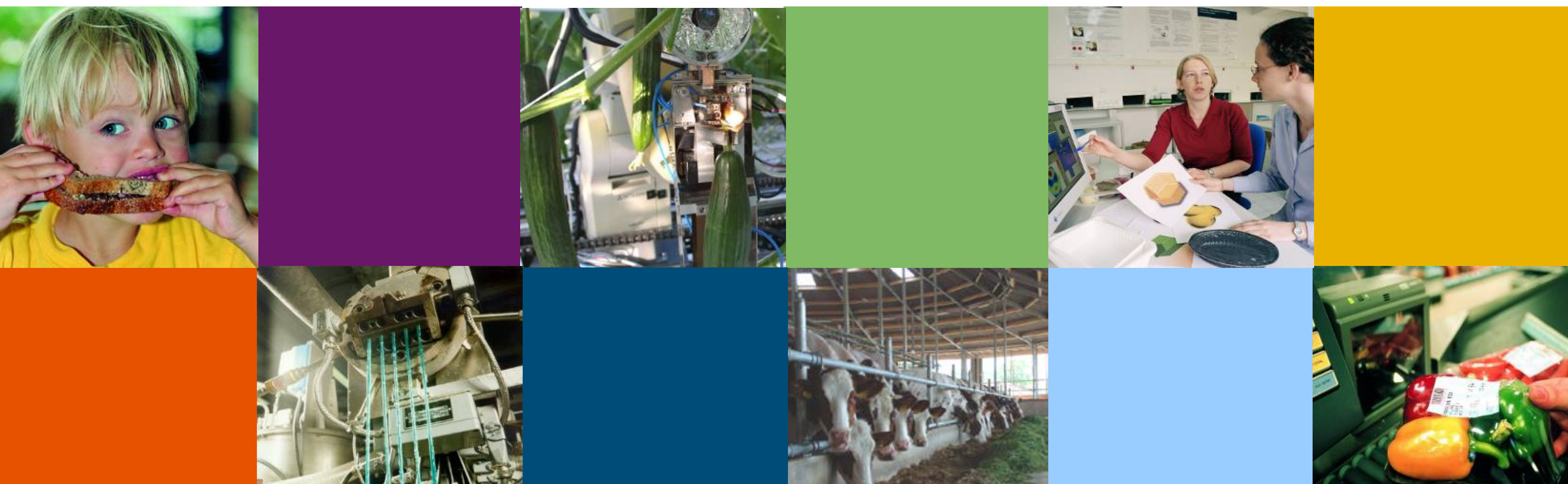
Effect of storage temperature and time on quality of Thompson seedless table grapes from Greece

A simulation of Reefer transport from South Africa or South America to the Netherlands
GreenCHAINge WP1 – Table Grapes

Manon Mensink
Eelke Westra

Report 1736



Colophon

Title	Effect of storage temperature and time on quality of Thompson seedless table grapes from Greece
Author(s)	Manon Mensink , Eelke Westra
Number	1736
Doi	https://doi.org/10.18174/503220
Date of publication	March 2017
Version	Final
Confidentiality	No
Approved by	Janneke de Kramer
Review	internal
Name reviewer	Bastiaan Brouwer
Sponsor	Foundation TKI Horticulture
Client	Bakker Barendrecht, VEZET, Albert Heijn, Maersk Line

Wageningen Food & Biobased Research
P.O. Box 17
NL-6700 AA Wageningen
Tel: +31 (0)317 480 084
E-mail: info.fbr@wur.nl
Internet: www.wur.nl/foodandbiobased-research

Abstract

The goal of this study is:

1. to investigate the effects of optimal and sub-optimal transport temperature, i.e. -0.5 °C vs. 3.5 °C during two and three weeks, on the quality of Thompson seedless grapes from Greece.
2. to investigate the effect of a decreased transport temperature, i.e. -1.5 °C, during two and three weeks on the quality of Thompson seedless grapes from Greece.

Table grapes produced in South Africa and South America are transported in Reefer containers to the Netherlands. This will take two to three weeks' time, depending on the route and the transport company.
The temperature setpoint of these containers is usually -0.5 to 0.5 °C. At the start of the season in January, when Brix values are under 14°, the transport temperature will be set to be around 1.5 °C, to prevent low temperature decay.
However, the temperature will only reach this setpoint close to the cooling unit, at de rear end of the container. Moving towards the door of the container, at the front end, temperatures will be higher and hot spots can occur when loading of the container is sub optimal. Temperature deviations of 2 to 3 °C from the setpoint have been reported, which will also affect product temperature.
A better temperature distribution throughout de load, that approaches the set point temperature, could lead to a more homogeneous product temperature. To see whether this results in a better and more homogeneous product quality during the retail phase, grapes were stored at either -0.5 or 3.5 °C for both two and three weeks. Furthermore, since Thompson seedless table grapes have relatively high Brix values, the question arose whether grapes with such high levels of soluble sugars can be transported at a lower temperature, i.e. -1.5 °C, without showing quality issues.

Our results show that on average, the quality of Thompson seedless table grapes from Greece is better when stored for two and three weeks at -1.5 and -0.5 °C than stored for those periods at 3.5 °C. However, within each temperature treatment the quality differences between replicates were large, involving punnets of moderate to bad quality in each treatment.
On average, the quality of the grapes is better when stored for two weeks than for three weeks. The biological variation of the starting material appeared to be high, complicating outcomes of this postharvest study. It is currently unclear what exactly causes this variation in this case.
The Brix values in week 38 to 42 were on average 19°. At start of the experiment, the question was whether grapes with relatively high levels of soluble sugars could be transported at a lower temperature, i.e. -1.5 °C, without showing quality issues. These grapes, with an average Brix value of 19° performed the same at -0.5°C as at -1.5°C, without showing more disorders at -1.5°C.

The average Brix values were higher in week 38 than in week 40 and 42, showing a difference of about 2 °Brix. Within each trial, Brix values varied a lot, the minimal and maximum values differing approximately 10 °Brix.
Both sampling methods for measuring Brix, the 3-berry method and the all-berry method, give comparable results. Brix values did not change significantly during storage.

Contents

1 Introduction

Table grapes, produced in South Africa and South America, are transported in Reefer containers to the Netherlands. This will take two to three weeks' time, depending on the route and the transport company.
The temperature setpoint of these containers usually is -0.5 to 0.5 °C. At start of the season in January, when Brix values are under 14°, transport temperature will be set to 1.5 °C, in order to prevent low temperature decay.
However, the temperature will only reach this setpoint close to the cooling unit, at de rear end of the container. Moving towards the door of the container, at the front end, temperatures will be higher and hot spots can occur, when loading is sub optimal. Temperature deviations of 2 to 3 °C from the setpoint have been reported, which will also affect product temperature.
A better temperature distribution throughout the load, that approaches the set point temperature, could lead to a more homogeneous product temperature. To see whether this results in a better and more homogeneous product quality during the retail phase, grapes were stored at either -0.5 or 3.5 °C for both two and three weeks.

Because of the transport history of grapes from South Africa or South America, this produce can't be used in a storage experiment in the Netherlands. Instead, we used Thompson seedless table grapes from Greece, which have a much shorter transport history.
Since Thompson seedless table grapes have relatively high Brix values, the question arose whether grapes with such high levels of soluble sugars can be transported at a lower temperature, i.e. -1.5 °C, without showing quality issues.

The experiment was set up over three trials, executed in weeks 38, 40 and 42 of 2016. In all three trials, quality inspection was performed both on the starting material and after storage. Quality inspection consisted of a non-destructive visual inspection, after which all samples went through a retail simulation, followed by a destructive final inspection.
Brix was measured using two sampling methods: the 3-berry method and the all-berries method, which were compared to each other.

Figure 1 Grapes in a sucrose solution: depending on their sugar concentration, grapes will float or sink

1.1 Goals

1. To investigate the effect of optimal and sub-optimal transport temperature, i.e. -0.5 °C vs. 3.5 °C during two and three weeks on the quality of Thompson seedless from Greece.
2. To investigate the effect of a lower transport temperature, i.e. -1.5 °C, during two and three weeks on the quality of Thompson seedless from Greece.

1.2 Research questions

The results of this study are aimed to answer the following questions:

- What are the effects of storage temperature and storage time on the quality of Thompson seedless grapes?
- What is the Brix level during the last 5 weeks of the Thompson season in Greece? And does the Brix vary between punnets?
- Do the 3-berry method and all-berry sampling method give comparable results?

2 Methods

2.1 Upon arrival in each trial

Figure 2 Grapes in cold store

2.1.1 Randomizing punnets

The grapes were delivered to Wageningen Food & Biobased Research (WFBR) in 8 to 10 carton boxes, each containing twenty 500 g punnets, in two layers.
To normalize potential differences in quality between boxes or layers, the punnets for a treatment were put together from different boxes and layers. A treatment consisted of 10 punnets in duplo. The grapes used in the first and second trial had different punnet codes. In the third trial, punnets with only two punnet codes were selected.

2.1.2 Storage treatments for transport simulation

To simulate transport under different temperatures, the grapes were put in cold storage for two or three weeks at -1.5, -0.5 or 3.5 °C. Each temperature treatment consisted of 20 punnets in a carton box carton box (Figure 2). The first and last boxes of each pile in the cold storage consisted of dummy boxes containing empty punnets.
The RH in the climate rooms was kept high, but was not controlled.
After storage, quality was visually inspected. Subsequently, the punnets went through the retail simulation followed by the final inspection (2.1.4).

Figure 3 Impression punnets in the HotBox and starting material in the retail simulation

2.1.3 Starting material

Ten punnets were taken to determine starting quality. After visual inspection, they went through the retail simulation followed by the final inspection.

2.1.4 Retail simulation

To simulate the retail phase, punnets were stored under shelf life conditions at 18 °C, 60% RH and 12 hr/day a light intensity of 12 $\mu mol\ m^{-2}\ s^{-1}$ for 7 days.

2.1.5 HotBox-test

To evaluate the fungal infection grade of the starting material, ten extra punnets were stored at 100% RH at 18 °C and 12 hr/day a light intensity of 12 $\mu mol\ m^{-2}\ s^{-1}$ for 7 days, followed by the final inspection.

2.2 Weight and weight loss

Before and after storage, as well as after the retail phase, the weight of each punnet was taken.

2.3 Measurement of Brix

For the measurement of TSS (total soluble sugars; here referred to as Brix), the Atago multi fruit device was used. The samples were taken in two ways:

1. The 3-berry method, from the starting material and from punnets before storage
2. The all-berry method, from the starting material and from punnets after storage

Both methods were executed on the same punnets, to compare both methods and to assess the effects of storage time.
The Brix of the fruit juice was measured after passing it through a tea strainer.

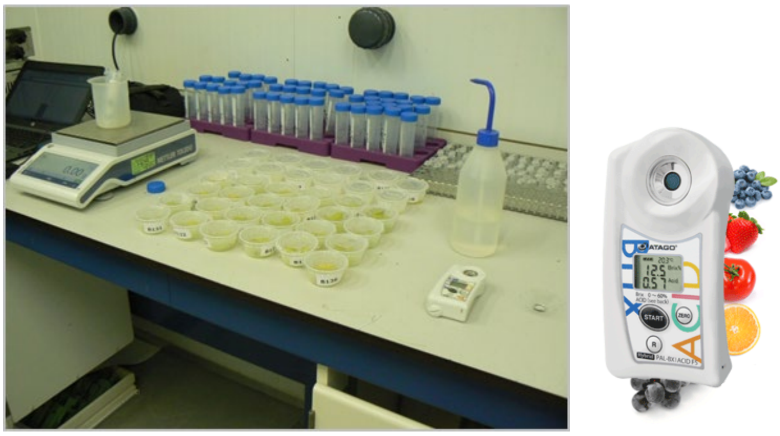


Figure 4 Sample pots to measure Brix and acid (left) and the Atago device (right)

2.3.1 3-berry method

This sampling-method is used by the service provider (Goodacre) for quality control of the grapes going to Bakker Barendrecht. After opening the lid of the punnet three berries were cut at the pedicel with scissors, from the middle, left and right sides of the punnet. The rest of bunch remained undisturbed.

2.3.2 All berries method

This sampling-method is used by the Taste Panel of Bakker Barendecht, in which all berries were taken from the stem and ground using a hand blender.

Figure 5 Sampling fruit juice for the 3-berry method (left) and the all-berry method (right)

2.4 Quality inspection

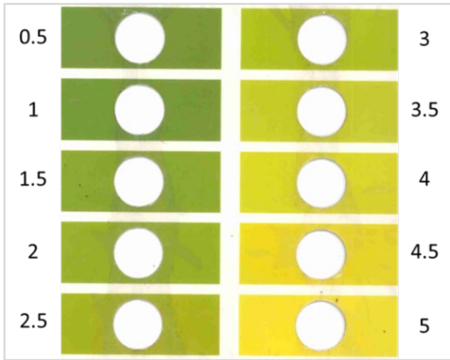


Figure 6 Apple/pear colour chart,1)

2.4.1 Visual inspection

During the non-destructive visual inspection, punnets remained closed. First overall impression was determined by giving a mark from 5 (excellent) to 1 (very bad quality):

- 5: excellent
- 4: small comment, good saleability
- 3: clear remark, still saleable
- 2: unsaleable
- 1: unsaleable and clearly very bad

This overall impression mark is a subjective measure. Following this, the number of visible bad berries were counted and separated into several classes (cracks, brown spots, fungal infection and SO_2 damage).

Additionally, the colour was evaluated using an apple/pear colour chart (Figure 6) ranging from 0.5 (dark green) to 5 (yellow)[1].

In the figures, the number of bad, inedible, berries was used as a measure of quality.

2.4.2 Final inspection

For the final inspection, all berries were taken from the stalk and distributed over several fractions. The weight was taken from all fractions:

1. Loose berries: edible and inedible
2. Edible berries
3. Inedible berries:
    a. Berries showing a brown attachment mark
    b. Berries showing fungal infection
    c. Berries with other defects, like brown spots, cracks and SO_2-damage

---

[1] *UniFruco Research services (PTY) Ltd, Belville, RSA, 1991*

4. Stem

In the figures, the percentage of good, edible berries and poor, inedible berries in the several fractions, as determined by weight, were used as a quality measure.

2.5 Statistical analysis

Data analyses were carried out using Genstat 18th edition (VSN International Ltd, 2015). To analyse differences between storage treatments, a general analyses of variance (ANOVA) was performed, using treatment structure: Trail number*Storage period*Storage temperature and also the interaction. In addition, a post-hoc test Least Significant Difference (LSD) was performed to reveal the nature of significant differences. In graphs, treatments that have a letter in common do not differ significantly. For all analyses, a value of $p < 0.05$ was used as criterion for statistical significance.

2.6 Planning

GreenCHAINge table grapes Q4-2016

Activities	19-9-2016	20-9-2016	21-9-2016	22-9-2016	23-9-2016	24-9-2016	25-9-2016	26-9-2016	27-9-2016	28-9-2016	29-9-2016	30-9-2016	1-10-2016	2-10-2016	3-10-2016	4-10-2016	5-10-2016	6-10-2016	7-10-2016	8-10-2016	9-10-2016
week	38							39							40						
Trial 1																					
Arrival		rand																			
Starting quality		B1/2-Vi							Fi												
Starting matrial HotBox		H							H												
Storage two weeks		B1														B2-Vi					
Storage three weeks		B1																			
Trial 2																					
Arrival																rand					
Starting quality																B1/2-Vi					
Starting matrial HotBox																H					
Storage two weeks																B1					
Storage three weeks																B1					
Trial 3																					
Arrival																					
Starting quality																					
Starting matrial HotBox																					
Storage two weeks																					
Storage three weeks																					

Activities	10-10-2016	11-10-2016	12-10-2016	13-10-2016	14-10-2016	15-10-2016	16-10-2016	17-10-2016	18-10-2016	19-10-2016	20-10-2016	21-10-2016	22-10-2016	23-10-2016	24-10-2016	25-10-2016	26-10-2016	27-10-2016	28-10-2016	29-10-2016	30-10-2016
week	41							42							43						
Trial 1																					
Arrival																					
Starting quality																					
Starting matrial HotBox																					
Storage two weeks		Fi																			
Storage three weeks		B2-Vi							Fi												
Trial 2																					
Arrival																					
Starting quality		Fi																			
Starting matrial HotBox		H																			
Storage two weeks									B2-Vi							Fi					
Storage three weeks																B2-Vi					
Trial 3																					
Arrival									rand												
Starting quality									B1/2-Vi							Fi					
Starting matrial HotBox									H							H					
Storage two weeks									B1												
Storage three weeks									B1												

Activities	31-10-2016	1-11-2016	2-11-2016	3-11-2016	4-11-2016	5-11-2016	6-11-2016	7-11-2016	8-11-2016	9-11-2016	10-11-2016	11-11-2016	12-11-2016	13-11-2016	14-11-2016	15-11-2016	16-11-2016	17-11-2016	18-11-2016
week	44							45							46				
Trial 1																			
Arrival																			
Starting quality																			
Starting matrial HotBox																			
Storage two weeks																			
Storage three weeks																			
Trial 2																			
Arrival																			
Starting quality																			
Starting matrial HotBox																			
Storage two weeks																			
Storage three weeks		Fi																	
Trial 3																			
Arrival																			
Starting quality																			
Starting matrial HotBox																			
Storage two weeks		B2-Vi							Fi										
Storage three weeks									B2-Vi							Fi			

Storage period

Retail simulation

Activity: i.e.

rand	Randomizing punnets over treatments
B1	Brix measurement on 3 grapes of a punnet
B2	Brix measurement on all berries of the bunch
H	HotBox test
Vi	Visual inspection (non desctructive)
FI	Final inspection (destructive)

3 Results and discussion

3.1 General observations

3.1.1 Punnet codes

All punnets were provided with a code after packaging, consisting of 8 digits. The codes revealed harvest date, packing station and packing time. For instance the code 21370837 meant:

- 2= packing station
- 137= day 1 (Monday) in week 37
- 0837= time hh:mm

The codes of all punnets in the trials were registered (Table 1).

Table 1: Information about packing date, station and transport time according to the punnet codes

Experiment	Packing date		Station	Time		Number of punnets in trial	Days from packing to arrival NL
	Week	Day					
Trial 1-wk38	37	1	2	8:35	8:37	35	7 days
			3	7:33	7:58	34	
Trial 2-wk40	39	4	1	11:11	11:11	6	4 days
			6	10:52	10:53	6	
			7	10:45	10:45	2	
			8	9:48	10:28	11	
	39	5	1	14:51	14:57	27	3 days
			2	14:56	15:00	18	
Trial 3-wk42	40	6	5	9:09	12:50	41	9 days
			8	9:04	9:05	28	

3.1.2 Punnet nett weight and weight loss

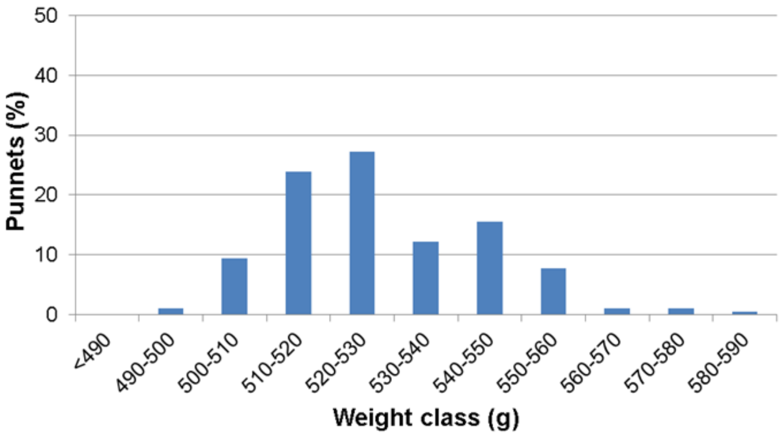


Figure 7 Distribution of (nett) packed weight of the punnets at arrival at WFBR

The average nett weight of grapes at arrival was 528.6g. However, the variation in packed weight was about 20%, varying from 500 to almost 590g as depicted in Figure 7.

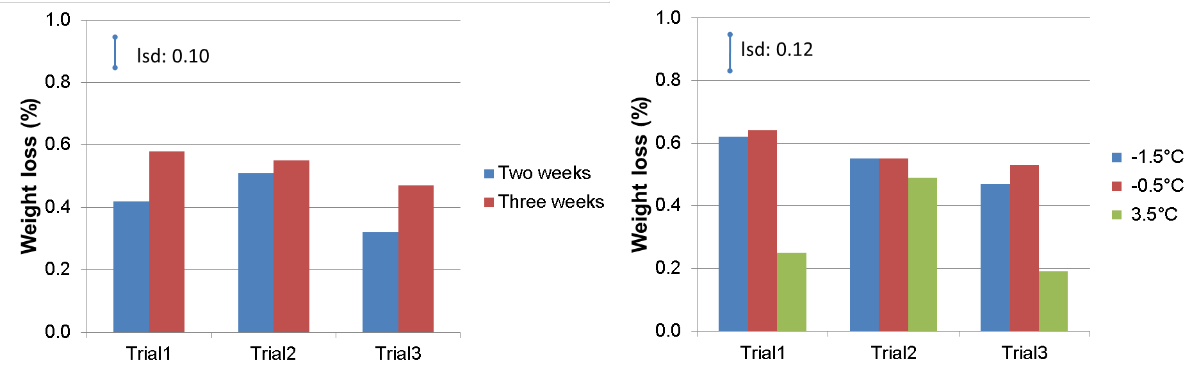


Figure 8 Weight loss during storage as a function of storage time (left) and storage temperature (right). Lsd: least significant difference

The average weight loss during storage time was 0.5%. Weight loss was dependent on storage time, temperature and also on the trial (Figure 8):

- Storage time: two weeks < three weeks,
- Storage temperature: 3.5 °C < (-0.5 and -1.5 °C),
- Trial 2 showed smaller differences in storage time and temperature (no explanation).

However, maximum weight loss during storage was about 0.6%. For the average weight punnet, this meant about 3 g of weight lost. The average weight loss during retail phase was much higher, about 4% (not in figure). For the average weight punnet, 4% weight loss is about 21 g.

3.1.3 Berry colour

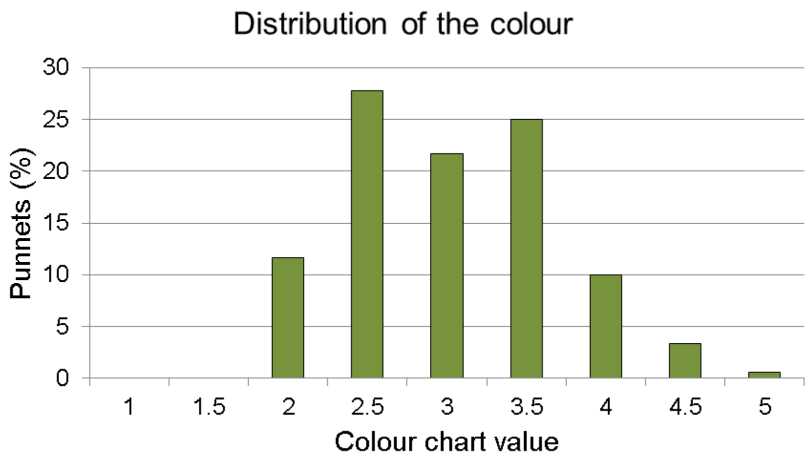


Figure 9 Distribution of fruit colour over punnets as measured with the apple/pear colour chart [1])

In each trial, colour differences of grapes in different punnets could easily be observed by eye. The grapes varied from 2 (green) to 5 (yellow) on the apple/pear colour chart, suggesting differences in ripening stage at arrival at WFBR.

3.2 Starting material

In each trial, the quality of the starting material was evaluated both at arrival and after the retail simulation.

At arrival, 10 punnets per trial were visually inspected, resulting in a (subjective) overall impression mark and the number of poor berries.

Figure 10 shows the overall impression and the number of poor berries in the starting material. The quality marks of the starting material ranged from 2 to 5, with an average per trial of:

- Trial 1: 3.6
- Trial 2: 3.2
- Trial 3: 3.9

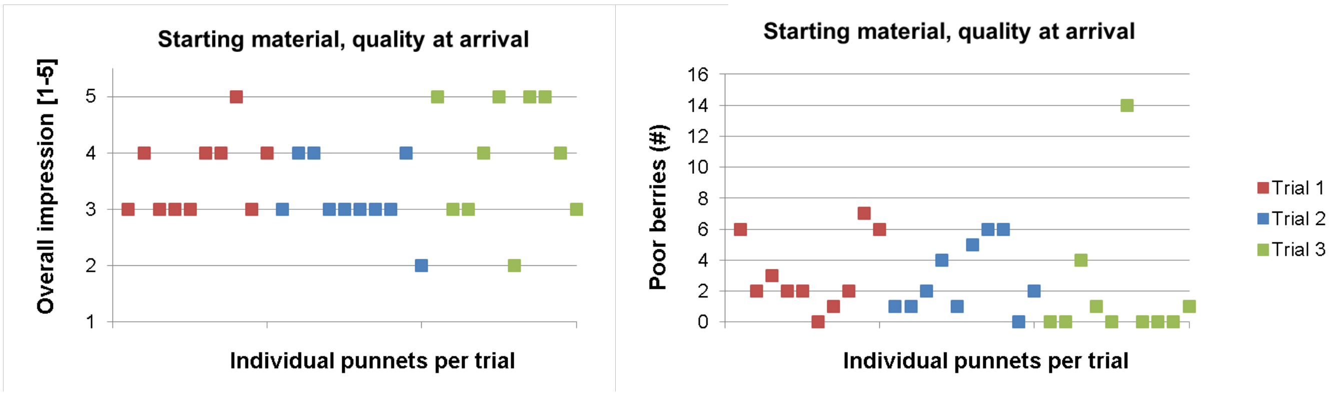


Figure 10: Overall impression (left) and number of poor berries (right) of individual punnets at arrival

However, quality differences between the punnets within a single trial were large. Almost all punnets showed one or more poor berries, already at start of the storage experiment.

After passing the retail simulation, the final inspection was performed and the percentages of good, edible berries and poor, inedible berries in the three fractions were calculated (Figure 11).

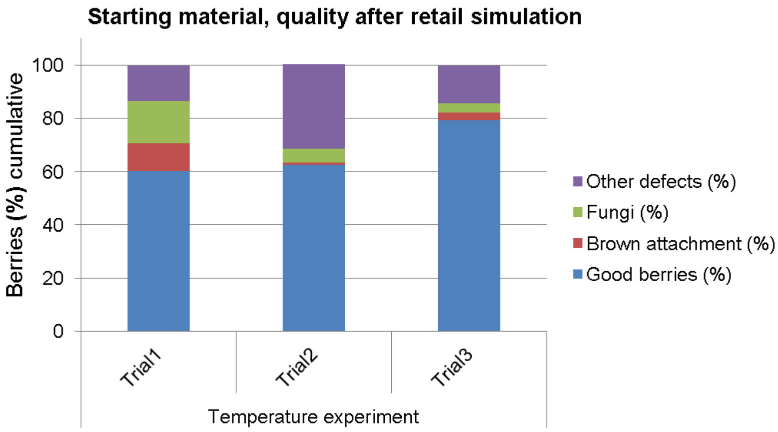


Figure 11: Percentage of berries in four quality fractions, after retail simulation

The punnets from trial 1 showed the most berries with brown attachments and fungal infection. The punnets from trial 2 showed more berries with other defects, which afterwards appeared to be SO_2-damage (R. Geelhoed, personal communication, Figure 12). These defects could be described as bleaching and sunken attachment areas.

Figure 12 An example of fruits showing defects due to SO2-damage (R. Geelhoed, personal communication): severe bleaching and sunken attachment areas.

The punnets from trial 3 on average had the highest percentage of good berries.
The punnets out of the HotBox showed elevated levels of fungal infection in trial 1 and 3 (Figure 13).

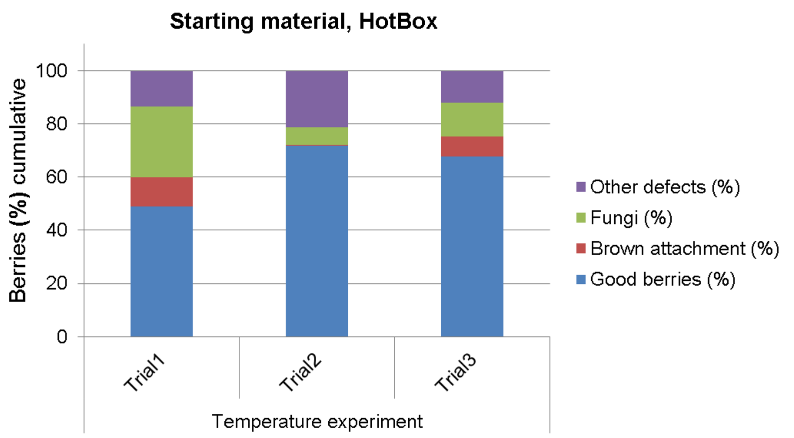


Figure 13: Percentage of berries in four quality fractions, out of the HotBox

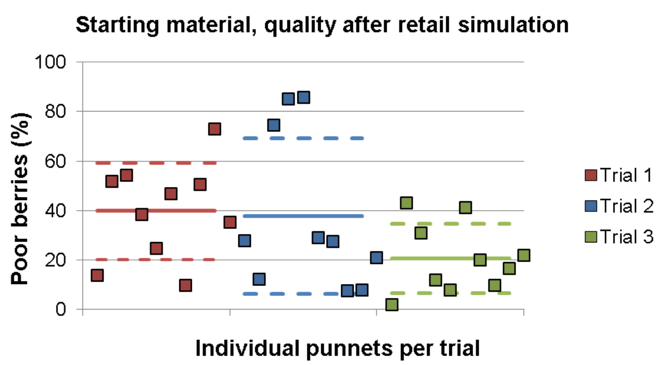


Figure 14: Percentage of poor berries from individual punnets per trial after retail simulation. Solid lines: average value, dashed lines: standard deviation.

Like the visual inspection data already showed, by the time of the final inspection, the quality differences between individual punnets were large (Figure 14), with the variation being highest in trial 2 and smallest in trial 3.

3.3 Brix

Figure 15 shows the average soluble sugar contents of the grapes from the three trials. The soluble sugar content of the grapes in Trial 1 was significantly higher with 20.6 °Brix, than of the grapes in Trial 2 and 3, both being 18.9 °Brix. However, the variation between punnets in each trial was much larger, than the difference between the averages per trial (Figure 16):

- In Trial 1 ranging from 12.1 to 24.7
- In Trial 2 ranging from 13.1 to 22.7
- In Trial 3 ranging from 11.3 to 23.3

Only a few punnets, in each trial, have a Brix value lower than 14°, which is used in practise as limiting factor for transportation at 1.5°C instead of -0.5°C. These punnets could have a higher risk at showing quality issues. However a direct link between Brix value of grapes in the punnet and their quality after storage could not be made with this experimental setup.

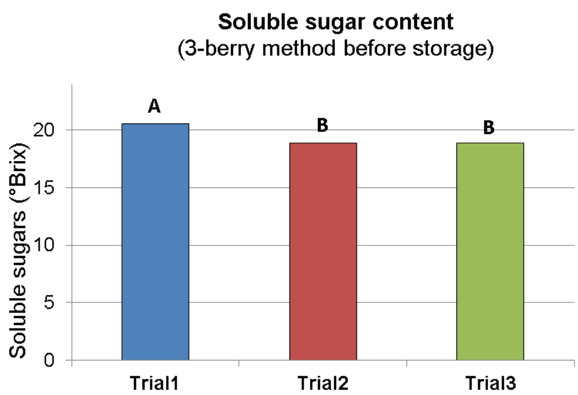


Figure 15: Average soluble sugar content (°Brix) of grapes in three trials, measured using the 3-berry sampling method, before storage. Columns with different letters differ significantly

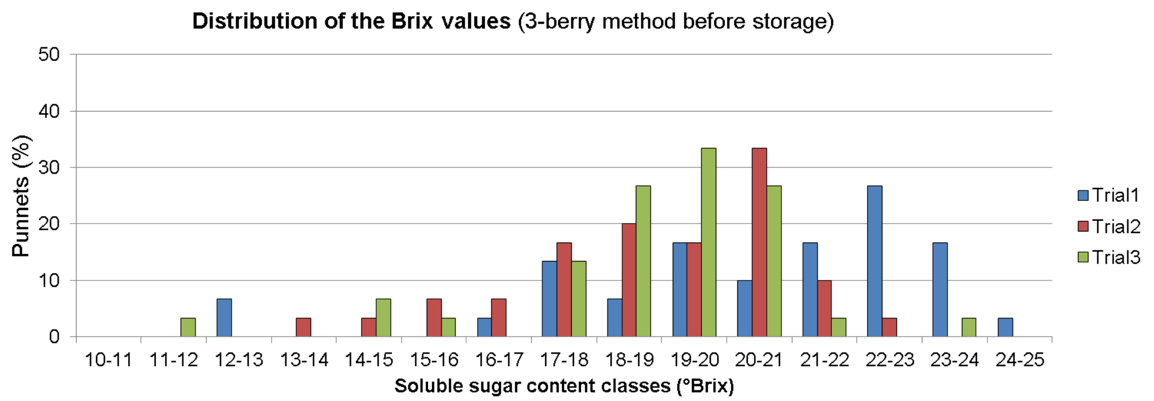


Figure 16: The distribution of the soluble sugar content (°Brix) of grapes in three trials, measured using the 3-berry sampling method, before storage

Figure 17 shows the relation of the soluble sugar contents measured before (3-berry method) and after storage (all berries method) of each punnet. The deviation of the points from the depicted line y=x is not depending on either sampling method or storage time.
This implicates that the measurement of Brix using 3 berries is comparable to sampling all berries and that Brix can be measured both before and after storage.

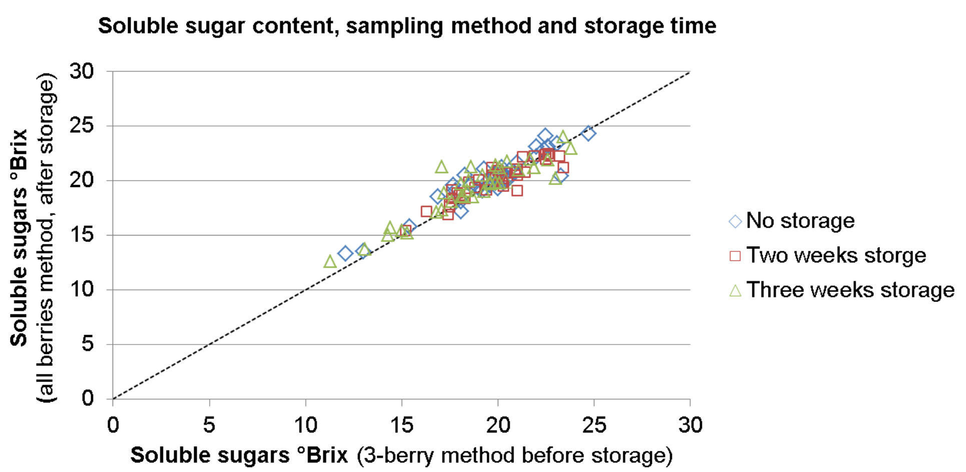


Figure 17: The relation of the soluble sugar content (°Brix) measured before (3-berry method) and after storage (all berries method). Each point represents a single punnet. Depicted line: x=y

3.4 After storage

3.4.1 Visual inspection

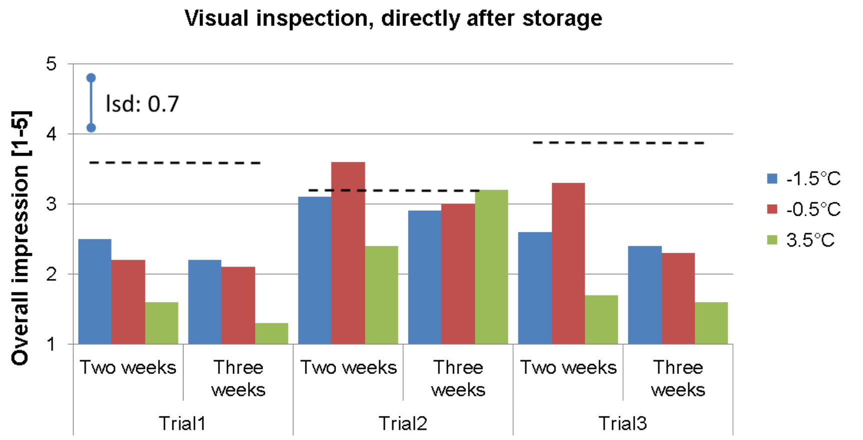


Figure 18: Overall impression directly after storage for two or three week at different temperatures. Dashed lines: starting material. Lsd: least significant difference.

Figure 18 shows the overall impression of the punnets directly after storage. On average, the quality of punnets stored at -1.5 and -0.5 °C is significantly higher than stored at 3.5 °C. The overall quality in trial 2 is better than in trial 1 and 3. The quality drop after storage in trial 2 is smaller than in trial 1 and 3. Like in the starting material, the variation within punnets of a treatment is also high after storage, resulting in a high least significant difference (lsd).

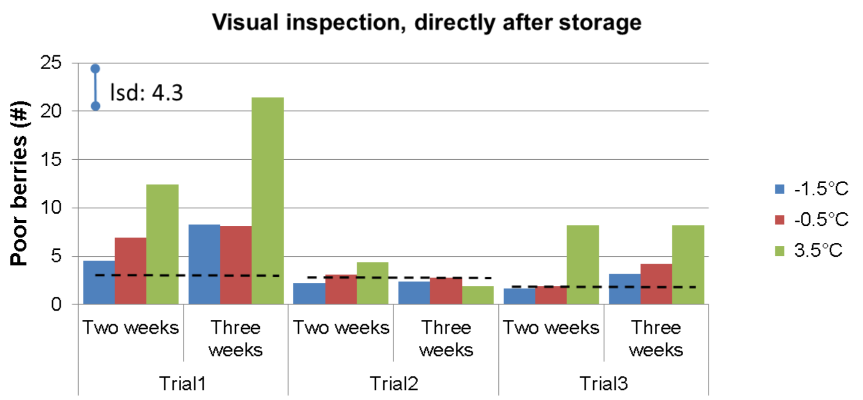


Figure 19: Number of poor berries directly after storage for two or three week at different temperatures. Dashed lines: starting material. Lsd: least significant difference.

The number of poor berries in a punnet, as visible from outside, is significantly higher when punnets are stored at 3.5 °C; at least in trials 1 and 3 (Figure 19).

3.4.2 Final inspection

The percentage of good, edible berries after storage and retail simulation is on average lowest in trial 1: 39.2%. The percentages of good berries in trial 2 and 3 are higher, 63.7 and 60.2%, respectively. However, compared to the quality of the starting material, in trial 1 and 3 the

decrease of good berries is about 20%, whereas on average the percentage of good berries in trial 2 has declined only by 10%.
Variation within punnets of a treatment was large and differences between the three trials were large as well. For that reason there is no clear effect of storage temperature and storage time (Figure 20).
The fungal infection was more severe in trial 1 than in trial 3. In trial 2 almost no fungal infection could be seen (Figure 21).

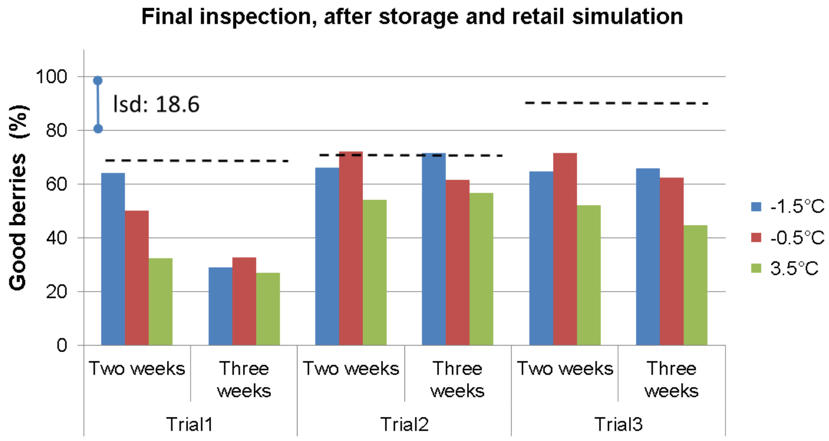


Figure 20: Percentage of good, edible, berries, after storage and retail simulation. Dashed lines: starting material. Lsd: least significant difference.

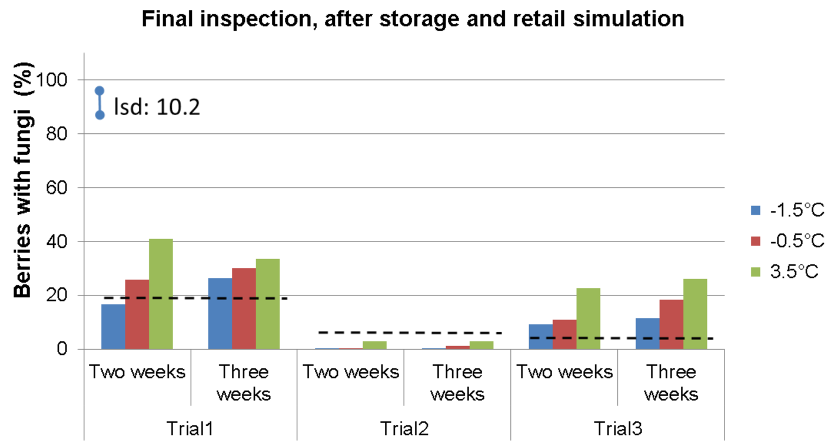


Figure 21: Percentage of berries with fungal infection, after storage and retail simulation. Dashed lines: starting material. Lsd: least significant difference.

In Figure 22 to Figure 24 the percentage good berries and the percentage of berries in the three fractions of inedible berries are depicted per trial.
In trial 1, the majority of the inedible berries was rejected because of fungal infection or brown attachment (Figure 22). In trial 2 almost all rejected berries showed SO_2-damage: bleaching and/or sunken attachments (Figure 23). In trial 3 rejected berries could be found in all three categories of inedible berries (Figure 24).

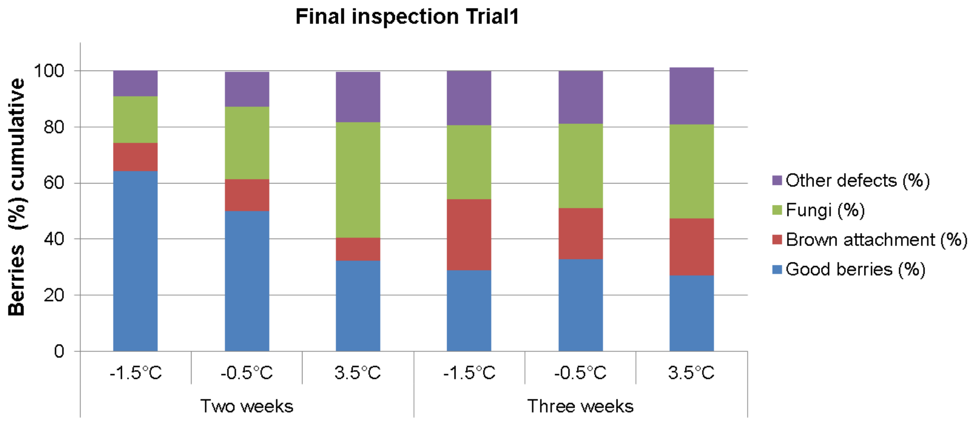


Figure 22: Percentage of berries in four quality fractions in Trial 1, after storage and retail simulation

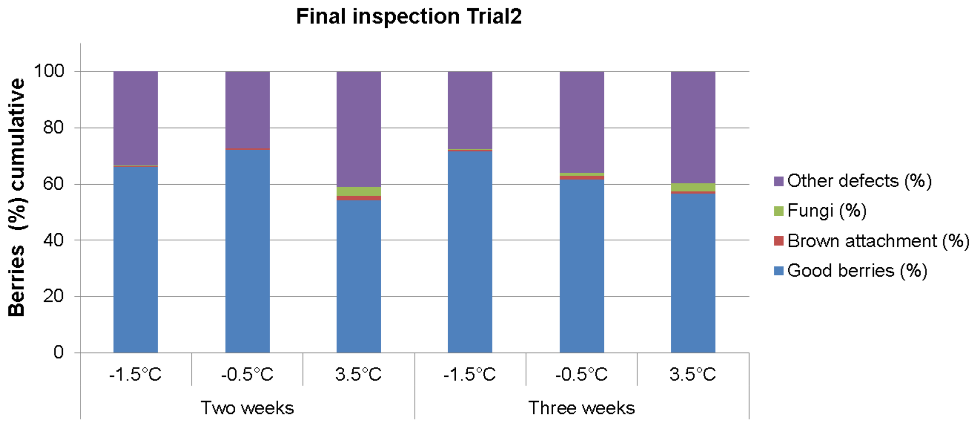


Figure 23: Percentage of berries in four quality fractions in Trial 2, after storage and retail simulation

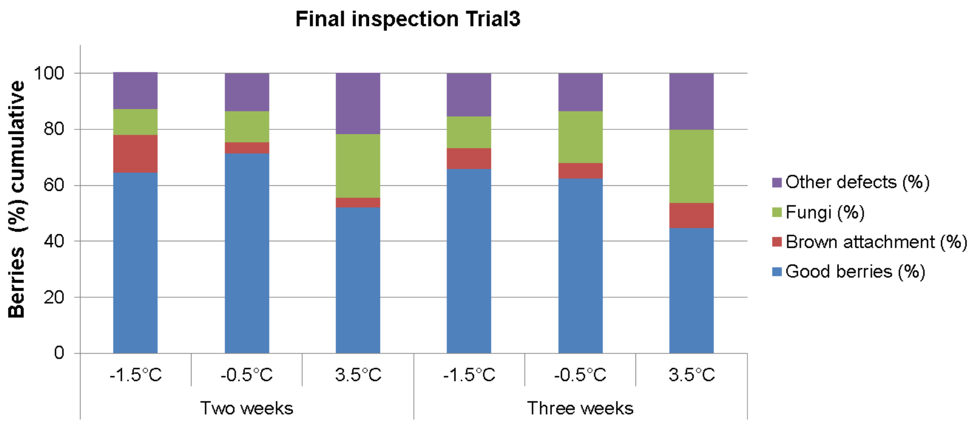


Figure 24: Percentage of berries in four quality fractions in Trial 3, after storage and retail simulation

3.5 SO_2-damage

As mentioned before, the fruits in Trial 2 showed a different pattern of damage, probably caused by SO2-treatment (Figure 12). Since no SO2-pads were found in the packaging, this suggests

SO2-treatment prior to arrival at WFBR. SO2-treatment could explain the low levels of fungi in comparison to Trials 1 and 3 and the high levels of other defects.

3.6 Stem-berry ratio

In this temperature storage experiment, variation between punnets within a treatment played an important role. This resulted in high values for the least significant difference of all quality measures. However, this variation could not be explained by punnet weight or berry colour. During evaluation of final quality, the impression grew that bunch morphology could be a factor in bunch quality.

With the available data, the stem to berry ratio (STB) was calculated from all evaluated punnets in the storage experiment:

- Three harvest dates: week 38, 40 and 42 in 2016
- Two storage periods: two and three weeks
- Three storage temperatures: -1.5 °C, -0.5 °C and 3.5 °C

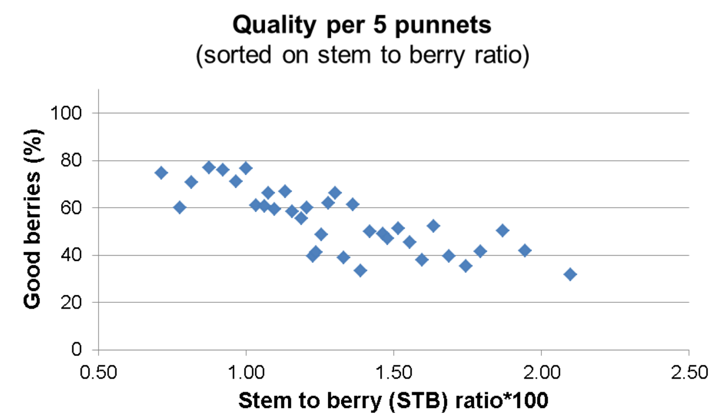


Figure 25: The relation of the stem to berry ratio with berry quality (% good berries)

Individual data points form a cloud with a tendency to decline. After sorting the STB-ratio and averaging the % of good berries per five following punnets, the relation became clearer (Figure 25).

In the literature, the relation between cluster morphology and bunch rot epidemic has already been demonstrated (Molitor et al., 2012, Živković et al., 2016).

In these articles, cluster morphology is described using de bunch density index (Ipach et al., 2005), cluster weight and average berry weight. The density index is a non-destructive measure. This method could be useful to select bunches with different densities before determining final quality. Their results show that loosening cluster density during growth reduces bunch rot disease severity (Molitor, et al., 2012):

“ In compact, dense grape clusters the conditions are generally favourable for infection and spread of fungal pathogens such as *B. cinerea* due to a combination of three effects:

1. In the interior parts of dense clusters, the air circulation and sun exposure are low, resulting in slow drying processes, high interior humidity, and, consequently, favourable conditions for the establishment of fungal pathogens.
2. The dense structure further reinforces the risk of berry burst induced by berries touching each other because of high internal pressure. Burst berries are easy for fungal pathogens to colonize and may represent starting points for rapid spread of bunch rot.
3. The close proximity of the single berries in compact clusters allows for faster berry to berry spread of fungal pathogens.

Further, results indicate that cuticles are thinner on berries touching each other, and cuticle and wax contents are negatively correlated with susceptibility to *B. cinerea*."

4 Conclusions

The results of this study answered the following research questions:

1) *What are the effects of storage temperature and storage time on the quality of Thompson seedless grapes?*

On average, the quality of Thompson seedless table grapes from Greece is better when stored for two and three weeks at -1.5 and -0.5 °C than stored for that period at 3.5 °C. However, within each temperature treatment the quality differences between replicates ware large, involving punnets of moderate to bad quality in each treatment. On average the quality of the grapes is better when stored for two weeks than for three weeks.

The biological variation of the starting material appeared to be high, which complicates outcomes of this postharvest study. It is currently unclear what exactly caused this variation in this case.

2) *What is the Brix level during week 38 to week42 of the Thompson season in Greece? And does the Brix value vary between punnets?*

The Brix values in this period were on average 19°. The average Brix values were higher in week 38 than in week 40 and 42, showing a difference of about 2 °Brix. Within each trial, Brix values between individual punnets varied a lot: the minimal and maximum values differed approximately 10 °Brix.

At start of the experiment, the question was whether grapes with relatively high levels of soluble sugars could be transported at a lower temperature, i.e. -1.5 °C, without showing quality issues. These grapes, with an average Brix value of 19° performed the same at -0.5°C as at -1.5°C, without showing more disorders at -1.5°C.

3) *Do the 3-berry method and all-berry method give comparable results?*

Both sampling methods for measuring Brix, the 3-berry method and the all-berry method, give comparable results. Furthermore, Brix values did not change significantly during storage.

References

Molitor, D., Behr, M., Hoffmann, L. and Evers, D., 2012. Impact of grape cluster division on cluster morphology and bunch rot epidemic. Am. J. Enol. Vitic. 63:4, p.508-514.

Molitor, D., Rothmeier, M., Behr, M., Fischer, S., Hoffmann, L. and Evers, D., 2011. Crop cultural and chemical methods to control grey mould on grapes. Vitis 50 (2), 81–87.

Živković, J., Šavikin, K., Zdunić, G., Gođevac, D., Marković, N., Pržić, Z. and Menković, N., 2016. Influence of bunch morphology on quality of wines produced from clones of grape variety Prokupac
J. Serb. Chem. Soc. 81 (8) 883–895.

Acknowledgements

We thank Bakker Barendrecht for supplying the grapes and their refrigerated transport. In particular we would like to thank R.Geelhoed for organizing the deliveries and providing all the required information on the deliveries.

Foundation TKI Horticulture is acknowledged for providing part of the project funding.

