Humidification in pear storage

Phase 1

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Colophon

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1 Introduction

1.1 Context

Contronics wishes to gain more insight into the operation of its in-house humidification system for pear storage. This is to aid the promotion of the implementation of its humidification techniques in the fruit sector. Contronics is interested in an independent opinion from Wageningen UR about the functioning of its system.

1.2 Goals

The goal of this project is to experimentally determine 1) what the effect of humidification is on the quality of pears during CA storage and 2) if the installed humidification equipment functions as it is designed to function.

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2 Test design

2.1 Humidification installation and test rooms

This practical test was performed in two test rooms at Fruitmasters Veiling B.V., Geldermalsen, that were as identical as possible in terms of technical layout and product batch : one without humidification, one with Contronics humidification, see *Illustration 1*. This humidification installation consists of an ultrasonic humidifier HU-25 placed outside the storage room with a yield of 0 to 1.2 kg per hour with a DZR-43 RH control that is placed in a gas-tight casing with its own circulation to and from the storage room without disturbing the CA regime (% O_2 and CO_2). All this was connected to an existing supply pipe using a T-section, where the supply to the room is placed through a pipe with a smaller diameter in the supply line. This means that there are no additional passages required in the room wall and maintenance can safely take place without disturbing the room climate.

Water provision is controlled by a connection to a water pipe via a filter module with a storage vat. Control of the ultrasonic humidifier in the module takes place on the basis of measuring the relative humidity of the air sucked in by the RH sensor/control unit.

[RH: Relative Humidity]

Illustration 1 *Set up of Contronics humidification installation in this test. Left the closed module when in use, right a view of the opened module 1) gas-tight system cabinet 2) water filter unit 3) filtered water storage vat 4) combined supply room air / discharge humidified air 5) RH sensor/control DRZ-43 6) Ultrasonic humidifier HU-25 7) collection vat for measuring melt water from evaporator in the room (part of the regular room installation)*

The RH value of the incoming air in the module is continuously monitored, and the ultrasonic unit is controlled on the basis of this measured value. The outgoing humidified gas flow was guided through a small pipe in the middle, just under the evaporator in front of the curtain; see *Illustration 2*.

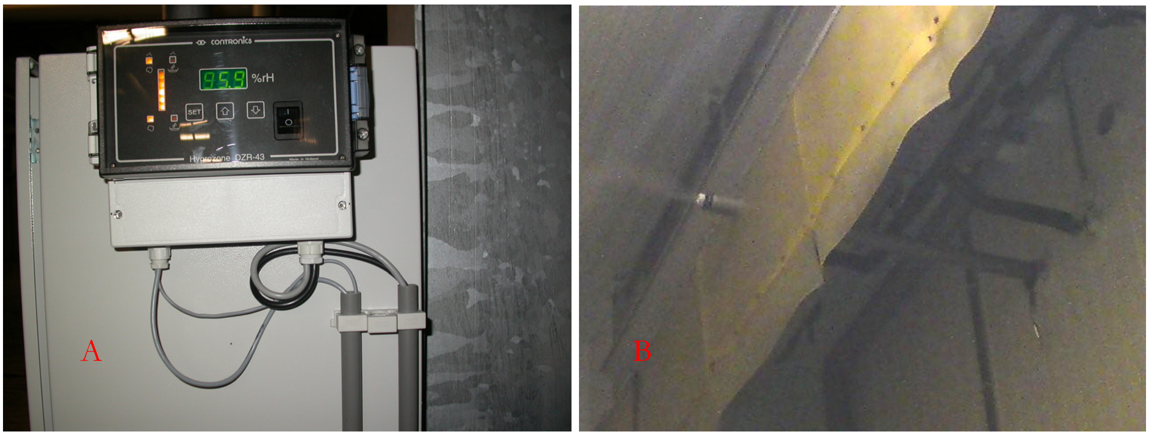

Illustration 2 *A) RH sensor/controller unit on the humidification module B) Outlet nozzle for the humidified air (in an empty room, in a filled room the bins touch the curtain)*

The control room was not equipped with this humidification installation. Both rooms were intended for CA storage of Conference pears until February. The pears are stored in wooden storage bins of about 450 kg, without a plastic cover sheet or sleeve. The Conference pears in both rooms were mostly from the same source. Twelve inventory bins were taken from this source, and after weighing these were placed back in the test rooms in the positions described in *Illustration 3* to be able to determine the loss of moisture during the storage period. Both rooms were conditioned according to the standard protocol for CA conditioning, including a 21-day waiting period before starting to reduce the oxygen content. The final oxygen content was 3%, % CO_2 <1% %. The water emission through the evaporator of the cooling installation was monitored during the storage period as well as any possible ice accumulation.

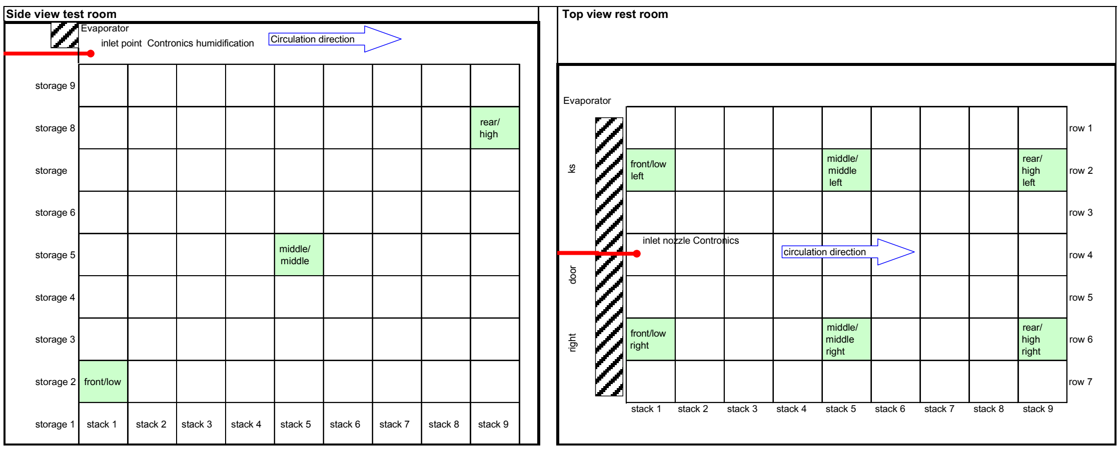

Illustration 3 *Side and top view of the configuration of the humidification installation in the storage room. The position of the sample crates monitored for moisture loss and quality are indicated in green; these positions were identical to those in the control room.*

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2.2 Quality Assessments

In addition to the monitoring of fluid loss described above, the quality of the fruit was also followed. Per object/position in the room two samples of 20 fruits were continually assessed for quality. This was done during the stocking and after the storage of the pears. In addition, the quality at the end of the chain is simulated (display life) after storage at a higher temperature. This is performed at 18 °C and 75% RH. At the time of stocking for the test, the display life period was 7 days, after storage, a period of 5 days was adhered to due to the usual quicker ripening after storage.

2.2.1 Quality determinations

When stocking the pears in the storage rooms, sample crates were marked at specific positions. These crates were weighed during storage and again during room opening to determine the weight loss at various positions in the test rooms.

In addition, during storage and removal, samples of 40 fruits were collected from the various objects, from which the following quality measurements were taken immediately and after a display period at 18°C:

- Hardness
  The firmness of the pears (kg/cm^2) is measured using an automated penetrometer (Fruit Texture Analyzer, Güss, South Africa) equipped with a pear plunger.
- Base color
  The color determination of the green base color is performed by scoring individual fruits using a color chart suitable for pears, and from this calculate a lot-average. This color chart has a score of 1 to 5 in 0.5 increments, where green is a low score and yellow is a high score.
- Weakness score
  The weakness score indicates the degree of "weak necks" of a lot, a quality problem in Conference pears associated with fluid loss. See clarification below.
- Sugar content
  The total content of dissolved substance is determined using a digital refractometer in °Brix. This is generally used as a convenient measurement for the sugar content. A representative selection per fruit is ground into a mixed sample per object from which the sugar content is determined in duplicate.
- External and internal abnormalities

Clarification of weakness score:
By giving a score by fruit on the basis of wrinkling that is or is not present according to the table below, an average weakness score by lot can be determined. The score goes from 0 (no single problem) to 4 (all fruits seriously weak)

Score	description	Explanation
0	OK	Visually no wrinkles can be observed, neck feels stiff at light attempt to bend it, still no wrinkling visible
1	Wrinkles at bending	Visually no wrinkles observable, at light attempt to bend using the thumb, the neck bends and a slight wrinkling becomes visible
2	First wrinkles visible	When examined closely, small wrinkles are visible
3	Slight wrinkles	Wrinkles in the neck are clearly visible without doubt
4	Clear wrinkles	Wrinkles in the neck are clearly pronounced

2.3 Statistics

To be able to determine whether differences in weight loss and quality parameters between pears stored with or without Contronics humidification are statistically reliable has been statistically tested using a Student T-test ($p<0.05$).

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3 Results and discussion

3.1 Execution of test

The tests were performed in two adjacent pear rooms.
Room 116 was equipped with Contronics humidification, room 118 was the control room.
Stocking was in week 37. In both rooms, pears of the same origin (10791) formed the bulk, the stacking crates for fluid loss and quality determinations were taken from this origin. Six stacking crates were marked and weighed per room during stocking according to the schedule in Illustration 3. In addition, samples for quality determination at harvesting were taken. Both rooms were opened in February: the control room on February 3, the room with the humidification on February 13. This ten-day difference is in practice quite acceptable. Experience has taught that for a storage duration of 175 days this ten days difference does not have a major impact on measured fluid loss and quality progress.

3.2 Humidification and fluid discharge

The humidification installation was activated in the test room upon stocking. During the entire period the installation ran without problems and functioned without malfunctions. During the beginning period an original RH controller was replaced by the type mentioned in the description among other reasons to make logging of data possible. During intermediary measurements an injection of 0.6 liter per hour was determined. During the entire period, the humidifier functioned practically continuously at maximum with an RH of the incoming air at 94 – 96%, which concurs with incidental measurements in the room.

3.2.1 RH measurements during the waiting period

Through the placement of calibrated RH sensors at the relatively most unfavorable location in the room, an attempt was made to obtain a picture of the effect of the Contronics humidification installation in the waiting period. The test was performed after the pears had already been cooled well for at least a week. In each room, a logger was placed on the lowest but one crate to the left by the door (about 1 meter high), on the pears. At this position, the vapor pressure deficit, the driving force for dehumidification, is usually the highest.

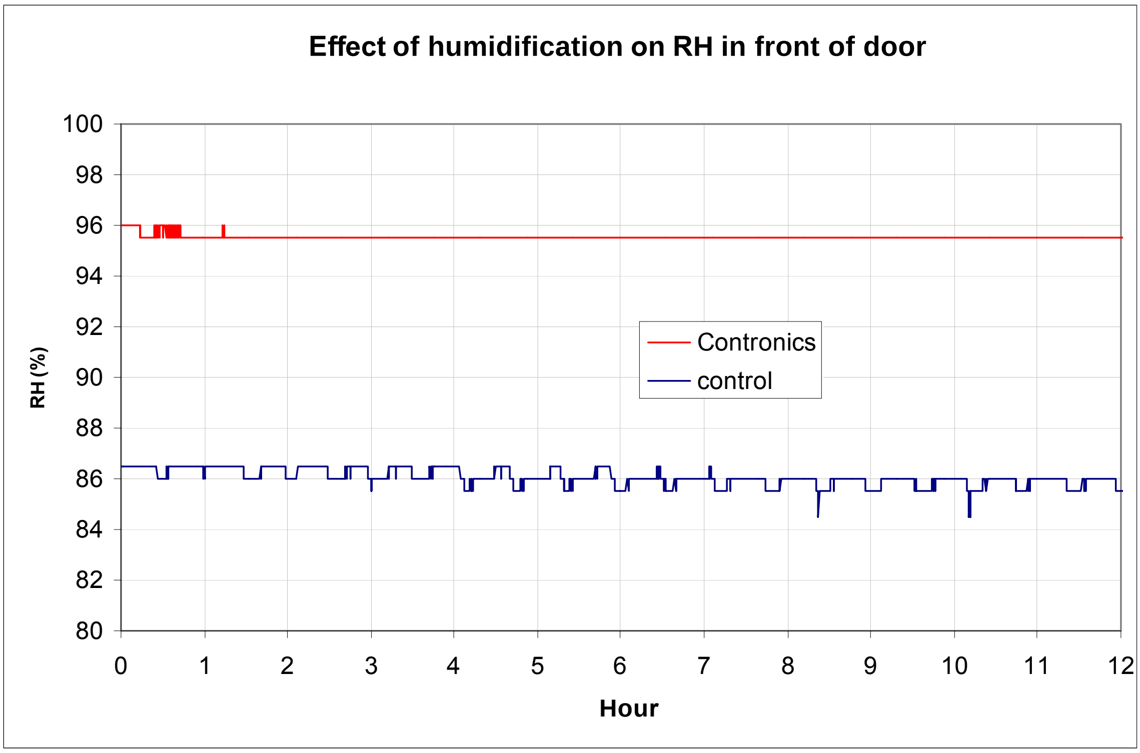

Illustration 4 *RH in the test rooms during the waiting period. RH in the room with the Contronics humidification installation is an average of 95.5% versus 86% in the control room without humidification.*

As shown in Illustration 4, the RH at this unfavorable position with humidification is significantly higher than without: resp. 95.5 and 86% RH. The temperature at this position at that moment was -0.05°C. The higher air humidity in the humidified room ensures a lower vapor pressure deficit, and thus less fluid loss. In this case, 0.22 and 0.67 g/m ^{3} resp., a substantial difference.

3.2.2 Course of humidification and water discharge during CA conditioning

By collecting the melt water from the evaporators and measuring it regularly, the quantity of water that leaves the room this way was recorded for both rooms. The quantity of water actually injected was determined halfway through the test by Contronics to be 0.6 liter per hour. The quantity of fluid is also expressed on the basis of 150 ton pears per room in % of the product weight in the room, see Illustration 5.

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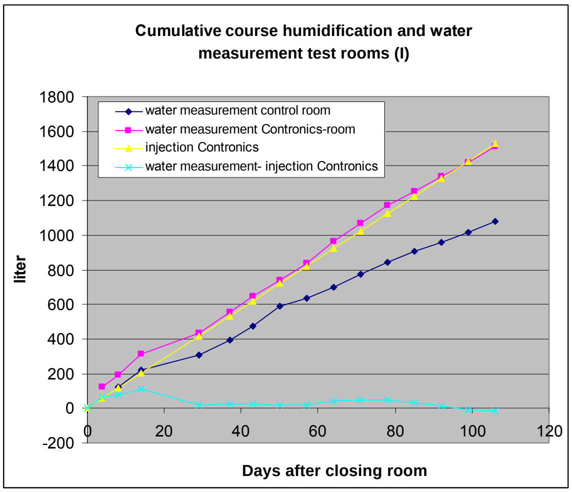


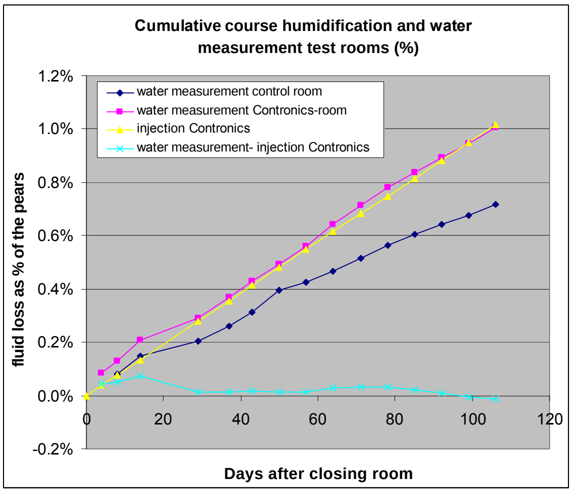


Illustration 5 *The cumulative course of the water discharge through the cooler in the control room and the room with Contronics humidification. Left in liters, right in %. The quantity of injected water and the difference water measurement – injection is also shown.*

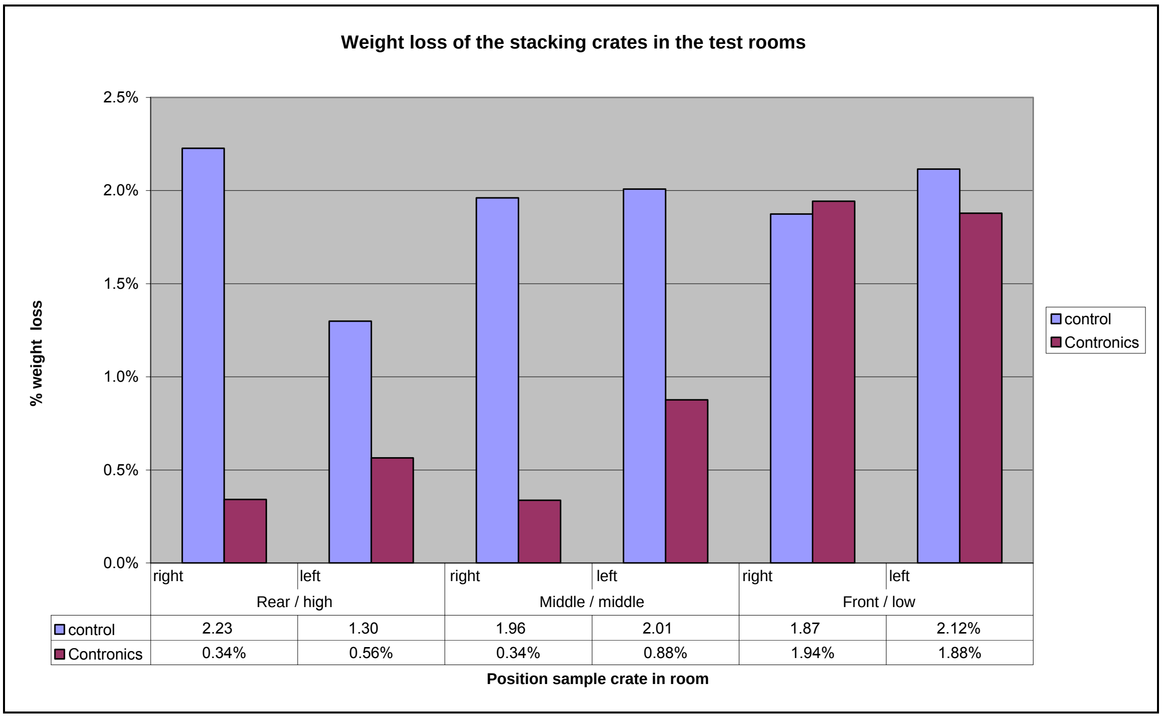
The water discharge of the control room is lower than in the room with the humidification, resp. 2.07 and 2.86 liter per ton per month. In the humidified room however, water is brought in by the humidification installation, which almost completely compensates for the fluid loss through the evaporator. Ultimately the net balance in the room with the humidification then comes to -0.07 liter per ton per month. Given that fluid also leaves the room through control actions, and that the fruit takes up fluid as well, the actual balance will not be negative, otherwise an increasing ice formation would have been visible but the fluid loss through the evaporator does seem to be almost completely compensated by the humidification. In the beginning period (first 3 weeks) there did seem to be a limited improvement present by applying a larger capacity evaporator, but the continuous maximum humidification has in this case therefore led to a very tight result. A larger humidification capacity would be able to work favorably on a further inhibition of the fluid loss particularly in the waiting period.

3.2.3 Ice formation

From the end of October, there was a slight growth of ice crystals under/in front of the inlet nozzle of the humidification in the room with the humidification installation. This was particularly noticeable on a stacking crate that protruded somewhat above the normal stacking height immediately behind the inlet nozzle. During the test, the ice formation remained limited to this position. It concerned a “light” powdery ice layer and did not create a problem. This could possibly be completely prevented by positioning the inlet nozzle somewhat higher and/or level stacking, so the chance of the saturated air blowing directly against the pears and freezing against them is decreased. However, given experiences with other humidification systems where there was sometimes an issue with serious ice formation over the entire room, this is an exceptionally good result.

3.3 Weight loss stacking crates during storage

Fluid loss is by far the most significant cause of weight loss in pear storage. Below are the results of the weight losses of the individual stacking crates.



	Rear / high right	Rear / high left	Middle / middle right	Middle / middle left	Front / low right	Front / low left
control	2.23	1.30	1.96	2.01	1.87	2.12%
Contronics	0.34%	0.56%	0.34%	0.88%	1.94%	1.88%

On average, the weight loss was 1.91% in the control room compared to 0.99% in the humidified room; this is a statistically reliable difference.

For both rooms, the position of the crates in the room to the left or right did not give a statistically reliable difference. This indicates that the room climate across the width of the room was not interrupted by, for example, unequal functioning evaporators in the rooms.

In the humidified room, the position of the stacking crates in the length/height of the room did make a difference: the low crates close to the door (front/low) provided a statistically reliable higher weight loss than those in the middle (middle/middle) or at the rear (rear/high), which remained the same. This distribution concurs with the findings from a previous study into the humidification of pears as part of the Kwalicon project, see Illustration 6. It is obvious that the bulk of the room load profits from the humidification.

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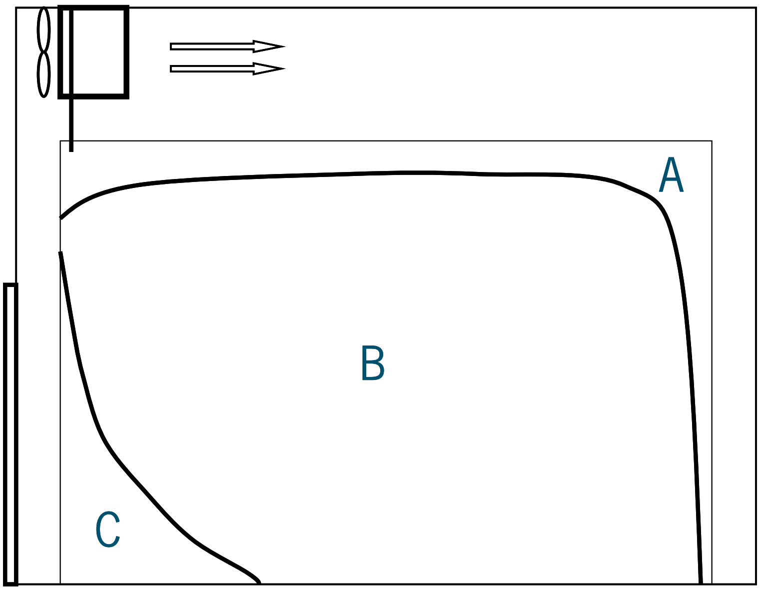


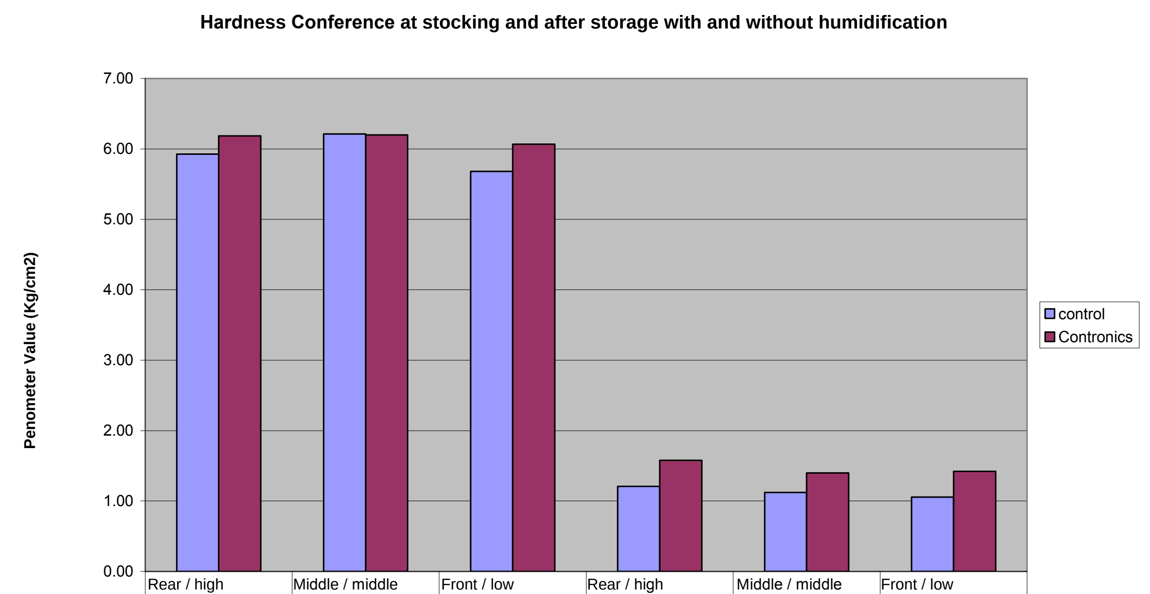
Illustration 6 *Global distribution of a pear room by temperature zones with A as coldest and C as warmest location in the room, this relates to the local fluid loss. In this test, the humidification resulted in a significant limitation of the fluid loss in zone A and B, such that the majority of the room load gained an advantage from this humidification.*

3.4 Quality evaluations

The quality of the pears was evaluated at the end of the storage period upon room opening and after a display period of 5 days. As a check to see whether the samples were homogenous enough to be able to generate reliable pronouncements, the weight of the flesh of individual fruits was determined for the various samples. This appeared to be 288 g with a standard deviation of 54 g. The differences between the treated samples and the control were statistically not significant.

For the remaining quality parameters, within the rooms there did not appear to be a statistically reliable difference between the samples to the left or right from the room, so that the results of these have always been displayed as an average.

3.4.1 Hardness



	Rear / high	Middle / middle	Front / low	Rear / high	Middle / middle	Front / low
	At room opening			After display		
control	5.93	6.21	5.68	1.21	1.12	1.06
Contronics	6.19	6.20	6.07	1.58	1.40	1.42

The firmness after storage is on average 5.9 (control) and 6.2 kg/cm ^{2} (Contronics). This difference is still correctly statistically significant. After display, the pears are significantly soft but the difference has become relatively greater, and clearly statistically reliable. It concerns a relatively small difference in hardness, which is not found in many other experiments with humidification. Given the limited character of this experiment it goes too far to place an emphasis on this effect.

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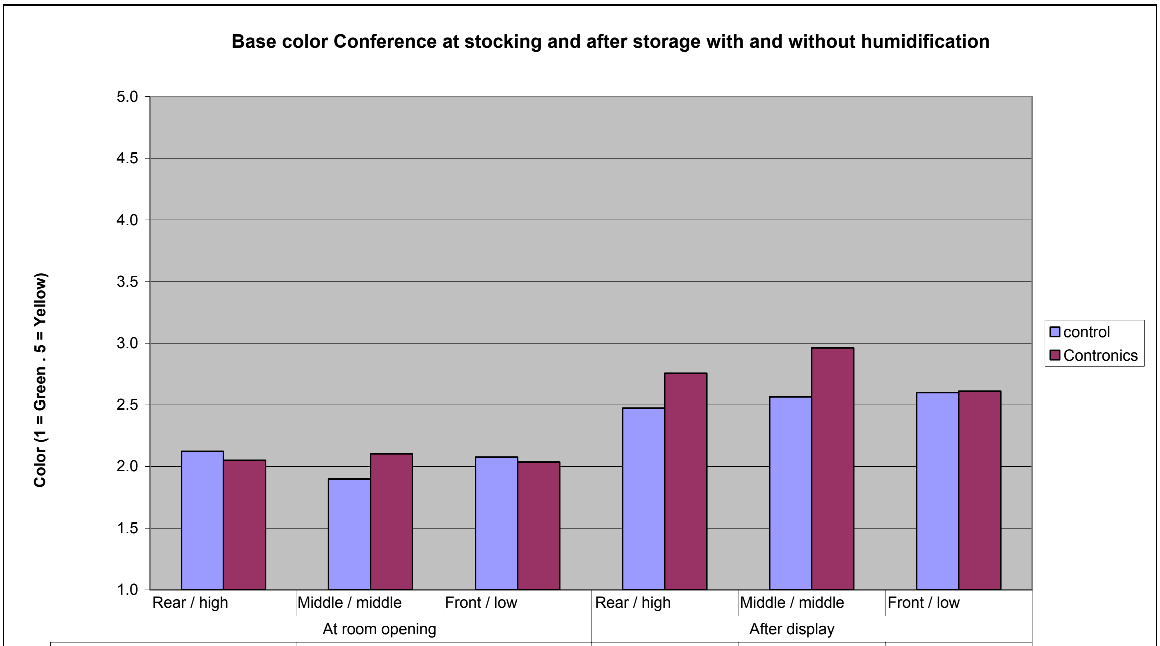
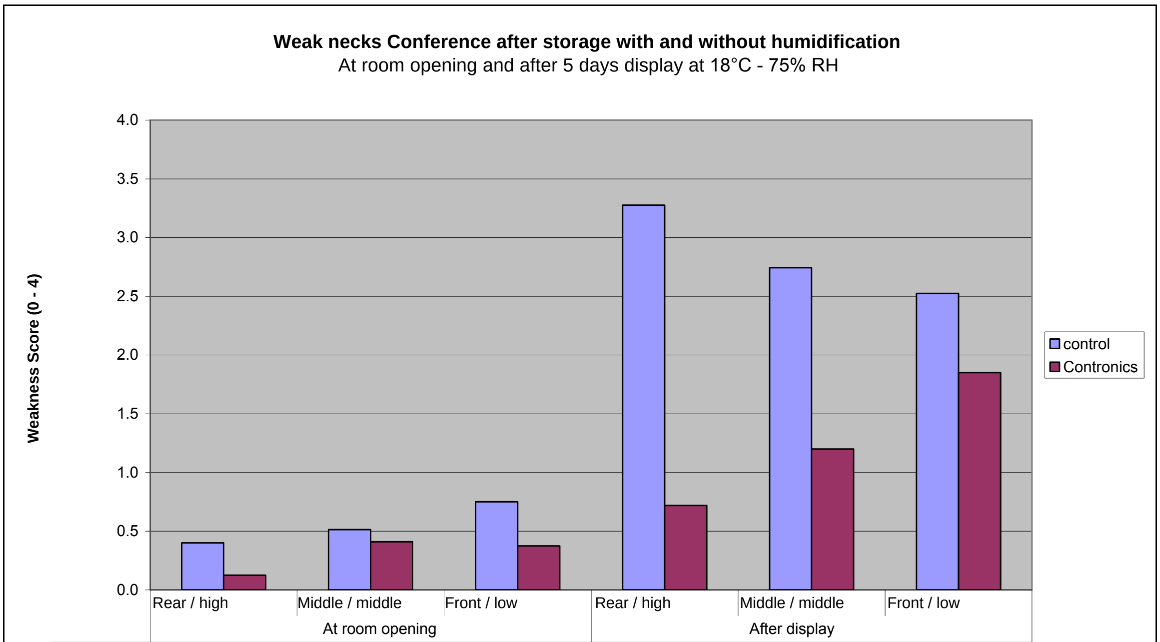
3.4.2 *Base color*



	At room opening			After display		
	Rear / high	Middle / middle	Front / low	Rear / high	Middle / middle	Front / low
control	2.12	1.90	2.08	2.48	2.56	2.60
Contronics	2.05	2.10	2.04	2.76	2.96	2.61

The base color was excellent at room opening and still very acceptable after display. The differences found were not statistically different.

3.4.3 *Weakness score*



	At room opening			After display		
	Rear / high	Middle / middle	Front / low	Rear / high	Middle / middle	Front / low
control	0.40	0.51	0.75	0.28	2.74	2.53
Contronics	0.13	0.41	0.38	0.72	1.20	1.85

The weakness score is a practical indication for weak necks. A lot with a weakness score greater than about 1 is considered in the trade as being of lower quality. Here also, the weakness score is determined after display to obtain an impression of the behavior later in the chain.
The weakness score after storage is an average 0.56 (Control) and 0.30 (Contronics). After display, these values are respectively 2.85 and 1.26 and all these differences are statistically reliable. The humidification has therefore provided a positive effect immediately at room opening that also continues to work during the display phase. The expectation is that in terms of fluid loss this effect can be commercially greater for lower quality pears or in case of longer storage duration.

3.4.4 Sugar content

The sugar content at storage was an average 13.6 °Brix. After storage this was an average 14.9 °Brix, the increase can be explained by starch conversion after the harvest. There were no statistically relevant differences found between the humidified/control, the positions in the room and the moment of the evaluation. This was also not expected.

3.4.5 External and internal abnormalities

The sample pears were of excellent quality, there were no abnormalities encountered.

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4 Conclusions

1. In this test in test rooms of unpackaged Conference pears, the Contronics humidification installation functioned technically excellently during the stocking and storage period:
    a. No significant malfunctions
    b. No interruption of the conditioning in regard to the control room
    c. No problems with ice formation
    d. Excellent compensation of the water discharge through the evaporator

2. Humidification provided a significant reliable reduction of the weight loss of the bulk of the stacking crates in the room compared to the control room (average respectively 1.0 and 1.9 %.) The effect locally under the evaporator however was limited, but this only concerned a small part of the room load.

3. Humidification resulted in a significant reliable reduction of the degree of "weak necks" in the pears, even in the most unfavorable position under the evaporator. This effect was more noticeable after 5 days of display at 18°C.

4. The quality of the pears used in this test was excellent.
    The firmness was statistically reliably higher (0.2 kg/cm^2) in the humidified room. This last effect had not been this clearly observed previously in other humidification/packaging tests, so not too much significance should be attached to this slight difference. Base color and sugar content were not measurably influenced.

5. The fact that the unit functioned well technically together with a clearly measurable quality advantage, indicates that humidification using this Contronics humidification is a practical tool to utilize in the storage of unpackaged pears.

5 Points to note and recommendations

- To limit the fluid loss of Conference during storage even further, increasing the capacity of the ultrasonic unit can be considered. This would be of interest especially during the stocking period.

- With the humidification installation utilized, the upper limit (overdosing, increasing ice formation) was not (quite) reached, so that control actions were not needed. However when increasing the capacity of the ultrasonic unit this will begin to play a role. The RHs measured currently in the module (94-96%) are a useful target if overdosing leads to undesirable ice formation.

- Achieving a better effect at the "worst location" in the room is also attainable by a further RH increase.

- Linking (registration of) the humidification system with the CA/temperature control/adjustment system can increase the appeal of using the system.

- It is important to pay sufficient attention to the leak-tightness of the humidification module.

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Acknowledgements

Practical tests such as performed here are only possible with the cooperation of the room manager. Therefore the cold-storage manager at Fruitmasters Veiling B.V., Mr. Harry Beelen, must be thanked for his active thinking and cooperation during the test.

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