ATO

# Performance of Egg Trays During Transport and Storage

## Report B530

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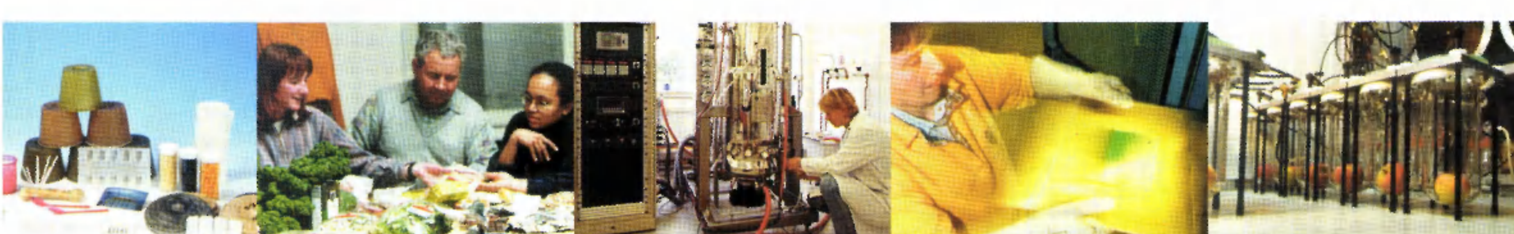

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# 1 Introduction

Moulded fibre trays are used to transport eggs from the poultry farmer to the packing station. Currently, Huhtamaki produces different types of moulded fibre trays for eggs. These trays differ with respect to geometry and composition. In practice the performance of those trays seems to differ, as users of the trays suggested. Therefore a comparison of those trays under equal, reproducible and realistic conditions was necessary. This project contained the comparison of three tray types: the Multi-K tray produced at Huhtamaki Netherlands (HNL), the Multi-K tray produced at Huhtamaki La Rochelle (HLR) and a competing type of tray (CDL). The performance of those trays has been judged with respect to the mechanical protection of the eggs during transport and storage. To achieve this, the quality of the trays and the eggshells has been assessed. The internal quality of the eggs has not been considered.

Fresh eggs are stored in trays during four days at most. The trays are stacked on a pallet (120 x 80 cm) for transport and storage. A pallet load contains 5 layers of trays separated by sheets of corrugated board. Each layer contains 12 stacks of 7 trays each (six trays contain eggs, the seventh tray is a cover tray). The dimensions of most trays are 29.5 x 29.5 cm, which means that the width of the pallet load (three trays wide) is larger than the width of the pallet itself. The trays along the edges of the pallet are supported by a sheet of corrugated board between the pallet and the load. During the four day storage period the eggs are transported during four hours at most. Although chilled storage and transport aren't common practice yet, a tendency towards chilled storage and transport can be observed. To reflect the actual conditions in the logistic chain, the experiments have been conducted at conditions that are considered being common during chilled transport. The static and dynamic loads acting on a tray vary with the vertical position of the tray in the pallet load. The loads acting on a tray also depend on the horizontal position of the tray, because some stacks stick out past the edge of the pallet, whereas others don't. As a consequence the experiments have been conducted with a entire pallet load for each type of tray. The quality of the eggshells has been assessed by an expert of the Dutch inspection bureau for poultry, eggs and egg products (CPE) by means of a random check of each pallet.

The experiments enable a comparison between the performance of the different trays under simulated transport- and storage conditions. It should be mentioned that both Multi-K trays have the same geometry, but a different composition. The geometry of the CDL tray differs from the Multi-K geometry. Comparison of the Multi-K trays makes it possible to assess the influence of the material properties, whereas a comparison between CDL and Multi-K trays indicates the influence of the geometry of the tray, assuming that the CDL tray and one of the Multi-K trays have the same material properties. The experiments to check this, are not contained in this project.

# 2 Goal of the project

The goal of the experiments is to compare the three different trays (Multi-K HNL, Multi-K HLR and CDL) with respect to the mechanical protection of eggs during simulated transport conditions i.e. temperature, relative humidity and vibrations. Given this comparison, the quality of the different trays can be assessed.

# 3 Results

The project has been carried out in two phases. During phase 1 an appropriate dynamic load has been determined. To achieve this, a stack of trays has been subjected to different load levels and subsequently the stability of the pile and the damage to the eggshells have been assessed. Phase 2 contained the storage and transport simulations using the dynamic load determined in phase 1. The quality of the eggs has been assessed at the packing station and after the experiments by a CPE expert.

## 3.1 Phase 1: determination of dynamic load

### Experimental set up

The quality of a tray is determined by assessing the trays themselves and the quality of the eggs in those trays after the transport simulation. The dynamic load should be such that the quality of sufficient eggs deteriorates or such that the height of the stack decreases measurable but the stability of the stack isn't severely disrupted.

To determine such an appropriate load, eggs in new (dry) and older (moist) Multi-K HNL trays have been used. A 45 minute transport simulation has been carried out with a stack of trays at a dynamic load of 10%, 30%, 50%, 60%, 70% and 100% of the transport norm ASTM 4169. All experiments were conducted at 12°C and 85% relative humidity. After the transport simulation, the CPE expert assessed the eggs with respect to cracks and broken shells.

### Result

The 100% ASTM norm 4169 test has been stopped after 10 minutes, because the load was clearly too heavy. The other tests have been performed as planned.

There appeared to be no significant relation between the applied dynamic load and the quality of the eggs (i.e. percentage of cracks and broken shells). Dynamic loads exceeding 50% disrupted the stability of the stack too severely due to compression of the trays and bouncing of the upper trays. The dynamic loads of 10% and 30% caused only very limited compression of the trays.

Given these results, it has been decided to carry out the transport simulations in phase 2 with a dynamic load of 40% of ASTM norm 4169.

## 3.2 Phase 2: simulation of logistic chain

### Experimental set up

The second phase of the project contained the examination of the influence of a realistic logistic chain (time, temperature, relative humidity, dynamic load) on the three types of trays. Below, the different stages of the logistic chain are listed.

1. Filling the trays and loading the pallet at the packing station, transport to ATO.
2. Storage: 72 hours at 18 °C and 85% RH
3. Transport simulation: 200 km at 25 °C and 50% RH
4. Storage: 8 hours at 15 °C and 60% RH
5. Transport simulation: 200 km at 25 °C and 50% RH
6. Storage: 8 hours at 15 °C and 60% RH
7. Transport simulation: 200 km at 25 °C and 50% RH
8. Storage: 12 hours at 10 °C and 85% RH
9. Storage: 12 hours at 18 °C and 85% RH
10. Storage: 24 hours at 7 °C and 85% RH
11. Storage: 12 hours at 18 °C and 85% RH

For each tray type a 120 x 80 cm pallet is loaded with 5 layers of trays, separated by sheets of corrugated board. Each layer contains 12 stacks of 7 trays each; six trays contain eggs, the seventh tray is a cover tray. The total number of trays per pallet is 420. The dynamic load applied was 40% of ASTM norm 4169.

During and after the experiments the following quantities are measured:

- temperature and relative humidity (continuous);
- weight of several trays to determine the effect of the climatic conditions on the moisture content of the trays (regularly);
- height of the sheets of corrugated board between the layers (at change of climatic conditions and before and after transport simulation);
- number of trays that stick together, like a press button, per layer (after the experiment);
- quality of the eggs (at packing station and after the experiment).

## Temperature and relative humidity

Figure 1 shows the temperature and the relative humidity measured during the experiment using an Escort data logger. The first part of the curve (until day 4.5) corresponds with transportation of the empty trays from Huhtamaki Nederland to the packing station, packing the eggs, building the pallet load and transportation of the pallets to ATO. After day 4.5 the experiment outlined in paragraph 3.2 starts.

It should be noticed that deviations between the setpoint and the measured relative humidity were inevitable. Disturbances were caused by opening the doors of the lab, which was necessary to be able to move the pallets with a fork lift truck.

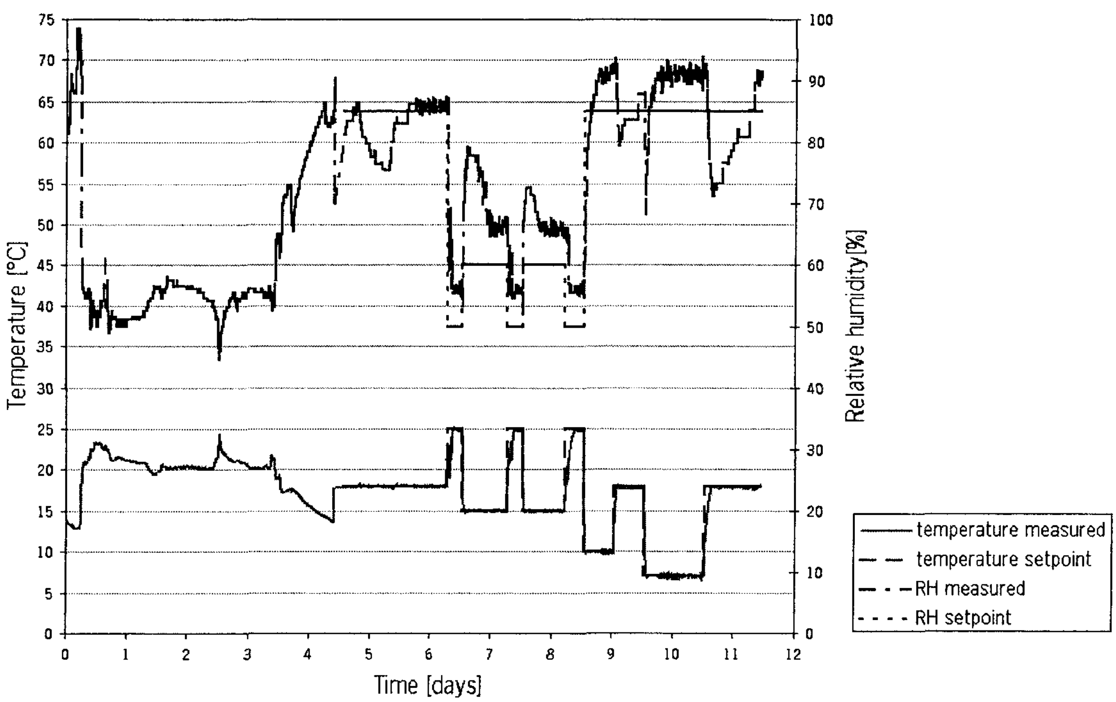



**Figure 1**. Temperature (bottom curve, left axis) and relative humidity (upper curve, right axis).

## Moisture content of the trays

Regularly empty trays have been weighed to determine the moisture content of the different types of trays. After the experiment these trays were dried in an oven to determine their dry weight. Given these data, the moisture content of the trays has been calculated. The results are shown in Figure 2. These results show that the moisture content of the Multi-K HLR trays is slightly lower than the moisture content of the other trays.

It should be noticed that these results have been obtained from empty trays. No measurements have been carried out to determine the moisture content of the trays in the pallet load, since this would have disrupted the experiment. However, at the end of the experiment, when the pallets were unloaded, the trays from the pallet load seemed to contain more moisture than the empty trays. This could have been caused by the occurrence of condensation on the eggs during the experiment. The trays could have absorbed this water partially or the relative humidity inside the pallet load could have been higher than the relative humidity just outside the pallet load. A higher moisture content might negatively affect the strength and stiffness of the trays.

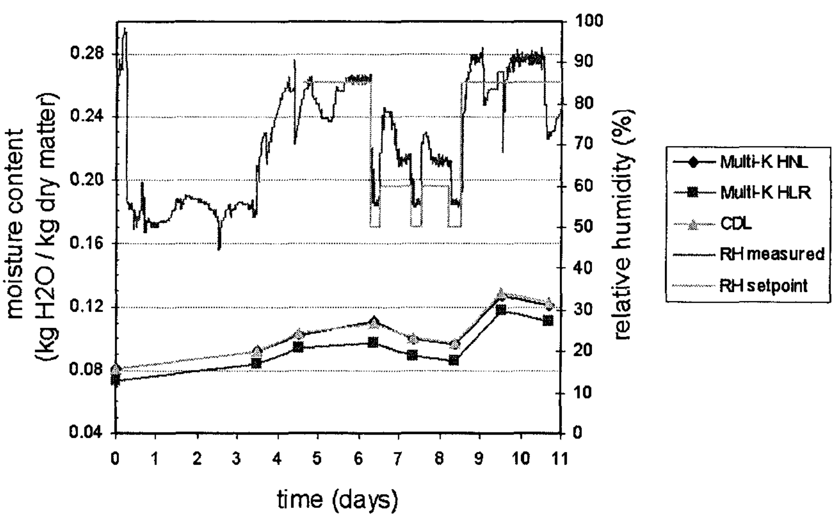
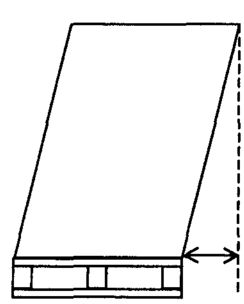



**Figure 2.** Moisture content of the trays (left axis) and relative humidity (right axis).

## Compression of the pallet load

To quantify the compression of the stacked trays in the pallet load, the distance between the corrugated board sheets and ground level has been measured at different moments during the experiment. The results are plotted in Figure 3. It should be remarked, however, that the pallet loads tilted slightly. The pallet load with Multi-K HLR trays tilted most (see Figure 10): the horizontal deflection (see sketch below) was at most 15 cm. The other two pallets had a maximum horizontal deflection of 7 cm.



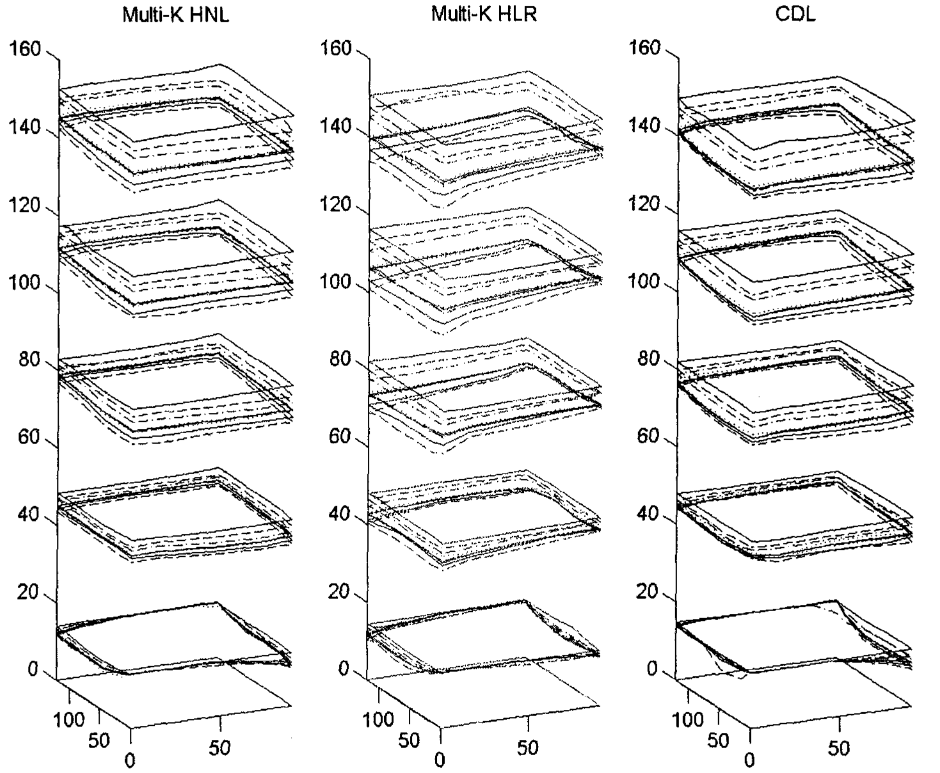



**Figure 3.** Compression of the pallet loads. The lines represent the sheets of corrugated board at different stages of the experiment. The sizes are given in centimetres.

| | |
|---|---|
| ——— | packing station, |
| — — — | arrival at ATO, |
| — · — · — | before first transport simulation, |
| · · · · · · | after first transport simulation, |
| ——— | before second transport simulation, |
| — — — | after second transport simulation, |
| — · — · — | before third transport simulation, |
| · · · · · · | after third transport simulation, |
| ——— | after one day storage, |
| — — — | after two days storage. |

After the experiment the pallet load consisting of Multi-K HNL trays and the pallet load consisting of CDL trays were, on average, 11 cm compressed, whereas the pallet load consisting of Multi-K HLR trays was 13 cm compressed. As a percentage of initial height of the pallet loads, the compression of the Multi-K HNL and the CDL trays was 8.5% and the compression of the Multi-K HLR trays was 9.6%. A statistical analysis revealed that this difference was significant. It should be noticed however, that only one pallet load was examined for each type of tray.

Examining the compression (averaged over all tray types) in the course of the experiment reveals that the first transport simulation had the largest impact on the pallet load (see Figure 4). At this stage the pallets had just left the 85% RH storage and the trays were still relatively moist. The Multi-K HNL trays withstood the first transport simulation better than the other trays.

Storage at 85% relative humidity without transport simulation (both at the start and at the end of the experiment) contributed significantly less, but still considerably to the compression of the pallet load. During the last stage of the storage, the (incremental) compression of the CDL trays was significantly smaller than the compression of the other trays. At this stage of the experiment several temperature changes occurred, which might have caused condensation on the eggs.

Transport simulation and storage at a lower relative humidity only caused a marginal incremental compression. No significant differences between the trays could be observed at this stage of the experiment.

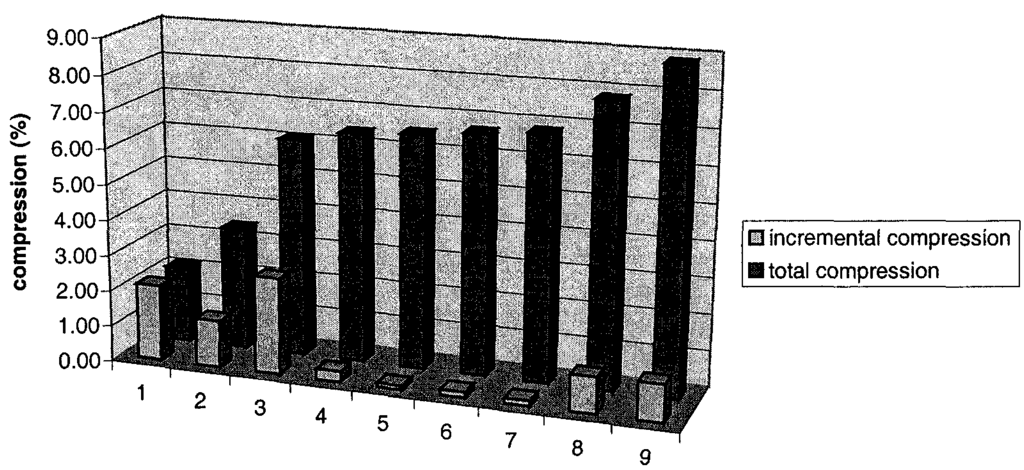
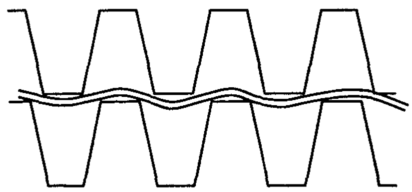



**Figure 4.** Average compression (percentage) of the pallet loads.

1. after transport from packing station to ATO
2. after storage at 85% RH
3. after first transport simulation
4. before second transport simulation
5. after second transport simulation
6. before third transport simulation
7. after third transport simulation
8. after storage at 85% RH (changing temperature)
9. after storage at 85% RH (changing temperature)

The compression of the pallet load is a combined effect of the compression of the trays and the occurrence of 'press buttons', the compression of the corrugated board sheets and the deformation of these sheets when the trays at both sides of it are not properly aligned (see sketch below).



As expected, the compression of the bottom layer of the pallet load is larger than the compression of the upper layers. Especially the bottom trays along the long edges of the pallet were severely deformed. Since the 'cross direction' of the corrugated board sheet between the pallet and the bottom trays was aligned with the long side of the pallet, the corrugated board folded relatively easy and hardly supported the trays (see Figure 5). All three pallets showed this effect.

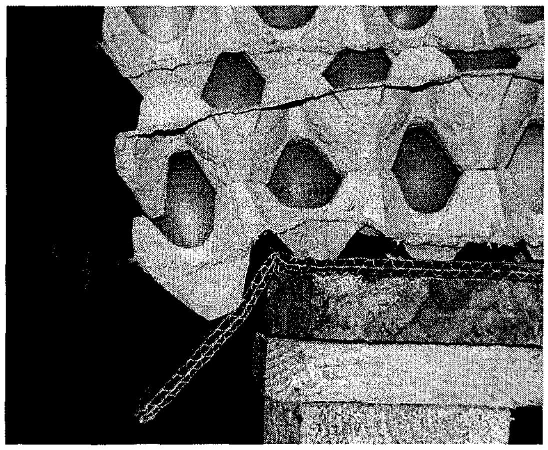


**Figure 5.** Sheet of corrugated board folds and hardly supports the bottom tray.

## Trays sticking together like press buttons

Eggs are not only damaged by shocks and vibrations during transport, but also indirectly due to deformation of the trays. Shocks and vibrations initiate the occurrence of 'press buttons': the tops of the trays are pushed into one another and stick (see Figure 6). Due to these 'press buttons' the trays stick together during (automated) unloading of the pallet, which causes problems. Therefore the occurrence of this phenomenon is important when assessing the quality of the trays.

During the unloading of the pallets at the end of the experiment, the number of trays has been counted that stuck together because of 'press buttons'. The results are shown in Figure 7. It is clear that both Multi-K trays mainly had 'press buttons' in the two bottom layers (each layer consisting of twelve stacks of six trays with eggs) of the pallet load, whereas the CDL tray mainly had 'press buttons' in the bottom layer of the pallet load.

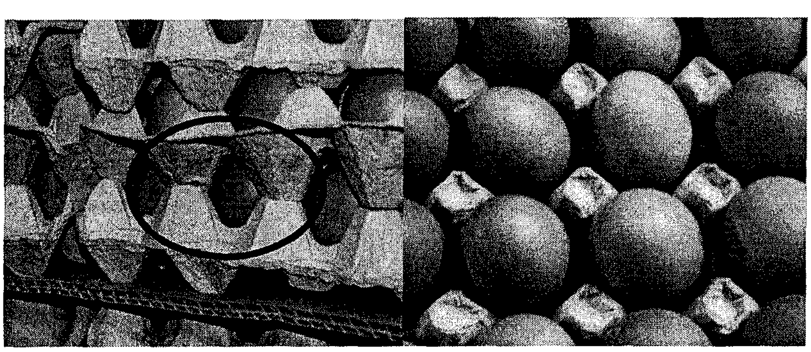


**Figure 6.** 'Press buttons': tops pushed into each other (left) and impressions of 'press buttons' (right).

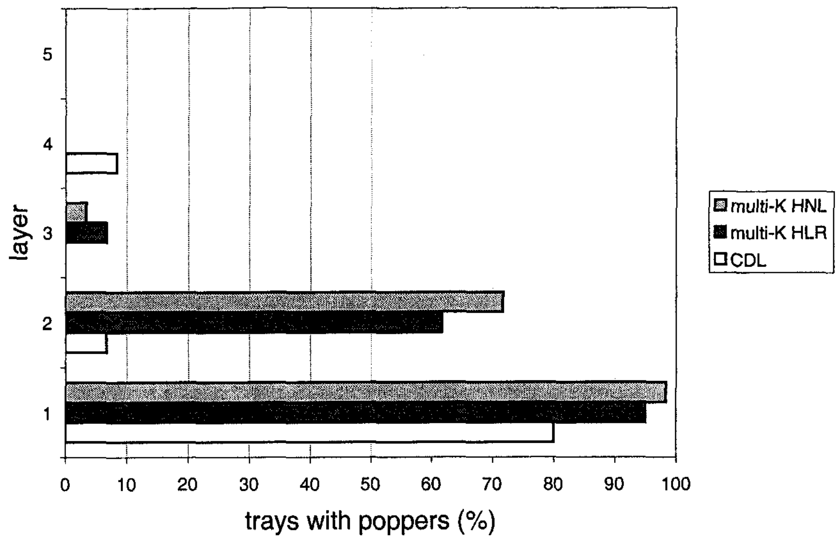



**Figure 7.** Percentage of trays with 'press buttons' per layer.

## Egg Quality

At the start of the experiment, at the packing station, the quality of the eggs has been determined. All eggs from thirty six trays have been assessed with respect to the occurrence of cracks and broken shells. The pallet with Multi-K HNL trays initially had 3.6% damage, the pallet with Multi-K HLR trays 1.2% and the pallet with CDL trays 1.9%. The average percentage of damage was 2.2%.

At the end of the experiment the egg quality of thirty six trays has been assessed again: two stacks of six trays from the bottom layer of the pallet load, two stacks from the second layer, one stack from the third layer and one stack from the fifth layer, i.e. the top layer. In case of the bottom layer and the second layer, one stack came from the middle of the layer and one from the edge; in case of the third and fifth layer, the stacks came from the middle of the layer. The eggs have been assessed with respect to cracks, broken shells and freshly broken shells. De results are plotted in Figure 8. This figure shows that the percentages of damage are relatively small. The average percentage of egg damage of the pallet loaded with Multi-K HNL trays increased from the initial 3.6% damage to 5.0% damage, the average damage of the pallet with Multi-K HLR trays increased from 1.2% to 3.4% and the average damage of the pallet with CDL trays from 1.9% to 3.8%. A statistical analysis showed that the differences between the tray types are not significant. It should be noted however, that all eggs were good quality medium sized eggs, which limited the percentage of damage.

In addition to the average percentages plotted in Figure 8, Figure 9 shows the observed percentages of damage per layer for each of the tray types.

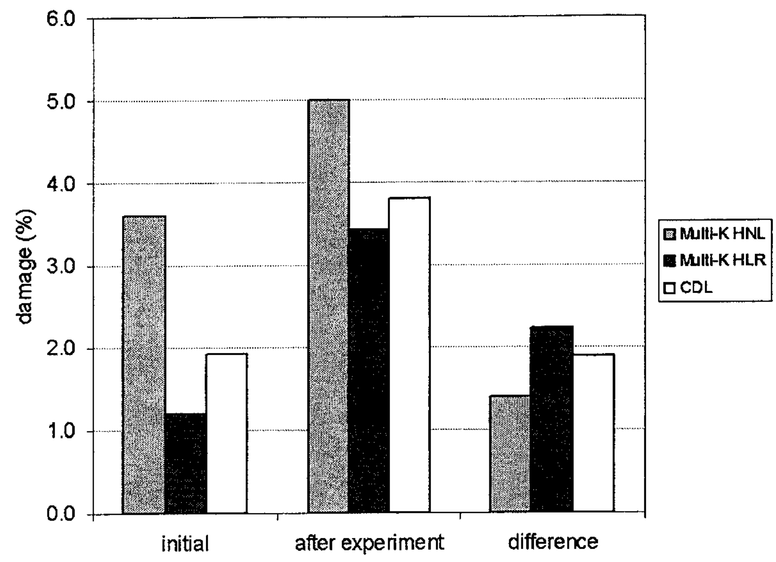



**Figure 8.** Average percentage of damage per pallet load: initially (at packing station), after the experiment, and the difference between these two percentages.

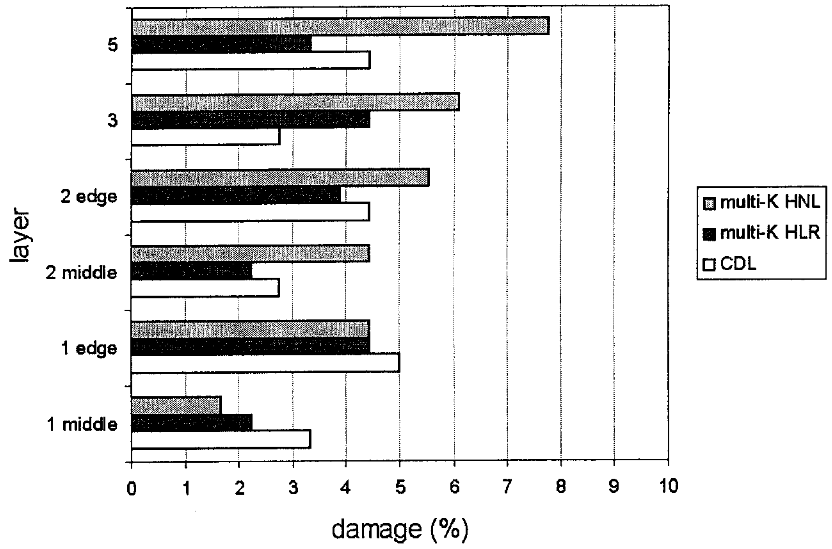



**Figure 9.** Percentage of damage after the experiment per layer for the different trays.

# 4 Conclusions and recommendations

From the experimental results the following conclusions can be drawn with respect to the quality of the different tray types:

- the Multi-K HNL trays and the CDL trays were equally compressed at the end of the experiment; the Multi-K HLR trays were compressed more;
- the Multi-K HNL trays suffered least from the first transport simulation when the trays had a relatively high moisture content;
- the CDL trays suffered least from the changing temperature, possibly accompanied by condensation, in the last phase of the experiment;
- the CDL trays showed the smallest number of 'press buttons', which might be caused by the different geometry of these trays;
- the three tray types protected the egg quality equally well: the differences between the percentages of damage (cracks, broken shells and freshly broken shells) were not significant;
- although the Multi-K HLR trays absorbed less moisture, this didn't result in a better performance regarding compression and the occurrence of 'press buttons';

Table 1 summarises these results schematically.

| | Multi-K HNL | Multi-K HLR | CDL |
|---|---|---|---|
| **material property** | | | |
| moisture content | – | + | – |
| **tray performance** | | | |
| compression | + | – | + |
| 'press buttons' | – | – | + |
| egg quality | + | + | + |

**Table 1.** Overview of the different quality aspects. '+' means a positive result (lower moisture content, less compression, less 'press buttons', low percentage damaged eggs); '-' means a negative result. Note that both positive and negative are meant relatively, i.e. compared to the results of the other trays.

With regard to the climatic conditions during storage and transport the following conclusions can be drawn:

- a high relative humidity during transport is disadvantageous for the trays, therefore it is beneficial to keep the relative humidity relatively low;
- a high relative humidity during storage causes considerable compression of the trays. Therefore control of relative humidity is sensible;
- abrupt changes in temperature can cause condensation on the eggs, which might lead to weakening of the trays;

Additionally some observations have been made with regard to the loading of the pallet and the stability of the pallet load, although this was slightly beyond the focus of the project.

- The sheet of corrugated board between the pallet and the bottom trays folds relatively easy (Figure 5). For a better support of the bottom trays the orientation of the sheet should be different: the cross direction of the sheet should be parallel with the short side of the pallet;
- the stacks along the long side of the pallet tended to bend over because the bottom trays were deformed. The current orientation of the sheets of corrugated board doesn't prevent the folding of those sheets (see Figure 10), which might limit their contribution to the stability of the pallet load;
- the bottom trays along the long edge of the pallet were loaded most heavily. By placing the bottom trays such that the side with five eggs is parallel with the short side of the pallet, no eggs in the bottom tray stick out past the edge of the pallet. This might lead to less damage to the eggs in the bottom trays.

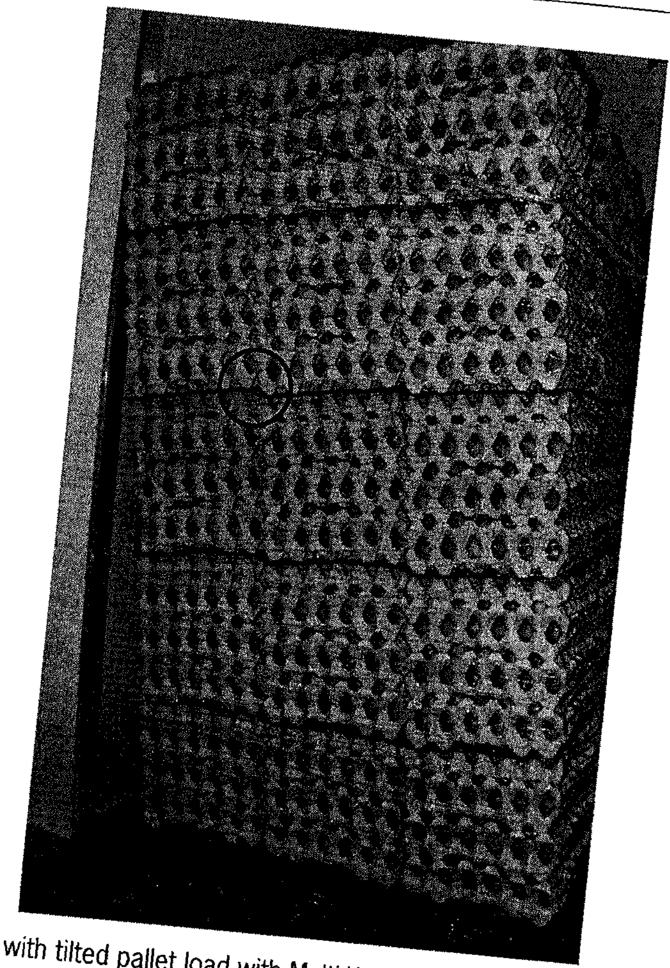


**Figure 10a.** Pallet with tilted pallet load with Multi-K HLR trays at the end of the experiment.

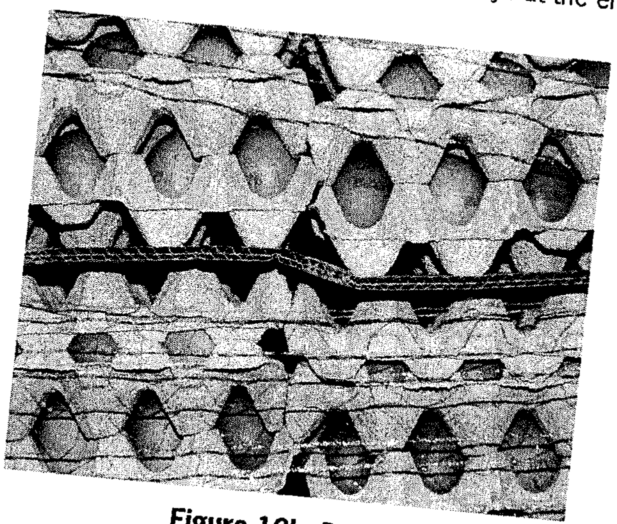


**Figure 10b.** Detail.