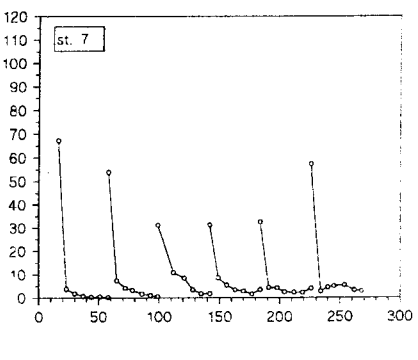
0.5 kg/t D 4046 + 6x75 ml/t/6 weeks L91105D



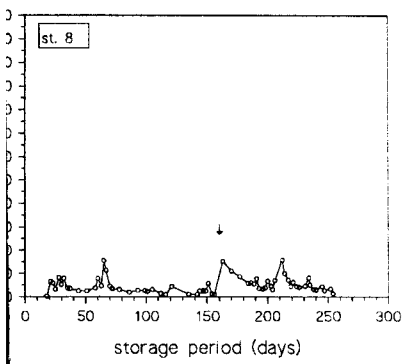
0.5 kg/t D 4047 + 6x75 ml/t/6 weeks L91105D



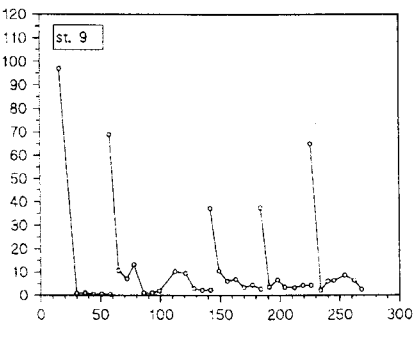
6x75 ml/t/6 weeks D 4066



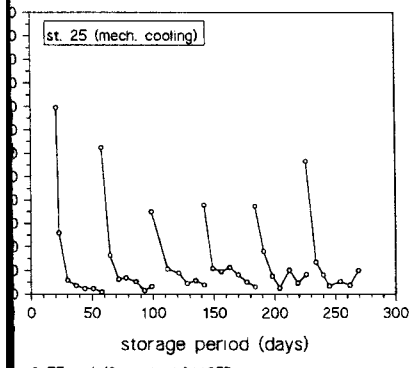
6x75 ml/t/6 weeks L91105D (aut.dos.)



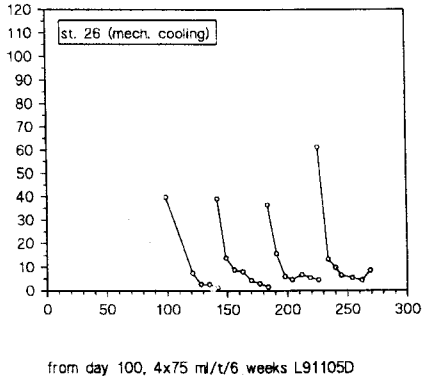
aut.dos. 4 ml/t L91105D/time + 1x100 ml(↓)



0.5 kg/t gro-stop + 6x75 ml/t/6 weeks L91105D



6x75 ml/t/6 weeks L91105D



from day 100, 4x75 ml/t/6 weeks L91105D

3.2 Quality aspects

3.2.1 Sprout suppression and tuber defects

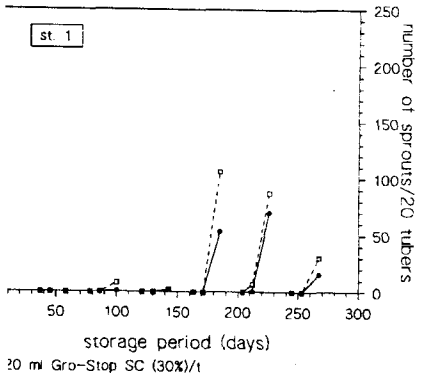
Sprout suppression

3.2.1.1 Sprout suppression during storage

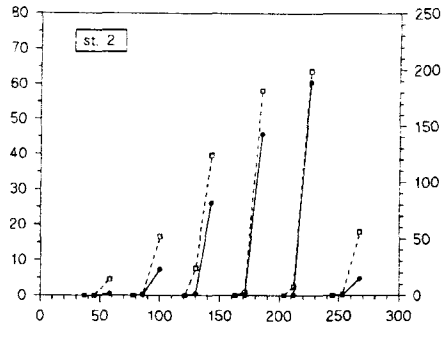
All stores were visually inspected every three weeks during the whole storage period. Beside this, sprout growth was determined on a representative sample at regular intervals of 6 weeks. Futhermore sprout regrowth of these samples was investigated after an additional storage period of three weeks at 15°C.
Although application of carvone containing formulations can control sprout growth during storage very efficient, as soon as the potatoes are removed from the stores, there can in general be a regrowth of the sprouts within a couple of weeks if then the storage conditions allowed the tubers to sprout again.
The sprout growth of small samples (20 tubers), removed at regular intervals during storage from the bulk stores and subsequently stored for one or three weeks at 15°C, is shown in Fig. 3.2.1.1.
Sprout suppression was in general still sufficient after one week storage at higher temperature. After three weeks the potatoes were heavily sprouted in some cases, especially between the storage period of ± 120 - 210 days.
The sprout weight and number of sprouts varied during the storage season and depended of the sprout suppression treatment. Nearly no sprouting occurred when potatoes were treated with a combination of a powder and liquid Gro Stop formulation (store no. 10). Minor sprouting was shown when the potatoes were treated with the liquid Gro Stop formulation (store no. 1) only, or when the combination of a powder Gro Stop formulation with L 91105D (store no. 9) was applied.

1.1

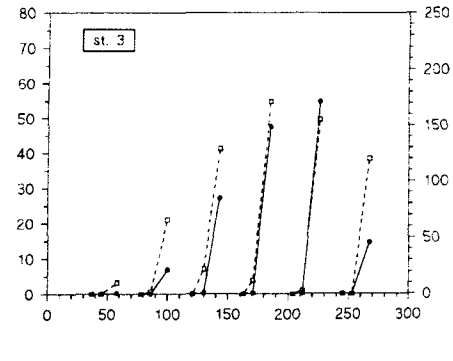
of sproutinhibitor treatments on sproutgrowth during storage
g an additional storage period of 1 or 3 weeks at 15 °C.
, season 1992/1993)



20 ml Gro-Stop SC (30%)/t

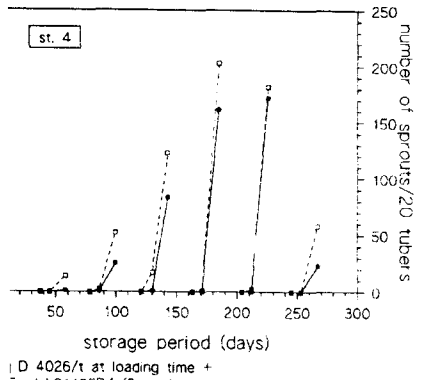


6 x 75 ml L91105D/t/6 weeks

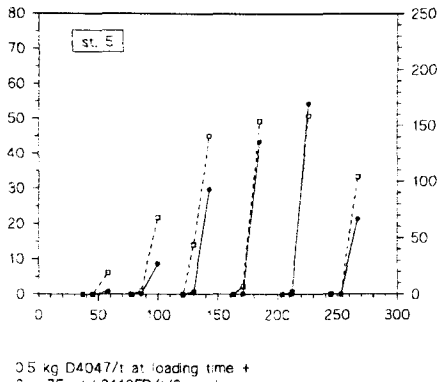


100 ml L91105D/t one day after loading +
6 x 75 ml l91105D/t/6 weeks

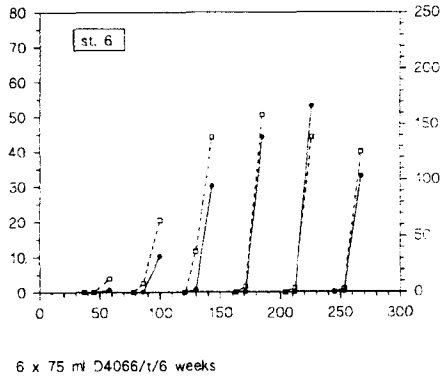
• sproutweight □--□ number of sprouts



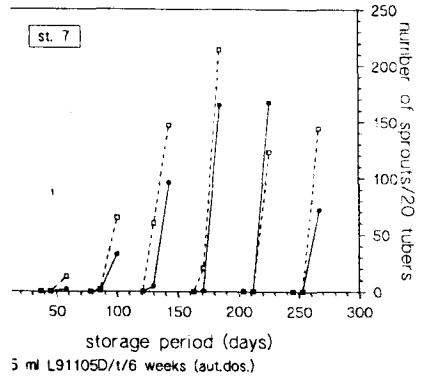
l D 4026/t at loading time +
5 ml L91105D/t/6 weeks



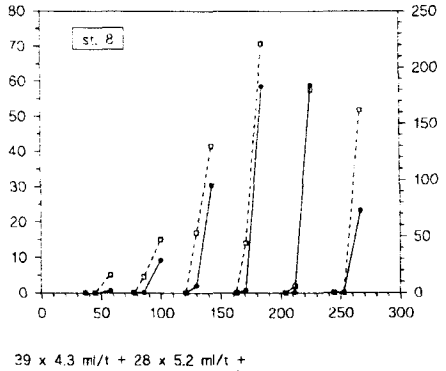
0.5 kg D4047/t at loading time +
6 x 75 ml L91105D/t/6 weeks



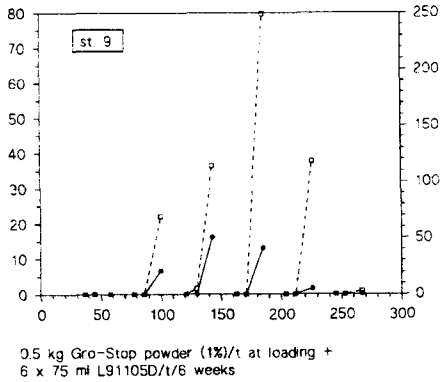
6 x 75 ml D4066/t/6 weeks



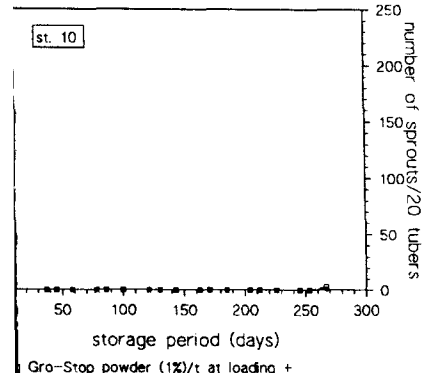
5 ml L91105D/t/6 weeks (aut.dos.)



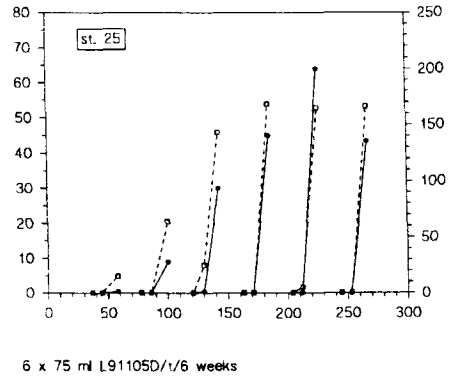
39 x 4.3 ml/t + 28 x 5.2 ml/t +
1 x 100 ml L91105D/t (aut.dos.)



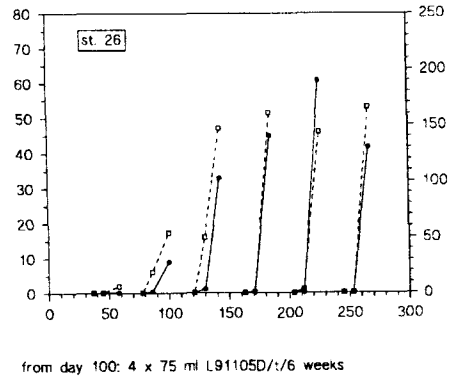
0.5 kg Gro-Stop powder (1%)/t at loading +
6 x 75 ml L91105D/t/6 weeks



Gro-Stop powder (1%)/t at loading +
3 ml ipc/cipc (30%)/t/6 weeks



6 x 75 ml L91105D/t/6 weeks



from day 100: 4 x 75 ml L91105D/t/6 weeks

3.2.1.2 Sprout suppression at unloading time

The average sprout suppression effects at unloading time of all stores are presented in Table 3.2.1.2.
All potatoes were stored until the beginning of June, except from the automatically dosed store no. 8. Although this store was in February treated with on extra 100ml L 91105D.1000 kg^{-1} (Table 2.2.2), it had to be unloaded already in May due to insufficient sprout suppression. All other sprout supprsession treatments gave equal or better results then the standard Gro Stop SC liquid application (store no. 1), except the other automatically dosed store (no.7). The best sprout suppression results were achieved when L 91105D was applied in combination with, either mechanical cooling (stores no. 25 and 26), or an additional treatment with Gro Stop powder (store no. 9) at loading time. Mechanical cooling however, is an expensive cooling technique and nearly not in use for storage of ware potatoes.
The combination of powder and liquid Gro Stop application is commonly used in practice nowadays. The sprout suppression within the three stores no.'s 9, 25 and 26 with L91105D was however equal or even better then this combined Gro Stop (store no. 10) treatment.
When compared with carvone treatments only at regular intervals (store no. 2) after the curing period, it seems that an additional treatment at loading time with with special formulations (store no.'s 3, 4 and 5) had a somewhat better effect. These experiments should however be repeated to confirm the results.
Regular applications of D 4066 had in this experiment a less sprout suppression effect. This result was however not in agreement with the results from previous storage experiments, were both carvone isomers had more or less the same effect (Hartmans & Buitelaar, 1993).

After unloading, small samples of 20 tubers were stored at 15°C for an additional period of three weeks in perforated plastic bags. After one week all samples were sprouted except from store no. 9 (Fig. 3.2.1.2). After three weeks all potato samples were sprouted with the smallest sprouts on tubers from store no. 10 and the largest sprouts on tubers from store no. 6. Regrowth of sprouts after unloading was at most suppressed by the combined treatment of Gro Stop powder with regular low dosages of Gro Stop SC (store no. 10). Potatoes treated with various carvone containing formulations only, showed in general at unloading time comparable sprout regrowth as the liquid Gro Stop SC (store no. 1) treated tubers.

Table 3.2.1.2 A survey of the storage periods and sprout suppressions indications at unloading time (cv. Bintje, season 1992/1993)

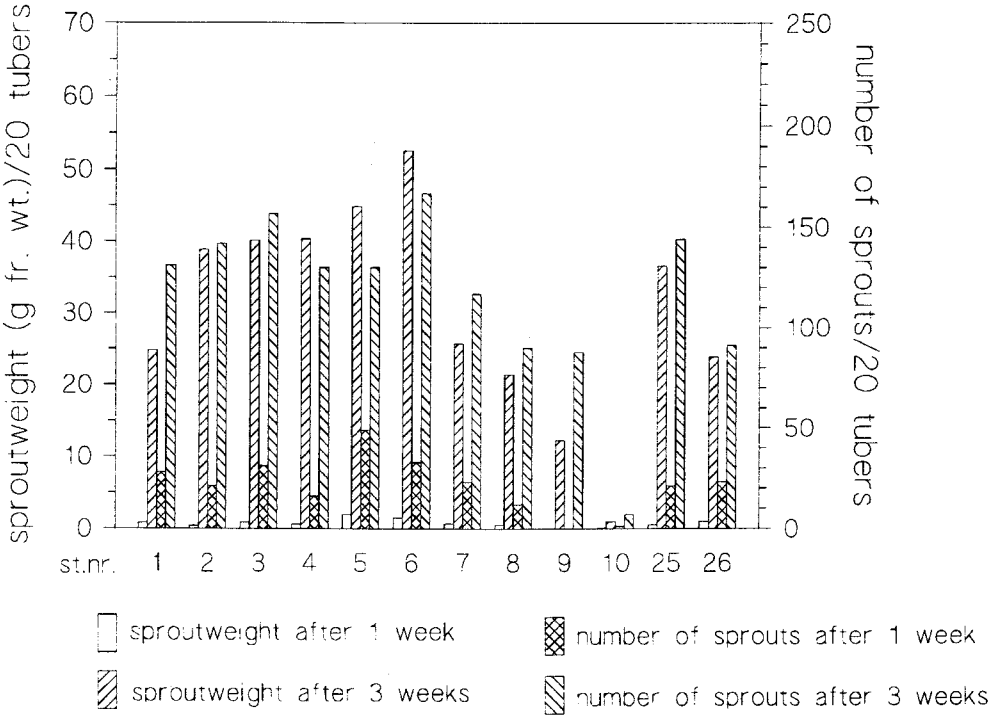
Store no.	Sprout inhibitor	Number of applications	Date of unloading	Storage period (days)	Sprout suppression indication (scale 1 to 7)	Sprout weight (g)	
						.10 kg^{-1}	.100^{-1} tubers
1	Gro Stop SC (30%) (80 ml) *)	4	7 June	266	4	44	78
2	L 91105D (450 ml)	6	7 June	266	4	22	32
3	L 91105D (100 ml) + L 91105D (450 ml)	1 6	7 June	266	5.5	16	24
4	D4046 (granules) (0,6 kg.) + L 91105D (450 ml)	1 6	8 June	267	5.5	20	29
5	D4047 (granules) (0,5 kg.) + L 91105D (450 ml)	1 6	8 June	267	5.5	29	46
6	D4066 (450 ml)	6	8 June	267	2.5	37	55
7	L 91105D (450 ml)	6	9 June	268	2	55	80
8	L 91105D (312 ml) + L 91105D (100 ml)	67	26 May	245	2	89	141
9	Gro Stop powder (1%) (0,5 kg.) + L 91105D (450 ml)	1 6	9 June	268	7	0	0
10	Gro Stop powder (1%) (0,5 kg.) + Gro Stop SC (30%) (78 ml)	1 6	10 June	269	6.5	4	5
25	L 91105D (450 ml)	6	10 June	269	7	1	1
26	L 91105D (300 ml)	4	10 June	269	7	4	6

*) total dosage.1000 kg $potatoes^{-1}.season^{-1}$

Sprout suppression indication:
1 = bad
2 = insufficient
3 = almost sufficient
4 = sufficient
5 = amply sufficient
6 = good
7 = excellent

Fig. 3.2.1.2

Influence of treatment on sprouting after unloading and during an additional storage period of 1 or 3 weeks at 15°C. (season 1992/93)



treatment. 1000 kg^{-1}

1) 4x20 ml Gro Stop SC (30%)
2) 6x75 ml L 91105D.6 w^{-1}
3) 1x100 ml + 6x75 ml L 91105D.6 w^{-1}
4) 1x0.6 kg D4046 + 6x75 ml L 91105D.6 w^{-1}
5) 1x0.5 kg D4047 + 6x75 ml L 91105D.6 w^{-1}
6) 6x75 ml D4066.6 w^{-1}
7) 6x75 L 91105D(aut).6 w^{-1}
8) 39x4.3 + 28x5.2 + 1x100 ml L 91105D
9) 1x0.5 kg Gro Stop powder(1%) + 6x75 ml L 91105D.6 w^{-1}
10) 1x0.5 kg Gro Stop powder(1%) + 6x13 ml Gro Stop SC.6 w^{-1}
25) 6x75 ml L 91105D.6 w^{-1}
26) from day 100: 4x75 ml L 91105D. 6 w^{-1}

Tuber defects

3.2.1.3 Skin damages and internal sprouting at unloading time

- Nearly no skin damages were determined on the potatoes from the different stores (Table 3.2.1.3).
- No internal sprouting occured within the samples collected at regular intervals from the stores during storage. Internal sprouting was only determined at unloading time. Internal sprouting was shown in the tubers from the stores cooled with outside air cooling (Table 3.2.1.3). Tubers from the two mechanical cooled stores (no. 25 and 26) had no internal sprouting. This means that the temperature at the end of the storage period (Fig. 3.1.1) was the most important factor controlling internal sprouting. Additional application of 0,5 kg. ton^{-1} of Gro-Stop powder at loading time had also a positive effect on the control of internal sprouting (stores no. 9 and 10). The type of sprout suppression treatments afterwards with or Gro Stop SC or L 91105D, did not seem to be of much influence in this case.
  Potatoes treated with various carvone formulations (stores no. 2 till 8) had in general comparable internal sprouting levels as those treated with liquid Gro Stop SC (store no. 1) only. Tubers from the stores no. 3 and 4 had a lower internal sprouting level, probably due to the additional treatments at loading time.
  The lower internal sprouting level of the potatoes from store no. 8, occured because of the shorter storage period during the season.

Table 3.2.1.3 A survey of the amount of skin damages and internal sprouting at unloading time.

(cv. Bintje, storage season 1992/1993)

Store no.	Sprout inhibitor	Date of unloading	Number of applications	Percentage of tubers with		
				internal sprouts	skin damages as a result of	
					IPC/ CIPC	Carvone
1	Gro Stop SC (80 ml)*	7 June	4	11	0	--
2	L 91105D (450 ml)	7 June	6	14	--	0
3	L 91105D (100 ml) L 91105D (450 ml)	7 June	1 6	6.5	--	0
4	D4046(granules) (0.6 kg) L 91105D (450 ml)	8 June	1 6	8.5	--	0,5
5	D4047(granules) (0.5 kg) L 91105D (450 ml)	8 June	1 6	15.5	--	0
6	D4066 (450 ml)	8 June	6	14.5	--	0
7	L 91105D (450 ml)	9 June	6	15.5	--	0
8	L 91105D (312 ml) L 91105D (100 ml)	26 May	67 1	7.5	--	0
9	Gro Stop powder (0.5 kg) L 91105D (450 ml)	9 June	1 6	1	0	0
10	Gro Stop powder (0.5 kg) Gro Stop SC (78 ml)	10 June	1 6	0.5	0	--
25	L 91105D (450 ml)	10 June	6	0	--	0
26	L 91105D (450 ml)	10 June	4	0	--	0

*) total dosage.1000 kg potatoes^{-1}.season^{-1}

3.2.1.4 Blackspot susceptibility at unloading time

Black spot susceptibility at the time of unloading was higher (Fig. 3.2.1.4), when the sprout suppression effect was less (stores no. 6, 7 and 8), which is a well know phenomenon. More sprouts mean higher water losses, wich causes in general during storage a higher black spot susceptibility.

3.2.1.5 Silver-scurf (Helminthosporium solani) index at unloading time

Carvone has been reported to suppress the growth of *Helminthosporium solani* (silver-scurf) in an *in vitro* assay system (Gorris et al., 1993). It was unknown however if silver-scurf inhibition with carvone occured *in vivo* as well, because of the difficulty of artificial infection with *Helminthosporium solani*. Natural silver-scurf infections occured however on the tubers of the semi-practical experiments described here.

Potatoes treated with Gro-Stop formulations only (stores no. 1 and 10) had a higher silverscurf index than the potatoes treated with some carvone formulations (Fig. 3.2.1.5). This means that also in practice carvone can suppress growth of *Helminthosporium solani* rather strongly, which is an important side effect.

The most striking differences in inhibition of silver-scurf infection were shown between the Gro Stop treated stores (1 and 10) and the carvone treated stores no.'s 2, 3, 5 and 9).

A regular low dosage of L 91105D applied automatically after every outside air ventialtion period (store no. 8) did not have an efficient sprout suppressing effect (Tables 3.2.1.2), neither a growth suppressing effect on *Helminthosporium solani.* The carvone head-space concentration during storage was too low in this store (Fig. 3.1.3)

Fig. 3.2.1.4
Influence of sproutinhibitors on the blackspot susceptibility
("De Eest" storage season 1992/1993, stores 1/10, 25/26)

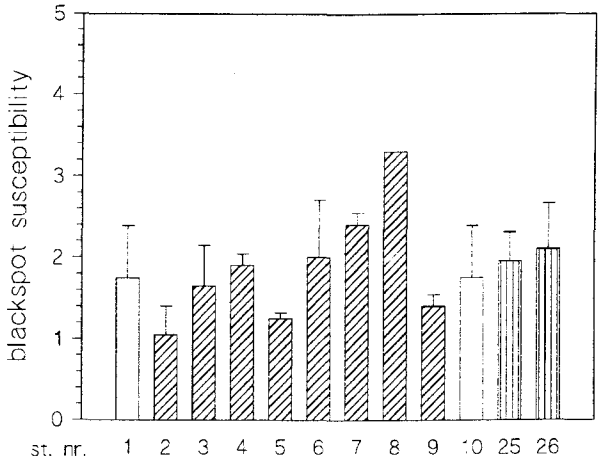
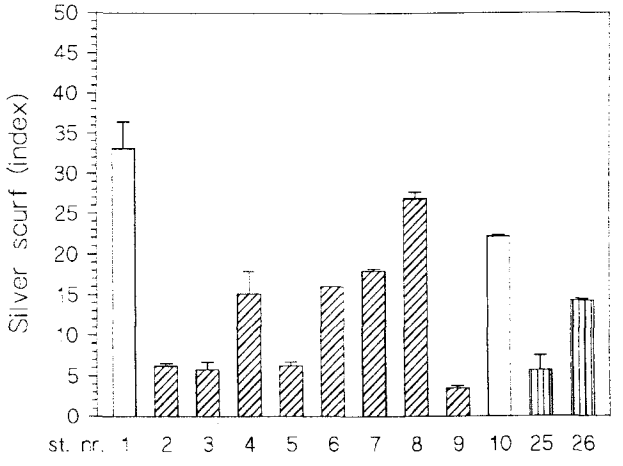


Fig. 3.2.1.5
Influence of sproutinhibitors on the silver scurf infection
(" De Eest" storage season 1992/1993, stores 1/10, 25/26)



treatment. 1000 kg^{-1}

1) 4x20 ml Gro Stop SC (30%)
2) 6x75 ml L 91105D.6 w^{-1}
3) 1x100 ml + 6x75 ml L 91105D.6 w^{-1}
4) 1x0.6 kg D4046 + 6x75 ml L 91105D.6 w^{-1}
5) 1x0.5 kg D4047 + 6x75 ml L 91105D.6 w^{-1}
6) 6x75 ml D4066.6 w^{-1}
7) 6x75 L 91105D(aut).6 w^{-1}
8) 39x4.3 + 28x5.2 + 1x100 ml L 91105D
9) 1x0.5 kg Gro Stop powder(1%) + 6x75 ml L 91105D.6 w^{-1}
10) 1x0.5 kg Gro Stop powder(1%) + 6x13 ml Gro Stop SC.6 w^{-1}
25) 6x75 ml L 91105D.6 w^{-1}
26) from day 100: 4x75 ml L 91105D. 6 w^{-1}

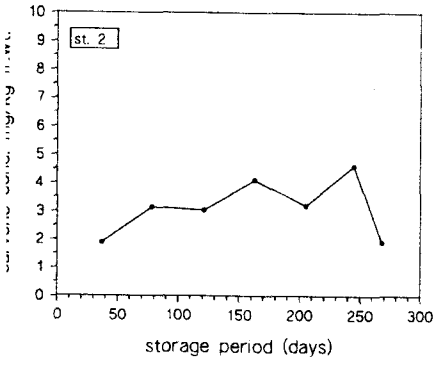
3.2.2 Residue contents of sprout inhibitors

Carvone residue during storage

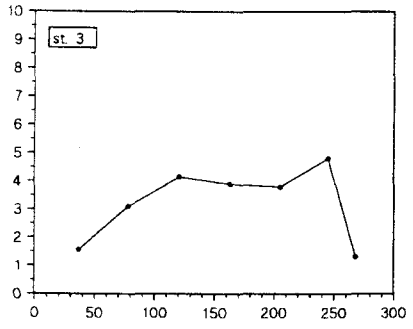
Samples from carvone treated stores were analysed every 6 weeks during storage. each time three weeks after application (Fig. 3.2.2.1 and (Table 3.2.2. Appendix)). The carvone residues in general did not exceed 5 $mg.kg^{-1}$ fresh weight.
The lowest residues during the whole storage season, existed in the automatically dosed store no. 8. An additional amount of L 91105D (100 $ml.1000\ kg^{-1}$) was applied after a storage period of 161 days, because of inefficient sprout inhibition. This provided for an increase in carvone residue.
In all other stores the residue values were low at the beginning and end of the storage season. During the period in between the residues reached their highest levels, probably due to repeated dosages and less ventilation half way the season. Before unloading, all stores were heated up by means of intensive ventilation with warm air. This caused in all cases a substantial decrease in carvone residue to average values of about 1 to 2 $mg.kg^{-1}$.
The carvone residue was also influenced by the time between application and sampling (Fig. 3.2.2.2 A and B). Two stores (no.'s 2 and 3), applied every 6 weeks with equal amounts of L 91105D during storage, were sampled once a week during a 6 weeks period at the beginning of the storage period. After application, the carvone residue in both stores (no.'s 2 and 3) increased, followed after one week with a gradual decline (Fig. 3.2.2.2 B). When the carvone residue was determined from samples taken every three weeks after application, then there were gradual changes in residue contents over the whole storage season (Fig. 3.2.2.2. A).
The carvone residue content was very much dependent of the moment of sampling between the applications.

Although in store 5 menthol (D4047) was applied on the potatoes at loading time, no detectable amounts of menthol were not found during storage.

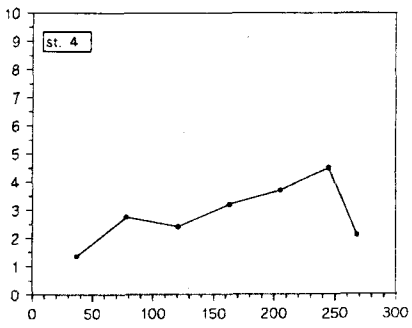
g. 3.2.2.1
ifluence of different Carvone treatments during storage
n the Carvone residue of the potatoes.



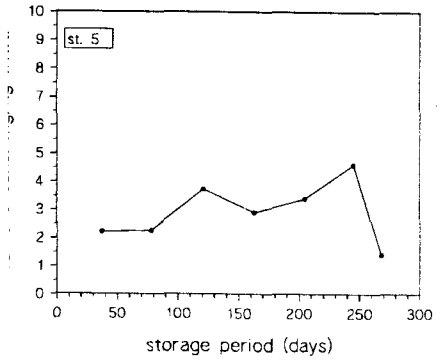
6x75 ml/t/6 weeks L91105D



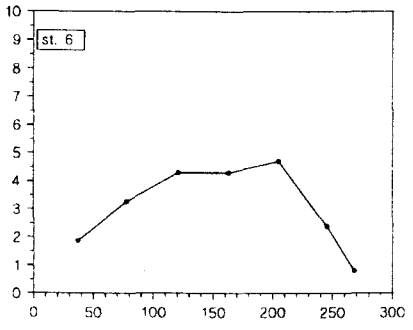
100 ml/t at loading time + 6x75 ml/t/6 weeks L91105D



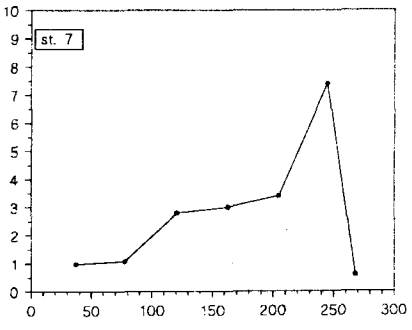
0.5 kg/t D 4046 + 6x75 ml/t/6 weeks L91105D



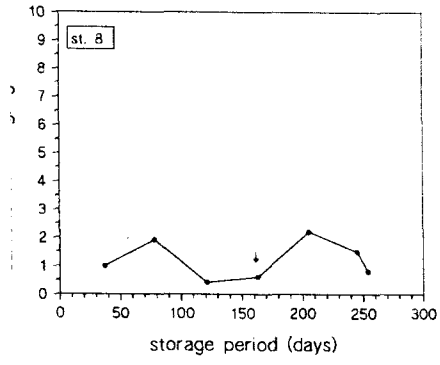
0.5 kg/t D 4047 + 6x75 ml/t/6 weeks L91105D



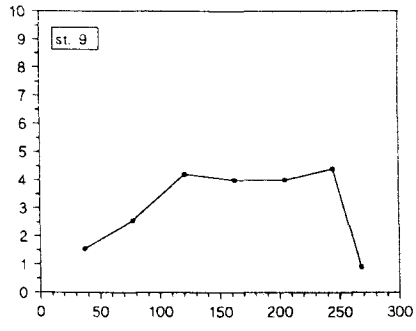
6x75ml/t/6 weeks D 4066



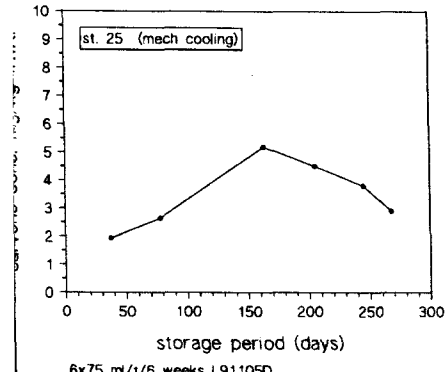
6x75 ml/t/6 weeks L91105D (aut. dos.)



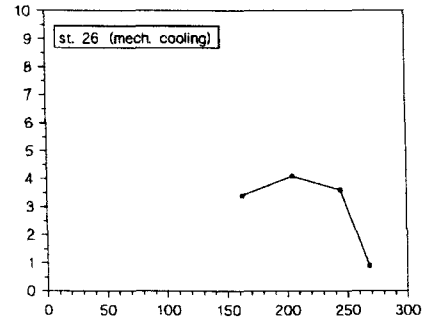
aut.dos. 4ml/t L91105D/time + 1x100 ml(↓)



0.5kg/t gro-stop + 6x75ml/t/6 weeks L91105D



6x75 ml/t/6 weeks L91105D

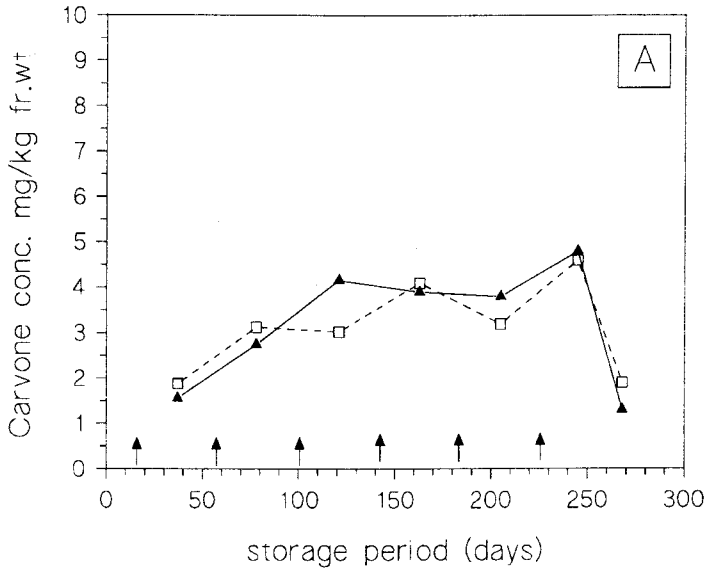


from day 100, 4x75 ml/t/6 weeks L91105D

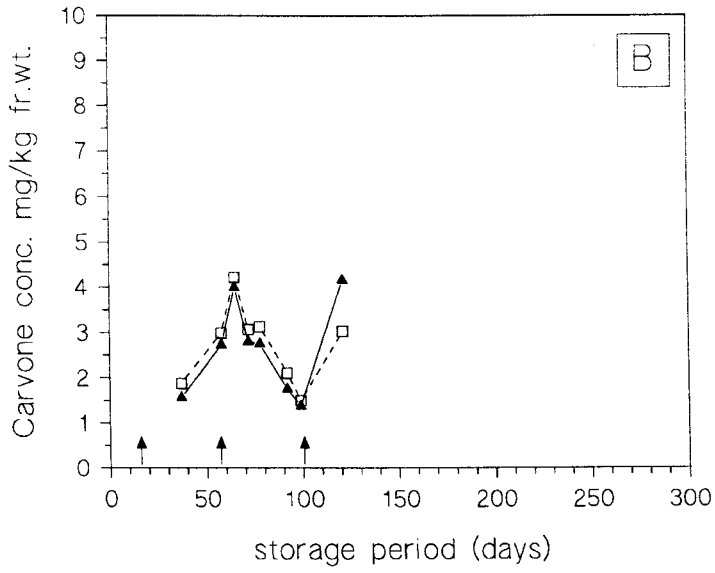
Fig. 3.2.2.2

Carvone-residue of potatoes from st.'s 2 and 3

(potatoes sampled every 6 weeks)



Carvone-residue of weekly sampled potatoes from st.'s 2 and 3



□---□ st. 2 (6x75 ml/t/6 weeks L91105D)

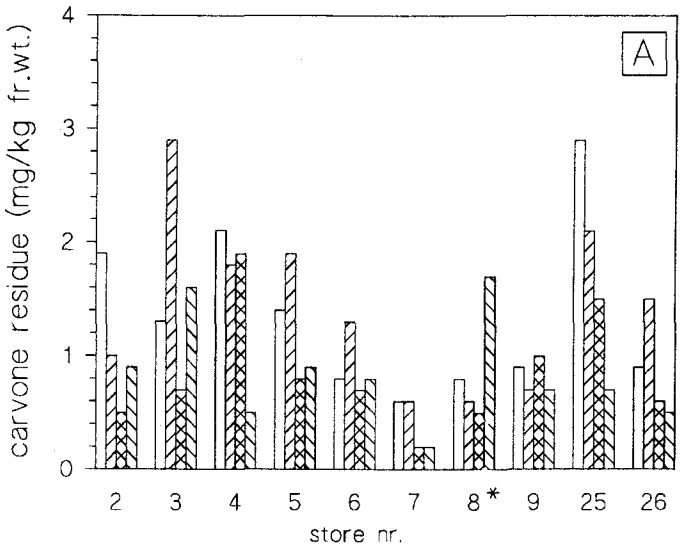
▲——▲ st. 3 (100ml/ at loading time + 6x75 ml/t/6 weeks L91105D)

↑ dosage time

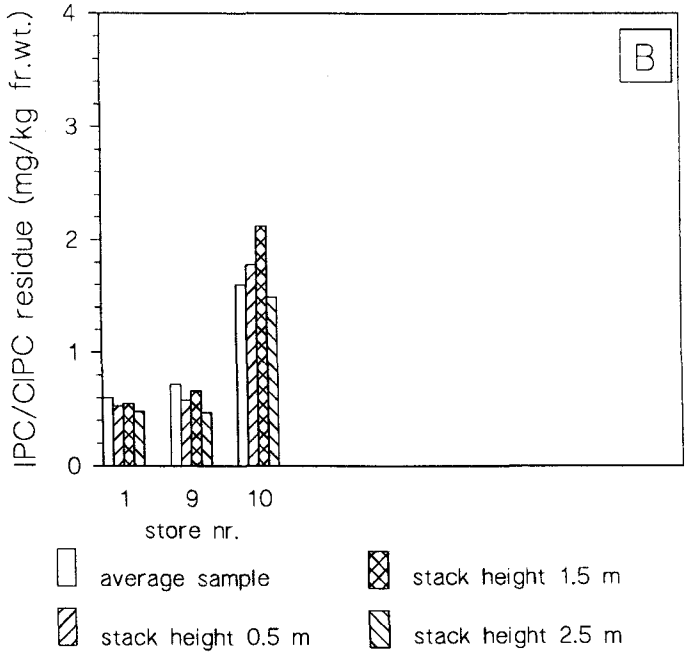
IPC/CIPC and carvone residue contents at unloading time

When the stores were unloaded, IPC/CIPC and carvone residues were measured from each store. Samples were taken at three different stack heights and from the whole store (Fig. 3.2.2.3 and (Table 3.2.2 Appendix)). The carvone residue's at loading time varied between stores (min. 0.2 $mg.kg^{-1}$ in store no. 8; max. 2.9 $mg.kg^{-1}$ in stores no. 3 and 25) and between stack heights. In most stores (no.'s 3, 4, 5, 6, 7, 25 and 26) the values were higher, when the samples were taken from the lower stack heigths. This could be expected while application took place as a fog combined with internal ventilation from the bottom to the top of the store.
The IPC/CIPC contents at unloading time were very low ($\leq$ 0,7 $mg.kg^{-1}$) in the stores 1 and 9 and somewhat higher ($\leq$ 2 $mg.kg^{-1}$) in store 10. Here a powder application at the loading time was combined with regular fog applications of small quantities during storage (Fig. 3.2.2.3 B and (Table 3.2.2)). The difference in IPC/CIPC concentrations between different stack heights, were small.
It seems as if IPC/CIPC was more equally supplied within the stores in this experiment, than the carvone containing formulations.

Fig. 3.2.2.3
Influence of different Carvone treatments on the Carvone residue content of potatoes of three stack heights at unloading time. (unloading time after 254 (*) or 268 days).



Influence of different IPC/CIPC treatments on the IPC/CIPC residue content of potatoes of three stack heights at unloading time. (unloading time after 268 days).



3.2.3 Sensory quality of steam cooked potatoes

The sensory qaulity of steam cooked potatoes was determined on potato samples from, the two stores treated with both carvone isomers (no.'s 2 and 5); the store treated with carvone and menthol containing formulations; and the store were carvone treatment was combined with mechanical cooling (no. 25).

Off Flavour

By 'off-flavour' is meant any 'unpotato-like' characteristic. Actually, unpotato-like characteristics - e.g. 'fishy' or 'metallic' - is not an unknown phenomenon during storage; especially with cv. Bintje. So Gro Stop SC treated as well as carvone treated samples were assessed individually for off-flavour. Comparison of frequencies of off-flavour detection gives a good idea of positive or negative effects due to treatments with carvone containing formulations.

Summarized over all assessments (Fig. 3.2.3; 4 stores in which different formulations and outside air or mechanical cooling was used), no significant effect -neither positive nor negative- due to carvone treatment was found during storage or at unloading time.
The number of off-flavour responses for individual assesments did not reach the significant 50% detection level (Table 3.2.3.1).

Flavour quality

Because treatment with carvone containing formulations could have a positive as well as a negative effect on flavour quality of potatoes, the ordinal paired comparison method (Gro Stop SC versus carvone treated) was used for quality evaluation.
Although carvone has a very specific flavour of its own, the panelists very seldomly labelled an off-flavour as 'carvone-like'.
Actually penalists did not label the off-flavour responses of carvone treated samples otherwise than those of the IPC/CIPC treated samples. Nevertheless, there will may be positive and/or negative effects.
As Table 3.2.3.2 shows, for only 8% of the pairs was found a significant difference in flavour quality in favour however of the carvone treated samples.

In general the conclusion can be made that no significant positive nor negative effects of carvone treatments, on flavour quality of steam cooked potatoes were determined. This is in agreement with the results from comparable experiments carried out in the storage season of 1991/1992 (Hartmans and Buitelaar, 1993).

Fig. 3.2.3

% number of off-flavour responses for IPC/CIPC and Carvone treated samples, summarized over all presentations during storage.

(significance at 50% level)

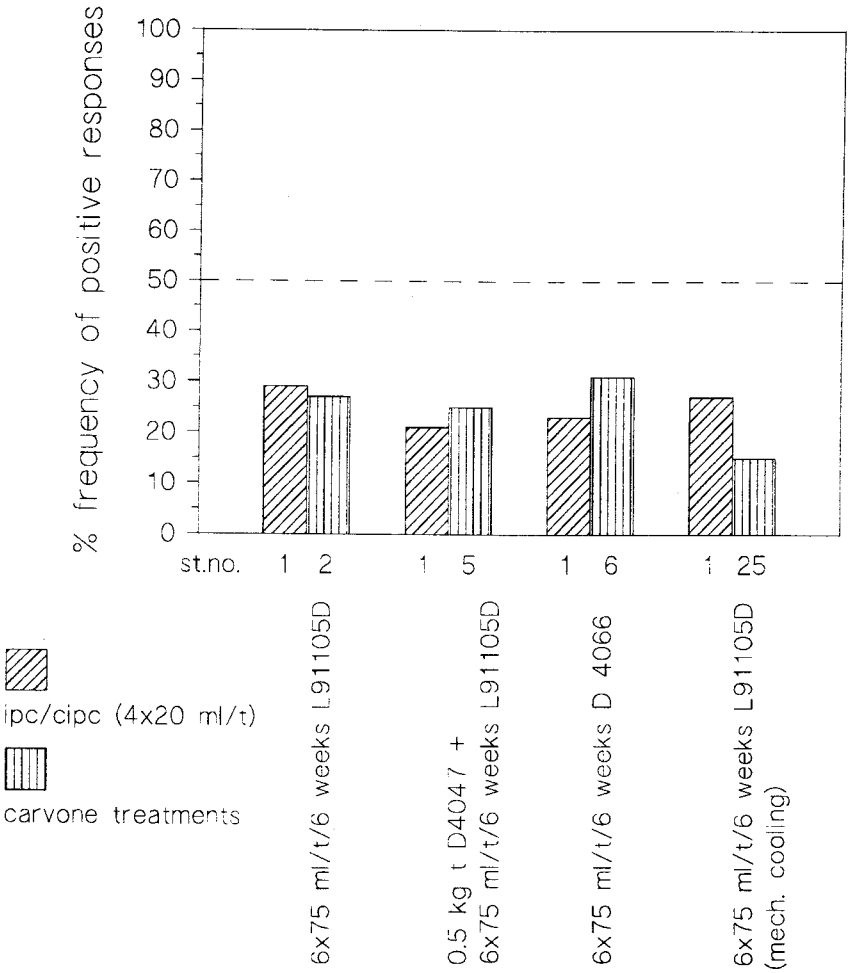


Table 3.2.3.1 Number of assessments, total responses and off-flavour of steam cooked potatoes of Gro Stop SC or carvone treated potatoes, summarized over the storage period. (cv. Bintje, storage season 1992/1993)

Store no.	2		5		6		25	
Treatment.1000 kg^{-1}	L 91105D 6x75 $ml.6w^{-1}$		D 4047 0,5 kg + L 91105D 6x75 $ml.6w^{-1}$		D4066 6x75 $ml.6w^{-1}$		L 91105D 6x75$ml.6w^{-1}$	
Total number of assesments during storage	3		3		3		3	
Total number of responses during storage	48		48		48		48	
*	R	C	R	C	R	C	R	C
Total % off-flavour responses	29	27	21	25	23	31	27	15
Number of assesments with high off-flavour responses (≥50%)	0	0	0	0	0	0	0	0

Significance: 50% detection level

Table 3.2.3.2 Number of pairs of steam cooked potatoes (Gro Stop or carvone treated) with significant differences in flavour quality summarized over the storage period. (cv. Bintje, storage season 1992/1993)

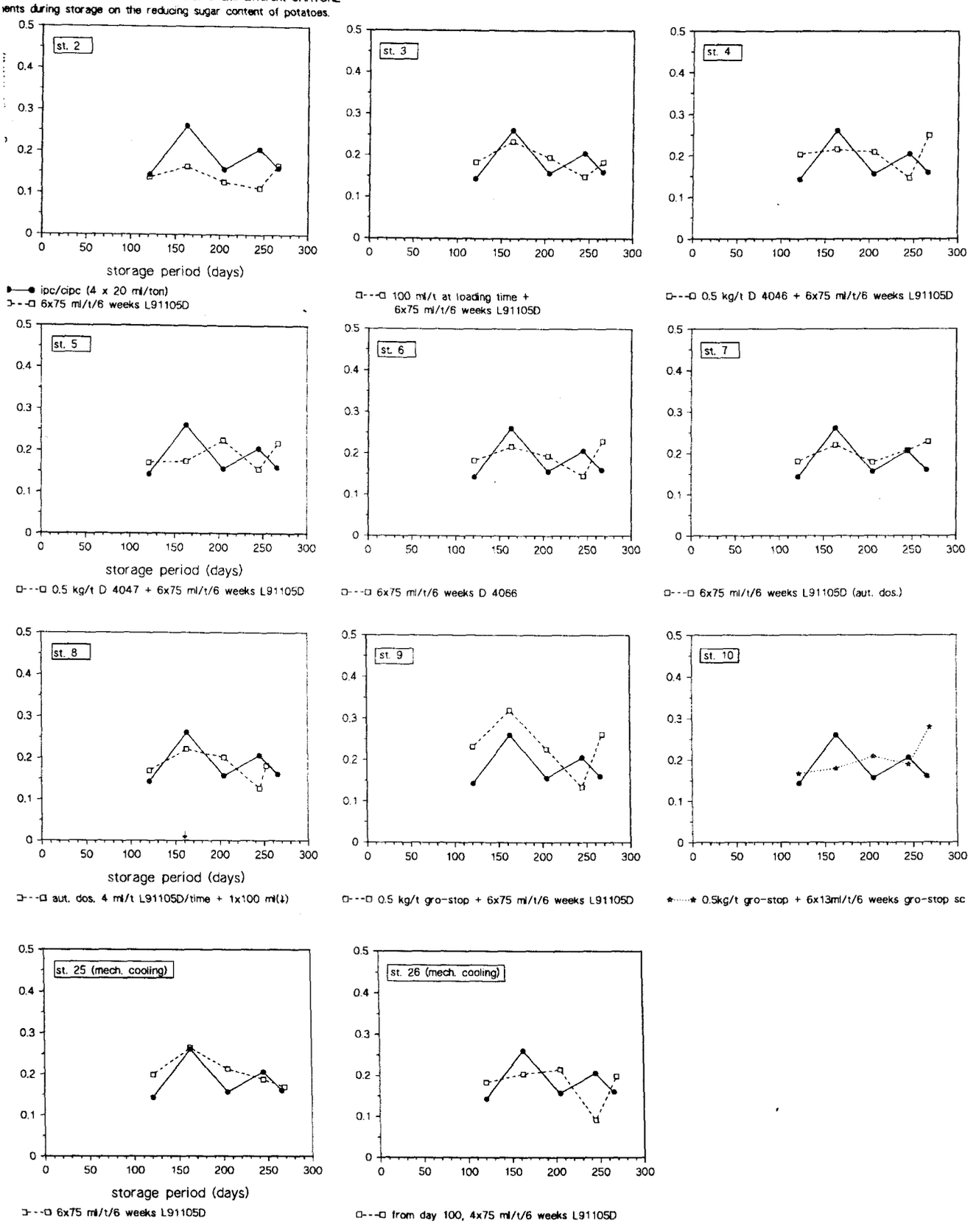
Store no.	2		5		6		25		Total	
Treatment.1000 kg^{-1}	L 91105D 6x75 $ml.6w^{-1}$		D 4047 0,5 kg + L 91105D 6x75 $ml.6w^{-1}$		D4066 6x75 $ml.6w^{-1}$		L 91105D 6x75$ml.6w^{-1}$			
Total number of assessed pairs during storage	3		3		3		3		12	
	Number of sign. different pairs ($p \leq 0.05$)									
*	R>C	C>R	R>C	C>R	R>C	C>R	R>C	C>R	R>C	C>R
More potato flavour	0	1	0	0	0	0	0	0	0	1 (8%)
Number of assesments with high off-flavour responses (≥50%)	0	0	0	0	0	0	0	0	0	0

* R= referenc (Gro Stop SC, store no.1)
C= carvone formulations

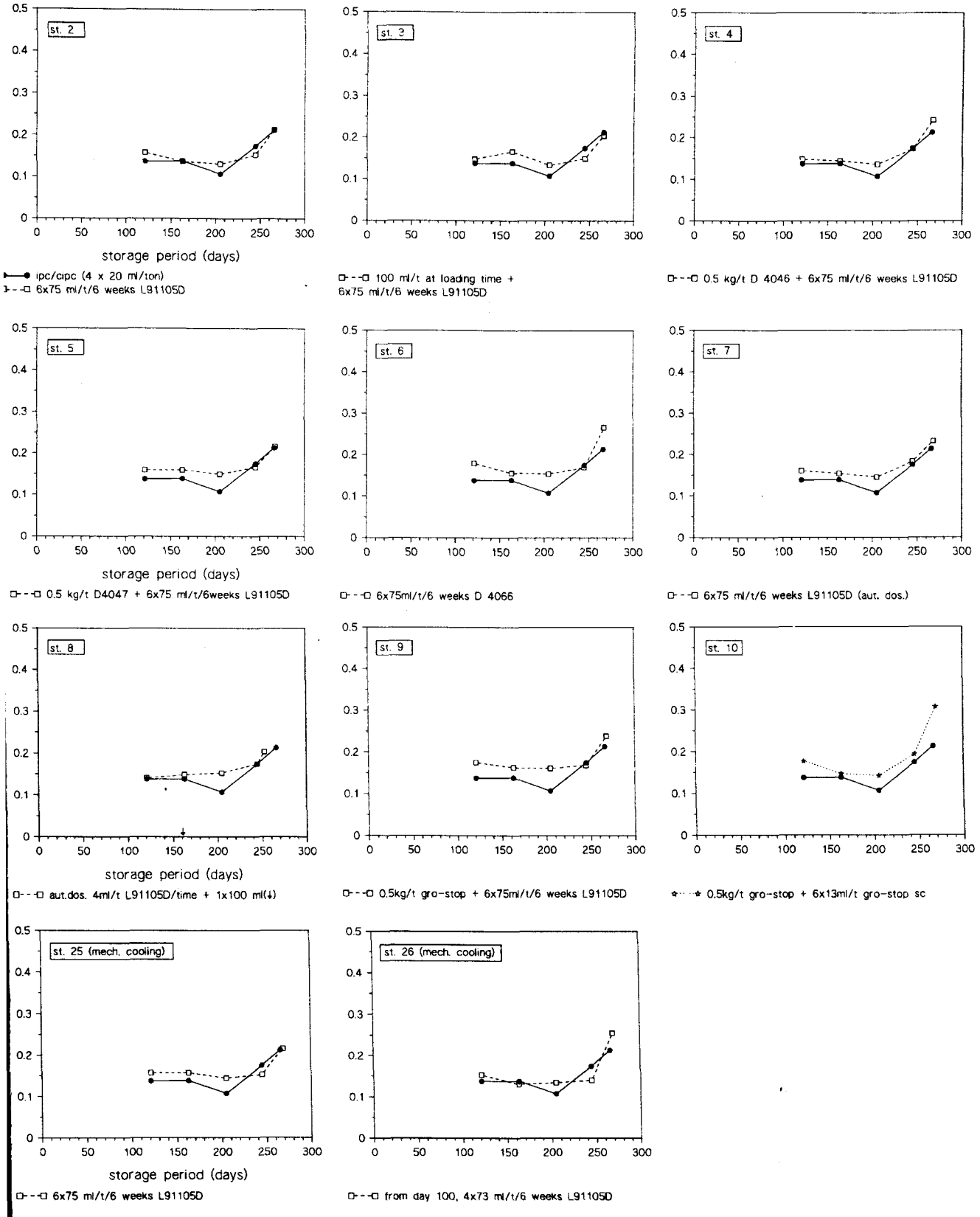
3.2.4 Processing quality (sugar content and French fry colour)

During the storage season the potatoes treated with carvone, carvone and Gro Stop or Gro Stop only, had comparable reducing sugar contents (Fig. 3.2.4.1), sucrose contens (Fig. 3.2.4.2) and French fry colour index(Fig. 3.2.4.3).
In all cases there was an increase in reducing sugars, sucrose and French fry colour index during storage. The long storage period and higher storage temperatures at the end of that storage period (Fig. 3.1.1), caused this so called senescence sweetening, which had no relation with the various carvone treatments.

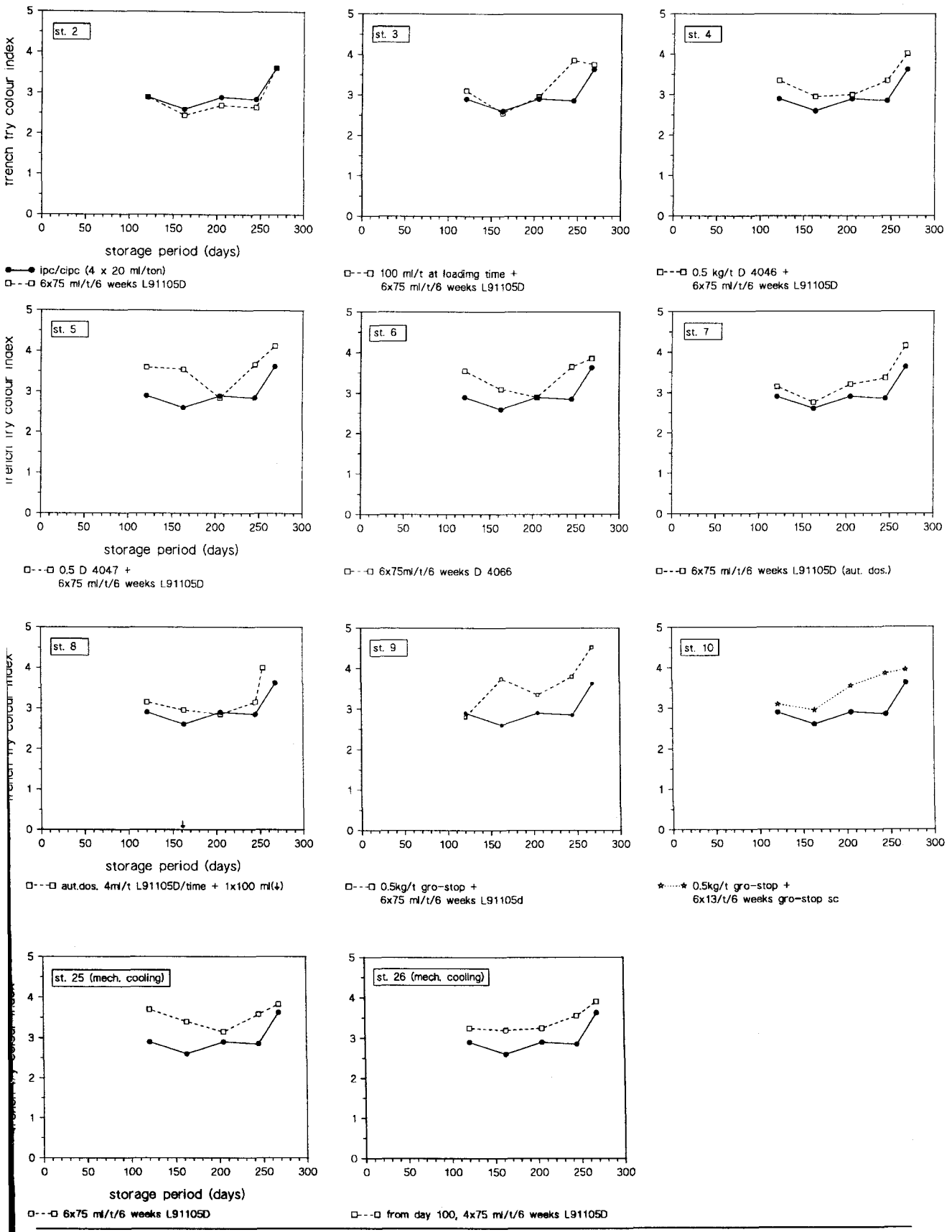
.4.2.1
arison between the influence of IPC/CIPC and different CARVONE
ients during storage on the reducing sugar content of potatoes.



L.2.2
ison between the influence of IPC/CIPC and different CARVONE
nts during storage on the sucrose content of potatoes.



2.3
ison between the influence of IPC/CIPC and different CARVONE nts during storage on the French fry colour of potatoes.



4. Conclusions

In the storage season of 1992/1993 semi-practical research was conducted on the sprout suppression effect of carvone containing formulations. Also application technologies were tested. The research was carried out in 10, 15 ton's outside air cooled stores and two mechanical cooled stores at the ATO-DLO experimental farm "de Eest" in Nagele. The cooling systems of these stores were computer controlled; the storage temperature required 5-7°C.
The research was carried out with the potato cultivar Bintje, grown at the experimental farm.
Table 4.1 gives a survey of the applied agents, dose rates and various dosing times.

During the research period, the following items were dealt with:

Storage

- *storage conditions*;
- *carvone content in the storage atmosphere.*

Quality aspects

- *sprout suppression*;
- *tuber defects*;
- *silver-scurf infection*;
- *residue contents*;
- *sensory quality*;
- *processing quality*

The main results of the research can be presented in the following way:

Storage
- *Storage conditions*;
  * From a few weeks after the curing period till about the middle of May, the average storage temperature was within the target range of 5 - 7°C.
  * The average number of hours of external ventilation was ± 210. The highest number of ventilation hours were at the beginning and at the end of the storage period.
- *Carvone concentration of the storage atmosphere*;
  * The concentration of carvone in the storage atmosphere depended on the different dose rates of carvone applied: as a result of external ventilation, this concentration strongly decreased after dosing.
    During periods of less ventilation, the carvone concentration in the storage atmosphere decreased less.

Quality aspects

- *Sprout suppression*

Results when outside air cooling was used.

* Application of the carvone containing formulation L 91105D 6 times (75 ml.1000 kg^{-1}) at intervals of 6 weeks during storage, resulted in a better sprout suppression (somewhat less sprouts) then with Gro Stop SC, dosed according to the label.
* Additional application of carvone containing formulations L 91105D or D4046 at loading time, followed by interval treatments during storage with L 91105D enhanced the sprout suppression effect when compared with only regular L 91105D treatments during storage.
* A combined application of Gro Stop powder at loading time, followed by regular treatments with L 91105D showed the best sprout suppression effect (no sprouts after about 270 days of storage). This effect was even somewhat better than the effect of a nowadays commonly used combined treatment with Gro Stop powder at loading time, followed by Gro Stop SC treatments during storage.

Results when mechanical cooling was used.

* The combination of mechanical cooling and regular applications of L 91105D during storage resulted in effective sprout suppression.

Sprout regrowth at 15°C

* Carvone applications could control sprout growth during bulk storage very efficiently. As soon as the potatoes were removed from the carvone containing stores and if the storage temperature was favourable for sprout growth however, a regrowth of sprouts generally occurred within a couple of weeks.

- *Tuber defects*

* No skin damages were determined when carvone or IPC/CIPC containing formulations were used.
* Internal sprouting was only observed at unloading time. The amount of internal sprouting was related to the sprout suppression effect.
  No internal sprouting was shown when L 91105D treatment was combined with mechanical cooling. This means that the temperature control at the end of the storage period was the most important factor controlling internal sprouting.
  Application of Gro Stop powder at loading time combined with or L 91105D or Gro Stop SC treatments afterwards, showed nearly no internal sprouting (± 1%).
  Additional application of carvone formulations at loading time, followed by regular L 91105D treatments during storage, seems to decrease the number of tubers with internal sprouts, when compared with regular treatments with L 91105D as such.

* There was a slightly negative correlation between the blackspot susceptibility

and sprout suppression. More sprouts mean higher weight losses, softer tubers and more blackspot.

- *Residue contents of the potato tubers*
  * During storage there was an increase in carvone residue contents, measured three weeks after application, with average maximum values of about 5 $mg.kg^{-1}$ fr.wt.
  * When prior to unloading the stores were heated up and ventilated, the carvone residue levels decreased rapidly to levels of about 1 to 2 $mg.kg^{-1}$ (most carvone is located in the periderm and can easily be removed).
  * At unloading time in general, the highest carvone residue levels were found within the potatoes stored at the lower parts of the stores.
  * Application 75 ml L 91105D.1000 kg^{-1} with intervals of 6 weeks caused a constantly changing carvone residue level within this period. The highest levels (± 4 $mg.kg^{-1}$) occurred 1 week after application and the lowest levels (± 1.5 $mg.kg^{-1}$) 6 weeks after application.
    The carvone residue content was very much dependent of the moment of sampling between the applications.
  * IPC/CIPC levels at unloading time were all far below (± 2 $mg.kg^{-1}$) the official allowed maximum residue level (MRL) of 5 $mg.kg^{-1}$.

- *Sensory quality*
  * No significant positive nor negative effects of various carvone containing formulations on off-flavour or flavour characteristics of steam cooked potatoes were observed during storage or at unloading time.

- *Processing quality*
  * During storage and at unloading time, the potatoes treated with carvone containing formulations, yielded a reducing sugar content and French fry colour, comparable with that of potatoes treated with Gro Stop SC.

- *Silver scurf (Helminthosporium solani) infection*
  * As an important side-effect, carvone containing formulations showed a striking growth inhibiting effect of the natural occuring silver-scurf infection.

Table 4.1 A survey of the applied agents during the storage season 1992/1993.

STORE NO.	SPROUT INHIBITOR	TREATMENTS. 1000 kg^{-1}
1	Gro Stop SC	4 X 20 ml
2	L 91105D	75 ml.6 w^{-1}
3	L 91105D + L 91105D	1 X 100 ml + 75 ml.6 w^{-1}
4	D 4046(gran.) + L 91105D	1 X 0.5 kg + 75 ml.6 w^{-1}
5	D 4047(gran.) + L 91105D	1 X 0.5 kg + 75 ml.6 w^{-1}
6	D 4066	75 ml.6 w^{-1}
7	L 91105D(aut.)	75 ml.6 w^{-1}
8	L 91105D(aut.)	67 x ± 4.7 ml + 1 x 100ml(d 161)
9	Gro Stop powder + L 91105D	0.5 kg + 75 ml.6 w^{-1}
10	Gro Stop powder + Gro Stop SC	O.5 kg + 13 ml.6 w^{-1}
25(mech. cool.)	L 91105D	75 ml.6 w^{-1}
26(mech. cool.)	L 91105D (start after sprouting)	75 ml.6 w^{-1}

---

5. Acknowledgements

We thank the ATO-DLO co-workers K. Groenewoud and J. Sinke for carrying out the storage experiments at the experimental farm "de Eest",
Sara Hertog and Janny Slotboom for the chemical analysis work, Riek de Gooijer and Dinie Slotboom for measuring the French fry quality, Ria van de Vuurst de Vries for measuring the sensoric quality, Truke Ebbenhorst-Seller for the sugar analysis, Piet Hak for measuring the silver-scurf index and the BV-Luxan co-workers dr.ir. P. Diepenhorst and J.M. Lenssen for their valuable discussions and comments.

6 Appendix

Table 3.1.3

Influence of different carvone applications on the carvone conc. of											
the storage atmosphere.											
start: 14-9-1992 (day 0)											
day ..* = sampled after application											
		Airsamples									
		carvone conc.			$\mu g.L^{-1}$	air					
store no ->		2	3	4	5	6	7	8	9	25	26
storage time (days)											
9			2,1	0,1	0,2						
16			1,8	0,1	-						
16*		78,1	57,0	59,4	98,3	100,8	67,2		97,0		
18		57,5				65,6		0,3			
21		2,3				2,7		6,7			
21*										79,6	
23		4,9	5,4	5,6	47,3	5,3	3,8	6,0		25,9	
25		4,9				5,3		3,3			
28		1,2				1,3		8,3			
29					0,8						
30		0,9	1,0	1,1		1,5	1,9	5,3	0,9	5,8	
32								8,0			
35								3,9			
37		1,3	1,6	1,2		1,1	0,8	3,6	1,1	3,7	
37*											
44		0,4	0,4	0,3		0,4	0,3	2,6	0,5	2,4	

51		0,6	0,8	0,6	0,9	0,8	0,5	2,6	0,6	2,4	
58		0,6	0,5	0,4	0,3	0,4	0,2	3,9	0,4	0,9	
58*		63,9	53,4	65,5	66,5	56,8	54,0		69,0	62,5	
60		25,2				25,0		7,9			
63		9,5				10,5		4,7			
65		10,6	9,5	10,6	9,9	8,9	7,4	15,7	10,7	16,5	
67		5,8				9,0		11,4			
70		7,3				11,1		4,6			
72		7,2	6,8	7,9	7,7	7,9	4,2	3,6	7,1	6,3	
78		2,2	2,4	2,5	2,6	2,5	3,2	3,2	13,2	6,9	
86		1,7	2,0	1,5	1,9	1,7	1,6	2,1	1,1	5,3	
93		1,3	1,1	1,0	1,2	1,1	1,0	2,9	1,1	1,5	
99		0,5	0,2	0,6	1,4	1,3	0,5	2,8	1,9	3,2	
99*		36,2	25,7	29,3	35,2	46,4	31,2		34,9	35,0	39,7
101		20,0				26,4		2,3			
105		13,6				15,3		3,2			
112		8,7	8,3	6,9	9,4	10,7	10,9	1,5	10,2	10,6	
116		8,0				7,7		1,1			
121		7,5	4,0	5,6	7,4	11,1	8,4	4,5	9,5	8,9	7,5
128		2,9	3,3	2,2	3,4	4,2	3,4		3,0	4,4	2,7
135		1,0	1,8	2,0	2,1	2,0	1,7	1,2	2,2	5,7	2,7
142		0,8	1,6	0,9	1,9	2,2	1,8	1,2	2,3	3,8	1,4
142*		28,8	25,0	37,8	36,9	73,4	31,3		37,2	37,8	39,1
144		26,7				24,2		2,6			
147		7,6				9,1		2,7			
149		11,0	5,1	10,7	11,7	9,3	8,6	2,6	10,4	10,8	13,9
151		10,0				8,1		5,8			
154		5,9				7,9		1,3			
156		5,1	4,2	3,4	5,1	7,2	5,4	1,1	6,1	9,5	8,8

161								2,0			
163		4,8	3,3	3,9	5,7	4,5	3,4	15,3	7,0	11,3	8,0
170		2,9	2,4	2,8	2,3	3,7	2,8	11,1	3,5	8,2	4,4
177		4,1	2,2	1,7	2,4	2,5	1,6	8,7	4,6	5,1	3,0
184		2,6	1,3	0,9	2,7	1,2	3,4	5,8	2,7	3,1	1,6
184*		29,3	28,6	37,4	35,0	32,0	32,6		37,5	37,3	36,4
186		10,3				17,3		6,2			
189		6,6				5,3		5,7			
191		3,2	7,0	8,2	10,3	3,7	4,4	7,9	3,6	18,1	15,7
191*											
193		3,7						3,7			
196		5,1				6,3		3,5			
198		4,1	5,1	3,9	5,3	5,3	4,2	4,0	6,7	7,6	6,0
200								6,8			
203								4,7			
204		2,0	3,2	2,1	2,6	2,5	2,4	3,3	3,6	2,6	4,6
206								7,1			
212		2,1	2,2	2,5	2,7	2,9	2,3	15,9	3,4	10,1	6,7
214								10,1			
217								7,3			
219		1,5	1,6	1,7	2,4	4,1	2,2	4,5	4,3	4,6	5,4
221								6,3			
224								4,5			
226		3,9	4,0	3,4	3,8	4,5	4,0	4,2	4,3	8,3	4,5
226*		65,4	41,4	51,7	55,5	85,1	57,4		64,9	56,6	61,2
231		7,5				7,9		4,7			
234		1,3	1,3	1,5	2,0	4,6	2,7	8,2	2,2	13,5	13,3
235		2,1				2,4		5,2			
238		2,5				5,6		3,2			

240		5,5	3,9	4,7	5,1	4,7	4,5	3,1	6,1	8,1	9,7
245		3,0	3,3	3,2	5,2	3,7	5,0	4,5	6,3	3,4	6,4
247								2,8			
252								3,5			
254		3,5	4,1	4,4	6,6	4,9	5,4	1,5	8,6	5,3	5,4
262		3,3	2,6	3,3	4,9	4,1	3,2		6,3	3,7	4,3
266		0,7	1,7								
267				1,3	1,3	1,2					
268							2,8		2,5		
269										10,0	8,5
* carvone application											

Table 3.2.2

Influence of different sprout inhibitor treatments on the residue content										
of the potatoes during storage and at unloading time.										
Exp.('92/'93) in 15-tons stores										
Start: 14-9-1992 (day 0)										
	mg carvone.kg^{-1} fresh weight									
store no	2	3	4	5	6	7	8	9	25	26
storage time										
(days)										
37	1,9	1,6	1,4	2,2	1,9	1,0	1,0	1,6	1,9	
78	3,1	3,1	2,8	2,3	3,3	1,1	1,9	2,6	2,6	
121	3,0	4,2	2,4	3,7	4,3	2,8	0,4	4,2		
163	4,1	3,9	3,2	2,9	4,3	3,0	0,6	4,0	5,2	3,4
205	3,2	3,8	3,7	3,4	4,7	3,4	2,2	4,0	4,5	4,1
245	4,6	4,8	4,5	4,6	2,4	7,4	1,5	4,4	3,8	3,6
unloaded:										
268										
stack height							*			
0.5 m	1,0	2,9	1,8	1,9	1,3	0,6	0,6	0,7	2,1	1,5
1.5 m	0,5	0,7	1,9	0,8	0,7	0,2	0,5	1,0	1,5	0,6
2.5 m	0,9	1,6	0,5	0,9	0,8	0,2	1,7	0,7	0,7	0,5
average										
sample	1,9	1,3	2,1	1,4	0,8	0,6	0,8	0,9	2,9	0,9
							* store 8 unloaded at day 254			

	mg IPC-CIPC. kg^{-1} f. esh weight									
unloaded	store 1			store 9			store 10			
at day 268	IPC	CIPC		IPC	CIPC		IPC	CIPC		
stack height										
0.5 m	-	0,53		0,10	0,48		0,11	1,67		
1.5 m	-	0,55		0,12	0,54		0,16	1,96		
2.5 m	-	0,48		0,09	0,38		0,10	1,39		
average										
sample	-	0,60		0,15	0,57		0,12	1,48		

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