Dienst Landbouwkundig Onderzoek
Instituut voor Agrotechnologisch Onderzoek

A superior solidboard box for bell peppers

The cooling performance of the standard and the new box, compared for different aspects:

the cooling rate,
the influence of forced air flow and
the dehydration of the included bell peppers

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Modified Atmosphere Packages:
the cooling characteristics of an improved box for bell peppers

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Summary

The quality of bell peppers can be retained most effectively by applying a low temperature and an appropriate package that establishes a specific gas atmosphere surrounding the bell peppers. For the latter, a new Modified Atmosphere package was developed: the MA box. The MA box forms a barrier for gas diffusion between the bell peppers inside and the air outside the package. The resistance for gas diffusion of the MA box is much higher than that of the standard box used by the Greenery International bv.

Obviously, not only the gas diffusion characteristic of the box was altered but also its temperature characteristics, especially in situations where air flow is partly responsible for the cooling or warming of enclosed product. In this study the cooling rate of both the standard and the MA box are addressed with respect to forced air flow through the box. In addition, the effect of the cooling performance on the bell pepper quality is determined for both box types. Finally, recommendations for appropriate actions to improve the cooling of MA packed bell peppers are provided. For this study, the cooling facilities with forced air flow of the Greenery International bv at Bleiswijk were used.

In a mixed pallet line-up, the cooling was slower for bell peppers packed in MA boxes compared to those packed in standard boxes. This difference was attributed to a difference in resistance to air flow between the two box designs. The higher resistance of the MA box limits the air flow through the pallet stack and as a consequence the efficiency of cooling. Forced air flow is more likely to occur through the low resistance pallets with standard boxes.

To test the assumption above, the experiment was repeated but this time with only MA pallets in a row. Despite the higher resistance for air flow, an efficient cooling of the enclosed bell peppers was achieved. In this situation, differences between the standard and the MA pallets in cooling efficiency were diminished.

The bell pepper quality, assessed by determining weight losses, was only slightly affected by the cooling procedure. Weight losses were lower for MA packed bell peppers in comparison to standard packed ones. Still, all weight losses (0.2% to 0.8%) were well within the acceptable range (< 7%) and did not lead to an unacceptable loss in firmness. With the values observed, there is a margin for more weight loss inevitably occuring in the distribution chain.

The results of these experiments were used to take measures at the Greenery International bv to improve the cooling performance of bell peppers packed in MA boxes. As a side effect, the cooling performance of standard packed bell pepper was improved as well.

Introduction

The quality of bell peppers can be retained most effectively by applying a low temperature and an appropriate package that establishes a specific gas atmosphere surrounding the bell peppers. For the latter, a new Modified Atmosphere package was developed: the MA box. The MA box forms a barrier for gas diffusion between the bell peppers inside and the air outside the package. The resistance for gas diffusion of the MA box is much higher than that of the standard box used by the Greenery International bv .

Obviously, not only the gas diffusion characteristic of the box was altered but also its temperature characteristics, especially in situations where air flow is partly responsible for the cooling or warming of enclosed product. In this study the cooling rate of both the standard and the MA box are addressed with respect to forced air flow through the box. In addition, the effect of the cooling performance on the bell pepper quality is determined for both box types. Finally, recommendations for appropriate actions to improve the cooling of MA packed bell peppers are provided. For this study, the cooling facilities with forced air flow of the Greenery International bv at Bleiswijk were used.

Material and Method

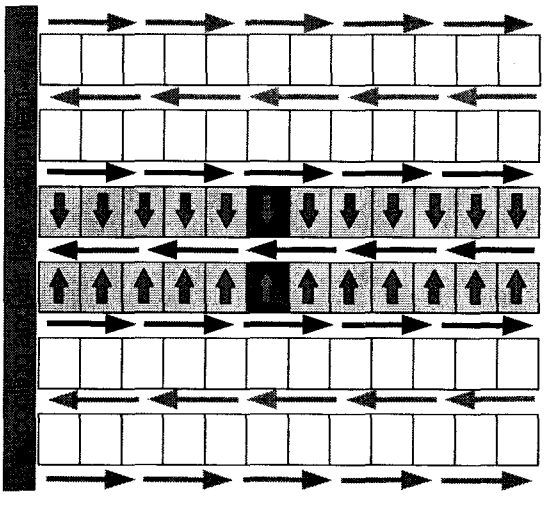


Figure 1
Top view of a cooling facility of the Greenery International bv indicating the pallet positions. Cooled air flows to and warm air flows from the pallet (arrows).

bell peppers

Bell peppers were harvested at the grower in the morning, packed in boxes of 5 kg net, stacked into pallets of 80 boxes each, and subsequently transported by truck to the auction in the late afternoon (± 4:00 pm). Here, the pallets were lined up in rows of 12 pallets each. Each cooling room contained 6 rows of 12 pallets. Every two rows formed a cooling unit characterised by a central air flow return (see figure 1).

data loggers

Two pallets were selected for the temperature and humidity registrations, conducted with Escort data loggers. Within each pallet, dataloggers were placed in boxes at different positions, defined by its layer number (counted from the bottom) and layer position (see figure 2).

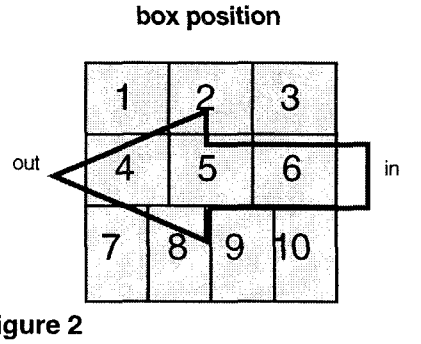


Figure 2
Box positions within a layer of a pallet (top view). The pallet consisted of 8 layers, counted from the bottom. The large arrow indicates the air flow through the pallet.

pallet positions

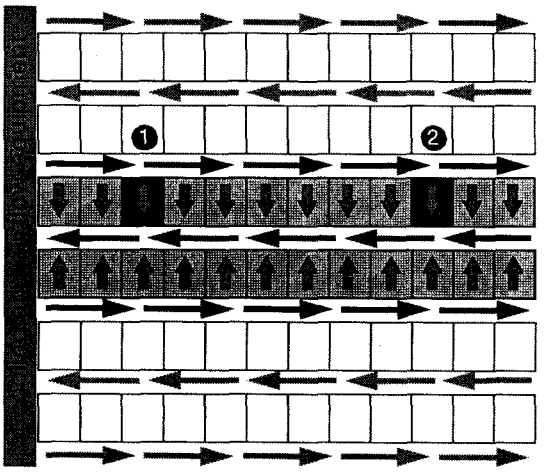


Figure 3
Top view of a cooling facility of the Greenery International bv indicating the pallet positions. Cooled air flows to and warm air flows from the MA pallet (arrows)

Two sessions of measurements were performed. The sessions differed in the type of pallets and the position of the dataloggers within the pallet:

❶ a cooling unit consisted of 2 rows of 12 pallets (23 standard- and one MA pallet). Pallets in the middle of a row (see figure 1) were selected for the measurements.

Dataloggers were placed in the layers 2, 4 and 6 (1=bottom; 8=top), sampling the box positions 2, 4 and 6 (see figure 2).

❷ a cooling unit consisted of 24 MA pallets, standard pallets were absent. Two pallets with MA boxes, in the third position from both row ends, were selected for the measurements (see figure 3). Dataloggers were placed in the layer 6, sampling the positions 1 up to 10 (see figure 2).

bell pepper quality

Effects of the cooling process on the quality of the bell peppers were determined by weighing the boxes with peppers before and after the cooling. The observed weight loss is a good estimate for the quality loss since weight loss and firmness of the bell peppers are linearly related.

data analysis

Temperature registrations were analysed by curve fitting. The temperature decreased according to an exponential function: $y = a_0 + a_1 * e^{-x/a2}$. The halftimes were calculated as $ln(½) * a_2$.
The function parameter a_0 represents the temperature in °C reached at infinity, a_1 the temperature decrease in °C, and $a2$ the rate of temperature change per minute^{-1}. y is the temperature in °C at time x in minutes after the onset of the cooling.

Results

mixed pallet arrangement

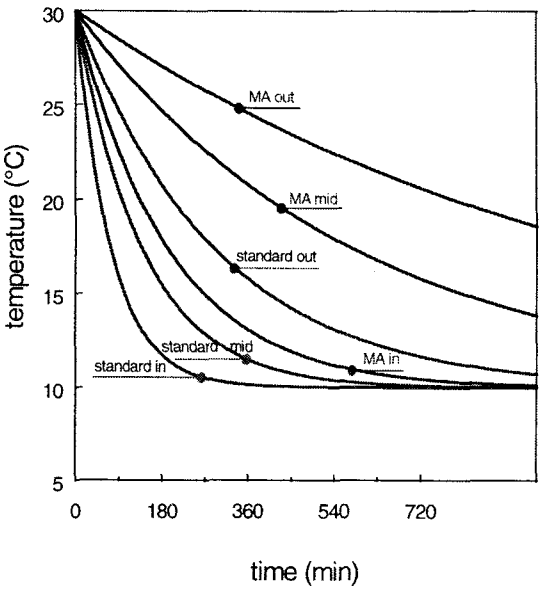


Figure 4
Temperature traces for standard and MA boxes in a pallet stacking, at the indicated positions witin a layer (see figure 2: in=6, mid=2, out=4). Vertical position variation did not influence the cooling rates. Start and end temperatures were defined.

The temperature traces of a cooling unit with a mix of standard and MA pallets (see figure 1) were analysed to determine the rates of temperature decrease for different layers and positions within the pallets. Figure 4 shows that the temperature decreases slower for a MA box (filled with bell peppers), compared to a standard box at the same position in the pallet.
Temperature profiles were similar for the layers 2, 4 and 6 of the standard pallet and for the MA pallet. In other words, temperatures were similar along vertical axis witin a pallet.

Significant differences did exist for the positions within a layer, which is shown in figure 4. Along a horizontal axis within a pallet, a temperature gradient was found per pallet type. Obviously, boxes at the side where cold air entered the pallet (marked *in*) are cooled much faster than those at the side where the air leaves the pallet (marked *out*). The centre position is intermediate in its temperature profile (*mid*).

This result clearly shows that cooling bell peppers in the MA box, in a mixed pallet arrangement, is significantly slower than that of the bell peppers in the standard box. Cooling rates per boxtype and pallet position are summarized in the table 1.

only MA pallet arrangement
The cooling characteristics were influenced by the type of pallets aligned in the two rows of a cooling unit. This was expected because the resistance for air flow through a MA pallet is much higher than for a standard pallet, due to less and smaller ventholes in the MA box. In a mixed pallet arrangement, standard pallets will largely contribute to the total air flow within a cooling unit and thus hamper the air flow through MA pallets. The large effects of the pallet arrangements is shown by comparing figures 4 (mixed arrangement) and figure 5 (only MA pallets).

The results are summarised in table 1, which shows the halftimes for cooling bell peppers in standard boxes (forced air flow), MA boxes in a mixed arrangement of pallets (limited air flow) and MA boxes in a MA arrangement (forced air flow). The halftime is the time required to achieve a temperature change of 50% of the difference between the start and end temperature. Provided that only MA boxes fill a cooling unit, the cooling characteristics of bell peppers in MA boxes closely resemble that of those in standard boxes.

It should be noted that for practical reasons (logistic procedures at the Greenery International bv) the maximal cooling time available is 12 hours. This implies a maximal halftime of 218 minutes (720*ln(0.5)/ln(0.1) when the temperature should drop 90% of the total range (begin to end temperature). For a 95% temperature drop the maximal halftime is 167 minutes (720*ln(0.5)/ln(0.05).

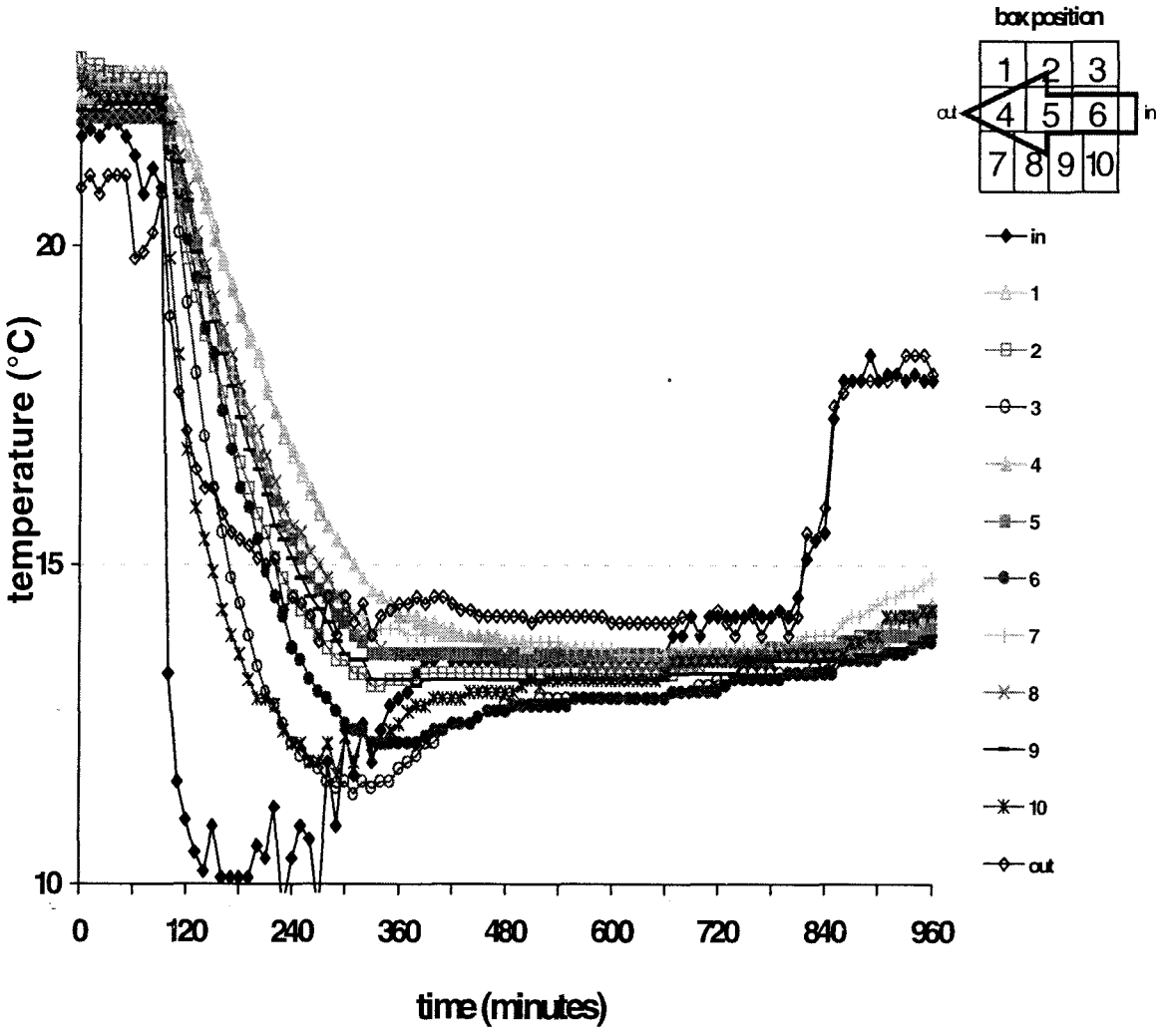
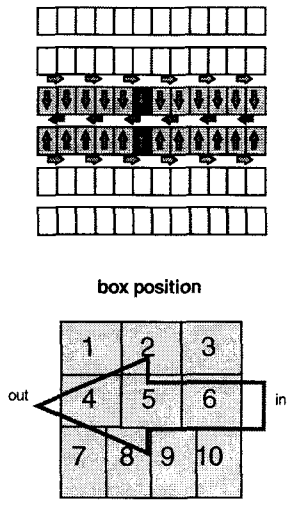


Figure 5
Temperature traces of a MA pallet in the forced air cooling facility of the Greenery International bv. The pallet was lined up with 23 other MA pallets to form a cooling unit of only MA pallets: 2 rows of 12 pallets. The temperature of all boxes in the 6 layer (bottom=1) was measured. The period of cooling started at 90 minutes. Forced air flow was active from 90 up to 270 minutes.



position	halftime for cooling (minutes)		
	mixed pallets: standard + MA		only MA pallets
	standard (forced air flow)	MA	MA (forced air flow)
1	*	*	185
2	96	402	119
3	*	*	66
4	200	786	202
5	*	*	137
6	51	133	98
7	*	*	273
8	*	*	262
9	*	*	107
10	*	*	38
avg	116	440	149

Table 1 The temperature decrease rates for bell peppers in the standard and in the MA box under different circumstances. Firstly, the forced air flow through a pallet is varied by applying a mixed pallet arrangement and an exclusively MA pallet arrangement (see figures 2&3). With a mixed arrangement, the air flow through standard pallets is maximal, and through MA pallets minimal. When only MA pallets are used, the air flow through MA pallets is maximal as well. Secondly, a temperature gradient along the pallet was observed which correponded with the flow of cold air through different box positions (see arrow and box position indication).

*: no data available

bell pepper quality

As mentioned before, the weight loss of bell peppers is used as an indication for their quality loss in terms of firmness. Loss of firmness was the most important quality aspect here. Rot and shriveling were not observed within the relatively short period required for the cooling of the bell peppers.

Weight losses were similar for all positions within the pallet tested. Thus, an average value per pallet can be presented. The table below summarizes the results.

Table 2: weight loss of bell peppers due to cooling procedure (ca. 12 hours) per boxtype and pallet lineup (mixed or MA only).

	standard, forced air mixed pallets	MA mixed pallets	MA, forced air only MA pallets
weight loss (%)	0.8	0.5	0.2

Weight losses above 7%, occuring after harvest, resulted in bell peppers with an unacceptable firmness (result of previous experiments). The observed weight losses here are well within the tolerable range. It should be noted that not only the line-up of the pallets was altered for the two succesive experiments but the origin of the bell peppers differed also. Thus, differences observed in weight losses may not only be attributed to the pallet line-up.

Conclusions

❶ MA boxes in a pallet stacking filled with bell peppers can be accurately cooled with forced air flow, according to the standard procedure used at the Greenery International bv facilities, when they are not mixed with standard pallets.

❷ In a mixed pallet arrangement, the cooling rate of MA pallets at the Greenery International bv is approximately four times slower than that of standard pallets with bell peppers.

❸ Large differences in cooling rates exist at different box positions within a pallet, both for standard and MA pallets. There is a gradient along a horizontal axis but not along a vertical axis within the pallet.

❹ The cooling procedure at the Greenery International bv leads to more weight loss of bell peppers packed in the standard box compared to the MA box.

❺ The weight losses of bell peppers due to the cooling procedure (0.2 to 0.8%) did not result in a too high dehydration (> 7%) of the bell peppers, thus avoiding a concomitant unacceptable firmness.

Recommendations

❶ Based on the result of this experiment, logistic measures at the Greenery International bv have been taken to achieve an effective cooling of MA packed bell peppers. Only MA pallets are lined up in the cooling facility. The number of MA pallets lined up is reduced when less than 24 MA pallets are available. Thus, clusters of even numbers of MA pallets up to 24 can be cooled effectively in the cooling facility.

❷ A further improvement of the cooling of bell pepppers is achieved by changing the setpoint of the cooling facility. An end temperature of 13°C was used, although the cold storage temperature that is advisable for red bell peppers is 8°C. This discrepancy results from experiences in the past with the standard box. The mechanical strength of this box suffers from condensation of water vapour occuring when bell peppers of 8°C are exposed to higher temperatures. Pallets with standard boxes at 8°C turned out to be unstable in the distribution chain. However, the MA box is far less sensitive to humidity and would allow a setpoint of 8°C. A compromise setpoint of 10°C was arranged to meet the requirements of both the standard and the MA box.