Grant Agreement No.
634699

Project Acronym
Fresh Demo

Project titel
Terugdringen van voedselverspilling en kwaliteitsverbetering van groente en fruit d.m.v. een innovatieve en energiezuinige bevochtigings- en disinfectietechnologie.

Rapport Nummer:	**D 4.0**
Titel:	**Rapport van alle Fresh-Demo testen**
Startdatum project:	**1 maart 2015**
Duur:	**24 maanden**
Versie:	**3 (Nederlands)**

Dit project wordt financieel ondersteund door het European Union's Horizon 2020 research and innovation programma onder grant agreement No 634699

1. Inleiding

Voor u ligt een uitvoerig rapport met de resultaten van het Fresh-Demo project. Deze (Nederlandse) inleiding bevat een samenvatting van, en nadere toelichting op het Fresh Demo project.

Het project

Groenten en fruit leggen in Europa een lange weg af alvorens ze in de schappen van de winkels liggen. Bij het doorlopen van deze logistieke keten wordt het product gekoeld om bacterie groei tegen te gaan. Dit leidt echter ook tot nadelige gevolgen. Koelsystemen onttrekken namelijk vocht aan de lucht waardoor de relatieve luchtvochtigheid daalt. Omdat groenten en fruit voornamelijk uit water bestaan zal dit water verdampen in de droge lucht die ontstaan is. Hierdoor drogen de producten uit en verliezen aan gewicht en versheid. Tegelijkertijd gaan de producten in een soort stressmodus en gebruiken hun eigen voedingsstoffen om te overleven. Deze voedingsstoffen (fytonutriënten en vitaminen) zijn zeer belangrijk voor onze gezondheid. Ze versterken ons immuun systeem en verbeteren onze vitaliteit. Hoe langer het duurt van de oogst naar de consument, des te erger is dit afbraak effect.

Contronics, producent van ultrasone bevochtigingsapparatuur voor verse producten, en TTZ, onderzoeksinstituut uit Bremerhaven, kwamen op het idee om tijdens het **gehele traject, van oogst tot en met de supermarktschappen, (ultrasone) bevochtiging toe te passen,** waarmee uitdroging en afgeleide nadelige effecten sterk konden worden teruggedrongen. Tezamen met nog zeven andere Europese partners: Univeg Duitsland en Italie, PLUS Van Gurp supermarkt Nederland, Deense Universiteit (DTU), Freshfel Europe Brussel, Bioazul Spanje, RFT Duitsland en Polypan Griekenland, werd het Fresh-Demo project opgezet, en na indiening in Brussel beloond met een subsidie. Het Fresh-Demo project was een van de eerste Horizon2020 projecten en behoorde tot de 10 geselecteerde projecten (uit 12.000 aanvragen)!

Doel van het project was om aan te tonen hoe groot het effect was op diverse groenten en fruit, indien de gehele logistieke keten werd bevochtigd en daarbij direct na oogst behandeld werd met een natuurlijk extract, Formule5. Bevochtiging vond plaats middels ultrasone bevochtingsapparatuur. Bij deze techniek wordt water hoogfrequent in trilling gebracht en wordt een mist van zeer kleine waterdruppeltjes (aerosolen) gevormd, die snel verdampen in de lucht. De luchtvochtigheid stijgt hierdoor en er vindt een natuurlijk koel proces plaats (adiabatisch effect). De mist maakt de producten niet nat maar verhoogt de luchtvochtigheid terwijl tegelijkertijd vrije aerosolen direct opgenomen worden door bijvoorbeeld groenten via poriën in het blad.

Naast de reeds bestaande bevochtigingsapparatuur, ontwikkelde Contronics ook bevochtigingsapparatuur voor vrachtwagens en apparatuur om Formule5 aan de mist toe te voegen.

Het Griekse Polypan ontwikkelde Formule5. Dit is een natuurlijk extract wat kan worden toegevoegd aan de mist. Het is een zogenaamde bioflavonoïde, die voorkomt in de schil van de Bergamot sinasappel en de vrucht beschermt tegen ziekten. Bij het toepassen van deze speciale mist, direct na de oogst, wordt schimmelvorming en bacteriegroei op de producten voorkomen.

Er werd een serie praktijkproeven georganiseerd. Parallel aan het normale transport werd een transport met mist uitgevoerd met gelijke producten die dezelfde tijd geoogst waren. Om wetenschappelijk verantwoorde resultaten te krijgen moest iedere transport 3x worden uitgevoerd

Bevochtigingapparatuur in de Fresh-Demo bus

Het was aanvankelijk de bedoeling om ook de distributiecentra, waar tussentijdse opslag plaatsvond, uit te rusten met bevochtigingsapparatuur, maar door de grote diversiteit in transporten en de complexe organisatie werd gekozen voor de Fresh-Demo bus. Deze bus werd uitgerust met koeling en bevochtiging. De helft van de lading werd direct na de oogst gedurende twintig minuten behandeld met Formule5, en na ventilatie van de bus werd de andere helft geladen. Gedurende het transport was de temperatuur in de Fresh-Demo bus rond de 1°C en de luchtvochtigheid rond de 98%. Vrachtwagen en bus vertrokken tegelijkertijd en kwamen ook op dezelfde tijd bij de supermarkt aan. Bij het normale transport werd doorgaans tussentijds tweemaal overgeslagen in een distributiecentrum en de volgende dag met een andere vrachtwagen weer verder vervoerd. In de supermarkt werd het normale transport in de normale koeling geplaatst en de bevochtigde lading in een bevochtigde koelcel, die hiervoor was voorzien met bevochtigingsapparatuur.

Bevochtigde koelcel

In de schappen van de supermarkt werd eveneens een mist systeem geplaatst.

Bevochtigingsapparatuur in supermarkt Plus Van Gurp.

Producten (bevochtigd en niet bevochtigd) werden gedurende 15 dagen na transport gevolgd, dagelijks werden zij getest op: gewicht, visueel (foto's), smaak, schimmelvorming, uiterlijk en kwaliteit. Op de eerste en de vijftiende dag werden er monsters naar laboratorium gebracht (bepaling suiker- en vitaminegehalte, BRIX-waarde, voedingsstoffen (fytonutriënten), zuurgraad (Ph) en bacterievorming).

Uitgevoerde proeven (3x):

- Aardbeien van Huelva (Zuid-Spanje) naar supermarkt Bremerhaven
- Asperges van Noord-Duitsland naar supermarkt Bremerhaven
- Nectarines en perziken van Midden-Italië naar supermarkt Plus Van Gurp in Roosendaal
- Druiven van Zuid-Italië naar supermarkt Plus Van Gurp in Roosendaal
- Bloemkool en krulandijvie van Cambrils (Spanje) naar Plus Schijndel/Den Dungen
- Opslag van sla in distributiecentrum in Spanje

Resultaten:

- **Het effect was zeer significant**
- Na transport van 3 dagen kwamen aardbeien in Bremerhaven aan en leken net geplukt, terwijl het parallelle transport na één dag al bijna niet meer verkoopbaar was
-

was.

Aardbeien na aankomst in supermarkt, links normale transport, rechts bevochtigd

Aardbeien na 11 dagen gekoeld opgeslagen. Links bevochtigd, rechts niet bevochtigd

Resultaten (vervolg)

- **Bij asperges, perziken, nectarines en krulandijvie was het gewichtsverlies ca. 50% minder, bij bloemkool 25% en bij aardbeien zelfs 70% minder!**
- **Langere levensduur bij alle testen tussen 10 en 25% (2 tot 5 dagen)**
- **Betere smaak, mooiere kleur, betere kwaliteit**
- **Voedselverspilling werd met 25% teruggebracht (gemeten bij PLUS Van Gurp) en leverde een jaarlijkse besparing op van € 5.200,-**

Tabel met resultaten

	aardbeien			druiven			perziken			nectarines			bloemkool			krulandijvie		
ID	**C**	**H**	**HD**	**C**	**H**	**HD**	**C**	**H**	**HD**	**C**	**H**	**HD**	**C**	**H**	**HD**	**C**	**H**	**HD**
gewichtsverlies	1	5	4	1	5	5	1	5	5	1	3	5	1	5	4	1	4	5
uiterlijk	1	5	5	1	5	5	1	5	5	1	5	5	1	5	5	1	5	5
Levensduur/schimmel	1	5	5	1	3	5	1	5	5	1	4	5	1	5	5	1	5	5
smaak	1	5	3	1	5	5	1	5	5	1	5	5	1	5	5	1	5	5
vitamines	3	5	1	3	1	5	1	4	5	3	1	5	3	1	5	5	1	3
Totaal	**7**	**25**	**18**	**7**	**19**	**25**	**5**	**24**	**25**	**7**	**18**	**25**	**7**	**21**	**24**	**9**	**20**	**23**

Verschil in score betekent verschillen in evaluatie
5 punten – beste resultaten
1 punt – slechtste resultaten

C = Normaal transport en opslag
H = Bevochtigd transport en opslag
HD = Bevochtigd transport en opslag en behandeld met Formule5

Omdat bij de praktijkproeven met de Fresh Demo bus geen bacteriën en schimmels werden aangetoond heeft Polypan, tezamen met TTZ het effect op schimmel- en bacterievorming met Formule5 nog apart getest. In laboratoria na besmetting bleek dat **met Formule5 behandelde producten verwaarloosbare groei van bacteriën** hadden, m.a.w. het middel is zeer effectief. Tevens werd onderzocht of er een residu achterbleef op het product en dit was niet het geval. Gebruik van Formule5 is toegestaan in Nederland**.**

Mist levert vanaf de eerste dag al winst op voor supermarkten:

Businessmodel:
Onderstaande tabel is tot stand gekomen door gedurende 4 jaar in een supermarkt dagelijks alle benodigde gegevens te registreren.

Supermarkt met 30m2 bevochtigde schappen 2 x 5 x 3m2						
Kosten per jaar Investering: €15.000,-	Afschrijving/ annuïteit 3%	Energie 7884 KW	Water 130m3	Onderhoud		Totaal
2 bevochtigers	€1.000,-	€946,08	€234,-	€1.000,-		€3.180,08
					Per dag	€8,71
Opbrengsten per jaar	Winst i.v.m. hogere omzet groente en fruit. 5%. (1)	Winst door hogere omzet op alle producten. Niet gemeten. (2)	Vermindering weggegooide groente en fruit. 25%. (3)	Lagere energie-kosten KwH. (4)	Besparing op arbeid. 28 minuten per dag. (4)	Totaal
	€9.600,-	€0,-	€5.200,-	€1.440,-	€2.138,98	€18.338,98
					Per dag	€50,24

(1) De omzet is gemeten gedurende vier jaar; gedurende het project en de tijd daarvoor. De gemiddelde klantomzet bleef gelijk, maar er kwamen meer klanten.
(2) De omzet in de winkel werd tien procent groter, echt is dat niet aantoonbaar te wijten aan de bevochtiging. Uit interviews bleek dat klanten er wel zeer over te spreken waren.
(3) De afvalstromen werden gedurende vier jaar gemeten. Iedere dag werd exact bijgehouden wat er werd weggooid (per product). Het eerste jaar zonder bevochtiging, de drie jaren er na met bevochtiging.
(4) Omdat de mist tevens koelt (circa vijf graden) is het niet nodig producten gedurende sluitingstijd in de koeling te plaatsen. In principe is hiermee de koelcel overbodig geworden en wordt er op energie bespaard.
Er wordt op arbeid bespaard doordat de producten niet meer naar de koelcel worden verplaatst. Dit tegen een uurtarief van €10,61, norm is exact vastgesteld voor supermarkten (28 minuten).

Uit bovenstaande tabel valt af te lezen dat er dagelijks een opbrengstpotentie is van ca. €40,- per dag , of **opbrengst op jaarbasis van ruim € 16.000. Belangrijker nog, jaarlijks hoeft er 25% minder te worden weggegooid en klanten krijgen kwalitatief betere en gezondere producten, die ook nog eens langer houdbaar zijn** en dus ook weer bijdragen aan de voedselverspilling.
Ook zorgt de bevochtiging van groenten en fruit voor een veel betere presentatie in de winkel en mede daardoor aan een grotere klanttevredenheid.

Bijdrage aan een beter milieu.

Voor het project heeft de DTU, de technische universiteit van Denemarken, de milieueffecten van het gebruik van bevochtiging in de keten onderzocht door middel van een levenscyclusanalyse. Enerzijds wordt er een bevochtiger geplaatst, en dit betekent milieu-impact door productie van de bevochtiger, en verbruik van water en energie tijdens het bevochtigen in de keten. Anderzijds is gekeken naar de milieuopbrengsten van het plaatsen van die bevochtiger. Doordat er minder groente en fruit wordt weggegooid, hoeft er dus ook minder geproduceerd te worden. Dit scheelt aanzienlijk in de uitstoot van broeikasgassen, het water- en het landverbruik van groente en fruit in alle schakels van de toeleveringsketen. Daarbij komt dat bevochtiging ook koelt, en om die reden energie bespaart. De uitkomst van dit uitgebreide onderzoek gaf aan dat al bij een geringe besparing op het weggooien van voedsel de milieu-impact (uitstoot van broeikasgassen en waterverbruik) positief is. Aangezien het Fresh-Demo project 25% bespaart op het weggooien van groente en fruit in de winkels mag worden gesteld dat er **een grote bijdrage is aan een beter milieu.**

Meer uitgebreide informatie kan op de website van Fresh-Demo worden bekeken. Wat bevochtiging doet met groente en fruit kunt u bekijken op de **time lapse video's** op deze website www.fresh-demo.eu. Te zien is wat het verschil is in bevochtigde producten en niet bevochtigde producten gedurende 10 dagen. Gefilmd zijn sla, bospeen en bananen.

Time lapse van sla na 4 dagen zonder (links) en met bevochtiging (rechts)

Time lapse van bananen na 9 dagen zonder (links) en met bevochtiging (rechts)

Onderstaand treft u het originele rapport aan met alle gedetailleerde resultaten en metingen.

2. Origineel rapport

Grant Agreement No.
634699

Project Acronym
FRESH-DEMO

Project title
Waste reduction and quality improvement of fruits and vegetables via an innovative and energy-efficient humidification/disinfection technology

Type of the action:	Innovation Action
Call identifier:	H2020-SFS-2014-2
Topic:	SFS-17-2014-Innovative solutions for sustainable novel food processing
Deliverable Number:	**D 4.0**
Title:	**Report all Fresh-Demo trials**
Due date of deliverable:	**Month 24**
Start date of project:	**1st March 2015**
Duration:	**24 Months**
Responsible Organisation:	**3 - TTZ**
Date of submission:	**06/03/2017**
Version:	**1**

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Dissemination Level		
PU	Public, fully open, e.g. web	X
CO	Confidential, restricted under conditions set out in Model Grant Agreement	
CI	Classified, information as referred to in Commission Decision 2001/844/EC	

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3. Introduction

The aim of this work package is to adapt, test and optimize the FRESH-DEMO systems under industrial conditions in the fruit and vegetable distribution facilities of UNIVEG-DE, UNIVEG-IT, and GURP. This includes the installation and integration of the prototypes at the respective case study sites, the implementation of comprehensive test series and 3 demonstration workshops for an interested audience from the fruit/vegetable distribution sector. Besides the determination of the overall performance, an analysis of system reliability is also important. The problem of process reliability is that different products have different requirements regarding to process parameters such as humidity, airflow, etc. The knowledge gained during these tests will be looped back for further optimization of the prototypes.

In report D4.1 "Installation and putting into opereration of the prototypes", the prototypes have been installed by CEN and RFT in the case study sites. CEN and RFT were in charge of the mechanical and electrical installations and put the prototypes into operation. Series of functional tests have been carried out before the actual demonstration trials begin. The personal from GURP, BIOAZUL and CEN have been trained at the test sites in the standard operating procedures of the FRESH-DEMO systems.

Figure A: FRESH-DEMO van

TTZ was responsible for the implementation of the test programme, BIOAZUL, RFT, CEN and GURP were responsible for the daily handling of the systems and CEN, RFT, POLYPAN, and BIOAZUL as the main manufacturers cared about mechanical and/or electrical modification and the maintenance of the prototypes which may became necessary during the demonstration trials. After successful completion of the test programme, TTZ assessed the results with respect to the overall efficiency in comparison to the standard procedures.

In the chapter 2 – 9 all trials, results and conclusions are described.

4. Installed equipment

The equipment which was installed for the trials during the project is:

- *Type 1:*
  Stationary humidifier for in-store, capable of delivering humidification in different amounts, including tubes, RO-unit, sensors and display.

  1. Supermarket Edeka Bremerhaven (Germany) - (humidifier HT85 and RO-unit LP10BP with drainunit)
  2. Supermarket Plus vanGurp Roosendaal (the Netherlands) - (humidifier HT25 and RO-unit LP10)
  3. Supermarket Plus vanGurp Roosendaal (the Netherlands) – (humidifier system HU-sys C-0030 with stainless steel tube)
  4. Supermarket unit for fairs Spain, Germany, the Netherlands etc. – (humidifier HT25 and RO-unit LP10)
  5. Supermarkets (the Netherlands) – (humidifier system HU-sys C-0030 with stainless steel tube)

- *Type 2:*
  Stationary humidifier for storage, capable of delivering humidification in different amounts including RO-unit, sensors and display.

  6. Supermarket Plus vanGurp Roosendaal (the Netherlands) - (humidifier HT25 and RO-unit LP10BP)
  7. TTZ Bremerhaven (Germany) storage room, for trials - (humidifier HT25 and RO-unit LP10)
  8. COHOCA facilities in Valencia (Spain) - (humidifier HT245 and RO-unit LP20BP)
  9. Supermarket Plus Schijndel/Den Dungen (the Netherlands) - (humidifier HT45 and RO-unit LP10)

- *Type 3:*
  Stationary unit for humidification with natural water acidifier.

  10. TTZ Bremerhaven (Germany) laboratory room, for tests - (humidifier HT25 and water treatment with dosing unit HP sys001)

- *Type 4:*
  Mobile humidifier capable of delivering humidification during transport.

  11. Fresh-Demo van (4 mobile humidifiers MHU10, with RO-unit LP10, water tanks, battery) and 5 for endurance tests
  12. Mobile humidifier for fairs Germany, the Netherlands- (mobile humidifier MHU10 with RO-unit LP10)

5. Trials

The trials the Fresh-Demo team have done:

1) Strawberries from Spain (Huelva) transported to Edeka supermarket in Bremerhaven (Germany) in March, April 2016
2) Aspargus from Germany, transported from Kirchdorf to Edeka supermarket in Bremerhaven (Germany) Apri, May 2016
3) Nectarines and Peaches transported from Gambettola (Italy) to van Gurp Supermarket Roosendaal (the Netherlands) June, July 2016
4) Table grapes from Polgnano a Mare (South of Italy) transported to van Gurp Supermarket in Roosendaal (the Netherlands) August, September 2016
5) Escarole and Cauliflower from Spain to Supermarket Plus in Schijndel/Den Dungen (the Netherlands) November, December 2016
6) Lettuce from Spain

6. Case study Strawberries

6.1 Way between Huelva and Bremerhaven

To detect the way between Huelva and Bremerhaven, the van is connected with a track and trace control: temperature, humidity, speed, kilometres and way could be seen via GPS.

Conventional transport:

Before transported the strawberries are packed in the wooden boxes (1 kg per box) directly on the field during the harvesting. The strawberries are neither washed nor treated with biocides.

The wooden boxes are transported to the factory, where they are cooled down to 10-12°C upon reception (reception chamber). Then the boxes are filmed with the perforated plastic lids and labelled in the working area (also at 10-12ºC). 1 pallet =480 boxes à 1kg with a height of 2,10m + pallet = 2,25m height 3 wooden boxes of 1kg strawberries are packed in 1 Cardboard

The cooling time depends of the outside temperature – no shock cooling takes place.

Before being cooled and stored at 4°C until transport. Shortly after packaging the transport starts (max. 1,5 – 2 hours after packaging). After receiving Bremerhaven, Strawberries will be stored in the cooling room at 4°c until they are displayed. For displaying they are directly disposed from 4°c at 20°C.

Transport temperature is: 2 – 4 °C

Fresh Demo Transport:

It is planned that after harvest, the strawberries are directly cooled in the Fresh-Demo van with humidification.

Additionally, it is planned to treat a first batch of strawberries with the Polypan natural extract in the van. These products will be transported in the Fresh-Demo van until Bremerhaven, where TTZ will directly take reception.

Transport temperature in the Fresh-Demo Van: 2 – 4 °C

Transport humidity in the Fresh-Demo Van suggested with 95%

After receiving the supermarket in Bremerhaven the Fresh-Demo transported strawberries will be stored in the Fresh-Demo van to keep on humidifying before they are displayed. If the strawberries should be displayed they will be temperatured for 90 minutes at 20 °C to avoid condensation during displaying. After aclimatisation the products will be presented in the ultrasonic humidification mist in the supermarket.

6.2 Product Characterisation in laboratory analysis

Upon reception and display of the fruit and vegetable in the selected supermarkets, TTZ will organise the characterisation of the products simulating the consumer stage.

After delivery following analysing were executed (detailed description see Del 1.4).

- Lab tests:

Humidified and non-humidified products are displayed in the supermarket. Humidified, non-humidified and the Formula 5 treated products are stored at +5°C for laboratory analysis (humidified with relative humidity of 90%, non-humidified at relative humidity of approx. 75%): taking pictures, weight, colour detection, softness, taste and flavour, phytonutrients, pH as well as dry mass are documented to demonstrate the influence on the products quality.

In Figure B: could be seen after which storage time which analysis was executed. End of storage day is, when one strawberry in the box offers moulds or yeast on the surface.

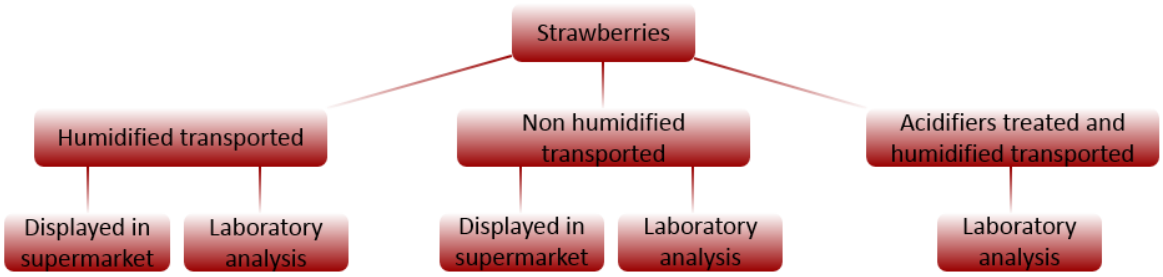


Figure B: Distribution of Strawberries in different control groups

Table 1: time schedule for analysis of strawberries

Analysis	Amount to be measured	Day 1	Day 2	Day 3	Day 4	Day 5	Day 6	last day
1-Pictures	whole box	x	x	x	x	x	x	x
2-weight	whole box	x	x	x	x	x	x	x
3-color detection	1 Strawberry	x	x	x	x	x	x	x
4-softness (Texture analyse)	1 Strawberry	x	x	x	x	x	x	x
5-Taste (panel)	whole box		x		x			x
6-hydration (dry mass)	purée	x						x
7-pH	purée	x						x
8-ascorbic acid	purée	x						x

- Pictures: TTZ will made pictures day by day.

- Weight: TTZ will measure the weight of strawberries boxes upon arrival and along the shelf-life tests daily.
- Colour detection: is done visually by making pictures
- Softness: TTZ will measure the texture of strawberries along the storage by using Texture Analyser by Micro Stable Instrument with the following test parameters:

Measurement device: cylinder 12 mm with measurement cell 5 kg

kind of test:	pressure
Test speed:	1 mm/sec
Back speed:	2 mm/sec
Aim parameter:	distance
Distance:	10 mm
Tripping value:	Force (0.01 lb)
Stop of measurement:	at start position

- Taste: TTZ will perform an in/out sensory test to assess whether the FRESH-DEMO humidified strawberries are conforming to the normal strawberries (IN) or not conform (OUT). Different sensory parameters such as appearance, firmness, dehydration, odour, freshness, etc. will be assessed via a trained panel. The panel meets Tuesdays and Thursdays at 10h.
- Time strawberries stay fresh: TTZ will perform shelf life tests storage of strawberries at 5°C (conventional) and at 5°C with humidification (90%) for the humidified with and without film and for the humidified and Formula 5 treated with and without film.
- Other lab tests: TTZ will measure the hydration (drying at 103°C until weight stability is achieved) and the pH.

6.3 Analysis of delivered Strawberries

The trip started in Huelva on Friday, 11.03.2016 at 14:00. By using track and trace control, the route could be seen online.

After 2700 km the FreshDemo van arrived at ttz Bremerhaven on Monday, 14.03.2016 at 16:00. Figure C shows the route of the FreshDemo can protocolled by Track and Trace control including humidity and temperature control during transport. It could be seen that both parameters were constant at approx. 1°C and 96% relative humidity.

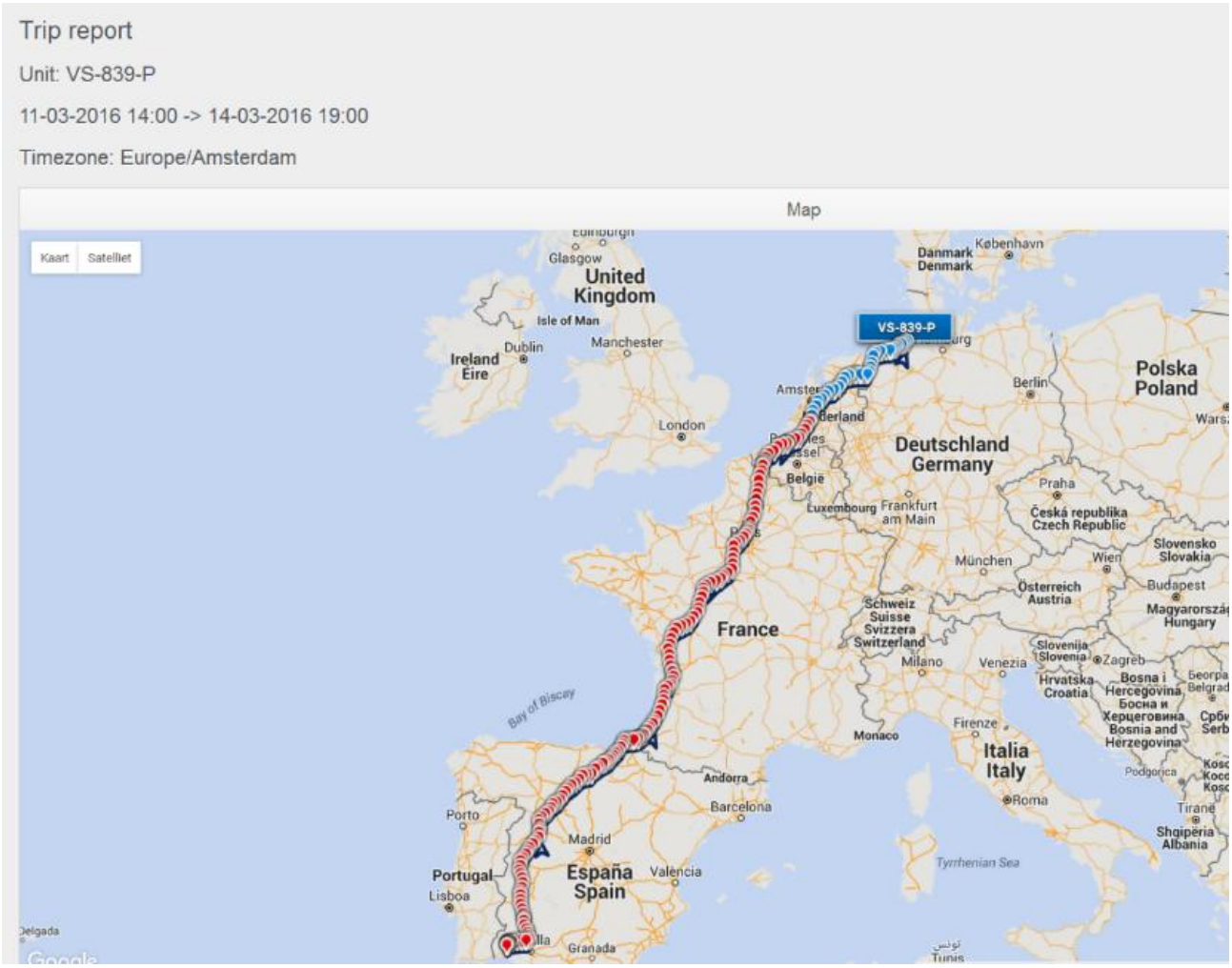


Figure C: Route of FreshDemo van

Start: 11.03.2016 13:41:07 average temperature 1.113 °C/average humidity 96,84 % End: 14.03.2016 15:41:07

Figure D: humidity and temperature during the transport time

6.3.1 Pictures

Arrival – Day 1 - 14.03.2016 (H = humidified; H+D = humidified and Formula 5 treated)

Control | H with film | H no film | H+D with film | H+D no film

Day 2 - 15.03.2016 (H = humidified; H+D = humidified and Formula 5 treated)

Control | H with film | H no film | H+D with film | H+D no film

Day 3 - 16.03.2016 (H = humidified; H+D = humidified and Formula 5 treated)

Control | H with film | H no film | H+D with film | H+D no film

Day 4 - 17.03.2016 (H = humidified; H+D = humidified and Formula 5 treated)

Control | H with film | H no film | H+D with film | H+D no film

Day 5 - 18.03.2016 (H = humidified; H+D = humidified and Formula 5 treated)

Control | H with film | H no film | H+D with film | H+D no film

Day 8 - 21.03.2016 (H = humidified; H+D = humidified and Formula 5 treated)

Control | H with film | H no film | H+D with film | H+D no film

Day 9 - 22.03.2016 (H = humidified; H+D = humidified and Formula 5 treated)

Control H with film H no film H+D with film H+D no film





Day 10 - 23.03.2016 (H = humidified; H+D = humidified and Formula 5 treated)

Control H with film H no film H+D with film H+D no film





Day 11 - 24.03.2016 (H = humidified; H+D = humidified and Formula 5 treated)

Control	H with film	H no film	H+D with film	H+D no film
				

Direct after delivery and each day photo documentation was done by taking pictures.

After delivery, the humidified transported Strawberries (H/H+D) are stored at +5°C and a relative humidity of 90%. The conventional transported Strawberries are stored at 5°C and approx. 75% relative humidity.

Figure E: products day 0 direct after delivery (left conventional transport; right humidified transport)

The humidified products (H/H+D) offer more intense colour than the conventional transported Strawberries direct after delivery. Furthermore, it could be seen, that the products from the conventional truck have a deadhead green whereas the humidified transported products (H/H+D) from the FreshDemo van have a fresh appearance and the green looks fresh harvested.

After day 3 of storage, less Strawberries get mouldy with humidified storing (H/H+D). Furthermore, they offer less dent and a fresher appearance.

On day 5 of storage the conventional products have a lot of dents and do not have a fresh appearance in contrast to the humidified and acidified treated + humidified products (H/H+D).

The products of both groups (H/H+D) with film have less dents than the products without film.

The evaluation of Day 9 shows that the humidified and Formula 5 treated+humidified products (H/H+D) have a fresher appearance than the reference products which offer lots of dents.

The non-Formula 5 treated and only humidified products (H) with film offer the best quality after day 9 storing.

On day 10 the conventional Strawberries offer lots of dents.

The humidified as well as the Formula 5 treated and humidified products (H/H+D) looks less dent. Differences could be seen between products with and without film (H/H+D). The Strawberries stored with film (H/H+D) looks fresher and offer a more intense flavour. Best products on day 10 are the Formula 5 treated and humidified products with film.

Day 11 – the conventional Strawberries have a lot of dents and mould growing. The humidified Strawberries (H) with film do not have dents but first mould growing. The humidified products (H) without film do not have dents or mould growing.

All products for the humidified and Formula 5 treated (H+D) products do not have dents and mould growing.

Furthermore it could be seen that the deadhead green on the humidified Strawberries (H/H+D left picture above) looks fresh as direct after harvest. The deadhead green of the conventional transported and stored Strawberries (right picture above) looks dry and brown.

Conclusion: Even after storage day 11 humidified transported and stored strawberries offer fresh appearance and fresh green calyx.

6.3.2 Weight

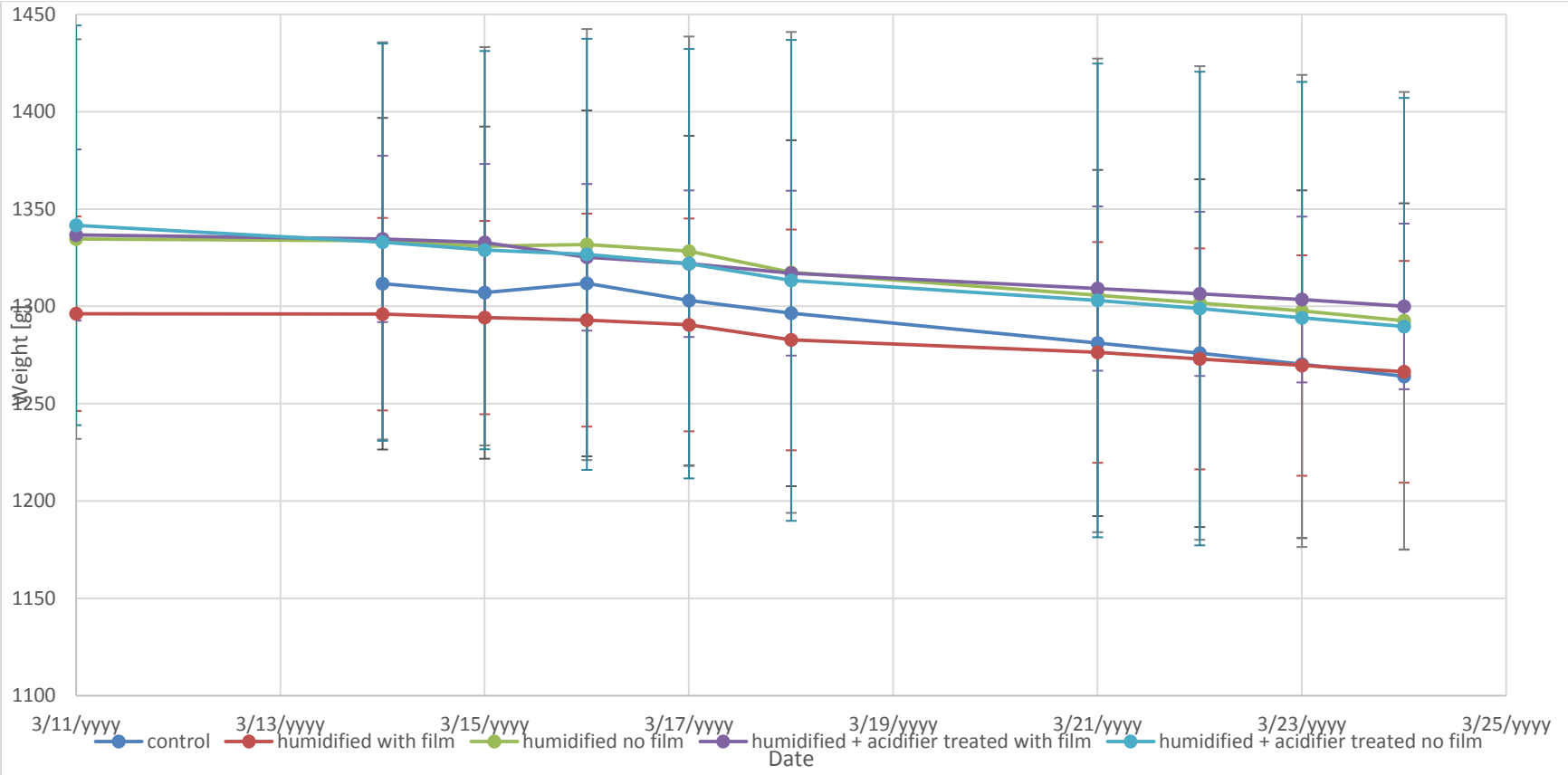


Figure F: influence of humidification on the weight of Strawberries during the storage time

Figure F shows the influence of the humidification on the weight during storage time. The control Strawberries offer the highest loss in weight.

Humidified (H) and humidified and Formula 5 treated (H+D) Strawberries offer less weight loss. The products transported and stored with film (H/H+D) offer less loss in weight than the products without film.

This means that humidified (H/H+D) products do not dry out or loss water as the conventional Strawberries do. The film is an additional barrier for reserving water in the Strawberries.

Conclusion: Humidified transported and stored strawberries offer minimized weight loss.

6.3.3 Softness

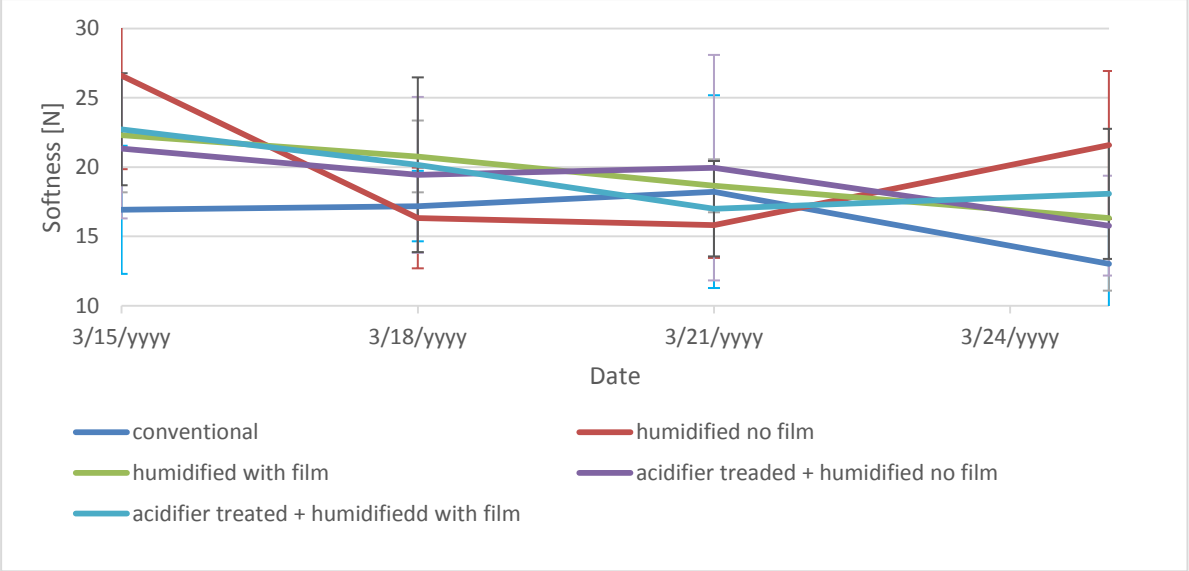


Figure G: Softness of Strawberries depending on the

Directly after delivery as well as each storage day was measured the softness by using Texture Analysis Measurements. With this measurement the power in Newton is measures which is needed to go 1 cm inside the product. In Figure G could be seen, that the humidified transported Strawberries without film (H) offer hardest appearance. The higher the needed power [N] the harder the Strawberries. After 3 days of storage those Strawberries offers the softest surface.

Strawberries humidified (H) with film and both charged (with and without film) of Formula 5 treated and humidified transported (H+D) offers same behaviour after delivery: an average softness (needed power for going through the surface between 21-23 N).

The conventional ones in comparison offers (17 N) the softest behaviour at delivery.

After day 3 of storage no changing in softness could be measured. But after day 6 of storage all products excluding humidified (H) without film offer similar power between 17 – 20 N. It has to be considered, that the softness of the humidified and humidified+Formula 5 treated Strawberries (H/H+D) with film as well as the humidified (H) Strawberries without film decreases. But the softness of the Strawberries humidified+Formula 5 (H+D) treated without film as well as the conventional ones' increases during storage time.

On storage day 11 the conventional Strawberries are very soft – the power in the softness measurement is very low, because no power is needed for going in the product.

Humidified with film and humidified and Formula 5 treated without film offer a minimal decreasing power for going in the product. This means that these Strawberries are a little bit soft but not so much than the conventional ones.

Humidified Strawberries without film and humidified and Formula 5 treated Strawberries with film offer an increasing power for going inside the product. This means that they do not offer soft appearance and offer best softness quality.

Conclusion: humidified transported and stored strawberries offer best soft quality after storage.

6.3.4 Sensorial analysis

Table 2: results of the sensorial expert panel (in/out test)

15.03.2016			17.03.2016	
humidified no film	sour	6 out	better than reference	best result better than reference
	not so intense flavour		sweeter	
	less sweetness		more intense taste and flavour	
	harder		riper/dark coloured	
humidified+ Formula 5 treated with film	very soft	best result 3 in/3 out	softer	4 in/2 out
	extrem juicy		no typical flavour	
	less sweetness		not ripe	
	taste and flavour typical		very hard	
humidified with film	not so intense taste	1 in/5 out	sour	1 in/5 out
	softer		non intense flavour	
	sour/less sweetness		not dark coloured	
	harder/stronger		lots of dents	
humidified+ Formula 5 treated no film	not so intense taste+flavour	worst result 6 out	sour and bitter	worst result 1 in/5 out
	less sweetness		less taste and flavour	
	sour		slushy	
	harder		moldy flavour	
	less coloured		moldy	

The sensorial evaluation of the Strawberries was done by an expert panel. 6 experts make an in/out evaluation with the conventional transported Strawberries (see Table 2). Directly after delivery, the humidified and Formula 5 treated (H+D) Strawberries with film are evaluated as best products. The products humidified and Formula 5 treated (H+D) without film are characterized as the worst products.

After storage time of 3 days same panel made the same evaluation. After this storage time, the humidified (H/H+D) transported and stored products achieved better evaluation than the reference products.

The products humidified and Formula 5 treated (H+D) without film are characterized as the worst products again.

Conclusion: humidified without film transported and stored as well as humidified and Formula 5 treated strawberries offer best sensory result by a trained panel.

6.3.5 Laboratory analysis (pH hydration) and vitamin C content

Table 3 shows the results of the laboratory analysis of pH and drying substance (hydration) on day 2 and day 5.

For pH measurements it could be seen that all samples offer similar pH for both analytic days. Only the Strawberries humidified (H) with film show an increase in pH from day 2 (3.63) to day 5 (3.81) which is a minimize changing and should not have strong influences on the quality.

For the drying substances control, humidified (H) with film and humidified and Formula 5 (H+D) treated without film samples offer no significant changing in hydration between storage day 2 and storage day 5. Humidified and Formula 5 (H+D) treated Strawberries with film offer an increasing drying substance which shows a water loss of the products between day 1 and day 5. In contrast for the humidified (H) Strawberries without film (blue coloured line in table 3) the drying substance decreases. This means that the Strawberries have on storage day 5 a higher water content than on day 2. This could be explained be the humidified transport and storage without film which avoid the water absorption.

Table 3: laboratory analysis results for detection of pH and hydration

	pH		drying substance ds [g/100g sample]	
	15.03.16	**18.03.16**	**15.03.16**	**18.03.16**
control	3.65	3.52	8.6	8.55
humidified with film	3.63	3.81	8.11	8.21
humidified no film	3.69	3.57	8.45	7.91
humidified + Formula 5 treated with film	3.77	3.62	7.96	8.5
humidified + Formula 5 treated no film	3.71	3.62	8.51	8.54

To analyse vitamin C, 100 g of strawberries were given to an external laboratory to detect the vitamin C content of strawberries via HPLC.

Table 4 shows the vitamin C content of strawberries direct after delivery (day 1) and after 15 days of storing. The humidified transported and stored strawberries offered a gain on vitamin C content of 23.86 % whereas the conventional transported and stored products offered the largest loss with approx. 16%.

Table 4: laboratory analysis results for vitamin C content of strawberries

sample ID		Vitamin C day 1 [mg/g drying substance]	Vitamin C day 15 [mg/g drying substance]	% changing [neg. value means gain]
strawberries	conventional	5,041666667	4,235294118	15,99416626
	humidified	3,526315789	4,367647059	-23,85864794
	humidified+Formula 5 treated	4,657534247	4,338235294	6,855536332

Conclusion: humidification during transport and storage of strawberries leads to a rise of vitamin C content.

6.4 Conclusion

In this deliverable the first trip of the Strawberry case study was evaluated exemplary to show all executed laboratory results as well as the specific requirements for the transport itself.

After evaluation of the different treated and transported (conventional and H/H+D) products it could be said that the product transported with the FreshDemo van (H/H+D) offer better quality than the conventional Strawberries direct after delivery as well as different storage days. Table 5 gives an overview of the best product category for the single analysis. The best products are the products (H/H+D) without film.

Table 5: summary of laboratory analysis

attribute	Best sample	explanation
Appearance shelf life	Humidified and Formula 5 treated (H+D) with film	Offset most fresh appearance with less dents and lowest visible mould growing
weight	Humidified and Formula 5 treated (H+D) and humidified (H) with film	Less weight loss during storage than without film and conventional
Sensorial analysis	Humidified (H) without film	Best taste, flavour, appearance and structure
Softness	Humidified and Formula 5 treated (H+D) with film and humidified (H)	No measurable changings in softness during storage
pH	Humidified (H) with film	Increasing pH
Hydration	Humidified (H) without film	Decreasing drying substance – highest water content

Humidified products without film - best quality in sensorial analysis, softness measurement on storage day 11.

Humidified products with film - best quality in minimized weight loss and no changing in pH during storage.

Humidified products and Formula 5 treated without film - best quality in shelf life.

Humidified products and Formula 5 treated with film - best quality in shelf life analysis, softness measurement and offer minimal weight loss during storage.

Summarized it could be said that humidified and Formula 5 treated (H+D) products as well as humidified products (H) during transport and storage leads to increasing product quality, fresher appearance and shelf life, better softness during storage and increasing taste and flavour. Additionally, packaging material could be reduced because without film and humidification Strawberries offer best quality.

The humidified product without film seems to be the best product because of having best sensorial evaluation result as well as best softness after storage day 11.

The humidified with film is the worst product in comparison to the other products of the FreshDemo van but offer high quality in contrast to the conventional Strawberries.

With this exemplary evaluation of the first Strawberry case study could be shown that humidification as well as Formula 5 treatment in combination with humidification leads to high quality products significantly better than conventional transported and stored products.

7. Case study asparagus

Asparagus is chosen as case study product because it is a very sensitive product with high water content and therefore a short shelf life. Typical shelf life of asparagus stored in a wet towel under cooling conditions is between 3 – 4 days. By using ultrasonic humidification technology, the shelf life is estimated to be prolonged up to 5-6 days.

In this case study unfortunately it was not able to use the ultrasonic humidification technology directly after harvest at the producers' side. But in general the using of ultrasonic humidification in each step of the supply chain leads to an improves products quality and an increasing shelf life.

The executed analysis are chosen because weight loss, drying substance as well as sensory analysis are relevant main criteria for the evaluation of products quality. HPLC analysis are executed additionally because asparagus offer a high content of vitamin C of 20 mg / 100 g [deutsche Gesellschaft für Ernährung].

7.1 Material

Asparagus was delivered to ttz and separated into three test groups:

1. Stored at 5°C in the storing room (dry conventional)
2. Stored at 5°C in the storing room involute in a wet towel (wet conventional)
3. Stored at 5°C with ultrasonic humidification (rel. humidity of 88%)

Stored for 7 days, analysed and evaluated. A humidified transport and disinfection tests unfortunately were not able because of producers' decision. To see the influence on products quality, different analysis were executed:

- Analysis done daily: measuring of weight and taking pictures
- Analysis done on storing day 1 and day 4: detection of vitamin C content, detection of drying substance and sensorial evaluation (only day 4)

7.2 Method

- Daily analysis:

7.2.1 Weight

For weight documentation each day 9 pieces of asparagus per type of product were weighted.

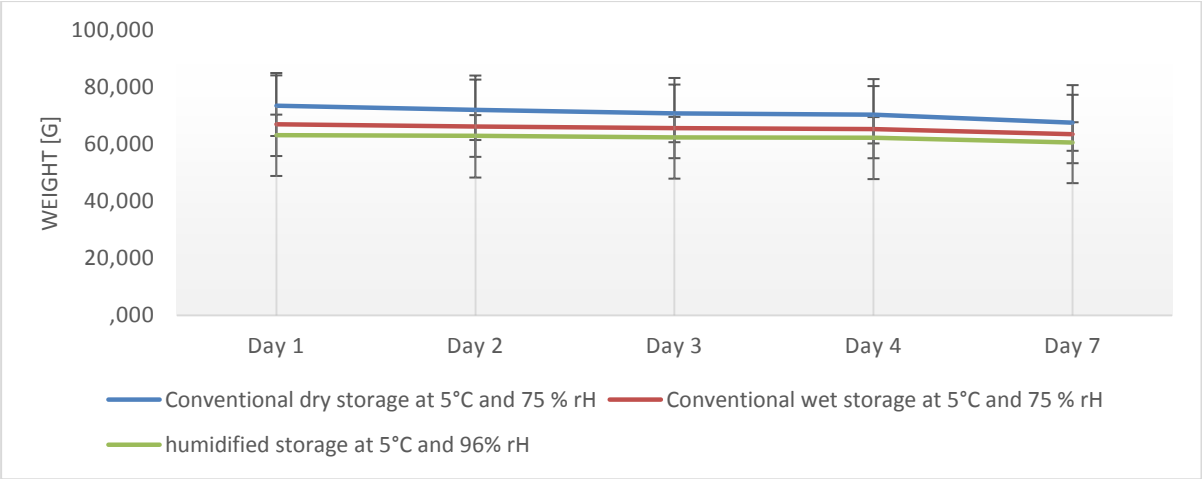


Figure H: influence of humidification on changings in weight

Percentage weight loss:

H: 4.10 %

C: 8.15 %

TC: 5.06 %

It could be seen that the conventional stored asparagus offer the highest weight loss of 8.15 %.

In comparison the humidified stored asparagus offer a lower weight loss (4.1 %) than the conventional asparagus in a wet towel (5.06). Although the conventional wet stored asparagus is in a closed wet system (towel) the humidification technology with the finest free floating aerosols offer better storing conditions.

Conclusion: Storing of asparagus with ultrasonic humidification leads to minimization of weight loss.

7.2.2 Photo documentation

Of 9 pieces of asparagus per type of product a picture was taken daily.

Trip 2 – exemplary photo documentation – for all three trips same results

Day 1

Day 2

Day 3

Day 4

Day 7

Humidified asparagus (H) – kindly humid surface
Wet conventional (TC) – too humid/greasy; first brown areas on the surface on storage day2
Dry conventional (C) – dry and brown on surface after end of day 1

Conclusion: In the photo documentation it could be seen, that the humidified stores asparagus offer less brown areas on the surface than the conventional wet and dry stores products.

By touching the products, the humidified stored asparagus felt very kingly not too wet and not to dry. The conventional humidified asparagus offer a feeling of drying out directly after day one and the conventional wet stores asparagus greasy and disagreeable.

- Non- Daily analysis

7.2.3 Microbiological analysis

Thin slices of asparagus are prepared 1:10 with NaCl and homogenized as good as possible and diluted 1:10. Different dilutions are given on plate count, inoculated for 2- 3 days at 30°C. After the inoculation time number of total viable counts is detected.

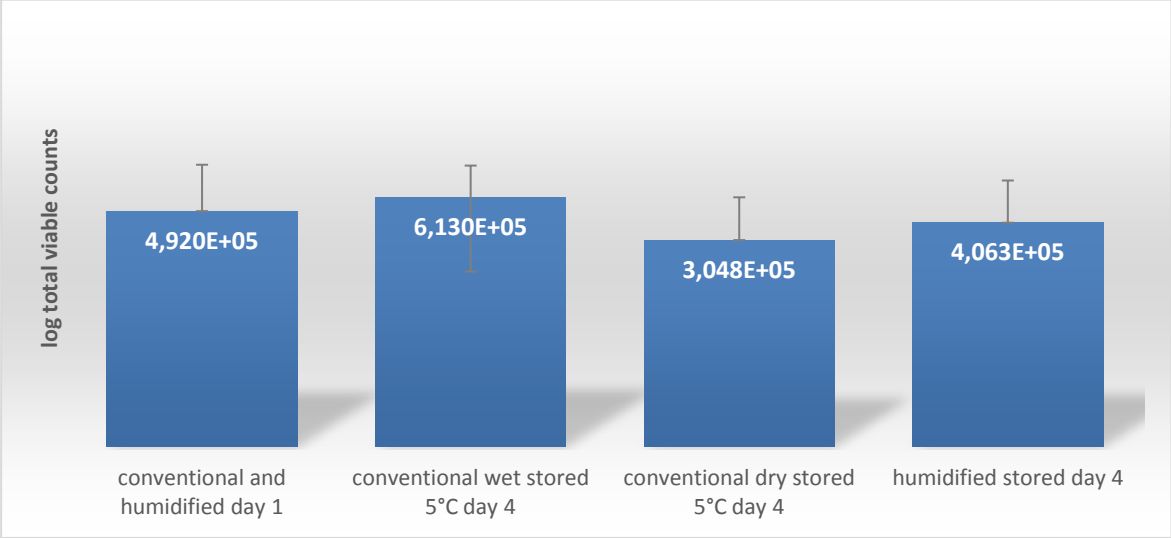


Figure I: Influence of humidification on total viable counts

The microbiological analysis show that conventional wet stored products offer gain in total viable count after 4 days of storing whereas the both other storing conditions (conventional dry and humidified) leads to loss of total viable counts (see Table 6).

Table 6: percentage changing of total viable counts

	total viable counts day 1	total viable counts day 4	percentage changing	
conventional wet	492000	613000	-24,59349593	gain
conventional dry	492000	305000	38,00813008	loss
humidified	492000	406000	17,4796748	loss

The conventional wet storing offer too wet conditions that the microbiological growing is fastened. At same wet conditions with relative humidity up to 96% the ultrasonic humidification system offer loss of total viable count between storage day 1 and day 4.

The conventional dry storing conditions offer loss in total viable counts too, but the storing conditions of asparagus offer drying out effects and bad product quality already after day 1.

Conclusion: Storing with humidification of asparagus leads to a minimization of microbiological growing.

7.2.4 Sensorial analysis

A trained sensory panel (5-6 tester) make an "in/out evaluation" on storing day 4. In this test products are tested against the conventional product which is defined as reference. First evaluation step is the evaluation of non-stripped and non-boiled asparagus, second one stripped and boiled.

The testers have to evaluate if the product is in or out of the range of the reference concerning:

- Appearance
- Taste
- Flavour
- Colour
- Hardness
- Appearance of surface
- Freshness
- Firmness

The non – boiled and non - stripped humidified stored asparagus is evaluated better and fresher than the conventional wet and dry stored with more attractive whiter colour of the surface (see

Table **7**).

The boiled humidified stored asparagus is evaluated as minimal less sweet, whiter and definitely better than both kinds of conventional stored asparagus (see Table 8).

To sum up, evaluation of taste and flavour as well as evaluation of appearance and shelf life showed, that humidified asparagus offer higher quality than conventional stored asparagus (wet and dry).

Table 7: sensory evaluation of non - boiled asparagus on storing day 4

Non boiled

TC	**IN**	**OUT**	**comment**
Tester 1		X	Thinner, not so many brown areas on the surface, bitter
Tester 2	X		
Tester 3		X	Brighter, less brwon areas on the surface, sweeter in taste, gentle taste
Tester 4		X	Whiter, less brown areas on surface, taste bitter, odor, less intense
Tester 5		X	Thinner, less matrix, taste bitter

H - better/more freshness better white colour	**IN**	**OUT**	**comment**
Tester 1		X	Thinner, looks better, non brown areas on surface, bitter
Tester 2		X	White heads, bitter in taste
Tester 3		X	More gentle taste, very similar
Tester 4	X		
Tester 5	X		Matrix, bitter, dry, identical peeling behaviour Standard more soft in mouth feeling, taste more than milk, butter, standard offer better and cleaner appearance

Table 8: sensory evaluation of boiled asparagus on storing day 4

boiled

H minimal less sweetness, more whiteness, better than TC	IN	OUT	comment
Tester 1		X	Not so sweet, more yellow colour, non intense typical odor
Tester 2		X	Not so sweet, more white colour
Tester 3		X	Less taste intensity
Tester 4	X		
Tester 5		X	Less intense, 1 piece dark yellow, harder, less taste, fibrous

TC	IN	OUT	comment
Tester 1		X	Not so sweet, fibrous, difficult to cut
Tester 2		X	Uniform, white heads, best taste
Tester 3		X	Very similar, but more nutty taste
Tester 4		X	Less taste
Tester 5	X		Less taste, harder

7.3 Conclusion and summary

Summarized it could be said that the ultrasonic humidification technology offers the possibility to create high quality asparagus during storage time.

In comparison to "hardcore reference wet towel" humidified stored asparagus offer less weight loss, clearly better taste, flavour and appearance as well as sensorial evaluation. These stores products offer more freshness and more white attractive colour.

In comparison to the conventional dry stored asparagus (non - typical storing method) humidified stored products offer in all kinds of analysis more than better results in quality.

In sum the ultrasonic humidification technology offers an easy to implement and easy to handle tool to store asparagus with high quality even after 5-6 days of storing.

8. Case Study peaches and nectarines

A case study with peaches and nectarines was executed to evaluate the influence of ultrasonic humidification during transport of products' quality. The products were transported three times from Gobbi Dino (North of Italy) to the supermarket van Gurp in Roosendaal (Netherlands).

Three different kinds of product groups (peaches and nectarines) were transported in 7 kg boxes without foil:

In the FreshDemo Van: humidified (H) peaches and nectarines as well as disinfected and humidified (HD) peaches and nectarines.

Unfoiled reference products were transported by the conventional LKW without humidification (C).

8.1 Material

To define the analysis a literature reserach was executed. Important parameter to evaluate the quality of peaches and nectarines is the analysis of Vitamin C.

A comprehensive analytic of pH, drying substance, sensory, weight loss, visual decay and moulding gave an evaluation of quality aspects documented additionally with pictures.

Due to literature (typical shelf life of peaches and nectarines at 5°C: 2 weeks at a maximum) an analytics plan was established:

Storage day 1: delivery of peaches and nectarines to van Gurp.

Humidified and disinfected (HD) and humidified (H) peaches and nectarines transported with the FreshDemo van (average 6-7°C at 60-70%) were stored at 5°C with an average relative humidity of 80-90%.

Conventional transported (C) peaches and nectarines were stored at 5°C without additional humidification.

All products (with and without humidification) were stored for 15 days at van Gurp, analysed and evaluated:

- Pictures are taken daily. –
- Weight loss, visual evaluation of decay and mould are executed all three days in the supermarket
- and a sensory evaluation takes place directly after delivery, on storage day 7 and storage day 15.

Products were delivered to ttz Bremerhaven to analyse pH, drying substance and to a laboratory in Bremen to analyse Vitamin C on delivery day and on storage day 15.

8.2 Results Nectarines

8.2.1 Weight loss

For weight documentation all three days each box of nectarines was weighed.

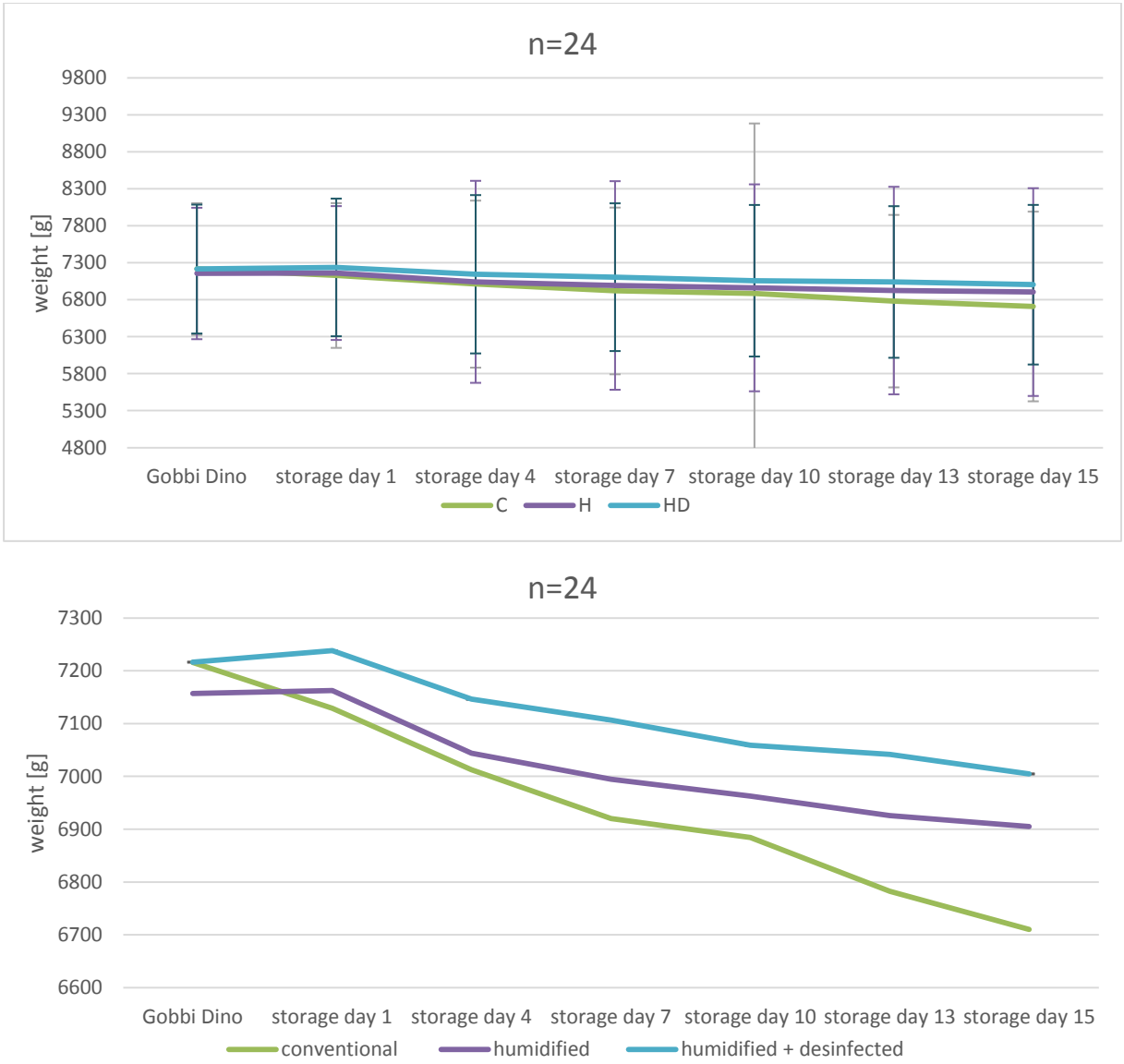


Figure J: influence of humidification on changings in weight

Percentage weight loss between start of transport and storage day 15:

Conventional: 7.00 %; Humidified: 3.52 %; Treated with Formula 5 and humidified: 2.98%

In Figure J it could be seen that the conventional (C) transported and stored nectarines offered the highest weight loss of 7.00%. In comparison the humidified and disinfected (HD) and humidified (H) transported and stored nectarines offered a lower weight loss (3.52% and 2.98%).

The transport time (4 days) lead to the highest weight loss of the conventional transported (C) nectarines whereas the humidified (H and HD) transported nectarines offered a minimal gain in weight during transport time. During storage all products offered weight loss, but the weight loss of humidified (H and HD) stored nectarines was minimized.

Conclusion: humidification during transport of nectarines have the largest influence on the minimized weight loss.

8.2.2 Pictures

Day 1

Conventional | Humidified | Humidified and treated with Formula 5

Humidified transported nectarines (HD and H) had a fresher appearance than conventional transported (C) nectarines directly after delivery.

Day 15

Conventional | Humidified | Humidified and treated Formula 5

After day 15 of storage conventional stored (C) nectarines offered first decay and non-equal areas on the surface (black marked area on left picture). Humidified stored (H and HD) nectarines did not have any decay or non-equal structures.

8.2.3 Visual decay and moulding – shelf life

The first day with visual moulding or decay on the products surface was documented for all three kinds of nectarines.

Humidified and disinfected (HD) and humidified treated (H) nectarines offered first moulding and decay on the surface 1 day later than conventional stored (C) peaches. But in sum it has to be considered, that the number of mould product variates:

Conventional stored nectarines:	20 pieces offered mould growing
Humidified stored nectarines:	14 pieces offered mould growing
Humidified+Formula 5 treated stored nectarines:	13 pieces offered mould growing

Conclusion: humidified and humidified and Formula 5 treated products offer lower number of pieces with mould growing – a reduction up to 25% is visible.

8.2.4 pH, drying substance and vitamin C

Table 9 shows the average pH and drying substance of nectarines of all three trips on storage day 1 and day 15.

No changings in pH were visible during storage time (all products had same pH).

For drying substance analysis, a thin layer of nectarine mousse was given in a dish and dried at 103°C until constant weight is detectable. This method is established for vegetables in dependence to official method § 64 LFBG 06.00 – 3 for the detection of meat and meat-products.

103 °C is the standard temperature for lots of products to detect the drying substance. The products are given in a hot cabinet with adjusted 103°C for evaporate the water inside. The product is weight out all 24 hours until weight stability is achieved. Drying substance is evaluation because lots of parameters use drying substance as base.

All three kinds of samples offered nearly same drying substance, only with a minimal reduction during storage time. The reduction for humidified stored nectarines (H and HD) was minimized in comparison to the conventional stored products (C).

Table 9: average pH and drying substance of nectarines on storage day 1 and 15

	Average pH Day 1	Average pH Day 15	average drying substance ds [g/100g sample] Day 1	average drying substance ds [g/100g sample] Day 15
conventional	4,00	4,01	11,56	10,67
humidified	4,01	4,14	11,62	11,43
humidified+treated with Formula 5	3,97	3,98	11,53	11,09

Conclusion: Optimal adjusted ambient humidity leads to stability in drying substance.

To analyse vitamin C, 100 g of nectarines were given to an external laboratory to detect the vitamin C content of nectarines via HPLC.

Table 10: laboratory analysis results for vitamin C content of nectarines

sample ID		Vitamin C day 1 [mg/g drying substance]	Vitamin C day 15 [mg/g drying substance]	% changing [neg. value means gain]
nectarines	conventional	0,517241379	0,831775701	-60,80996885
	humidified	0,560344828	0,868421053	-54,97975709
	humidified+Formula 5 treated	0,573913043	1,009009009	-75,81217581

In Table 10 could be seen the results of the analysis of vitamin C content of nectarines directly after delivery (day 1) and after 15 days of storing. All three kinds of products offered a gain in vitamin C content during storage time, but the humidified and Formula 5 treated nectarines had the highest increase with 75.8%.

8.2.5 Sensorial analysis

Direct after delivery as well as on storage day 8 and 15, one non-trained sensory person evaluated the nectarines concerning:

- Appearance/Differences to conventional product
- Taste
- Flavor
- Color
- Decay
- Softness

In sensory analysis directly after delivery no difference were detected between humidified (H and HD) and non-humidified (C) transported nectarines. On storage day 8 and 15 the humidified stored nectarines (H and HD) offered better sensorial characteristics: better appearance concerning intensity in colour and little bit more typical taste and flavour than the non-humidified reference products (C).

Conclusion: Evaluation of taste and flavour as well as evaluation of appearance showed, that humidified nectarines (H and HD) offered higher quality than conventional stored products (C) on storage day 8 and 15.

8.3 Results Peaches

8.3.1 Weight loss

For weight documentation all three days each box of peaches was weighed.

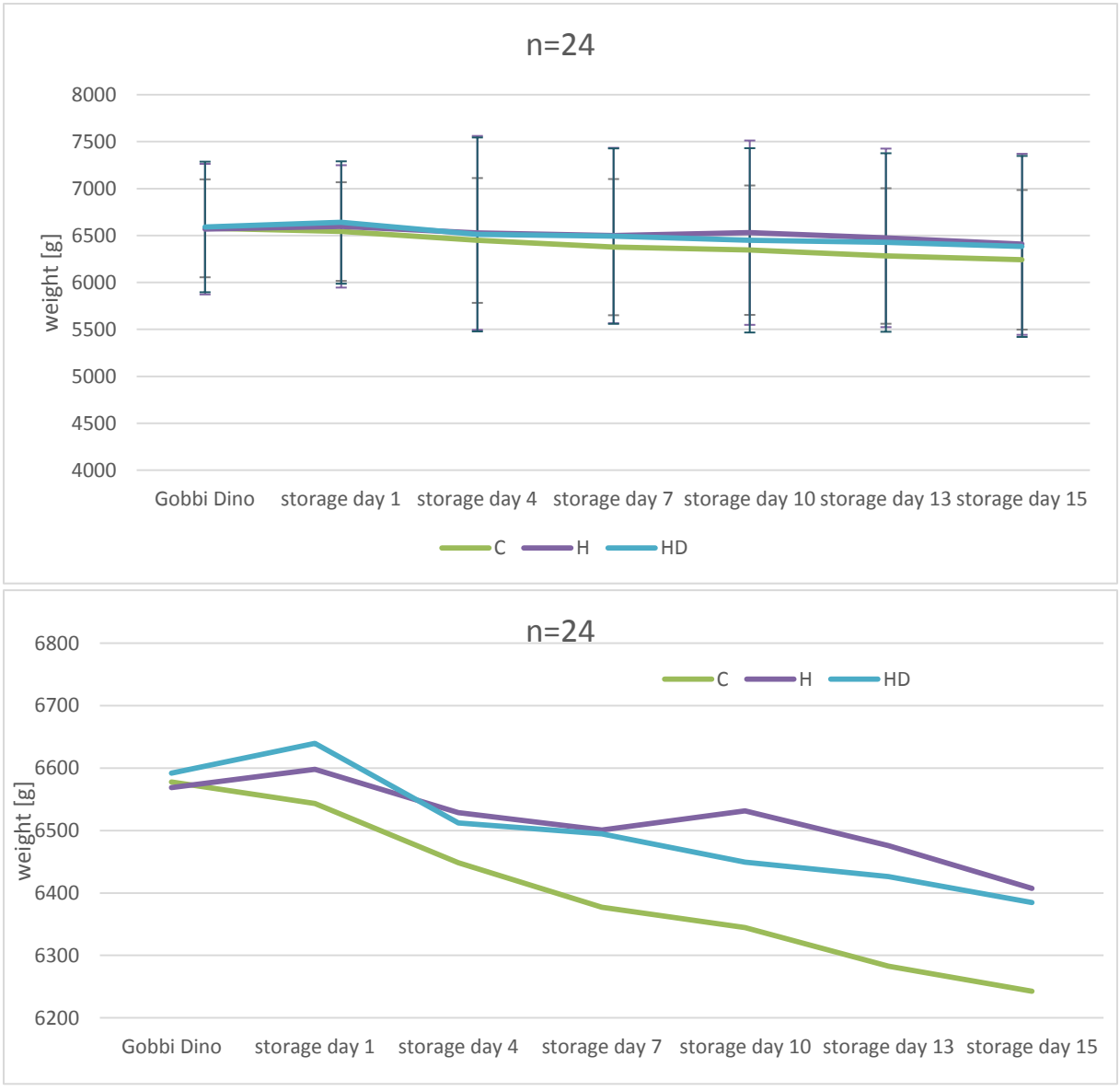


Figure K: influence of humidification on changings in weight

Percentage weight loss between start of transport and storage day 15:

Conventional: 5.10 %; Humidified: 2.46 %; Treated with Formula 5 and humidified: 3.15%

It could be seen in Figure K that the conventional transported and stored (C) peaches offered the highest weight loss of 5.10 %. In comparison the humidified (H) and disinfected and humidified (HD) transported and stored peaches offered a lower weight loss of 2.46% and 3.15%.

During time of transport (first fourth days) the conventional transported peaches (C) offered the highest weight loss whereas the humidified transported peaches (H and HD) offered a gain in weight. During storage the weight loss of humidified stored peaches (H and HD) was minimized.

Conclusion: humidification during transport of peaches have the largest influence on the minimized weight loss.

8.3.2 Pictures

Day 1

Conventional Humidified Humidified and treated Formula 5



Humidified transported peaches (H and HD) had a fresher appearance than conventional transported (C) peaches directly after delivery.

Day 15

Conventional Humidified Humidified and treated Formula 5



After day 15 of storage conventional stored peaches (C) offered first decay and non-equal areas on the surface (black marked area on left picture). Humidified stored peaches (H and HD) did not have any decay or non-equal structures.

8.3.3 Visual decay and moulding – shelf life

The first day of visual moulding or decay on the products surface was documented for all three kinds of peaches.

In average the humidified (H) and disinfected and humidified (HD) treated peaches offered 2 days longer freshness documented by first moulding and decay on the surface. Due to the average value no significant absolute difference could be identified.

Conventional stored peaches: 8 pieces offered mould growing
Humidified stored peaches: 4 pieces offered mould growing
Humidified+Formula 5 treated stored peaches: 4 pieces offered mould growing

Conclusion: humidified and humidified and Formula 5 treated products offer lower number of pieces with mould growing - a reduction up to 50% is visible.

8.3.4 pH, drying substance and vitamin C

Table 11 shows the average pH and drying substance of peaches on storage day 1 and day 15. During storage no changings in pH were visible. All three kinds of samples offered same pH.

For drying substance analysis, a thin layer of peach mousse was given in a dish and dried at 103°C until constant weight is detectable. This method is established for vegetables in dependence to official method § 64 LFBG 06.00 – 3 for the detection of meat and meat-products.

103 °C is the standard temperature for lots of products to detect the drying substance. The products are given in a hot cabinet with adjusted 103°C for evaporate the water inside. The product is weight out all 24 hours until weight stability is achieved. Drying substance is evaluation because lots of parameters use drying substance as base.

For drying substance all samples offered nearly same values with a minimal gain during storage time. The gain for humidified stored peaches was larger in comparison to the conventional stored products.

Table 11: average pH and drying substance of peaches on storage day 1 and 15

	Average pH Day 1	Average pH Day 15	average drying substance ds [g/100g sample] Day 1	average drying substance ds [g/100g sample] Day 15
conventional	4,47	4,46	15,00	15,31
humidified	4,45	4,80	13,85	14,90
humidified+treated with Formula 5	4,49	4,49	13,47	14,15

Conclusion: Optimal adjusted ambient humidity leads to stability in drying substance.

To analyse vitamin C, 100 g of peaches were given to an external laboratory to detect the vitamin C content of peaches via HPLC.

Table 12 shows the results of the vitamin c analysis of peaches directly after delivery (day 1) and after 15 storing days. It could be seen that all products offered a gain of vitamin C content during storage but humidified products (with and without Formula 5 treatment) had the largest gain between 40.6%-47.5%.

Table 12: laboratory analysis results for vitamin C content in peaches

sample ID		Vitamin C day 1 [mg/g drying substance]	Vitamin C day 15 [mg/g drying substance]	% changing [neg. value means gain]
peaches	conventional	0,413333333	0,562091503	-35,98987982
	humidified	0,467625899	0,657718121	-40,65049045
	humidified+Formula 5 treated	0,42962963	0,633802817	-47,52306945

8.3.5 Sensorial analysis

Direct after delivery as well as on storage day 8 and 15, one non-trained sensory person evaluated the peaches concerning:

- Appearance/Differences to conventional product
- Taste
- Flavor
- Color
- Decay
- Softness

In sensory analysis directly after delivery no difference were visible between humidified (H and HD) and non-humidified transported(C) peaches. On storage day 8 and 15 the humidified stored (H and HD) peaches exhibited better sensorial characteristics: better appearance concerning intensity in colour and little bit more typical taste and flavour than the non-humidified reference products (C).

Conclusion: Evaluation of taste and flavour as well as evaluation of appearance showed, that humidified peaches (H and HD) offer higher quality than conventional stored products (C) on storage day 8 and 15.

8.4 Conclusion and summary

The influence of ultrasonic humidification technology on peaches and nectarines during transport and storage was evaluated in this case study.

Evaluation parameter of weight loss, appearance, decay/moulding, pH, drying substance, vitamin C and sugar content as well as sensory were assessed for a storage time of 15 days.

An overview of all results is shown in the following table Table *13*.

Table 13: summary of results with C as reference (evaluation in comparison to C)
+ means positive effect; - negative effect; o no significant effect

parameter	peaches	nectarines
Weight loss	++	++
Appearance	++	++
Visual decay/moulding/shelf life	++	+
Drying substance/pH	o	o
Vitamin C content	++	+
Sensory analysis	Better day 8 and day 15	Better day 8 and day 15

Humidification especially during transport minimized the weight loss of the products. Peaches as well as nectarines (H and HD) exhibited a gain in weight after the transport time whereas the conventional transported (C) products had a lost in weight.

Directly after delivery the appearance of both products (transported with humidification H and HD) was fresher than the appearance of the conventional transported (C) products.

During storage time of 15 days a positive effect of humidified storage on the vitamin C content of peaches and nectarines (H and HD) was detected.

On storage day 8 and storage day 15 the sensorial analysis identified a better taste and flavour as well as a better appearance and freshness for humidified (H and HD) products.

All other parameter (visual evaluation, drying substance, pH) did not showed significant effects on the product quality.

In sum humidification during transport and storage effected the quality of peaches and nectarines (H and HD) in a positive way. Nutritional parameters of vitamin C were influenced as well as sensory and weight.

9. Case study table grapes

9.1 Introduction

A case study with table grapes was executed to evaluate the influence of ultrasonic humidification during transport of products' quality. The products were transported only two times from Polignano a Mare (South of Italy) to the supermarket van Gurp in Roosendaal (Netherlands). Originally three trips were plant. But due to bad weather conditions the third trip was cancelled: table grapes were moulding before harvest.

Three different kinds of product groups (table grapes) were transported unfoiled in the two trips: In the FreshDemo Van: humidified (H) table grapes as well as disinfected and humidified (HD) table grapes and Unfoiled reference products were transported by the conventional LKW without humidification (C).

9.2 Material

To define the analysis a literature reserach was executed. Important parameter to evaluate the quality of table grapes is the analysis of Vitamin C.

A comprehensive analytic of pH, drying substance, sensory, weight loss, visual decay and moulding gave an evaluation of quality aspects documented additionally with pictures.

Due to literature (typical shelf life of table grapes at 5°C: 2 weeks at a maximum) an analytics plan was established:

Storage day 1: delivery of table grapes to van Gurp.

Humidified and disinfected (HD) and humidified (H) table grapes transported with the FreshDemo van (average 3-4°C at 70-80%) were stored at 5°C with an average relative humidity of 80-90%.

Conventional transported (C) table grapes were stored at 5°C without additional humidification.

All products (with and without humidification) were stored for 15 days at van Gurp, analysed and evaluated:

- Pictures are taken daily. –
- Weight loss, visual evaluation of decay and mould are executed all three days in the supermarket

Products were delivered to ttz Bremerhaven to analyse pH, drying substance and to a laboratory in Bremen to analyse Vitamin C on delivery day and on storage day 15.

9.3 Results

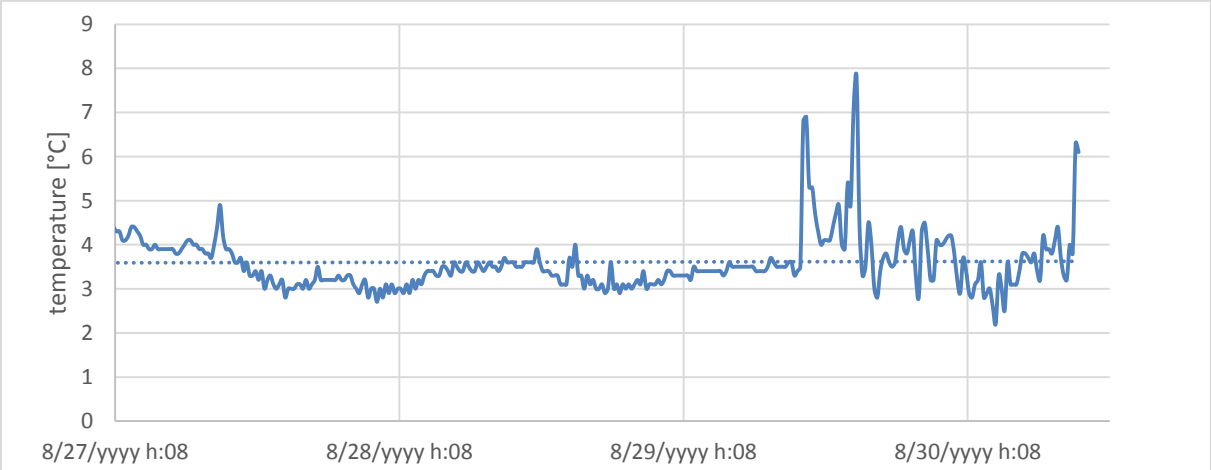


Figure L: exemplary data of trip 2 (average temperature 3.7°C): the two peaks on 29.08.2016 are during unloading of products at van Gurps supermarket.

9.3.1 Weight loss

For weight documentation all three days each box of table grapes was weighed.

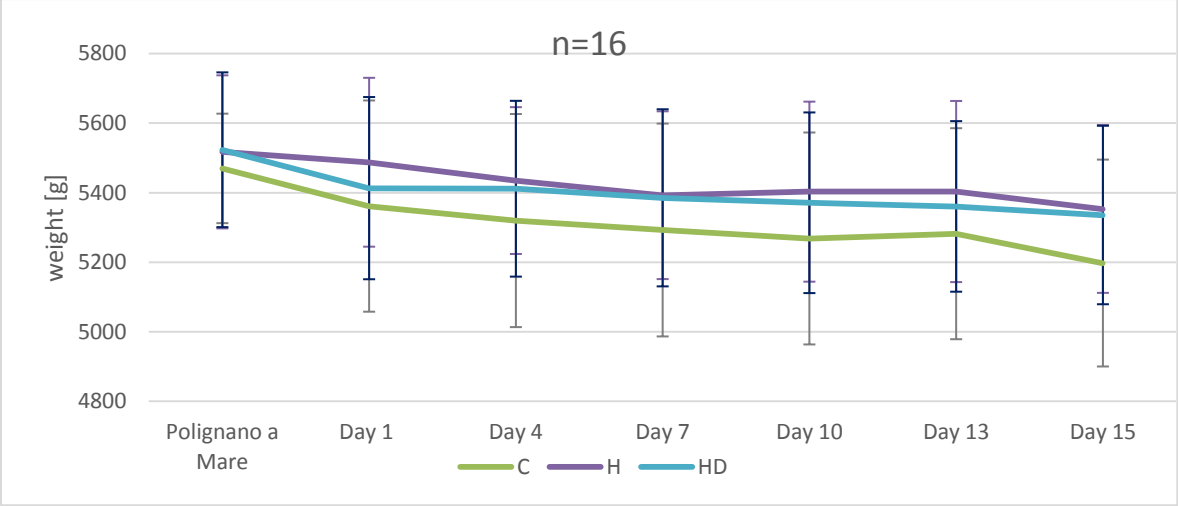


Figure M: influence of humidification on changings in weight

Percentage weight loss between start of transport and storage day 15:

Conventional: 4.98 %; Humidified: 2.98 %; Treated with Formula 5 and humidified: 3.40%

In Figure M it could be seen that the conventional (C) transported and stored table grapes offered the highest weight loss of 4.98%. In comparison the humidified and disinfected (HD) and humidified (H) transported and stored table grapes offered a lower weight loss (2.98% (H) and 3.40% (HD)).

The transport time (4 days) lead to the highest weight loss of the conventional transported (C) table grapes whereas the humidified (H) transported table grapes offered nearly no changing in weight during the transport time. The humidified and disinfected table grapes offered similar weight loss during transport than the conventional grapes.

During storage all products offered weight loss, but the weight loss of humidified (H and HD) stored table grapes was minimized and long-time constant.

Conclusion: humidification during transport of table grapes have the largest influence on the minimized weight loss.

9.3.2 Pictures

Day 15

Conventional Humidified Humidified and treated with Formula 5

After day 15 of storage conventional stored (C) table grapes offered first decay and non-equal areas on the surface (black marked area on left picture). Humidified stored (H and HD) table grapes did not have any decay or non-equal structures.

9.3.3 Visual decay and moulding – shelf life

The first day with visual moulding or decay on the products surface was documented for all three kinds of table grapes.

Due to weather conditions the first day of moulding and decay documentation is very different between table grapes of trip 1 and trip 2 (see Table 14):

Table 14: documentation of first day of visible moulding and decay formation of table grapes

	1 day moulding trip 1	1 day moulding trip 2	1 day decay trip 1	1 day decay trip 2
C	15	4	15	4
H	13	4	13	4
HD	10	4	15	4

On trip 2 all products offer decay and moulding on day 4 of storage.

On trip 1 there could be seen differences: Humidified and disinfected (HD) and humidified treated (H) table grapes offered first moulding on the surface 2-5 days later than conventional stored (C) table grapes. The formation of decays was delayed for 3 days for humidified table grapes (H) in contrast to conventional and humidified and disinfected products.

Conventional stored grapes: 3 pieces offered mould growing
Humidified stored grapes: 2 pieces offered mould growing
Humidified+Formula 5 treated stored grapes: 2 pieces offered mould growing

Conclusion: No significant difference between treated and non-treated table grapes could be seen concerning decay. The formation of visible moulds was

reduced between 2-5 days for humidified and humidified and disinfected products.

9.3.4 pH, drying substance and vitamin C

Table 15 shows the average pH and drying substance of table grapes of all two trips on storage day 1 and day 15.

No changings in pH were visible during storage time (all products had same pH).

For drying substance analysis, a thin layer of table grapes mousse was given in a dish and dried at 103°C until constant weight is detectable. This method is established for vegetables in dependence to official method § 64 LFBG 06.00 – 3 for the detection of meat and meat-products.

103 °C is the standard temperature for lots of products to detect the drying substance. The products are given in a hot cabinet with adjusted 103°C for evaporate the water inside. The product is weight out all 24 hours until weight stability is achieved. Drying substance is evaluation because lots of parameters use drying substance as base.

The conventional and humidified and treated with Formula 5 samples offered nearly same drying substance with a minimal reduction during storage time. The humidified transported stored table grapes (H) offered higher drying substance in the beginning of storage and no reduction but an increase of drying substance during 15 days of storage.

Table 15: average pH and drying substance of table grapes on storage day 1 and 15

	Average pH Day 1	Average pH Day 15	average drying substance ds [g/100g sample] Day 1	average drying substance ds [g/100g sample] Day 15
conventional	3,92	3,89	13,27	13,22
humidified	3,92	3,80	14,44	15,27
humidified+treated with Formula 5	3,92	3,84	13,45	13,12

Conclusion: Optimal adjusted ambient humidity leads to stability in drying substance.

To analyse vitamin C, 100 g of table grapes were given to an external laboratory to detect the vitamin C content of table grapes via HPLC.

Table 16: laboratory analysis results for vitamin C content in table grapes

sample ID		Vitamin C day 1 [mg/g drying substance]	Vitamin C day 15 [mg/g drying substance]	% changing [neg. value means gain]
Table grapes	conventional	0,07518797	0,098484848	-30,98484848
	humidified	0,076388889	0,098039216	-28,34224599
	humidified+Formula 5 treated	0,081481481	0,145038168	-78,00138793

Table 16 show the results of the analysis of vitamin C content of table grapes: It could be seen that transport and storage with humidification with Formula 5 treatment resulted in a gain of vitamin C content after storing time of 78%.

9.4 Conclusion and summary

The influence of ultrasonic humidification technology on table grapes during transport and storage was evaluated in this case study.

Evaluation parameter of weight loss, appearance, decay/moulding, pH, drying substance, vitamin C and sugar content as well as sensory were assessed for a storage time of 15 days.

An overview of all results is shown in the following table Table 17

Table 17: summary of evaluation results with C as reference (evaluation in comparison to C) + means positive effect; - negative effect; o no significant effect

parameter	H	HD
Weight loss	++	+
Visual decay	+	+/-
moulding/shelf life	+	++
Drying substance/pH	+	+/-
Vitamin C content	+	++

The humidified products offer a minimized weight loss as well as better visual decay, moulding and an elongation of shelf life up to 2 days. Drying substance and vitamin c content increase after 15 days of storage.

The humidified and disinfected products exhibit a little bit higher weight loss but less the conventional stored products. Parameters of shelf life and vitamin C content increase significantly in comparison to the conventional transported and stored table grapes.

In sum humidification during transport and storage effected the quality of table grapes (H and HD) in a positive way. Nutritional parameters of vitamin C were influenced significantly as well as a reduction of weight loss and a significant longer shelf life up to 5 days.

10. Case study cauliflower and escarole

10.1 Trip

Cauliflower and escarole were transported from Savasun S.A. Mas Damia S/N Vilanova D'escornalbou (Spain) 1600 km to a supermarket in the Netherlands in Den Dungen (see Figure I). Before starting the trip, sanitizer treated and humidified products were loaded and treated for 25 minutes with 10% Formula 5. After treatment doors were open and the humidified transported products were loaded. Temperature, relative humidity and trip is documented via online GPS monitoring (see Figure I and Figure J). The average temperature is around 4-5°C during the trip.

Conventional transported products were tramsported at same temperatures (and not humidified). After arriving in Schijndel weight, pictures, decay/visual molding as well as sensory had been evaluated during storage time of 2 weeks. For analysing pH, drying substance, the products were delivered to ttz Bremerhaven. In an accredited laboratory in Bremen Vitamine K for escarole and Vitamin C for cauliflower had been detected via HPLC method.

Figure N: Route from Spain to the Netherlands

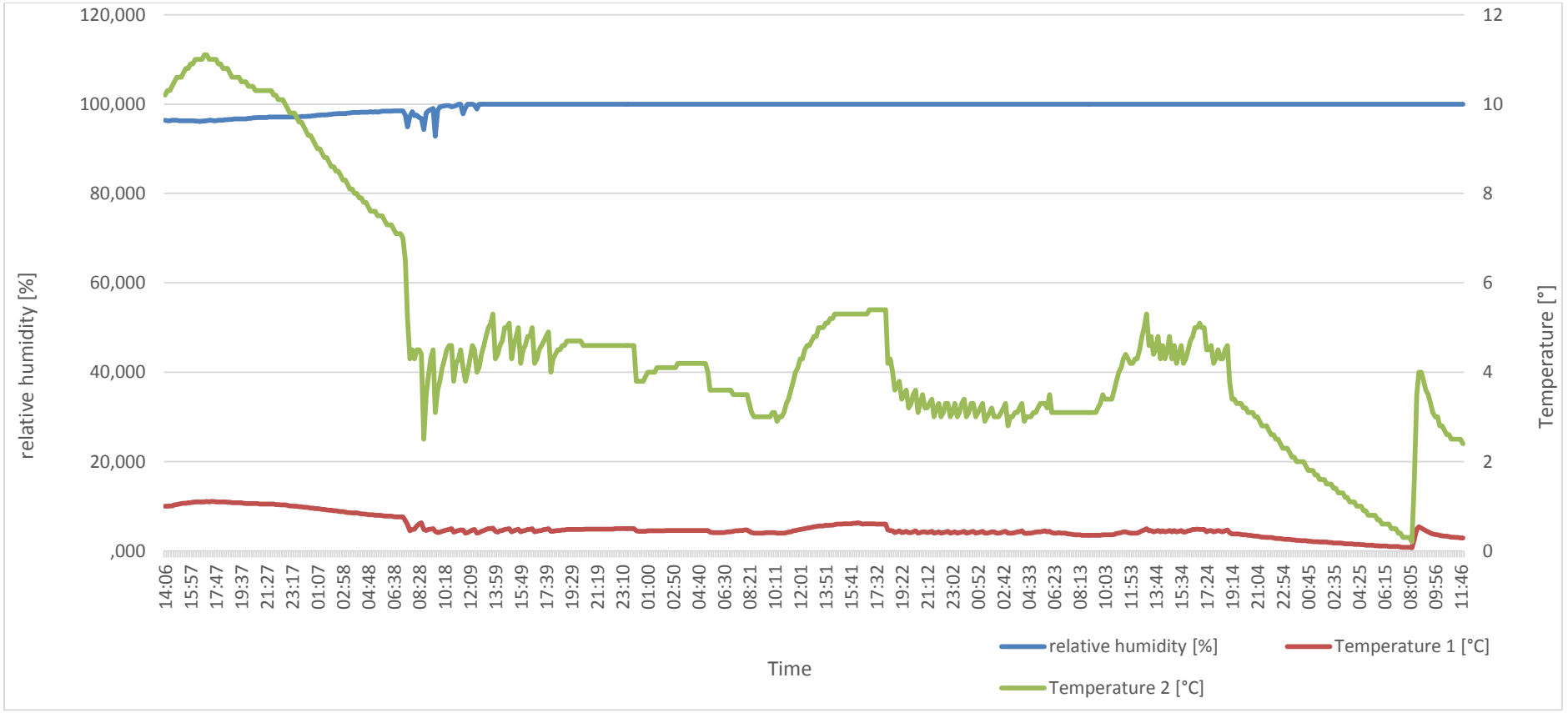


Figure O: Temperature during transport in the Van

Regarding the humidification systems, all type of systems have functioned well during the trial period. We have faced a minor problem with a fan. This was easily solved.

10.2 Results

10.2.1 Pictures and sensory evaluation

For the visual evaluation the pictures of trip 1 were used exemplary:

Escarole

Day 1: Conventional

Humidified

Humidified and Formula 5 treated

Day 4: Conventional

Humidified

Humidified and Formula 5 treated

Day 8: Conventional

Humidified

Humidified and Formula 5 treated

Day 11: Conventional

Humidified

Humidified and Formula 5 treated

The conventional escarole offered directly after delivery a brown stalk whereas the humidified and humidified and Formula 5 treated escarole even on day 11 do not have such dark brown stalk.

Additionally the leafs looked fresher and more intense green directly after delivery and on all storing days.

The humidified and humidified and Formula 5 treated escarole offered more taste and flavour and a better freshness.

Cauliflower

Day 1: Conventional

Humidified

Humidified and Formula 5 treated

Day 4: Conventional

Humidified

Humidified and Formula 5 treated

Day 8: Conventional

Humidified

Humidified and Formula 5 treated

Day 11: Conventional

Humidified

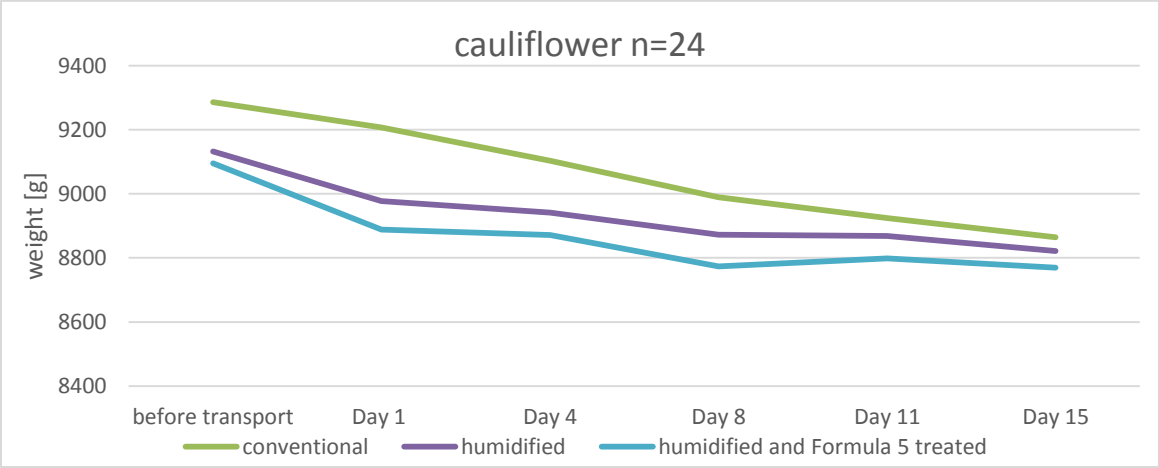
Humidified and Formula 5 treated

The conventional cauliflower offered after 11 days of storing less fresh appearance.

Additionally on the cauliflower brown areas were visible. The humidified and humidified and Formula 5 treated cauliflower offered more taste and flavour and a better freshness.

Conclusion: humidification during transport and storing leads to fresher appearance and longer shelf-life up to 4 days for escarole and increasing sensory parameter

10.2.2 Weight

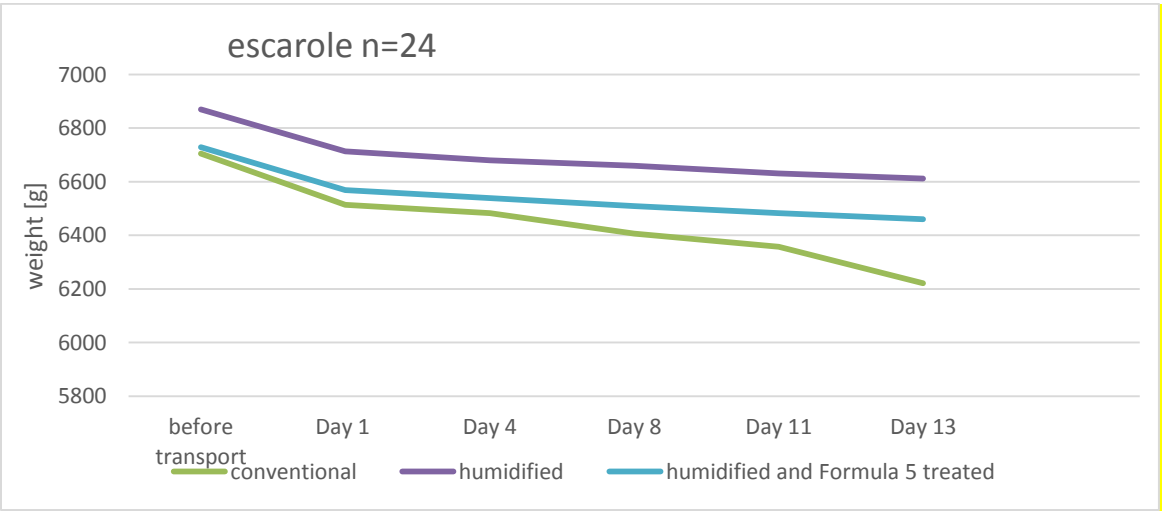


Sample ID	Percentage weight loss
C	4.54%
H	3.41%
HD	3.59%

Figure P: influence of transport and storing conditions on cauliflowers changings in weight

Conventional transported and stored cauliflower offered the largest weight loss (4.54 %), especially on the transport and the first 4 storing days (see Figure K).

Humidified and humidified and Formula 5 treated cauliflower offered an average weight loss of 3.50 %.



Sample ID	Percentage weight loss
C	7.22%
H	3.75%
HD	3.98%

Figure Q: influence of transport and storing conditions on escaroles changings in weight

Conventional transported and stored escarole offered the largest weight loss of 7.22% whereas the humidified and humidified and Formula 5 treated escarole offered an average weight loss of 3.87% (see Figure L). This means that the weight loss was minimized of approx. 50% by using humidification during transport and storing!

Conclusion: Humidification during transport and storing of cauliflower and escarole leads to minimization of weight loss of approx. 50% for escarole in comparison to conventional transported and stored products.

10.2.3 pH/drying substance and vitamin C/Vitamin K

For escarole as well as for cauliflower no significant changings in pH and drying substance were visible.

Average pH (escarole): 5.60 on day 1 and on day 15
Average pH (cauliflower): 6.36 on day 1 and 6.33 on day 15
Average drying substance (escarole): 7.60 on day 1 and on day 15
Average drying substance (cauliflower): 6.60 on day 1 and 6.50 on day 15

Conclusion: Humidification during transport and storing of cauliflower and escarole did not have a significant effect on pH and drying substance.

To analyse vitamin C, 100 g of cauliflower were given to an external laboratory to detect the vitamin C content as well as the vitamin K content from 100 g of escarole via HPLC. All results are shown in Table 18:

Table 18: laboratory analysis results for vitamin C content in cauliflower as well as vitamin K in escarole

sample ID		Vitamin K day 1 [µg/g drying substance]	Vitamin K day 15 [µg/g drying substance]	% changing [neg. value means gain]
escarole	conventional	22,01282051	30,12195122	-36,83821754
	humidified	23,76315789	24,97402597	-5,095568883
	humidified+Formula 5 treated	24,12857143	27,26027397	-12,97922902
sample ID		Vitamin C day 1 [mg/g drying substance]	Vitamin C day 15 [mg/g drying substance]	% changing [neg. value means gain]
cauliflower	conventional	3,089552239	3,712121212	-20,15078319
	humidified	3,353846154	3,661538462	-9,174311927
	humidified+Formula 5 treated	2,646153846	3,515625	-32,85792151

The vitamin K content of escarole increased for all three kinds of products whereas the conventional transported and stored escarole offered the highest gain with 36.8%.

For cauliflower the humidified and Formula 5 treated products offered the highest gain of vitamin C after storage time with 32.86%.

10.3 Summary

The influence of ultrasonic humidification technology on cauliflower and escarole during transport and storage was evaluated in this case study.

Evaluation parameter of weight loss, appearance, decay/moulding, pH, drying substance vitamin C and Vitamin K as well as sensory were assessed for a storage time of 15 days.

An overview of all results is shown in the following table

+ means positive effect; *- negative effect* ; *o no significant effect* (compared to C)

summary of evaluation results cauliflower with C as reference (evaluation in comparison to C)

parameter	H	HD
Weight loss	+	+
Visual decay	+	+
moulding/shelf life	+	+
Drying substance/pH	o	o
Sensory evaluation	+	+
Vitamin K content	-	++

summary of evaluation results escarole with C as reference (evaluation in comparison to C)

parameter	H	HD
Weight loss	+	+
Visual decay	+	+
moulding/shelf life	++	++
Drying substance/pH	o	o
Sensory evaluation	+	+
Vitamin C content	-	-

The case studies demonstrated the effect of the ultrasonic humidification technology on the product quality and their shelf-life.

All products achieved high quality in freshness, shelf-life, appearance and improved sensory parameters after transport and storing with humidification (relative humidity approx. 85-95%). The weight loss was minimized up to 3%.

By addition of a natural sanitizer (Formula 5) a positive effect on cauliflower was detectable:

After 15 days of storing the Formula5 treated cauliflower offered the highest gain of Vitamin K content in comparison to the conventional transported and stored cauliflower.

11. Case study lettuce

11.1 Executive Summary

A comparative laboratory test (ADESVA Pilot Plant) was carried out with two storage chambers of 11 m3, one with the installed technology of ultrasonic humidifiers (HR 80%), supplied by BIOAZUL, and the other without humidifier, simulating typical storage. The development of the experiment was carried out in 2 lettuce cultivars Iceberg (V1) and Romana (V2), using an experimental design of random blocks, with three replicates and four samples. In the experiment the cultivars were preserved, 3 days at 3 ° C (simulating the transport) and the rest on days at 9 ° C-10 ° C, simulating their temperature in the exhibitor. The study lasted up to 14 days of life.

The variables studied throughout their useful life were weight loss, firmness, external and internal appearance, wilting, stem darkening, rotting and mold development. The results indicated highly significant differences between the two cold storage systems, with a better performance in less weight loss and better firmness and appearance, the ultrasonic humidifier conservation system (supplied by BIOAZUL). This system improves the weight loss of 43% for the Iceberg variety and 82% for the Romana variety.

As a general conclusion, the validation of this test demonstrates that the preservation of lettuce stored in cold-storage and with the ultrasonic humidification system improves the quality and along the shelf-life.

Table 19: Trial Schedule

FEBRUARY 2017						
L	M	X	J	V	S	D
30	31	1	2	3	4	5
		TM0		TM1		
6	7	8	9	10	11	12
TM2				TM3		
13	14	15	16	17	18	19
TM4						
20	21	22	23	24	25	26
27	28					

11.2 Design and execution of the project

For the design and the experimental analysis of the data we used the Excel programs and the statistical specific MINITAB.

In the analysis of the data, ANOVA was used to find the significant differences with a confidence level of 95% (p = 0.05).

The work includes the development of the experiment in which it is tried to evaluate if there are differences between theses. The samples tested have been lettuces of 2 different varieties (V1 Iceberg; V2 Romana).

For the elaboration of the experimental design, we have collected 48 units of lettuce selected in the most homogeneous way possible. The input of raw material is performed on 31/1/17.

The samples remain 3 days at 3 ° C simulating transport, and the rest of the test at 9-10 ° C simulating the sales chain.

Two different theses are tested: Thesis H: BIOAZUL ultrasonic humidification technology, with a humidity index of 80%; And Thesis C: thesis control, conventional technology of frigoconservation.

For each thesis were executed with 4 samples of 3 replicates in each variety. Carrying the test at 14 days of life. The nomenclature of the samples is as follows:

Variety 1	Variety 2
V1CTM1R1	V2CTM1R1
V1CTM1R2	V2CTM1R2
V1CTM1R3	V2CTM1R3
V1HTM1R1	V2HTM1R1
V1HTM1R2	V2HTM1R2
V1HTM1R3	V2HTM1R3

Figure R: Sample Nomenclature

Being (V) Variety, (C) thesis Control, (H) thesis BIOAZUL technology (TM) Sampling that corresponds to each output, (R) Replica.

Figure S: Raw material, variety Romana.

Figure T: Raw material, variety Iceberg.

Samples are received at the ADESVA facilities, in field boxes, on January 31 with a 1-day shelf life. The samples were placed in plastic boxes washed and disinfected, each box corresponding to an output of a variety. For this test, there are 48 lettuces in total, divided into two varieties. For each variety, there were 4 exits and 3 replicates per exit, in two different test theses.

During the development of the test the raw material has been analyzed up to 14 days of life.

Samples are stored in the chamber at 3 ° C for 3 days and the remainder at 9-10 ° C. On February 1, an initial sampling (tm0) is carried out to evaluate the state of the raw material. Samples are then taken according to the test schedule. In these samples the following parameters are evaluated and analyzed: weight, firmness, appearance, internal appearance, stem darkening, wilt, rot and presence of mold.

Figure U: Camera with BIOAZUL technology

Figure V: Control camera

Output 4 of each variety and thesis are weighed and photographed every day that a sampling is done, in order to track the weight.

Figure W: Sampling

11.3 Measurement parameters

The parameters analyzed in the sampling are as follows:

- **Firmness**: Measurement of firmness on a rating scale based on manual pressure on the product. Scale:

Table 1. Rating scale for head firmness based on hand pressure

Score[z]	Firmness description
1	*Soft*, easily compressed or spongy
2	*Fairly firm*, neither soft nor firm, good head formation
3	*Firm*, compact but may yield slightly to moderate pressure
4	*Hard*, compact and solid
5	*Extra-hard*, over-mature, may have cracked mid ribs

Figure X: Firmness rating scale. Source: Kader, A., W. Lipton and L. Moms. 1973

- **Appearance or visual quality**: assessment of the external appearance of the product based on the appearance of defects, discoloration and general visual appearance. Scale:

Table 2. Rating scale for visual quality

Score	Visual quality description
9	*Excellent*, essentially free from defects
7	*Good*, minor defects; not objectionable
5	*Fair*, slightly to moderately objectionable defects; lower limit of sales appeal
3	*Poor*, excessive defects, limit of salability
1	*Extremely poor*, not usable

Figure Y: Appearance Rating Scale. Source: Kader, A., W. Lipton and L. Moms. 1973

- **Internal appearance**: subjective assessment of the internal appearance of the fruits. Based on the same parameters as the external appearance. Scale:

Table 2. Rating scale for visual quality

Score	Visual quality description
9	*Excellent*, essentially free from defects
7	*Good*, minor defects; not objectionable
5	*Fair*, slightly to moderately objectionable defects; lower limit of sales appeal
3	*Poor*, excessive defects, limit of salability
1	*Extremely poor*, not usable

Figure Z: Internal appearance rating scale. Source: Kader, A., W. Lipton and L. Moms. 1973

- **Rottenness**: subjective measure of rot. Scale:

Score	Degree of severity
1	*None*
3	*Slight*
5	*Moderate*
7	*Severe*
9	*Extreme*

Figure AA: Rating scale for rot. Source: Kader, A., W. Lipton and L. Moms. 1973

- **Mold**: subjective measure of the appearance of mold. Scale:

Score	Degree of severity
1	*None*
3	*Slight*
5	*Moderate*
7	*Severe*
9	*Extreme*

Figure BB: Mold assessment scale. Source: Kader, A., W. Lipton and L. Moms. 1973

- **Wilt**: subjective measure of wilting, based on dehydration and leaf decay. Scale:

Table 5. Rating scale for wilting

Score	Wilting description
1	*None*
3	*Slight*, not objectionable
5	*Moderate*, becoming objectionable
7	*Severe*, definitely objectionable
9	*Extreme*, not acceptable under normal conditions

Figure CC: Wilt assessment scale. Source: Kader, A., W. Lipton and L. Moms. 1973. Source: Kader, A., W. Lipton and L. Moms. 1973

- **Darkening of the stem**: Scale to evaluate the degree of darkening of the stem. Scale:

Score	Butt discoloration description
1	*None*, fresh cut appearance
3	*Slight*
5	*Moderate*
7	*Severe*
9	*Extreme*, very dark

Figure DD: Stem darkening titration scale. Source: Kader, A., W. Lipton and L. Moms. 1973

11.4 Results

11.4.1 Firmness

Firmness shows a downward trend along the useful life. Statistical analysis reveals that there are no significant differences between theses for any of the two varieties (p> 0.05). For both varieties the thesis H has presented better results.

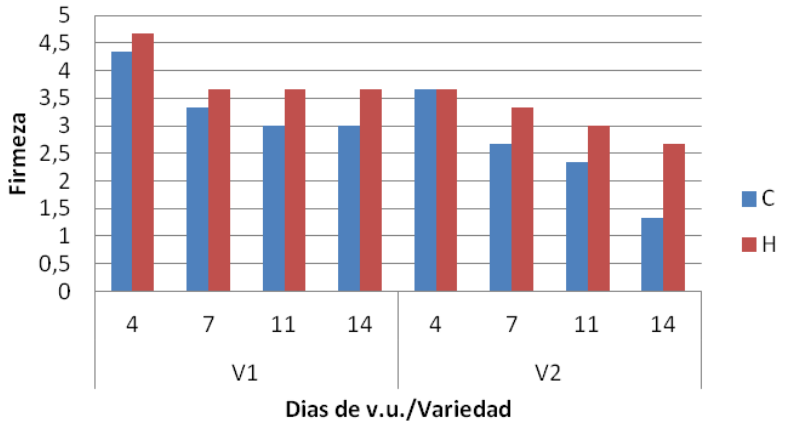


Figure EE: Firmness graph

11.4.2 Stump darkness

There are no significant differences in stem darkening, nor are there

Significant differences after statistical analysis. In the case of variety 2, a sample with a worse behavior appears, but this is an isolated case.

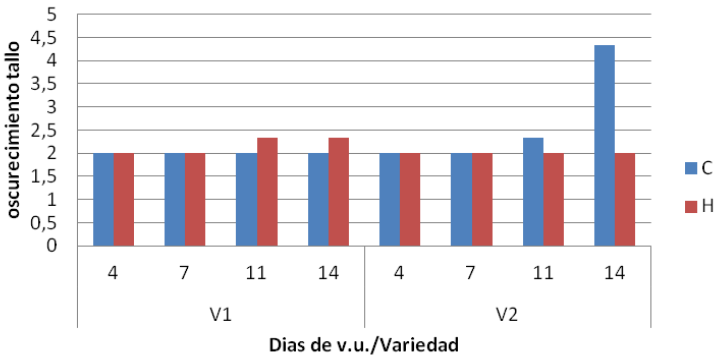


Figure FF: Stem obscuration graph

11.4.3 Appearance

Appearance is a very significant parameter when evaluating the quality of crops. Both varieties present evident differences between theses, being more evident when increasing the useful life. For the two varieties, the H thesis presents the best results. Statistical treatment shows that there is an improvement of up to 1.5 points for the two varieties in appearance.

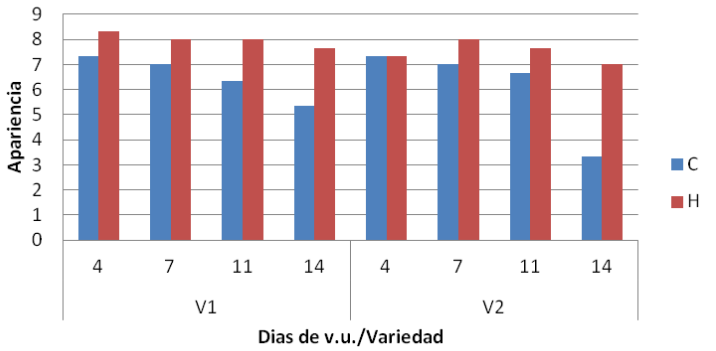


Figure GG: Appearance graph

11.4.4 Internal appearance

Statistically neither of the two varieties show significant differences for internal appearance. In the case of variety 1, a greater degree of difference is appreciated than variety 2. The thesis that presents the best results is thesis H.

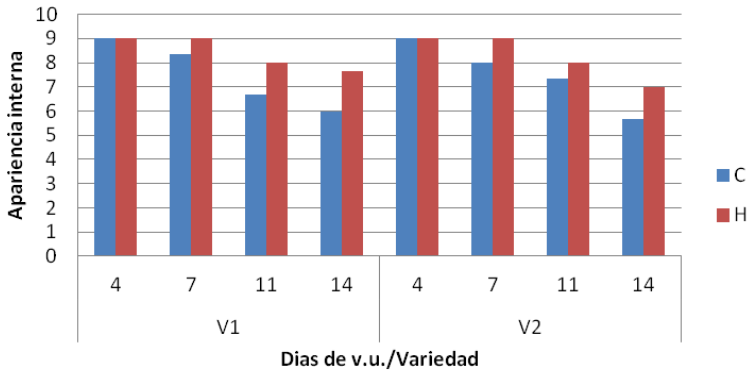


Figure HH: Internal appearance graph

Figure II: Thesis sample cut H **Figure JJ: Cut thesis sample Control**

11.4.5 Wilting

In the case of variety 1, there are clear differences between theses, such as shows the statistical analysis of the data ($p < 0.05$). For variety 2 the value of p is very close to 0.05 although a little higher, statistically we cannot affirm that there are significant differences. But there are clear visual differences between theses.

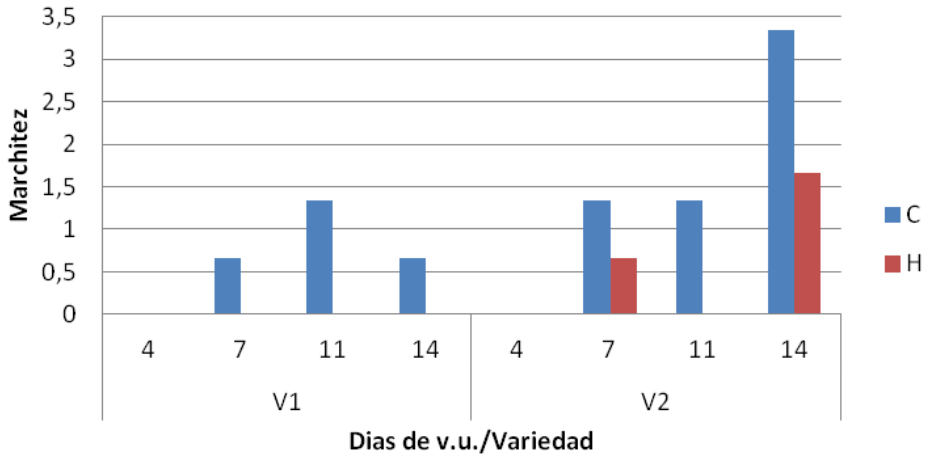


Figure KK: Graph of wilting

Figure LL: Thesis sample H

Figure MM: Thesis sample Control

11.4.6 Rottness

Both varieties have shown very similar behavior in terms of rot. Rot has appeared for end-of-life control theses. Statistical analysis did not show significant differences.

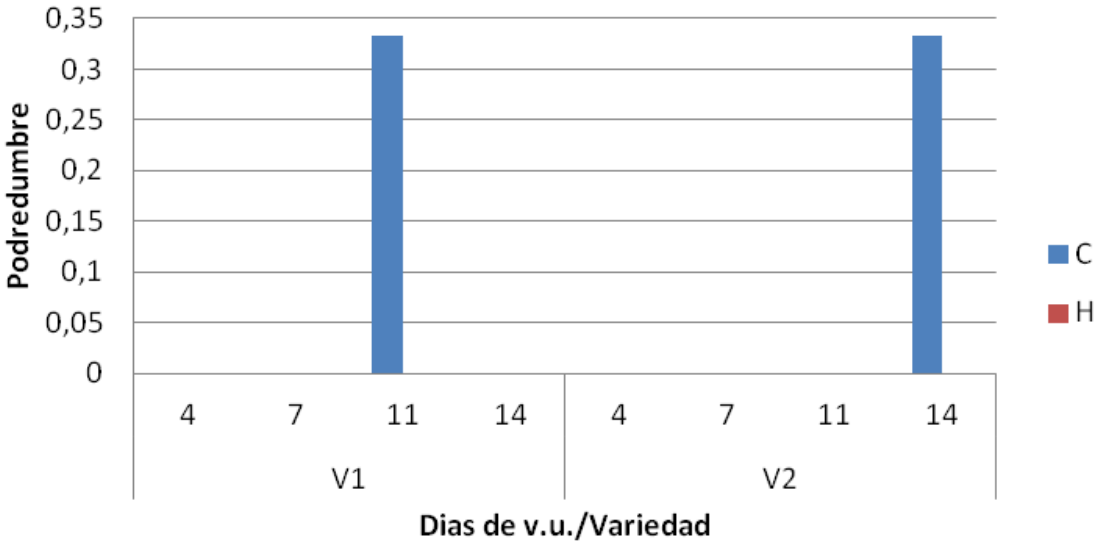


Figure NN: Graph of rottness

11.4.7 Mold

Only one case of mold has occurred, it has been in the thesis control of the Variety 2 at the end of the useful life.

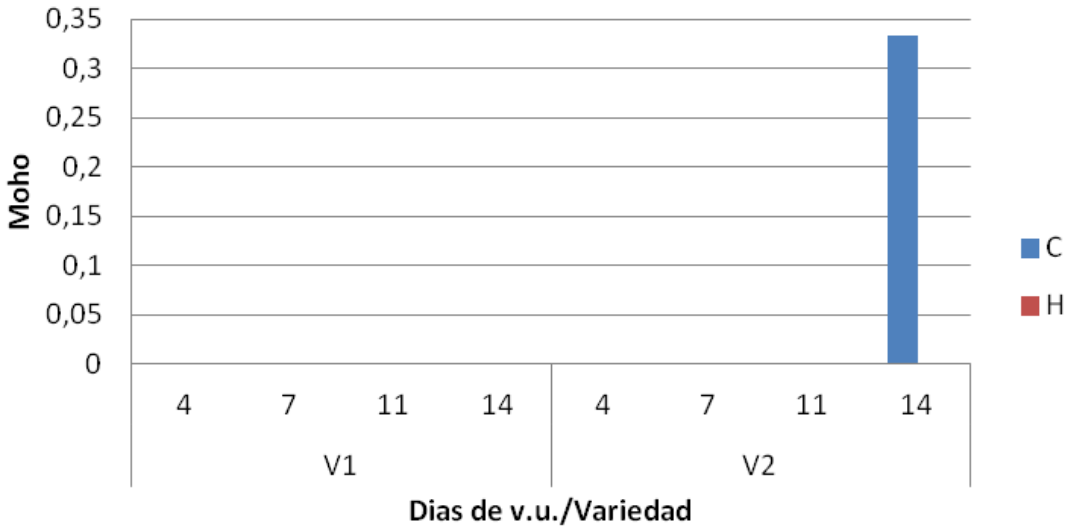


Figure OO: Graph of mold

11.4.8 Weight loss

There is a clear difference between theses for weight loss. Thesis H has presented a reduction in weight loss of up to 43% for variety 1 (iceberg) and up to 82% for variety 2 (Roman).

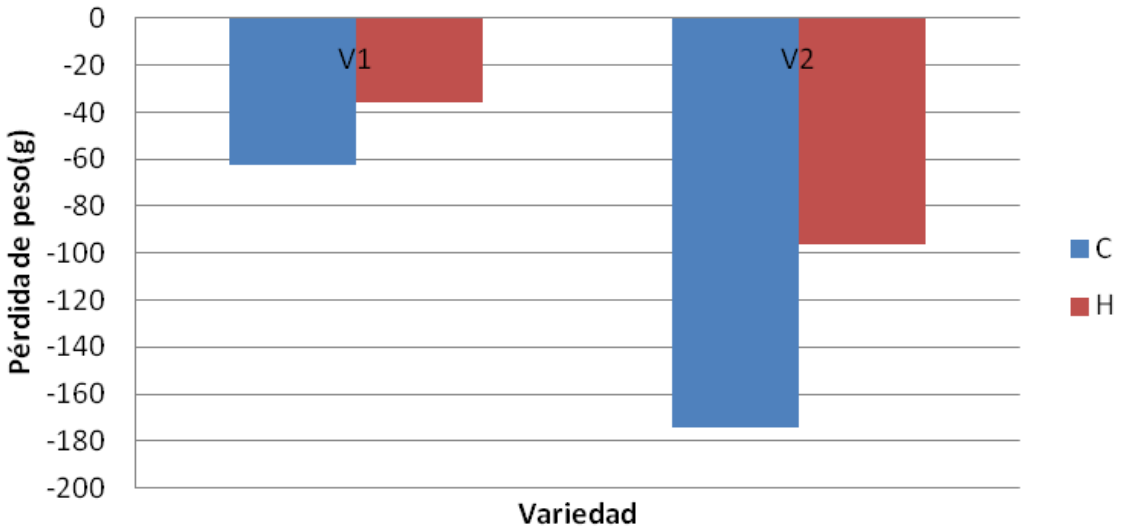


Figure PP: Weight loss graph

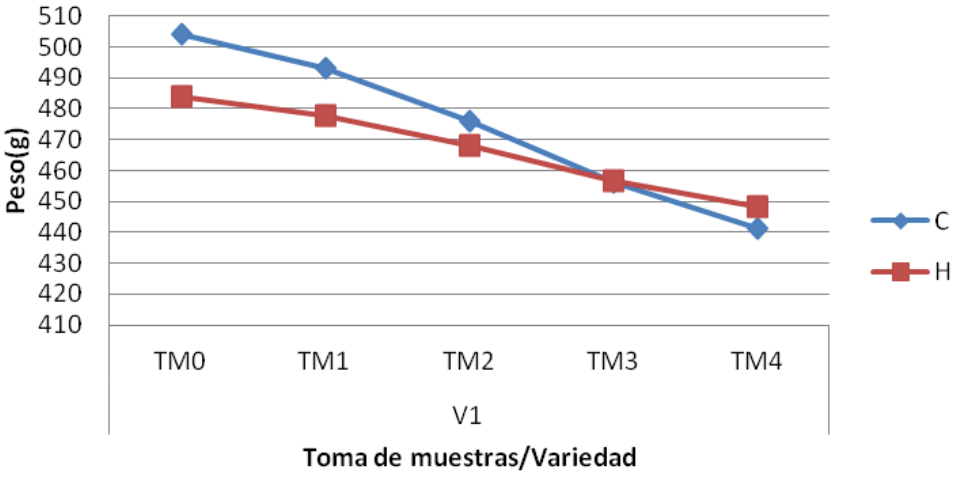


Figure QQ: Graph of weight evolution. Variety 1

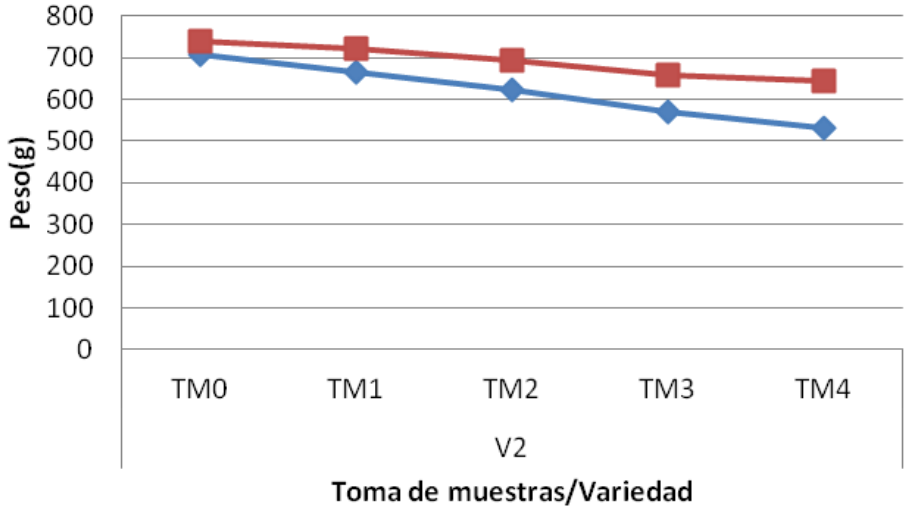


Figure RR: Graph of weight evolution. Variety 2

11.5 Conclusions

The conclusions of this study are briefly summarized in the following statements:

I. The weight loss along the days of shelf life has been a variable significant difference between both treatments (chamber with ultrasonic humidifier system) vs (chamber without humidifier treatment). Repeating the same behavior in both varieties tested. It has been achieved with the system proposed by the company BIOAZUL, 43% less weight loss in the Iceberg variety and 82% in the variety Romana.

II. The external appearance has also shown significant differences. The Humidification system improves the external appearance along of shelf life, with an improvement over the control of 1.5 points by the Kader scale. Like the previous case with the loss of weight the variety Roman has shown a greater distinction in the appearance, when they have been both treatments compared.

III. The wilting, evaluated as leaf decay and wrinkling, has been a parameter that has increased with the days of life mostly in the control samples and in the variety

Romana. In the Roman variety, the samples preserved with the humidifier system have improved this value by 2 points (Kader scale) with respect to the control.

IV. The rest of the parameters considered in the study did not show significant differences in the quality throughout the useful life. No significant differences were found.

V. As a general conclusion, the validation of this trial indicate that the preservation of lettuce stored in cold and with the ultrasonic humidification system improves the quality and increase the days of its shelf life.

12. Additional laboratory analysis (ttz)

Products romaine lettuce, peaches and nectarines

Organism:

- *E. coli* and *Listeria inoccua* for romaine lettuce,
- *Penicillium expansum* for peaches and
- *Botrytis cinerea* for grapes

Trials should be executed to determine the optimal treatment duration and the effectivity of the used formula. Additionally, trails to demonstrate that the treatment does not lead to any changings of the products.

- Changings of products with HPLC analysis – An HPLC analysis to reference and treated products was performed to verify that there are no different peaks.

  Results:

  Formula 5 treated romaine lettuce offered a content of citric acid of 328.5 ppm, whereas the non-treated romaine lettuce exhibited a citric acid content of 74.6 ppm.

  Conclusion: Formula 5 is detectable on the products surface after treatment.

- Determination of treatment time - The misting intervals should be 10min 20 min & 30 min. The best one will be the treatment which will show a reduction of initial count after treatment.

  Results:

  - Directly after treatment (after 2 hours incubation time) romaine lettuce and peaches offered lowest numbers of organism after a treatment time of 20 minutes. But it is very curious, that a higher treatment time of 30 minutes leads to higher number of organism for peaches and romaine lettuce.
    For grapes treatment times of 20 minutes and 30 minutes offered nearly same results.
  - After storing at 5°C for 48 hours romaine lettuce and peaches offered lowest numbers of organism after a treatment time of 20 minutes. But it is very curious, that a higher treatment time of 30 minutes leads to higher number of organism for peaches.
    For the romaine lettuce treatment time of 20 minutes leads to no other organism growing in comparison to treatment times of 10 minutes and 30 minutes.
    For grapes treatment times of 20 minutes and 30 minutes offered nearly same results.

  Conclusion:

  A treatment time of 20 minutes for products of romaine lettuce, peaches and grapes with *E. coli, Botrytis* and *Penicillium* seems to be the optimal treatment time from microbiological side.

  But from scientific point of view, it is very curious that a longer treatment time of 30 minutes leads to a higher number of organism directly after treatment incubation time for peaches and romaine lettuce and after storing time of 48 hours for peaches.

  Additionally, a treatment with a sanitizer should lead to a reduction of organism at least of one power. But for all used treatment times, same dilutions were

evaluation. From scientific point of view, no significant determination of best treatment time could be given with this trials.

- Effectivity of formula:

1) **preparation & number of the cells is the following**

bacteria cultures were bought from DSMZ (freeze dried). The cultures had been reactivation and were cultured until great growing was visible. The total number of cells was detected photometrically (10^8 cfu/mL should be achieved).

2) **Innoculation**

Delivery of the challenge culture dose was achieved by pipetting of the challenge culture over each fruit/vegetable item with a 200µl dose of the 10^7 solution.

3) **Trial parameters**

	Pathogens	**Molds**
Dilution	10% w/v	10% w/v
2 hours holding temp. Temperature	22 °C	22 °C
Storage temp.	Refrigeration temp.	Refrigeration temp.
Holding Temp. after treatment	22 °C	22 °C
Duration	According to shelf life in retail selves (~ 7 days)	Until all the fruits have been contaminated
Intervals	Every second day	Daily record of rotted fruits with Penicillium or Botrytis

4) **Preparation of samples**

For instance BS ISO 16649-2:2001 & BS EN ISO 11290-2:1998 for *E.coli* and *Listeria* respectively.

Penicillium expansum and *Botrytis cinerea*: measure the amount of spoiled fruits every day to identify the percentage of rotted fruits until all fruit are rotted. Of course a sample of fungus filament from the spoiled fruit should be seen under microscope to confirm that is the targeted one.

Results

- Grapes:

Day 1 – inoculated

inoculated and treated with Formula 5

Day 2 inoculated inoculated and treated with Formula 5

Day 5 inoculated inoculated and treated with Formula 5

Day 6 inoculated inoculated and treated with Formula 5

Day 7 inoculated inoculated and treated with Formula 5

Day 8 inoculated inoculated and treated with Formula 5

Day 10 inoculated inoculated and treated with Formula 5

Day 20 inoculated inoculated and treated with Formula 5

Evaluation

The evaluation was done via photo-documentation to evaluate the time till mold growing is visible after inoculation and inoculation and treatment with Formula 5.

The grapes treated with Formula 5 after inoculation offer a more typical and fresher colour than the non-treated table grapes. Concerning decay and mold both products do not offer it after 20 days of storing.

Peaches:

Day 1 – inoculated inoculated and treated with Formula 5

Day 2 – inoculated inoculated and treated with Formula 5

Day 5 – inoculated inoculated and treated with Formula 5

Day 6 – inoculated inoculated and treated with Formula 5

Day 7 – inoculated inoculated and treated with Formula 5

Day 8 – inoculated inoculated and treated with Formula 5

Day 10 – inoculated inoculated and treated with Formula 5

Day 20 – inoculated inoculated and treated with Formula 5

Evaluation

The evaluation was done via photo-documentation to evaluate the time till mold growing is visible after inoculation and inoculation and treatment with Formula 5.

The peaches only inoculated (always left picture) offer from the beginning dark areas, where the inoculation takes place.

Peaches inoculated and treated with Formula 5 offer a development of mold growing: On storage day 7 molds are visible on the surface.

After 20 days of storing, inoculated and treated peaches offer minimal less growing of molds than the non-treated products.

Romaine lettuce

The evaluation of the romaine lettuce was done microbiologically. Samples were taken all two days, dilutions were prepared and given on agar plate.

The bacteria were counted after 1 day incubation.

Table 20 and Figure SS: show the total number of cells for inoculated products and inoculated and treated products on storing day 1. 3. 6 and 8.

It could be seen, that all Formula 5 treated products offer nearly no countable viable cells although the samples had been inoculated with 10^8 numbers of bacteria.

In contrast the inoculated products offer in average 10^6 total viable counts.

Table 20: total number of viable cells after different storing days

Probe	KbE/g Probe day 1	KbE/g Probe day 3	KbE/g Probe day 6	KbE/g Probe day 8
E. coli	1,9 x 10^6	2,4 x 10^6	8,9 x 10^5	8,1 x 10^5
E. coli F 5	1,0 x 10^2	< 10^2	< 10^2	< 10^2
Listeria	6,5 x 10^6	6,0 x 10^6	2,4 x 10^6	6,1 x 10^5
Listeria F 5	< 10^2	1,5 x 10^2	< 10^2	< 10^2

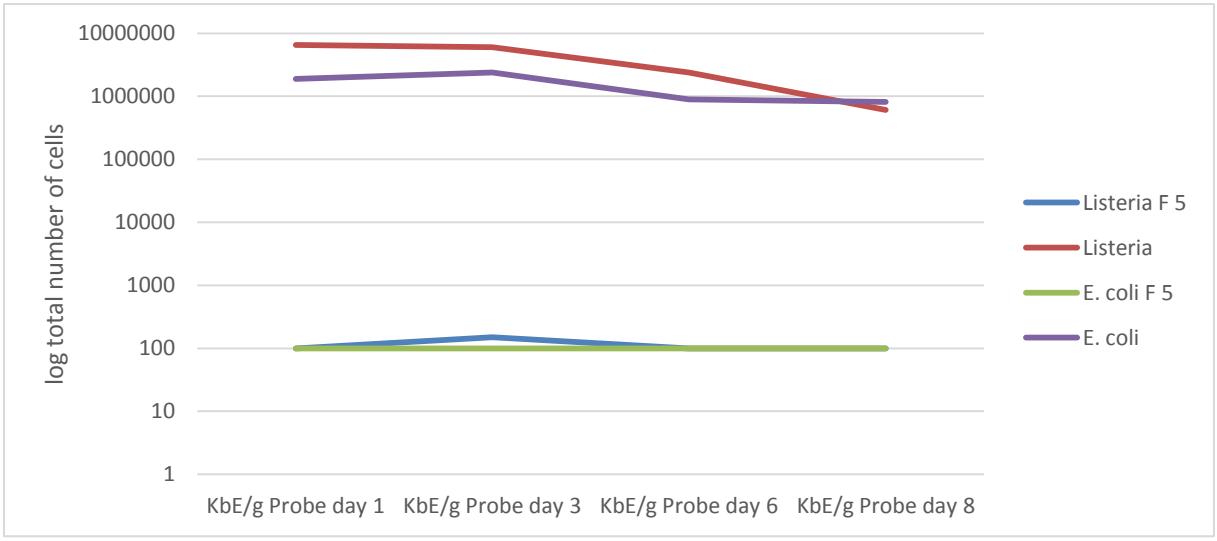


Figure SS: comparison of total number of cells of inoculated and inoculated and Formula 5 treated romaine lettuce

Conclusion

The evaluation of the different inoculated products showed that for bacteria a significant effect of Formula 5 is detectable:

The Formula 5 treated products offered 10^4 lower total number of cells for *E. coli* and *Listeria innocua* than the non-treated products.

For yeast and molds no real effect was visible: Peaches inoculated with *Penicillium expansum* and table grapes inoculated with *Botrytis cinerea* exhibited no significant difference between Formula 5 treated and non-treated products.

13. Summary and conclusion

Regarding the humidification systems, all type of systems have functioned well during the trial period. We have faced a minor problem with an outlet tube of a humidifier a cold store and have had some bigger problems with the mobile humidifiers in the van, which forced us to make a redesign and several modifications. All problems were solved and all systems are ready to install everywhere in the chain.

The case studies demonstrated the effect of the ultrasonic humidification technology on the product quality and their shelf-life.

All products achieved high quality in freshness, shelf-life, appearance, quality and nutritional parameters after transport and storing with humidification (relative humidity approx. 85-95%).

The application of ultrasonic humidification in general and especially the treatment with Formula 5 leads to high quality vegetables and a minimization of food waste. All results could be seen in the following table on the next page.

Highest influence of humidification during transport and storing were detectable for strawberries.

Highest influence of humidification and treatment of Formula 5 during transport and storing were detectable for nectarines, peaches, table grapes, escarole and cauliflower.

In general humidification as well as humidification and treatment with Formula 5 offered always increasing product quality, minimized weight loss, better shelf-life and freshness in comparison to conventional transported products!

	strawberry			table grapes			peaches			nectarines			cauliflower			escarole		
ID	**C**	**H**	**HD**	**C**	**H**	**HD**	**C**	**H**	**HD**	**C**	**H**	**HD**	**C**	**H**	**HD**	**C**	**H**	**HD**
weight loss	1	5	4	1	5	5	1	5	5	1	3	5	1	5	4	1	4	5
appearance	1	5	5	1	5	5	1	5	5	1	5	5	1	5	5	1	5	5
shelf life/moulding	1	5	5	1	3	5	1	5	5	1	4	5	1	5	5	1	5	5
sensory	1	5	3	1	5	5	1	5	5	1	5	5	1	5	5	1	5	5
Vitamin content	3	5	1	3	1	5	1	4	5	3	1	5	3	1	5	5	1	3
Sum	**7**	**25**	**18**	**7**	**19**	**25**	**5**	**24**	**25**	**7**	**18**	**25**	**7**	**21**	**24**	**9**	**20**	**23**

Different scores means differences in evaluation
5 points – best results
1 point – bad result

C = Conventional
H = Humidified
HD = Humidified and treated with Formula5