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Cooling behaviour of QuaMA packages and Capespan corrugated packages

A comparison of packages regarding cooling and heating

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1 Introduction

This research was carried out at the request of Capespan and Kappa Packaging. In order to implement the QuaMA concept in the operating procedures of Capespan, it had to be decided where the QuaMA box was to be closed and cooled and in what order this had to be done.
This question can be answered partly by looking at the logistic procedures used by Capespan. Hence, this part of the research will be done by Capespan in close co-operation with Kappa Packaging. However, a sound decision requires knowledge about the cooling characteristics of the various boxes and their settings. A good comparison between the QuaMA box (various concepts) and the corrugated boxes used nowadays by Capespan regarding cooling and heating is necessary.
In the experiments, realistic conditions are simulated as much as possible. Because of the differences between the various forced air cooling facilities used by Capespan, there will always be a difference between the results of these experiments and the results in practice. On the other hand, the obtained results give a very good and reliable idea how the different boxes/settings behave under similar circumstances regarding cooling and heating. It is not expected that the order of the different boxes will change by using other cooling facilities.

2 Method and material

The grapes used in this experiment were from the cultivar Dauphine. If desired, Capespan can provide more information on the product. The required 350 boxes for the experiments were cleared from storage in Vlissingen by Capespan. The grapes arrived at ATO on Thursday 23 March. The grapes were repacked on March 24 in the different packages and the experiments were started. The experiments continued until Thursday 13 April. In this period the tests were carried out with 5 packaging alternatives. All were given 3 different treatments: forced air cooling, static cooling and heating.

2.1 Packages used and pallet stacking

5 different settings were tested in the experiment. In all settings, the original carry bags for the grapes were used. An SO_2 pad and a corrugated paper sheet were also applied in all boxes. An exception was in setting 5 where the SO_2 pad was removed. Application of the SO_2 sheet and corrugated paper was necessary to maximise keepability to be able to conduct all the cooling experiments. The experiments were carried out with a 7 layer pallet. This was necessary to have the same temperature distribution in the central layers as in a complete pallet.

The settings used in de experiments are summarised below:
1) Capespan "standard",
2) Capespan "perforated bag",
3) QuaMA "standard",
4) QuaMA "handle",
5) QuaMA "holes",

The stacking pattern for Capespan boxes is shown at the right side of figure 3. The stacking pattern for the QuaMA boxes is shown at the left side in the same figure.

1). Capespan "standard"
The packaging that was used in this setting is shown in figure 1. It is a combination of a polyethylene bag and a corrugated board box. This combination is the by Capespan commonly used transport packaging for export of table grapes. The dimensions of this box are 40 x 30 x 12 cm. The used polyethylene bag is 20 µm thick without holes. It is shown in figure 1.

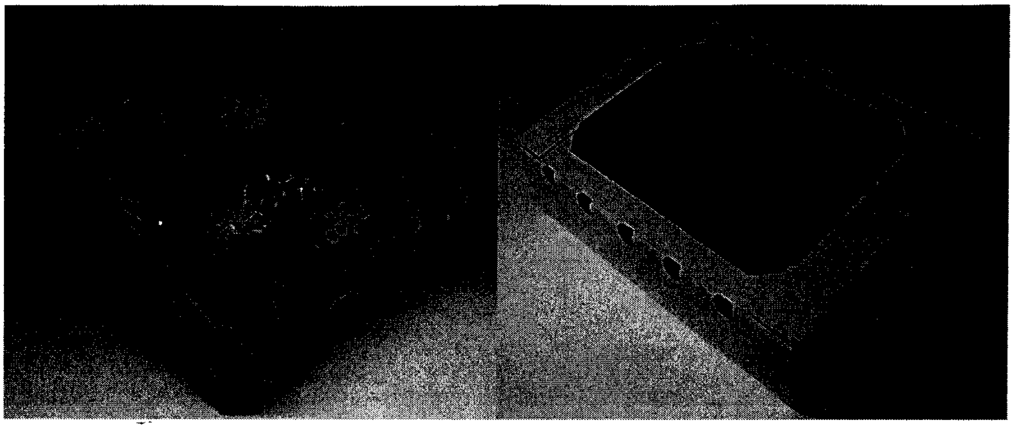


figure 1 Capespan box and QuaMA box with holes.

2). Capespan "perforated bag"
The only difference between a Capespan "perforated bag" and a Capespan "standard" is the polyethylene bag used. In this packaging, the bag is perforated with 108 perforations of 6 mm to allow more air circulation through the packaging and not only between the packages.

3). QuaMA "standard"
The QuaMA box is also shown in figure 1 (right hand side). The Standard QuaMA box is a solid board box of 38,5 x 28,5 x 12 cm without any holes. The packaging is closed before cooling and there are no additional features to improve cooling. The box is closed with a 30 μm thick polypropylene film. This makes the box air tight and therefore a modified atmosphere packaging. Due to the design of the box, the space between boxes in a stack is minimal; only the glue used for the cover sheet creates space (2 á 3 mm) between the columns.

4). QuaMA "handle"
In this setting the box is the same as the one described above (without holes) and shown in figure 1. The packaging is also closed before cooling. It differs from setting 1 in that after closing the box with the polypropylene sheet, a handhold is glued onto the packaging, see figure 2. This corrugated board handhold has various functions:
1) improving handling of the box,
2) giving extra stability to the boxes when stacked,
3) creating space (10 à 11 mm) between boxes in a stack.
The outside dimensions of the stack still fit on a standard pallet 100 x 120 cm.

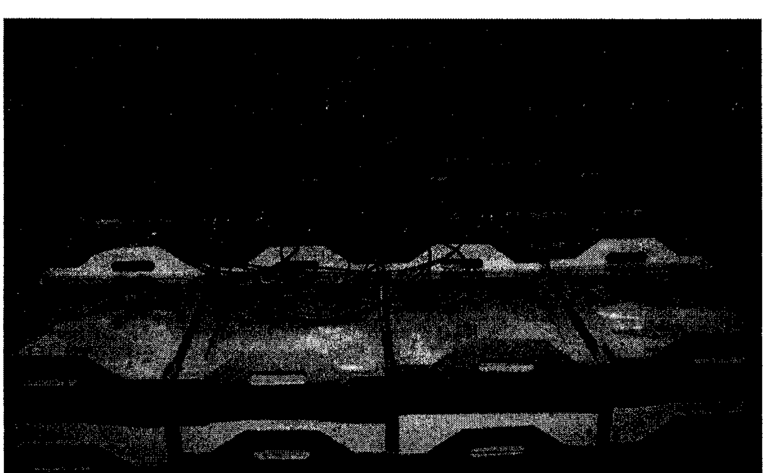
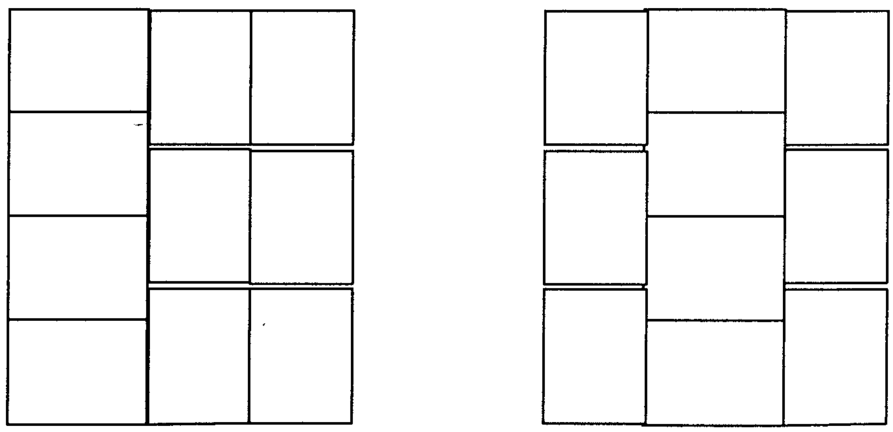


figure 2 QuaMA box with handholds.

5). QuaMA "holes"
This is a setting with QuaMA box which has to be sealed after cooling. The elementary design of the box is the same as in settings 3 and 4. The difference with the standard QuaMA is that there are holes in the long side of the boxes (see figure 1). These holes (5 holes on each side, 4 cm^2 area) are at the upper edge of the box. These holes enable air circulation through the box during forced air cooling. After cooling, this box has to be closed, and the holes are covered with the polypropylene sheet while closed. After closing, this packaging is also an air tight MA packaging.



QuaMA stacking pattern Capespan stacking pattern

figure 3 Stacking patterns used in the experiments for the two different boxes.

2.2 Methods used for cooling and heating

The whole experiment was focussed on comparison of the different packaging alternatives regarding forced air cooling, static cooling and heating. To be able to do this properly, all the settings were treated in the same way. The practical situation was simulated as much as possible. The methods used for forced air cooling, static cooling and heating are described below. The differences between experimental set-up and the practical situation are discussed in the results.
Cooling time is given in half times ($t_{1/2}$). This is the time in hours needed to half the temperature between start temperature and ambient temperature. The temperature in the packaging can be described as:

$$T_{pack}(t) = T_{amb} + (T_{pack}(0) - T_{amb})e^{-\frac{t}{C}}$$

Were T is temperature (in ° Celsius), t the time (in hours), T_{amb} and C constants. the half time is equal to $t_{1/2} = C \ln(2)$.
In all pallets 7 thermocouples were divided over the different box positions, covering al box positions, centre, edge, corner and 4 layers (layer 4, 5, 6 en 7 counting from the bottom) of the pallet. One thermocouple was used to monitor the ambient temperature. The temperature was registered automatically every 5 minutes by a computer.

2.2.1 Forced air cooling

In practice forced air cooling is applied as shown in figure 4. This method is not feasible for experiments because of the needed amount of similar pallets. If different pallets are used in this system, they will influence the different pallets on the cooling behaviour of other pallets. In order to avoid the influence of different pallets, only one pallet at the time was cooled by forced air. This was done as shown in figure 5.

During experiments, the temperature at which cooling started was different from practice. In practice, this can be up to 35 °C. The combination of these high temperatures, the number of times the grapes had to be cooled and the fact that the product had already been in storage cause a risk of serious botritus infections. Such an infection would influence the results of the test and therefore make the results unreliable. Before cooling, the pallet with grapes was heated until the temperature in al boxes had reached 5 °C. The temperature at start of the cooling was not always the same. These differences in start temperature and the relatively low temperatures at the beginning of the test make full cooling times not comparable. To compare cooling behaviour, half times were calculated.
Before moving the pallet in the cold storage room (-0,5 °C) with forced air cooling, the pallet was covered with an air tight sheet leaving the 1 meter sides of the pallet stack free. In this room, one of the 1 meter sides of the pallet was placed against a chamber. Air was forced out of this chamber by an air fan creating low pressure. The pressure drop forced cold air through the pallet. The pressure drop across the pallet was measured by the difference between the ambient room pressure and the pressure in the chamber. By measuring air speed at the free side of the pallet, the amount of air sucked through the pallet was calculated. Using the same set-up for each pallet, all measured differences were caused by the packages used in a pallet.

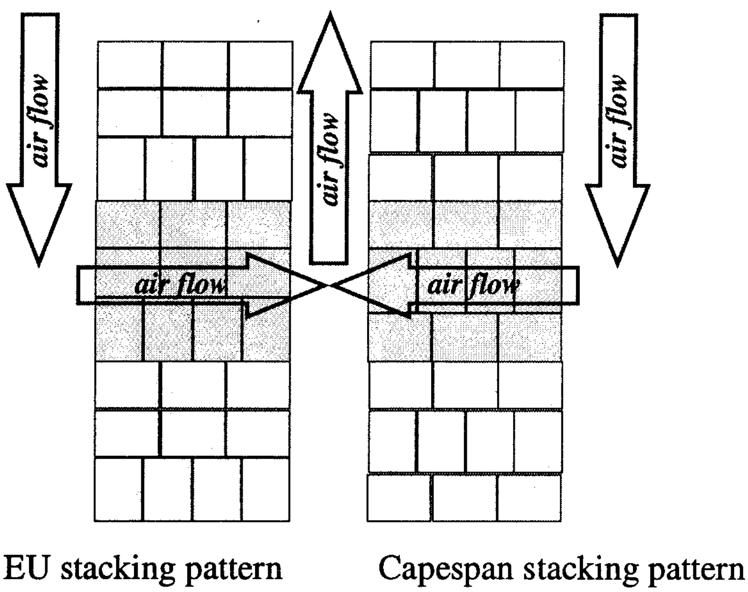


figure 4 Method used for forced air cooling

Full cooling time was not always applied, due to the number of experiments and the time available for the research. Cooling was carried out until enough data were gathered for a reliable calculation of half times.

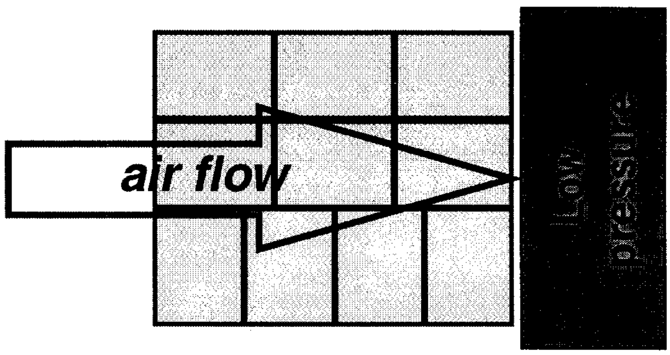


figure 5. Experimental setting forced air cooling

2.2.2 Static cooling

For static cooling, the pallets were also heated until the temperature in all the boxes was at least 5 °C. After this, the pallet was placed in a cold store (-0,5 °C) with normal air circulation. No air was forced through the pallet.

2.2.3 Heating

Pallets were moved from a cold store which was at –0,5 °C to a climate room at 25 °C. For reasons described in chapter 2.2.1 the grapes were only heated until they reached a temperature of about 10 °C (max). The results are in °C / hour. In this treatment, the effect of radiation of the sun had not been included.

3 Results and conclusions

Using the formula shown in paragraph 2.2 the half times were calculated. The average fit was 95 %, with a minimum of 84 %. The 5 % deviation can be explained by deviations in the measurement errors and a small second order effect. Looking at these results there is no reason to assume that there are significant second order effects involved. The full cooling times can be calculated by using half times. The results are shown in table 1 and table 2. The half times are calculated with starting temperatures of 25 °C and cooling with – 0,5 °C air. (6 times the half time, 98,4 % of the difference between $T_{(0)}$ and T_{amb} is realised). It is not known if a lower set-point is used in practice for cooling. A lower set-point will improve the full cooling time.

Packaging	Forced Air Cooling		Debit (m^3/hour)	Pressure drop (mm water)
	Half time	Full time		
Capespan Standard	13.1	79	39	19
Capespan Perforated	5.5	33	95	17
QuaMA Standard	10.8	65	31	20
QuaMA Handle	7.8	47	78	17
QuaMA Holes	4.0	24	125	16

table 1 Results of forced air cooling

Pressure drops in South African forced air cooling facilities are between 6 mm and 30 mm water (Jeff Wedgwood Worthington-Smith & Brouwer). The measured values are within this range. It may be expected that measured half times and full times in the experiments are comparable with practice.

Packaging	Static cooling		Heating (°C/ hour)
	Half time	Full time	
Capespan Standard	38.4	230	0.39
Capespan Perforated	33.8	203	0.27
QuaMA Standard	45.4	272	0.42
QuaMA Handle	20.8	125	0.40
QuaMA Holes	22.8	137	0.24

table 2 Results of static cooling and heating

The slow heating of the Capespan Perforated and QuaMA Holes setting are probably due to evaporation of water. A part of this water is condensed from the air on the inside of the packaging but the major amount is probably evaporating from the grapes. This has an effect on weight loss and quality of the grapes (not specified). In these open boxes (Capespan perforated and QuaMA Holes) this is a point of consideration. Extra evaporation has probably a positive effect on cooling times but it may have a negative effect on weight loss and product quality.