Dienst Landbouwkundig Onderzoek
Instituut voor Agrotechnologisch Onderzoek

A superior solidboard box for bell peppers

The performance of the box in a fytosanitary fumigation process, comparing the standard to the new box on different aspects:

the killing of insects,
the diffusion characteristics and
the bell pepper quality

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Confidential

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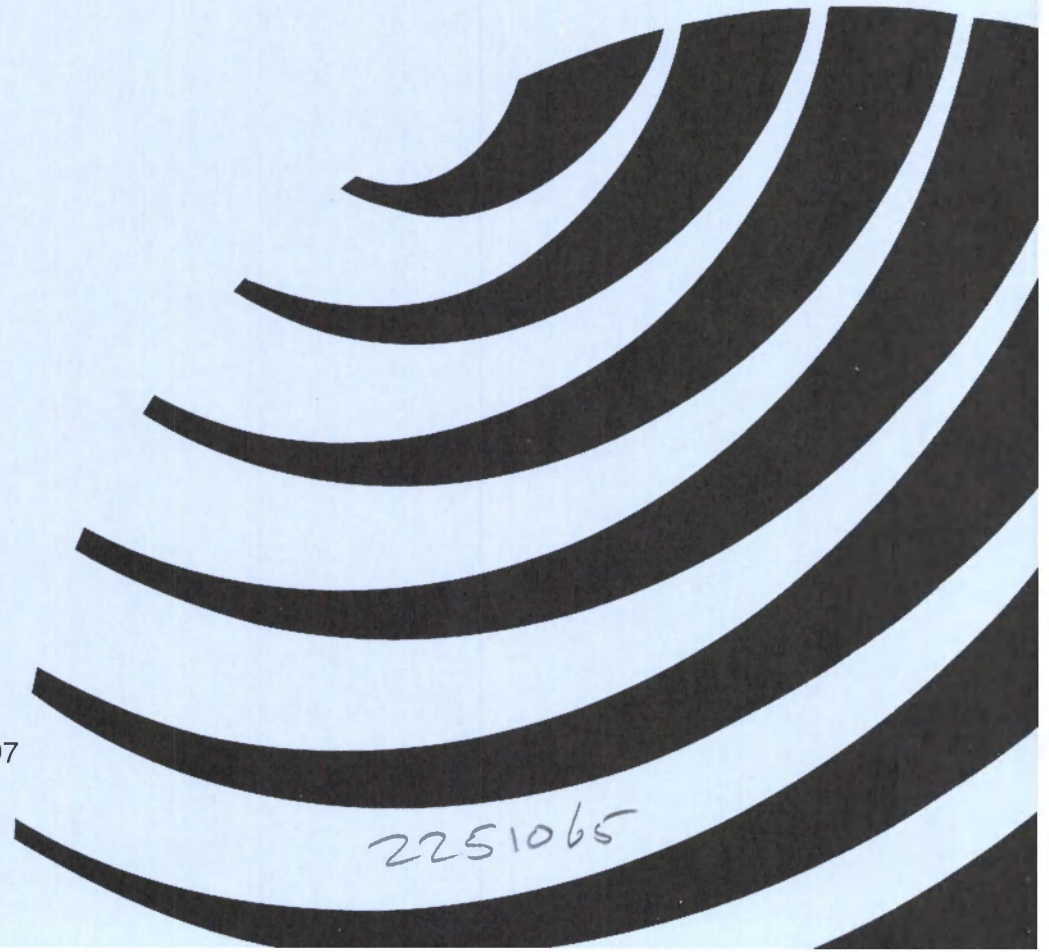

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Contents

Handout

Real-life experiment on the fumigation of bell pepper boxes

Laboratory experiments on the fumigation of bell pepper boxes

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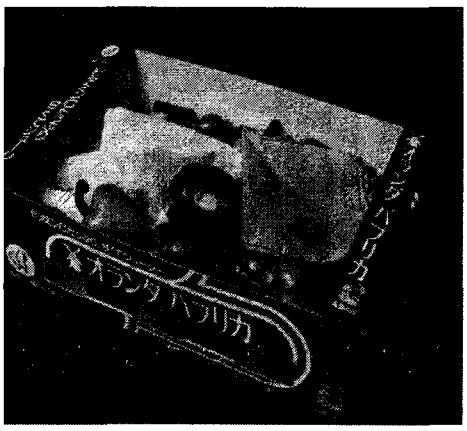
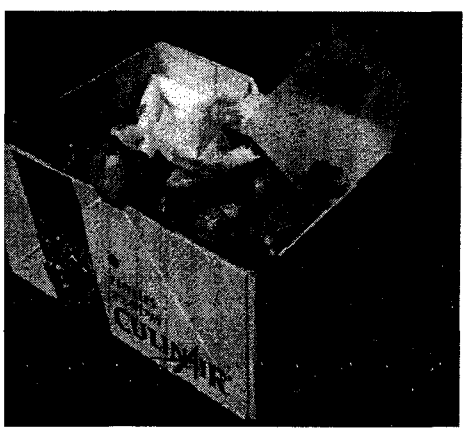


Japan export box



new MA box for bell peppers

introduction

For KNP BT, a new solid board box for bell peppers was developed by the ATO-DLO. This so-called MA box was specially designed to retain the quality of bell peppers much more effectively than the present packages available.
The benefit was achieved by well designed gas diffusion characteristics of the MA box, a result of both material and construction aspects.

In this study, the performance of the MA box in a phytosanitary fumigation procedure was addressed to test if a standard fumigation procedure çan be applied for bell peppers packed in MA boxes and subsequently stacked into pallets.
The phytosanitary fumigation procedure followed is applied in the US and Japan for imported vegetables and fruits to kill insects, if applicable.

setup

The performance of the MA box in a standard fumigation procedure was compared to that of the Japan export bell pepper box used by the Dutch auctions. Two pallets with boxes, one for each box type, were fumigated in a closed container. Thrips and plant-louse in nettings were added to boxes with red, orange and yellow bell peppers prior to the fumigation.

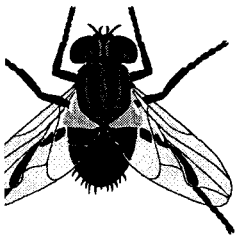
Several aspects of the phytosanitary fumigation procedure were addressed, comparing the MA box to the Japan export box:

❶ the efficiency of killing insects
❷ the gas concentrations around and within the pallet
❸ the quality of the red, orange and yellow bell peppers after the fumigation.

In addition to the 'real-life' fumigation procedure, a laboratory experiment was performed to assess the gas diffusion characteristics of both box types in a pallet stacking. Gas concentration measurements determined how fast the gas entered the pallet, and subsequently left the pallet.

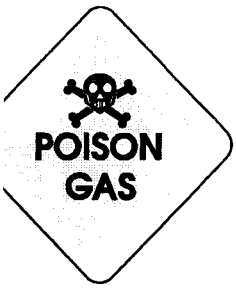
Results

The performance of the MA box in the phytosanitary fumigation procedure was similar to that of the Japan export box. This with respect to several aspects addressed: the efficiency in which insects were killed, the gas penetration of pallet stacked boxes and the influence on the bell pepper quality.



killing insects

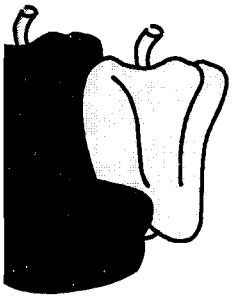
The MA box performed as well as the Japan export box: *all insects were killed* by the fumigation procedure. This result was confirmed and officially documented by a phytosanitary inspector of the Plant Protection Service of the Dutch Ministry of Agriculture, Nature Management and Fisheries.



gas concentration

Within the pallet, the maximum gas concentration was maintained for more than 90% of the total fumigation time. Gas concentrations at different pallet positions (corner and middle) were equal: a clear indication for a homogeneous gas concentration throughout the pallet.

After the fumigation, the gas left the boxes slightly slower than that it entered. Still, the gas was completely removed within the time prescribed to ventilate. Laboratory experiments also confirmed the fast and complete penetration and subsequent removal of gas in a pallet of boxes. These results apply to both box types tested. Thus, *the performance of the MA box and the Japan export box in terms of gas penetration and removal was quite similar.*



bell pepper quality

The quality of the bell peppers was assessed directly after the fumigation. For two weeks, the quality aspects loss of firmness and the occurrence of rot were inspected daily. The fumigation procedure had no significant effect on firmness, but the rot sensitivity increased. Control and fumigated bell peppers both showed the same decrease in firmness with time. Only fumigated bell peppers showed rot, occurring after approximately one week. *The influence of the fumigation on the bell pepper quality was similar for both the MA box and the Japan export box.*

Appendix:
a document of the phytosanitary inspection by the Plant Protection Service of the Dutch Ministry of Agriculture, Nature Management and Fisheries.

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Real-life experiment on the fumigation of bell pepper boxes

1. Introduction

In conjunction with KNP BT, the ATO-DLO developed a new solid board box for bell peppers, the so-called MA box. Compared to the standard export box of the Dutch auctions, the MA box has an increased functionality. It does not only mechanically support bell peppers but also extends their storage and shelf-life considerably. Furthermore, weight losses of the bell peppers occuring during transport are reduced. A fine tuning of the gas exchange between bell peppers, the interior of the box and the surrounding atmosphere underlies the achieved benefits.

This study addresses the implications of the altered gas diffusion characteristics of the MA box for the efficiency of a phytosanitary fumigation procedure. The performance of the standard- and the MA box were compared for several aspects: the killing of insects, gas concentrations within the pallet and the effect of fumigation on the bell pepper quality. The standard box is used as a reference with an proven functionality in this respect. Two types of tests were performed:

❶ a simulation of a regular fumigation procedure of bell peppers, simulating the 'real-life' situation,

❷ a laboratory fumigation test, resolving the gas diffusion characteristics of both boxes in a pallet stacking.

The objective of this study is to test if the MA box allows an effective fumigation of the enclosed bell peppers, without having to unpack the bell peppers.

1.1 'real-life' fumigation procedure

All bell peppers need to pass a phytosanitary inspection to get an approval for the import in the US, respectively Japan. A fumigation with methyl bromide (US) or cyanide (Japan) is obligatory in all cases where a phytosanitary inspector finds insects. During the fumigation, the bell peppers may stay in their boxes when the vent holes account for more than 3% of the total area of the boxes. Otherwise, bell peppers must be unpacked. Unpacking bell peppers is expensive, cumbersome, unhygienic and leads to product losses. For obvious reasons, a box that enables an effective fumigation of the enclosed product is preferred over a box that prevents one.

1.2 'laboratory' gas diffusion experiments

The gas diffusion characteristics of the standard and the MA box were analysed in order to assess the gas penetration of boxes at different positions in a pallet. These experiments directly address the gas barrier function of the boxes, the time constants and the gas concentrations at different positions in a pallet. The effects found for the efficiency of the 'real life' fumigation procedure directly relate to the gas concentrations that can be expected at different positions within the pallet. As such, the results of monitoring gas concentrations must be consistent with the effects found for killing insects and harming the bell pepper quality.

2. Material and Method

2.1 bell peppers

Bell peppers were harvested by hand in the early morning, mechanically sorted on size (grade: 'Super' 80/100 mm) and subsequently packed in standard Japan export boxes of 5 kg net weight. Two pallets of 80 boxes each (8 rows of 10 boxes) were filled with red bell peppers. Additional boxes with bell peppers of the colours red, orange and yellow were also supplied, four boxes per colour. The 12 extra boxes were used to determine fumigation effects on the bell peppers quality, which required a shelf-life test at the laboratory. The bell peppers were repacked by hand in order to obtain 12 boxes (6 standard & 6 MA) with 8 red, 8 orange and 8 yellow bell peppers per box (see figures handout). Each colour bell pepper was supplied by a different grower. All bell peppers were brought to the fumigation facility in the early afternoon by an uncooled truck (± 18°C).

2.2 insects

Californian thrips and aphids ('aardappeltopluis') were purchased at the CPRO-DLO at Wageningen. These insects were propagated in green-houses on host plants. In the early morning prior to the fumigation, insects were collected by hand and put into netbags. The thrips were anaesthetized in order to select the larger female specimens, which are more resistant to fumigation due to a larger volume/area ratio. Insects were placed in netbags.

Two type of netbags were used. Nine netbags (25% open, 125μm holes) contained 50 female Californian thrips each, 8 other net bag (50% open, 250μm holes) contained 50 aphids each. Thrips and aphids were added to the boxes with three colour bell peppers, prior to the fumigation. Thus, 4 standard and 4 MA boxes each contained two netbags with insects. The remaining 4 boxes (2 standard & 2 MA) contained no insects. The 9th netbag with thrips was not fumigated and was used as a control, to check if the insects survived in the netbag during the experiment.

2.3 boxes and pallet positions

The boxes which contained three colour bell peppers were used as follows:

- 2 boxes were not fumigated, these are control boxes without insects
- 2 boxes were placed at corner positions at the top row, and were fumigated
- 2 boxes were placed in the centre position of the middle row, and were fumigated.

This applied to both a pallet with the standard box and a second pallet with the MA box. Besides the 4 boxes with mixed colour bell peppers and insects, the pallet also consisted of 72 boxes with only red bell peppers and no insects. Boxes with mix colour bell peppers were used for the quality determination at the laboratory of ATO-DLO. Boxes with red bell peppers only were exported to Japan, after the fumigation procedure.

2.4 fumigation procedure

The standard fumigation procedure (50 g.m^{-3} methyl-bromide, 2 hours, 21°C),used in the US and Japan, was applied for two pallets in a gastight 20 foot container. A pallet with 80 standard boxes and a pallet with 80 MA boxes were fumigated. The pallet with MA boxes was covered by a net (50% open, Ø 0.2mm) to meet the requirements of a maximum opening size, according to the Japanese legislation. The Japan standard export box itself has nettings covering the vent holes for this purpose.
During the fumigation procedure, the methyl-bromide concentration was measured for both pallets. Gas concentrations were monitored at different positions:

1) the concentration within the 30m^3 container (20 foot container)
2) inside the box at the corner position of the pallet (corner top row)
3) inside the box in the middle position of the pallet (middle of the 5th of 8 rows).

2.5 fumigation facility

The fumigation facility was characterized by the following:

- methyl-bromide is supplied in a liquid form (volume dose) and evaporated to the gas form by heating (1500g/30m^3). The gas is dispersed homogeneously in the container by a tube along the ceiling.
- The gas volume in the container is circulated and heated to 21°C to activate the insects.
- The fumigation is performed at an atmospheric pressure, a low pressure is not used.
- After the fumigation, the gas is removed by ventilation with fresh air. An extractor fan combined with an active carbon filter removed all methyl-bromide. The exhaust contains less than 0.002 ppm methyl-bromide. With this exhaust concentration, the fumigation can take place at the auction facility.

2.6 bell pepper quality

The quality of the bell peppers was determined by a sensoric inspection. The quality aspects firmness and rot were determined for individual bell peppers and for all bell peppers in a box.

Firmness is judged on a discontinue scale of 0 until 5 (good .. bad).

Zero means fully firm, five means fully softened bell peppers. The range 0 to 5 is linearly related to the amount of weight loss due to water evaporation since the picking. Zero stands for no loss, 3 for 4-5% loss and 5 for 10%(or more) loss of weight.

Rot is judged for indivudual bell peppers on a discontinue scale of - (no rot) and + (rot).

Bell peppers with just visible rot spots (2Ø mm) or larger are judged to be rotten.

The quality of bell peppers, displayed at living room conditions (18°C, 75% rh), was inspected daily for maximal 14 days. The average firmness per 8 bell peppers was determined. For individual bell peppers, the number of peppers with firmness > 3 (unacceptable soft) and/or rot were determined.

A total of 288 bell peppers was used to determine the quality. These bell peppers consisted of:
- 96 bell peppers of a colour red, orange and yellow: 3*96=288.
- The 96 bell peppers of a colour consisted of:
  - 32 not fumigated bell peppers (2 box types * 2 repetition * 8 bell peppers) and
  - 64 fumigated bell peppers (2 box types * 2 pallet positions * 2 repetition * 8 bell peppers).

The quality of the bell peppers was expressed in a number: the time until the quality reaches a defined minimal level, the shelf-life in days. Obviously, the selected minimal level determines the absolute value found. A lower level leads to a higher number. Here, the level frequently used by traders is selected as a criterium.

A statistical personal computer program 'Genstat 5 release 3.2' of the Rothamsted Experimental Station, UK was used for the analysis. The results were tested on a 5% significance level. Differences in shelf-life were analysed by an ANOVA (ANalysis Of Variances).

$$Q(t)=\frac{C}{1+e^{-A*(t-B)}} \quad (1)$$

$$t=\frac{B-\log(C/c-1)}{A} \quad (2)$$

The quality aspects firmness and rot are discreet variables (fixed values) that needed preprocessing before an ANOVA could be performed. A sigmoidal function (1) was fitted for the time versus average firmness of 8 bell peppers. Per 8 peppers two function parameters *A & B* were estimated. *C* was set to 5. The time to reach a certain quality class *c* was subsequently calculated (2): the shelf-life value in days.

The quality aspects firmness and rot were also determined for individual bell peppers. The number of bell peppers not acceptable (firmness class >3, respectively rot observed) were counted. A sigmoidal function (3) was fitted for the time versus the fraction unacceptable bell peppers α (a binomial parameter) per 8 peppers. Two function parameters *A & B* were estimated. The time to reach a certain fraction unacceptable bell peppers per box was calculated (4): the shelf-life value in days. For firmness, a fraction less than 25% was acceptable. For rot, a fraction less than 10% was acceptable.

$$\alpha=\frac{e^{A+B*t}}{1+e^{A+B*t}} \quad (3)$$

$$t=\frac{\log(\frac{\alpha}{1-\alpha})-A}{B} \quad (4)$$

3. Results

3.1 killing of insects

Table 1 below clearly shows that all insects were killed by the applied fumigation procedure, regardless the box type or position of the box in the pallet. Without a fumigation, the insects stayed alive. Thus, the killing of insects can be solely attributed to the fumigation.
The fact that the insects were killed, and not merely temporary paralysed, was confirmed by an independent phytosanitary inspection by the Plant Protection Service of the Dutch Ministry of Agriculture, Nature Management and Fisheries. The corresponding document is enclosed as an appendix.

	control	standard box				MA box			
	-	corner		middle		corner		middle	
	thrips	aphids	thrips	aphids	thrips	aphids	thrips	aphids	thrips
prior	*50*	*50*	*50*	*50*	*50*	*50*	*50*	*50*	*50*
after	*50*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*

Tabel 1 The number of alive insects (aphids and thrips) present in a box with 8 red, 8 orange and 8 yellow bell peppers. Counts prior to and after a fumigation with 50g/m^3 for 2 hours at 21°C are shown for different box types and pallet positions. Each number represents the average result of two boxes.

3.2 gas concentration

A direct way of assessing the effect of the fumigation procedure is to measure the gas concentration around and within the pallet. After all, the gas is the primary cause responsible for the effects on the lives of insects and the quality of the bell peppers.

The penetration of methyl-bromide in the MA boxes is almost as fast as found for the standard boxes (figure 1, on the left). The slight differences observed were not significant for a fumigation procedure of 2 hours (figure 1, on the right). Furthermore, the removal of gas is also slightly slower for MA boxes compared to standard ones (figure 2). Thus, the action of the gas (concentration*time) is similar for both box types. Finally, within the 30 minutes available in the standard procedure all gas can easily be removed.

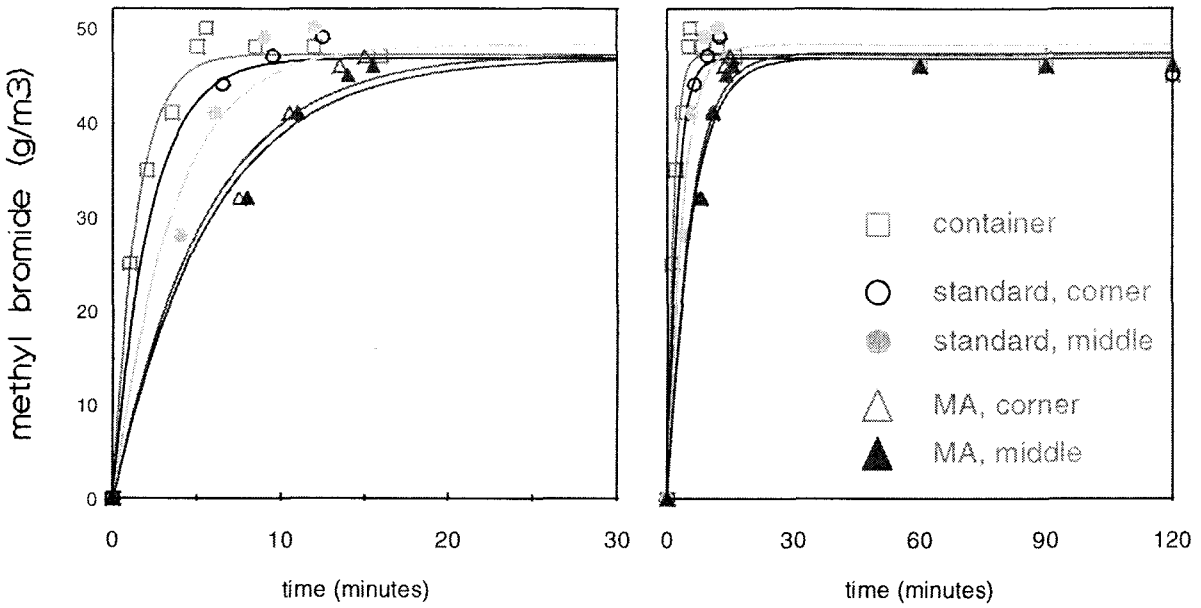

Figure 1 The penetration of methyl-bromide into boxes at different positions within a pallet stack, together with the concentration surrounding the pallets inside the container. The first 30 minutes of the 2 hours fumigation procedure is exploded (on the left) to elaborate the small differences. The results are shown for two pallets: one with only standard boxes and one with only MA boxes filled with bell peppers. The corner box of a palllet is maximally exposed to the gas inside the container. The middle box is minimally exposed to the gas due to a complete shielding by surrounding boxes.

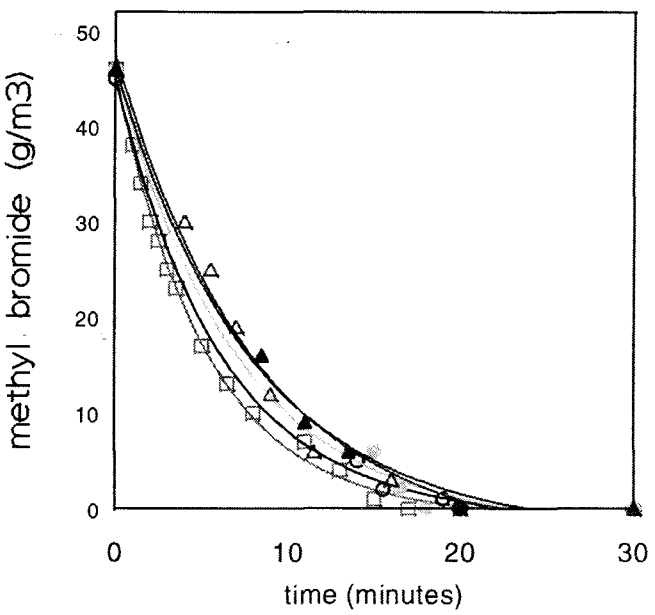

Figure 2 The removal of methyl-bromide from boxes at different positions in a pallet stack. Within the thirty minutes of ventilation time available, all gas is completely removed from the boxes.

A careful examination of the figure 1 reveals an initial peak in the methyl-bromide concentration inside the container and inside boxes at corner positions of the pallets. Subsequently, methyl-bromide concentrations slowly decreases to a final steady state level.

3.3 bell pepper quality

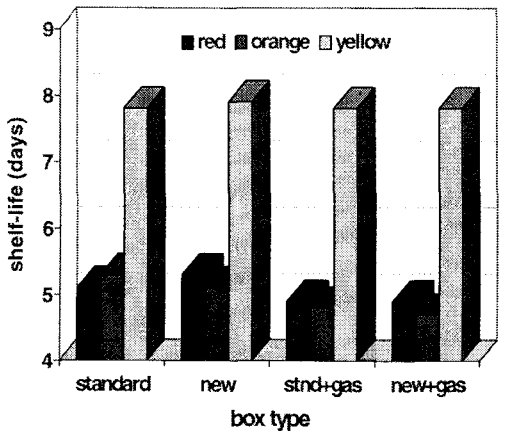

Figure 3 The time to reach a just acceptable firmness per box. Influences of box type, bell pepper colour and fumigation procedure are shown.

3.3.1 average firmness per box

Bell peppers lost their firmness during the display under shelf conditions. The time needed to reach a just acceptable firmness (grade 3) is used as a quality criterium: the shelf-life in days (figure 3). The firmness was judged per colour as an average value for 8 bell peppers per box.

The fumigation did not affect the bell pepper quality in terms of firmness. Furthermore, this result was found for both box types tested and for all three colours bell peppers of a different variety.

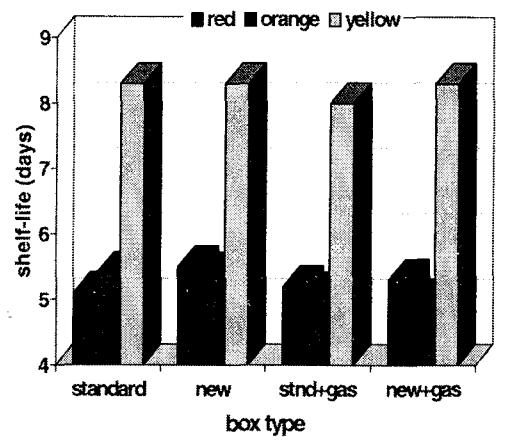

Figure 4 The time until 25% of the bell peppers in a box have an unacceptable firmness. Influences of box type, bell pepper colour and fumigation procedure are shown.

3.3.2 firmness per pepper

Now in stead of the average firmness per box, the firmness of individual bell peppers is selected as a quality criterium. Here, the time until maximal 25% of the bell peppers of a specific colour in a box became too soft is used as a criterium for an acceptable quality (figure 4). The results based on this selection criterium are consistent with those found for the average firmness per box (see 3.3.1).

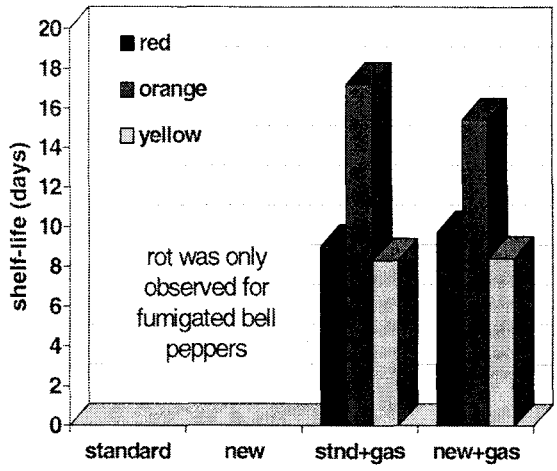

Figure 5 The time until 10% of the bell peppers in a box showed rot. Influences of box type, bell pepper colour and fumigation procedure are shown.

3.3.3 rot per pepper

Large effects were found on the development of rot during the display of the bell peppers at 18°C and 85% relative humidity. The fumigation clearly stimulated the occurrence of rot (figure 5).

The stimulation of rot by the fumigation was independent of the box type (see figure 5). Both peppers packed in the standard box and in the MA box developed rot to the same degree. This result is consistent with the measured gas concentrations.

Furthermore, rot was found for all colour bell peppers. The severeness of rot depended on the colour of the bell pepper. Orange bell peppers showed less rot than the red and yellow ones, which is expressed as a longer shelf-life in days. However, this can also be attributed to the origin of the bell peppers, which differed per colour. This experiment is not conclusive in this respect.

4. Conclusions

4.1 gas concentrations

- Methyl-bromide penetrates a MA box pallet with bell peppers slightly slower than a pallet with standard box pallet with bell peppers.
- Removal of methyl-bromide from the MA box pallet is also slightly slower than that for the standard box pallet.
- The active concentration (concentration * time) of methyl-bromide achieved was independent on the box type standard or MA.
- Within the available ventilation time of 30 minutes, all methyl-bromide could be removed from the boxes in a pallet stack, irrespective of the box type.

4.2 effects of fumigation

- A standard fumigation procedure applied for pallets with standard or MA boxes resulted in the complete killing of insects (thrips and aphids).
- The standard procedure can be applied as well for the MA box in a pallet stacking as for the standard box.
- Fumigating with methyl-bromide leads to an increase of the rot susceptability of bell peppers.

5. Recommendations

- The results of this experiment can be used to convince officials that the '3% vent hole' rule does not apply to the MA box tested here. Bell peppers in a pallet stacking of MA boxes don't have to be unpacked for a standard fumigation procedure.
- The negative effects on the bell pepper quality resulting from a fumigation procedure strongly recommend to take all possible precautions to prevent the presence of insects that create the need to fumigate. To take action at the grower (fight insects) and at the auction (sort product) is recommended. However, it should be noted that the presence of predators of insects, used in a biological fight against insects in glasshouses, can be misunderstood by phytosanitary inspectors and lead to the obligation to fumigate the bell peppers.
- Application of methyl-bromide is likely to be prohibited in the future, a further reason to take precautions at an early time.

Laboratory experiments on the fumigation of bell pepper boxes

Introduction

For a more detailed investigation of the fumigation of a stack of the newly developed MA-box for bell peppers, laboratory experiments are performed. The change of gas concentration during fumigation is measured in several boxes, which are part of a larger stack. For comparison, the same experiment is also performed for the standard auction export box.

Materials and Method

For safety reasons the stack of boxes is not fumigated with the toxic methyl-bromide but with ethylene in low concentrations (1.3 ppm), assuming similar diffusion characteristics of both gasses. The stack of boxes consists of 5 layers of 10 boxes, and is placed on a 1.00 m by 1.20 m wooden pallet. Each box is filled with artificial lemons, which are assumed to have similar characteristics as bell peppers, with respect to obstructing gas transport. The stack is placed in a storage room with active ventilation, leading to air velocities of about 1 m/s. The storage room is sealed, such that a constant gas concentration can be maintained during the course of the experiment.
After injecting 35 ml of pure ethylene gas in the storage room, air samples are taken from the inside of several boxes in the central layer of the stack at certain times. The positions of the boxes are indicated in figure 1. The ethylene concentration of the air samples is determined with gas chromatography.

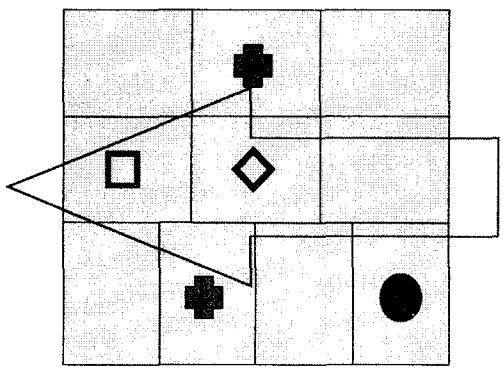

Figure 1. Positions of the sampled boxes (symbols) in the central layer of the stack. Air flow direction is indicated with an arrow.

Results

In figure 2 the measured values of the ethylene concentration in the central layer are shown for the MA-box and the auction export box. The times needed for the gas concentrations to rise to the 7/8 level of final level are estimated and are given in Table 1. These experimental results clearly show that the gas concentrations in all boxes reaches the level of the ambient ethylene concentration (1.3 ppm) very quickly (within 15 minutes), in comparison to the duration of fumigation in practice (2 hours).

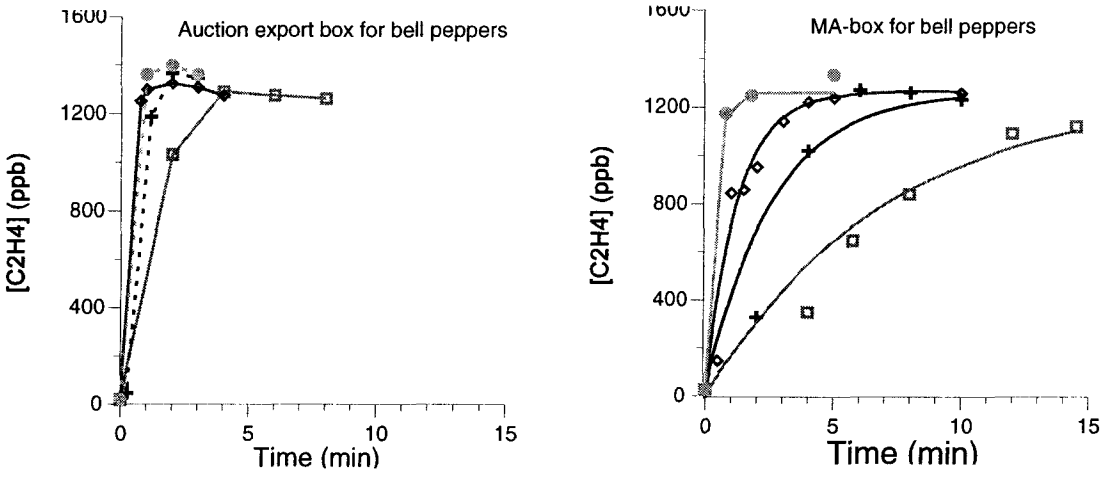

Figure 2. The change in ethylene (C_2H_4) concentration in parts per billion (ppb) for two types of boxes at several locations in the central layer of the stack (for positions see figure 1).

Table 1. Rise time of ethylene concentration (min)

Position	Japan export box	MA box
●	½	1
◇	½	3
✚	1	6
◘	3	15

Differences in rise times of the ethylene concentrations are found between the two boxes types and between boxes at different locations (in the same stack), as indicated in Table 1. At all locations the rise time of the MA-box is (about 5 times) larger than the time of the auction export box. This difference is due to the difference in vent hole design. The auction box has vent holes at all four sides, and the total openings percentage = 2.2%, where as the MA-box has holes at the front and back end of the box with an openings percentage of 0.9%.

The rise time is also much dependent of the location in the stack. The rise time of the box at the front side of the stack (directed towards the air flow) is (15 times) smaller than at the opposing side of the stack. For both types of boxes we have found similar patterns in the rise time.

So it seems that the contribution of the position of the box in the stack to the rise time of the fumigation gas concentration by far exceeds that of the contribution of the vent hole design. In this experiment, box position and vent hole design seemed independent of each other. However, a follow up experiment with vent hole design variation would be more conclusive in this respect.

Conclusions

During fumigation gas enters the tested bell pepper boxes very quickly. The found differences in rise time of the fumigation gas concentration are insignificant compared to the duration of fumigation in practical conditions. So based on the measured gas concentrations, *the performance of the MA-box with respect to insect disinfection by fumigation can be expected to be equal to that of the auction export box,* which is commonly used in practice.

Landbouw, Natuurbeheer en Visserij

Appendix: document phytosanitary inspection

plantenziektenkundige dienst

uw brief van	uw kenmerk	ons kenmerk	datum
		fd97-80	06-05-1997
onderwerp		doorkiesnummer	bijlagen
begassing insekten		0297-320951	

Op uw verzoek heeft de Plantenziektenkundige Dienst een onderzoek ingesteld naar het resultaat van een begassing van een 16 tal gaaszakjes gevuld met insekten.

Het betrof hier twee soorten insekten namelijk luizen en tripsen. De gaaszakjes met de insekten zijn verzorgd door de heer H.A.M. Boerrigter en de heer L.H.J. Janssen van het Instituut voor Agrotechnologisch Onderzoek te Wageningen.

Zij zijn er tevens getuige van geweest toen de 16 gaaszakjes met insekten in de begassings ruimte geplaatst zijn bij de firma Verhart op de Verenigde Bloemenveiling Aalsmeer te Aalsmeer. De begassing is uitgevoerd op 1 mei 's middags. Na deze begassing hebben de heer Boerrigter en de heer Jansen zich met de gaaszakjes gewend tot de heer H.J. Bullee van de Plantenziektenkundige Dienst te Aalsmeer.

Deze heeft na uitvoerige controle van de inhoud van de gaaszakjes geen levende insekten aangetroffen.

Vertrouwende u hiermede volledig te hebben geïnformeerd.

Voor dit onderzoek wordt u separaat een factuur toegezonden.

Districtshoofd,

M.L. Gijzel

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