Fresh on Demand, DP4: Optimization of the tropical fruit supply chain

Papaya 'Tainung', experiments 2019-2021

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VERTROUWELIJK

WAGENINGEN UNIVERSITY & RESEARCH

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Summary

This report describes the results of trials done in the first three years of the four-year program Fresh on Demand, subproject 'Optimization of the tropical fruit supply chain'. This subproject aims at maintaining a good quality papaya for the consumer, while taking into account sustainability requirements. Therefore, the transport of 'Tainung' papaya by sea transport instead of by air is relevant. This brings economic and environmental advantages. The challenge is to keep papaya quality as high as possible in the supply chain. The main points of attention for papaya quality are better control of the ripening, less water loss, and reduction of mould. To reach this, focus was on two new technologies: Modified Atmosphere (MA) Packaging based on a high precision laser perforation system (PerfoTec) and the use of managed-atmosphere chambers (RipeLocker). In shipments from Brazil to the Netherlands, tests were done on shipments that used these technologies.

Trial MA packages (2019)

In this first trial, 4 different bag types were compared:

- HN-bag (Hot-needle) on individual fruit (current standard)
- PerfoTec biodegradable liner
- Combination of the above
- Xtend liner (Xtend®)

Papayas were packed at Agricola Famosa in Brazil and transported to the Netherlands by sea reefer under cooled conditions. After arrival in Wageningen (25 days after packing in Brazil), a period of shelf-life at 20 °C started. The bags were removed from half of the boxes before being transferred to shelf-life conditions. The bags remained closed for the other half of the boxes during the shelf-life. This is a simulation of two possible scenarios for papayas being delivered to retail.

The main results and conclusions are:

- The temperature control during the supply chain showed a serious problem as it increased to 26 °C around the time of loading the reefer container in Brazil. Temperature control during the total chain is very important to retain a good quality papayas.
- CO_2 in the PerfoTec liner was often higher than the target value of 8% CO_2 The permeability of the liner should be increased in the next trial.
- Pitting on the skin was occasionally observed, but especially when the Xtend liner was used.
- The HN-bags performed best among the packages, although, also here, several quality issues were found.
- A method to analyse the percentage of yellow skin was developed and proved to be useful.

Trial MA packages (2020)

In search of opportunities to optimize the post-harvest chain for 'Tainung', a second trial was carried out with different bags for transport from Brazil to the Netherlands. The bags were removed before the papayas were transferred to shelf-life conditions at 20 °C.

Three different types of bags were compared:

- HN-bags on individual fruit
- PerfoTec biodegradable liner (modified based on previous trial, higher transmission)
- Xtend liner

Papayas were packed in Brazil and transported to the Netherlands by sea reefer (target temperature 10 °C). Shelf-life conditions (20 °C) started 26 days after harvest.

The main results and conclusions are:

- The chain temperature during the first days was too high. Following the 26-day period between packaging and first quality assessment, the quality decreased very quickly during shelf-life.
- The PerfoTec liners had a favourable CO_2 percentage on arrival after transport probably resulting in inhibition of yellowing.
- Overall, both the PerfoTec and Xtend liner now outperformed the HN-bags with benefits of less weight loss, less shrivelling and less rots.

Trial RipeLocker (2020)
Papaya ‘Tainung’ of 3 maturity stages were selected at Agricola Famosa (Brazil). Maturity stages were: green, standard for export to Europe, and 60% tree-ripe. Fruits were divided over 4 RipeLockers (hypobaric pressure containers) and cardboard boxes as controls. Various O_2 and CO_2 conditions were applied to the RipeLockers. The fruit was shipped to the Netherlands by sea reefer.

Papayas of maturity stage ‘60% tree-ripe’ turned out to be damaged because of a too fast release of the hypobaric pressure of the RipeLockers. The quality assessments during the next shelf-life focused on the ‘green’ and ‘standard’ stages.

The main results and conclusions are:

- When the RipeLockers were opened in the Netherlands, the ‘green’ and 'standard' papayas looked very fresh. The observed mould growth on the stems was due to the fact that the normal practice for treatment against stem-end mould was not applied.
- Overall, RipeLockers scored good for general appearance, less weight loss, less shrivelling, less lenticel browning, and higher firmness (for ‘standard’ harvest maturity) compared to control boxes,
- In conclusion, this first trial with RipeLockers showed potential for a better papaya quality, knowing that improvements can be made in decommission of RipeLockers at arrival (slow vacuum release), mould control, and fine-tuning of RipeLocker conditions. The realization of the proper cold chain before leaving the port in Brazil also remains an important point of attention.

Trial MA packages (2021)
As a follow-up to the previous trials, new tests were conducted with PerfoTec MA packages. The treatments were carried out with two harvest maturities packed in:

- HN-bags
- PerfoTec consumer pack. PerfoTec’s high precision laser perforation system was used, based on previous data from the PerfoTec’s respiration meter.

Papayas were packed at Agricola Famosa in Brazil and transported to the Netherlands by sea reefer. The quality was assessed over a period of shelf-life.

After arrival in the Netherlands, an internal disorder was identified, which is probably a chilling injury. Together with the unusual transport conditions (long time and too cold temperature) it makes the comparison of the two packaging types of limited relevance for practice. Nevertheless, the trials have contributed to useful insights for future trials and adaptations of technology. In summary, the papayas packed in PerfoTec and HN-bags both scored good on external fruit appearance. The PerfoTec liner led to less weight loss than the HN-bag. The modified O_2 and CO_2 did not affect quality in this trial, but have potential to do so in a realistic supply chain, perhaps including a storage buffer period or retail phase after arrival in Europe.

Trial RipeLocker (2021)
As a follow-up to the first RipeLocker trial (2020), RipeLockers with papayas of two harvest maturities were shipped from Brazil to the Netherlands. This was a combined shipment with the previously described trial (MA Packages 2021). Here too, the occurrence of the internal disorder together with unusual transport conditions made the trial of low relevance for practice. Papayas from the RipeLockers showed less weight loss, and therefore less shrivelling, than the control boxes with HN-bags. Differences in performance between the individual RipeLockers with different gas conditions can help to refine the search for the optimal conditions.

Scientific progress
Scientific progress has been made for colour imaging and near-infrared spectroscopy (NIR).
Colour imaging was developed to provide an objective analysis of flesh colour of longitudinal sections of papaya fruit, yielding good estimations of the % ripe (dark coloured), % half ripe an % unripe (green/white) tissue.

The % of ripe tissue was used to calibrate NIR measurements taken from outside the papaya. NIR measurements were performed non-destructively, after which the % of ripe tissue was assessed through colour imaging and used to calibrate NIR measurements. This is interesting because the external colour, visible to humans, does not correlate well with the internal colour. Therefore, the developed NIR model needs validation with a new set of data of the colour imaging measurements (in a following trial).

General conclusions

- The quality at harvest (ripeness stage) and a good control of temperature during transport are of high importance to fulfil consumer demands and avoid product waste. Obviously, limiting the time between harvest and retail phase contributes to a better result.
- Both MA packaging (PerfoTec) and the use of dynamic-atmosphere chambers (RipeLocker) showed positive results. Both technologies will be further fine-tuned in next trials.

The described results and conclusions are valid for the delivered papayas, under the tested circumstances. The research was performed independently by researchers from Wageningen Food & Biobased Research, funded by Stichting TKI Tuinbouw & Uitgangsmaterialen (TKI number TU18098) and by project partners Agricola Famosa (producer and exporter, Brazil), Frankort & Koning (importer, the Netherlands), PerfoTec B.V. and RipeLocker LCC.

The scope and details of the research are described in the report. For additional information about this report, see the colophon.

Abbreviations

HN-bag	Hot-needle bags (flowpack)
NIR	Near-infrared spectroscopy
RH	Relative Humidity
RL	RipeLocker
WFBR	Wageningen Food & Biobased Research

1 General introduction

The popularity of the papaya (Carica Papaya L.) fruit in Europe is growing. Brazil is one of the largest producing countries and has Europe as an important export market. The 'Tainung' (Formosa) belongs to the most important varieties. It has a relatively long storage life compared to other varieties such as the 'Golden' variety. That is why transport by sea from Brazil to Europe should be possible for 'Tainung', under the condition of a good initial quality. The transport of 'Tainung' papaya overseas, instead of by air, has economic and environmental advantages. However, quality must be kept as high as possible mainly by controlling maturity, water loss, and reduction of moulds.

Within the four-year Fresh on Demand program, the subproject 'Optimization of the tropical fruit supply chain' aims at good quality for the consumer, taking into account sustainability requirements.
Looking for opportunities to optimize the postharvest chain for 'Tainung', this project started in 2019 with an assessment of already available knowledge and identification of the main postharvest quality problems for papaya 'Tainung'. These main quality problems are the following:

- Fungal diseases. These are mainly *anthracnose* in the rainy growing season and stem-end rots *Fusarium* and *Alternaria* in the dry season.
- Skin damage. The highly sensitive fruit skin gets easily damaged which then leads to cosmetic problems and an increased susceptibility to fungal growth.
- Dehydration leading to shrivelling.
- Limited storage life of about 3 weeks, which is critical for overseas transport to Europe.

Chilling injury was not seen as a problem, transport temperature at a minimum of 10 °C is considered safe for the product.

The focus of this project is on two new technologies: Modified Atmosphere Packaging based on a high precision laser perforation system (PerfoTec) and the use of managed-atmosphere chambers (RipeLocker). With the PerfoTec technology, the film permeability can be adapted during packing via perforation. The permeability can be based on the PerfoTec fast respiration meter that measures the product respiration rate and thus enables to respond to product and seasonal variations. In the course of this project, a new PerfoTec biodegradable liner became available, and was tested, with the goal to achieve the low O_2 while keeping sufficient permeability for water vapor leaving the packaging. The RipeLocker technology makes use of pallet-sized hypobaric storage chambers. This system can precisely manage its internal atmosphere (pressure, humidity, oxygen) and is remotely-monitored.

With both technologies, shipments in sea reefers (target 10°C, 3-4 weeks) from the production area (Northeast Brazil) to Europe (Rotterdam, the Netherlands) were realized. The reefers were then transported by truck from Rotterdam to Venlo (2 hour drive) and subsequently to Wageningen (1.5 hour drive). This supply chain could be realized thanks to the 4 industrial partners in this project: Agricola Famosa (producer and exporter, Brazil), Frankort & Koning (importer, Venlo, the Netherlands), PerfoTec B.V. (packaging technology, Woerden, the Netherlands) and RipeLocker LLC (hypobaric storage, Bainbridge Island, WA, USA).

The use of hot-needle (HN) perforated packaging for individual papayas had already been implemented to reduce dehydration and better protection against skin damage. These bags lead to higher humidity around the fruits, while O_2 and CO_2 are similar to the environment. On the other hand, MA packaging (PerfoTec) and atmosphere-managed chambers (RipeLocker), with reduced O_2 and increased CO_2 compared to normal atmosphere, are interesting due to the expected additional effect on ripening inhibition. In addition to extending storage and shelf-life, these technologies potentially can reduce mould growth and keep the skin firm, and therefore damage resistant, for a longer period of time.

This report describes the results of the sea transport trials carried out in the period 2019-2021. In addition to focusing on the PerfoTec and RipeLocker technologies, colour analysis and near-infrared spectroscopy were also explored as objective and non-destructive techniques for evaluating papaya maturity and quality.

2 Trial MA packages (2019)

2.1 Introduction

During the first trial, 4 different bag types were compared (Table 1). Papayas were packed at Agricola Famosa in Brazil and transported to the Netherlands by sea reefer. The quality of the fruit was assessed over the subsequent shelf-life period. The bags were removed from half of the boxes before being transferred to shelf-life conditions. The bags remained closed for the other half of the boxes during the shelf-life. This is a simulation of two possible scenarios for papayas being delivered to retail.
This trial was also used to develop a method to analyse external papaya colour with a standardized colour imaging cabinet.

2.2 Methods/Design of the research

2.2.1 Materials

Papayas 'Tainung' were selected at Agricola Famosa (Brazil) on 17 October 2019. Quality was classified as class II, though suitable for the trial. The selected maturity was the Agricola Famosa's standard for export to Europe, with 1-2 yellow stripes. Boxes contained 5 or 6 fruits. The boxes were randomized over the 4 different treatments (***Table 1***). Figure 1 shows an example of a box at the start of the trial in 2019.

Table 1 Overview of 4 treatments (bag types) of trial MA packages (2019)

Treatment (bag type)	Way of packaging	Remark	# boxes
HN-bag (Hot-needle) Individual fruit	Flowpack machine	Stem end treatment	16
PerfoTec (biodegradable liner, 19000)	Manual		16
Combination HN-bag and PerfoTec	Flowpack and manual	Stem end treatment	16
Xtend liner (Papaya, 815-PP64)	Manual		16

Figure 1 Papayas 'Tainung' at start of the trial 2019

In Brazil, a packaging machine was used for the HN-bags. In this process, these papayas received a stem-end treatment as a standard procedure (containing potassium sorbate as active ingredient). Papayas without a HN-bag were packed manually and accidently did not receive this stem end-treatment. The later quality assessments indicated that this difference in stem-end treatment had not affected the results in this specific trial

All boxes were labelled with a unique code and the total fruit weight per box was noted. For every treatment, two temperature loggers (LogTag TRIX-8, LogTag Recorders Ltd) were added in 2 separate boxes. When liners were present, the loggers were placed inside the liners.

2.2.2 Realized chain conditions

The realized timetable and temperature log data are given in ***Table 2*** and ***Figure 2***. The temperature log started from October 17th 2019 at the time of packing at Agricola Famosa. There was a high temperature rise up to 26 °C for about 24 hours on 19-20 October, with a subsequent slow cooling that lasted two days. This seems to be related to loading activities of the reefer container. The temporary peak on 7-8 November 2019 (up to 13 °C) is linked to the period in The Netherlands from arrival in Rotterdam to arrival and first measurements in Wageningen.

Table 2 Realized timetable of trial MA packages (2019)

Date	Location	Average air temperature (°C)
17 October 2019	Packaging at Agricola Famosa, Brazil	15 °C
19 October	Container ready to be loaded, Brazil	16 °C
20 October	Loading activities, Brazil	21 °C with maximum 26 °C
26 October	Departure Fortaleza, Brazil	11 °C
6 November	Arrival Rotterdam, the Netherlands	11 °C
7 November	Arrival at Frankort & Koning in Venlo, the Netherlands	12 °C
8 November	Transport to WFBR Wageningen and placed at ±10 °C, the Netherlands	12 °C with maximum 13 °C
11 November	Transfer to 20 °C in WFBR facilities	Transfer from 10.5 °C to 20 °C

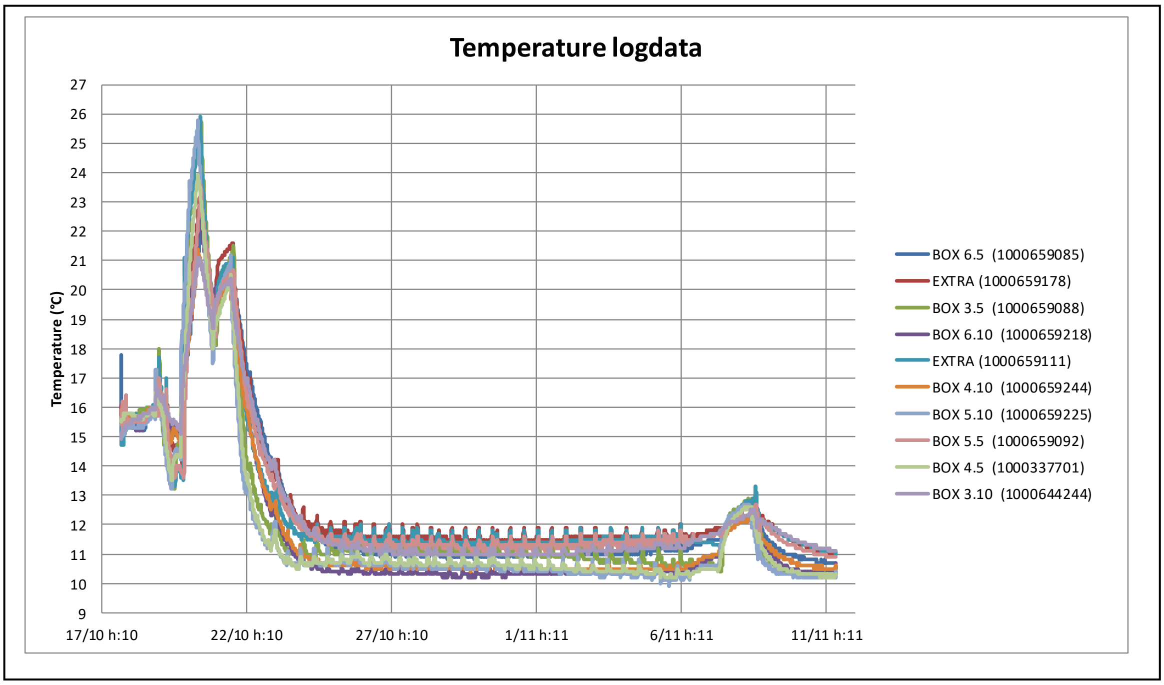


Figure 2 Temperature log data between packaging in Brazil and start of shelf-life in Wageningen of trial MA packages 2019

2.2.3 Quality assessments in the Netherlands, general information

After arrival in Wageningen on November 8th 2019, the boxes were stored for another 3 days at the target temperature of 10 °C. Some liners and HN bags were not completely closed and these were excluded from the quality assessments.

On November 11th 2019, gas measurements (O_2, CO_2) and quality assessments took place on 2 boxes per treatment, i.e. 25 days after packaging. The remaining boxes were then transferred to shelf-life conditions at 20 °C and 75 % RH. The bags were removed from half of the boxes (8 boxes per treatment) before the boxes were transferred to shelf-life conditions. The bags remained closed for the other half of the boxes during the shelf-life.
Gas measurements in liners and quality assessments of papayas took place after 2, 4 and 7 days of shelf-life. On each of these days, analysis took place for the 4 treatments on 2 boxes with bags removed before shelf-life and on 2 boxes with bags present during shelf-life.

2.2.4 Data analysis

Data are expressed in mean values per 2 boxes with 95% confidence interval error bars.

2.2.5 Measurements

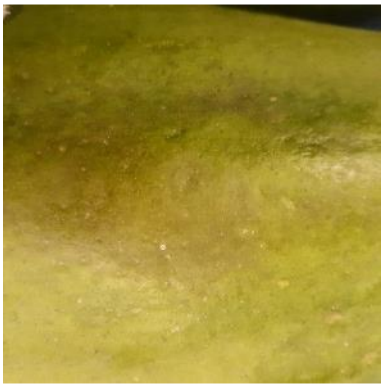
The CO_2 and O_2 percentages in the bags were measured with a CO_2/O_2 headspace gas analyzer (CheckMate 3, Dansensor A/S, Ringsted, Denmark) connected to a needle to sample directly from the bags. For ethylene analysis, first 5 mL of the headspace was sampled from the bags with a syringe. The ethylene analysis was done using a Thermo Trace 1300 GC-FID (Interscience, Breda, the Netherlands) mounted with a multiport injection system (Interscience). This system injected 250 µL samples onto a J&W GS-Gaspro column (30m, ID 0.32mm, 60 °C) using Helium as carrier gas at 250 kPa pressure. Data processing occurred using Chromeleon 7.2 (Thermo Fisher Scientific, Waltham, MA, USA).

With the exception of the weight (done per box with correction of box weight), all papayas were scored individually on the parameters as stated in ***Table 3***. Various disorders and diseases are illustrated in ***Table 4***, which photo collection is based on observations made during the overall course of the project.

Table 3 Measurement and methods used of trial MA packages 2019

Measurement	Method / Classes
Weight loss (%)	Total fruit weight per box was measured with a balance (Mettler Toledo XS10001L/XS320001L)
Shrivelling	Yes/No. Resulting in % of fruits with shrivelling symptoms.
Sunken spots	Number of spots per fruit.
Mould (fungus hyphae visible) on stem, crown or fruit belly	Yes/No. Resulting in % of fruits with mould.
Rot (fruit tissue affected) on stem-end, crown or fruit belly	Yes/No. Resulting in % of fruits with rot.
Lenticel browning (spots)	Yes/No. Resulting in % of fruits which show the disorder.
Brown spots on the skin	Yes/No. Resulting in % of fruits which show the disorder.
Pitting of the skin	0: no pitting 1: up to 25% of skin surface shows pits 2: 26-50% of skin surface shows pits 3: 51-75% of skin surface shows pits 4: more than 75%
Bruising	0 = no bruising, 1 = some bruising (insignificant), 2 = clear bruising
Firmness	Firmness was measured on slices of fruit flesh from the equatorial region of the papaya using a Fruit Texture Analyzer (Güss Manufacturing Ltd, Strand, South Africa) with a 11 mm diameter (1.0 cm^2) probe.
Skin colour	Image analysis with a RGB camera (MAKO G-192C POE, Allied Vision, Germany) positioned in a LED light cabinet (designed by WFBR and built by IPSS Engineering, the Netherlands). (Smart Colour Inspector). Analyses were done with the in-house software tool developed at WFBR.
Other disorders (with description/photo)	Yes/No. Resulting in % of fruits which show the disorder.

Table 4 Several disorders and diseases of papayas

Sunken spot 	Lenticel browning (spots) 	Brown spot/discoloration skin 
Shrivelling (stage 3 = severe) 	Pitting (small sunken pits) 	Flesh disorder (chilling injury) 
Stem mould (on pedicel only) 	Stem-end mould/rot (on fruit) 	Crown mould/rot (calyx end) 
Mould and rot on fruit belly 	Rot on fruit belly (*anthracnose*) 	Abrasion damage (mechanical) 

Source: WFBR

2.3 Results

2.3.1 Realized gas conditions

Measurements on November 7th 2019 (on the day of arrival at location Frankort & Koning, Venlo) showed a very high % CO_2 (16-18%) for the two treatments with PerfoTec liners. The Xtend liner also led to a high % CO_2 (9-11%). Measurements on November 11th in Wageningen, still under cooled conditions (10.5 °C), showed again the highest % CO_2 for the PerfoTec liners (6.3% and 5.0%) (
Figure 3 top panel, left part). It is not clear why the % CO_2 was clearly lower compared to the same treatment on November 7th.
For boxes where bags were not removed from the papayas, the CO_2 levels in the PerfoTec liners ranged between 11 and 18% for the next 7 days shelf-life at 20 °C. The CO_2 in the Xtend liners increased to levels between 8 and 11%. HN-bags reached a maximum of 0.7% CO_2. The O_2 in Perfotec liners declines rapidly during shelf life (<5%). In the HN-bags the O_2 levels were similar to ambient air, whereas in the Xtend liners the O_2 levels were in between the ones of the HN bags and Perfotec liners (***Figure 3*** middle panel). The ethylene concentration was highest in the PerfoTec liners. Under cooled conditions, the levels were around 5700 ppb (5.7 ppm) (***Figure 3*** bottom panel).

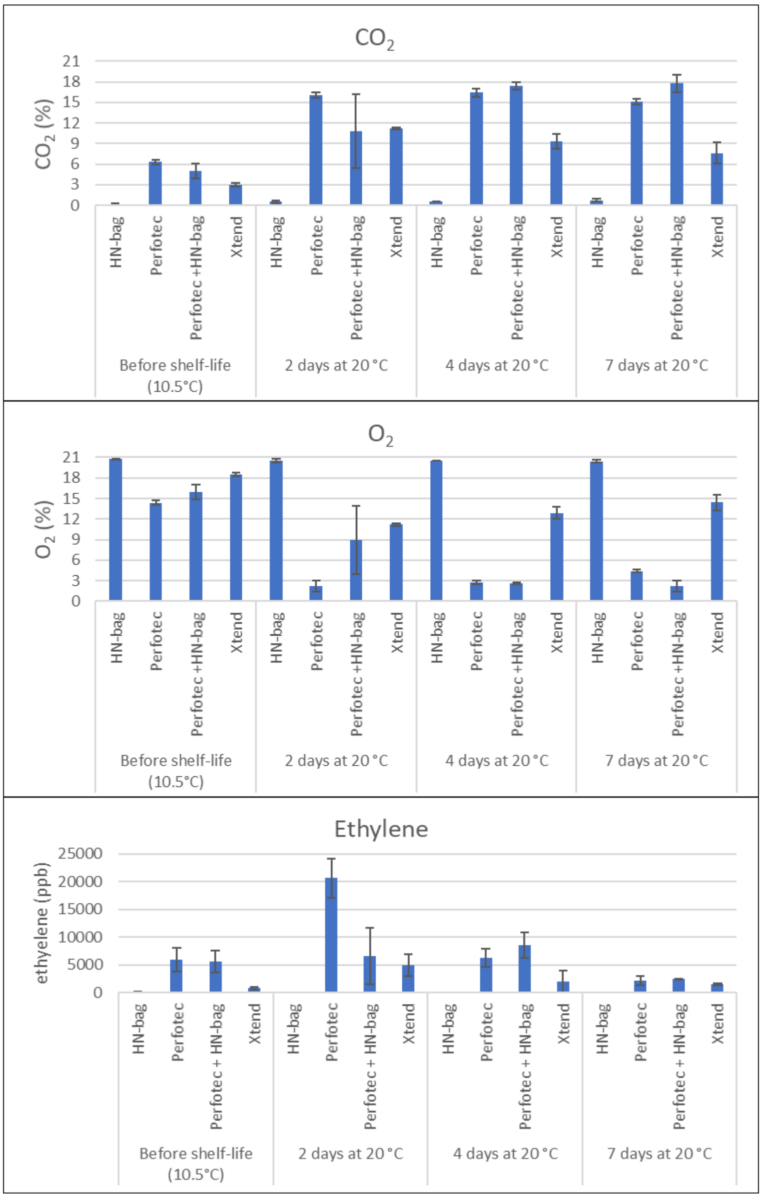


Figure 3 ***Concentrations CO_2, O_2 and ethylene (mean of 2 boxes ± standard error) in bags at 10.5 °C before shelf-life (left quarter of each panel) and during subsequent 2, 4 and 7 days shelf-life at 20 °C. (trial MA packages 2019)***

2.3.2 Condensation

As soon as the papayas arrived in Wageningen, the status of the packages was inspected. The following table mentions the observations.

Table 5 Observations at arrival in Wageningen of trial MA packages 2019.

Bag type	Observations
HN-bag (Hot-needle)	About ¼ of the HN-bags have a slight condensation. (***Figure 4*** left).
PerfoTec (biodegradable liner)	The bags are dry. Most stick to the fruit somewhat. (***Figure 4*** right).
Combination HN-bag and PerfoTec	About half of the liners show a few small condensation droplets.
Xtend (liner)	No condensation.

Figure 4 HN-bag (left) and PerfoTec biodegradable liner (right) (trial MA packages 2019)

2.3.3 Weight loss

The weight loss in the period between packaging on October 17th 2019 and November 11th 2019 (before start of shelf-life) varied between the treatments (Table 6). The papayas in HN-bags lost an average of 2.0% during the 25-day period between packaging in Brazil and start of the shelf-life in Wageningen. The weight loss was higher for the PerfoTec liner and lower for the combination and for Xtend. The same trends were found for the papayas in closed bags in during the 7-day shelf-life (Table 6).

Table 6 Weight loss (%) for the different treatments of trial MA packages 2019. Data represent means of 2 boxes ± standard error

Bag type	Average % weight loss in closed bags		
	25-day period between packaging and start shelf-life	**During 7 days shelf-life (20 °C)**	**Total period**
HN-bag (Hot-needle)	2.0 ± 0.4	1.4 ± 0.2	3.8 ± 0.3
PerfoTec (biodegradable liner)	2.9 ± 0.2	2.2 ± 0.3	5.5 ± 0.8
Combination HN-bag and PerfoTec	1.2 ± 0.0	0.9 ± 0.0	2.2 ± 0.0
Xtend (liner)	0.9 ± 0.2	1.3 ± 0.2	2.6 ± 0.5

2.3.4 General appearance

The following photos of different timepoints during the trial give an impression of the appearance and colour development of the fruits (***Figure 5***).

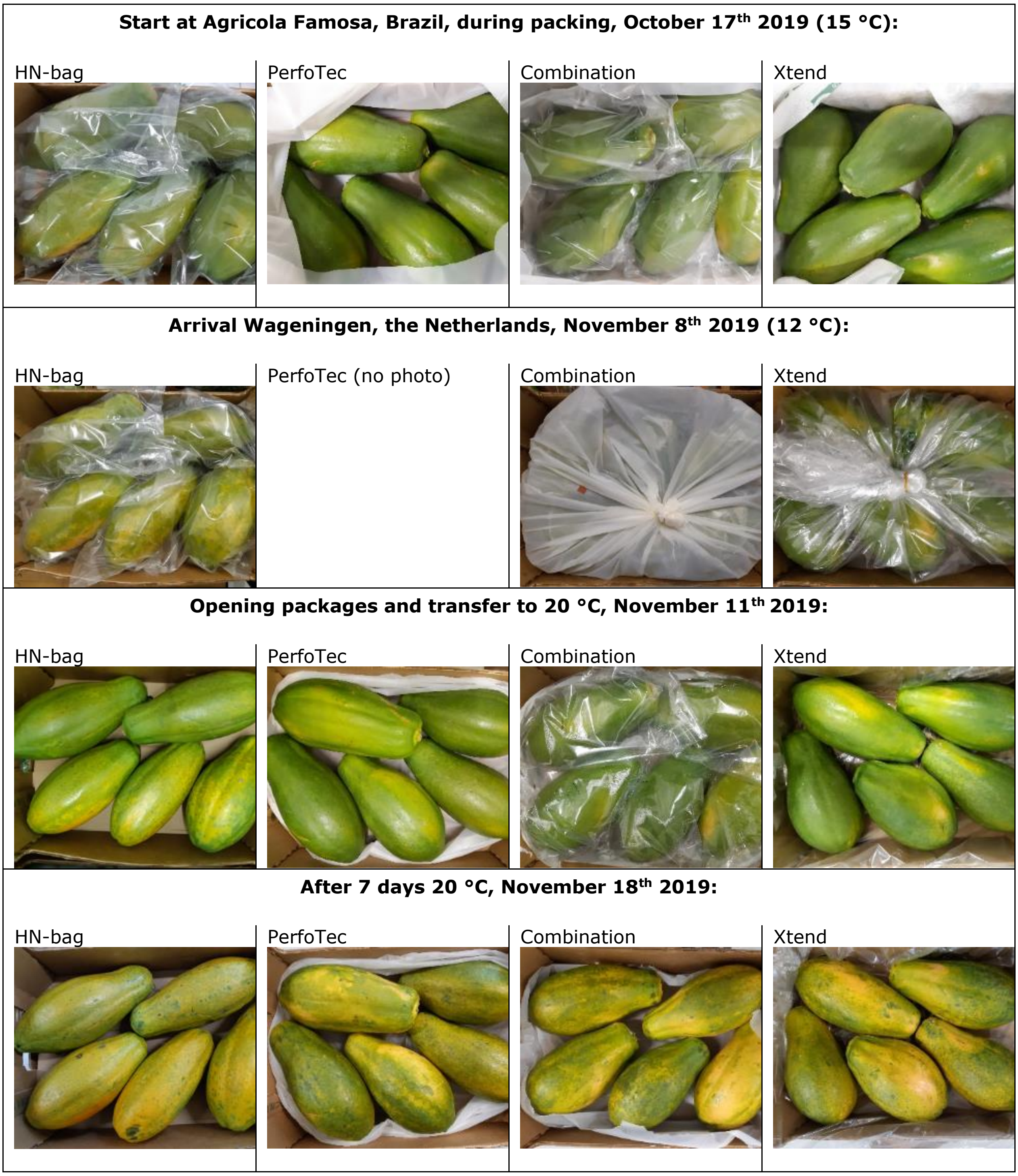


***Figure 5** Photos taken at different timepoints during the trial giving an impression of general fruit appearance of trial MA packages 2019*

2.3.5 Firmness

Firmness was measured on slices of fruit flesh of the papayas. Due to the high variation between fruits and in fruit slices, this data is not considered useful. The exact measuring position within a fruit disc turned out to be of great importance, where the firmness was clearly related to colour of the flesh (Figure 6).

Figure 6 ***Firmness measurement of fruit flesh with Fruit Texture Analyser (left) and variation in colour/firmness in the slices (right)***

2.3.6 Method development for skin colour

In the course of this trial, a method was developed for objective analysis of skin colour expressed in % yellow. By using standardized RGB-images of fruits throughout the ripening range, colour learning software (ColorLearning V1.20, developed by WFBR) was taught the colour scale for green and yellow (and visible mould growth). The colour analysis software (ColorAnalysis V3.40) calculates the area in pixels for the three colour classes per fruit. Both sides of individual fruits were taken into account.

The following figure shows an example of an image taken, after which the % yellow is calculated by the software. The upper photo is taken by the RGB camera and the lower picture shows the image after analysis by the software.

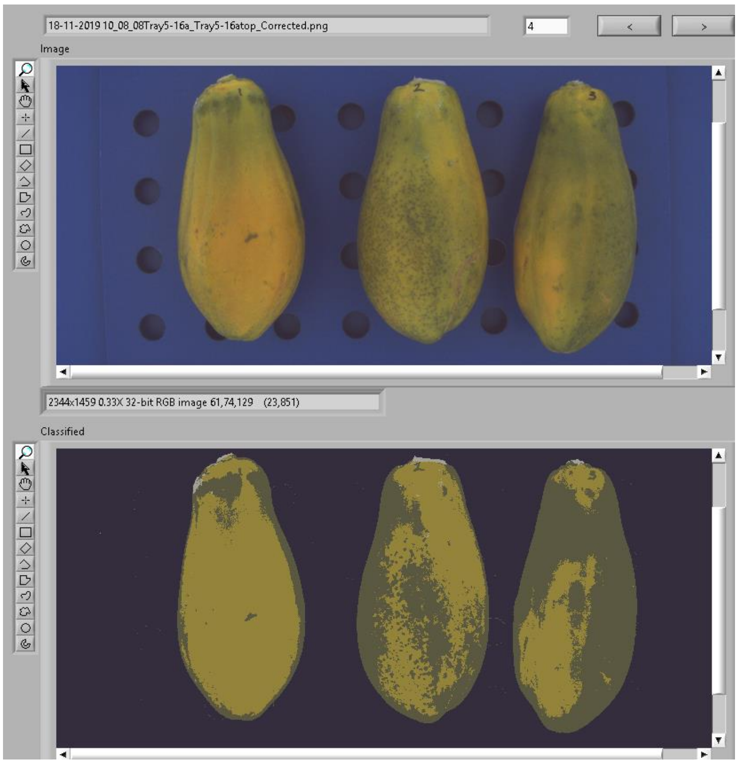


Figure 7 ***Example of an image taken after which the fruits are segmented from the background, and the yellow area per fruit is calculated and transferred in % yellow***

2.3.7 Disorders, diseases, and skin colour

Table 7 shows the results for the papayas before shelf-life (upper part of table), for papayas where the bags were removed before transfer to shelf-life conditions (middle part) and for papayas where the bags were not removed during shelf-life conditions (lower part).

<u>Before shelf-life (upper part of Table 7):</u>
After a period of 25 days transport and storage, papayas were generally still green (low % yellow skin) and had no signs of shrivelling. Pitting was visible for all treatments with the highest score for the Xtend bag. The combination of HN with PerfoTec liner had a high percentage of mould and rot.

<u>Shelf-life without bags (middle part of Table 7):</u>
During the shelf-life without bags, the percentage of fruits with signs of shrivelling was clearly the lowest for the papayas from the Xtend bags. However, papayas from the Xtend bags had the highest scores for pitting. The papayas that came from the PerfoTec liners remained the greenest. Papayas originating from the HN-bags and the Xtend bags had the lowest incidences of mould and rot.

<u>Shelf-life with bags (lower part of Table 7):</u>
The score for shrivelling was variable. Overall, the Xtend bags showed again the lowest percentage of fruits with signs of shrivelling. The scores for pitting on the papayas were at the same level as for the papayas where the bags were removed. Again, the Xtend bags had the highest scores for pitting.
The yellowing of the papayas in HN-bags was similar to papayas where the HN-bags were removed. Keeping the Xtend liner during shelf-life seemed to delay the yellowing a bit. Keeping the PerfoTec liners during 7 days of shelf-life had a big effect, papayas remained green.
The total mould and rot was highest for the combination of HN with PerfoTec liner. This was due to both an increase in crown mould/rot and belly mould/rot. The incidence of mould and rot was relatively low for Xtend.

Papayas in the HN-bag reached a higher incidence of fungus/rot compared to the papayas where bags had been removed.

<u>Brown spots (discoloration) of the skin</u>
In the ‘PerfoTec’ and ‘HN-bag and PerfoTec’ liners, some fruits where found with brown spots (discoloration) of the skin. This colour became more intense during shelf-life, while the number of fruits with this discolouration did not increase. However, it proved difficult to reliably assess this disorder in the presence of rot.

Table 7 Results of quality assessments for papayas harvested at different maturities followed by 25 days shipment plus 0, 2, 4 and 7 days shelf-life. Data represent means of 2 boxes (±standard error) (trial MA packages 2019)

	Days shelf-life	Treatment	Shrivel-ling (%)	Pitting (score 0-4) (mean ± st.error)	Stem mould (%)	Stem-end rot (%)	Crown mould + rot (%)	Belly mould + rot (%)	Total mould+ rot (%)	% yellow skin (mean ± st.error)
Before shelf-life	**0 days at 20 °C**	**HN-bag**	0	0.6 ±0.4	0	0	0	9	9	10 ± 7
		PerfoTec	0	1.2 ±0.0	0	0	0	0	0	6 ± 4
		HN + PerfoTec	0	0.4 ±0.0	0	0	18	27	45	2 ± 3
		Xtend	0	2.2 ±1.9	0	0	0	0	0	5 ± 7
Shelf-life without bags	**2 days at 20 °C**	**HN-bag**	70	2.5 ±0.6	0	0	0	0	0	4 ± 2
		PerfoTec	90	1.2 ±1.1	10	0	0	50	50	2 ± 2
		HN + PerfoTec	30	0.2 ±0.2	20	0	20	50	50	1 ± 1
		Xtend	0	2.8 ±0.4	0	0	0	0	0	11 ± 4
	4 days at 20 °C	**HN-bag**	40	0.6 ±0.0	10	0	0	10	10	13 ± 6
		PerfoTec	40	2.0 ±1.6	30	0	20	80	80	3 ± 1
		HN + PerfoTec	40	2.2 ±1.6	20	20	10	60	60	16 ± 3
		Xtend	0	2.8 ±0.8	0	0	0	0	0	23 ± 19
	7 days at 20 °C	**HN-bag**	40	1.0 ±0.0	10	0	0	0	10	44 ± 36
		PerfoTec	50	1.9 ±0.2	30	0	20	70	70	19 ± 2
		HN + PerfoTec	30	2.1 ±1.4	70	0	30	80	80	35 ± 10
		Xtend	10	3.7 ±0.2	0	10	0	20	20	54 ± 20
Shelf-life with bags	**2 days at 20 °C**	**HN-bag**	58	1.8 ±0.2	0	8	0	10	8	9 ± 0
		PerfoTec	67	1.4 ±0.2	8	8	8	30	25	0 ± 0
		HN + PerfoTec	8	0.8 ±0.3	17	8	50	40	50	2 ± 0
		Xtend	0	2.5 ±0.6	0	0	0	0	0	4 ± 7
	4 days at 20 °C	**HN-bag**	17	1.6 ±0.8	8	0	0	20	17	18 ± 9
		PerfoTec	25	1.1 ±0.2	0	0	8	50	50	2 ± 2
		HN + PerfoTec	0	1.3 ±0.3	8	0	83	100	100	1 ± 1
		Xtend	0	2.8 ±0.3	0	0	0	10	8	12 ± 1
	7 days at 20 °C	**HN-bag**	58	1.2 ±0.3	42	8	8	50	50	49 ± 9
		PerfoTec	75	1.1 ±0.5	33	8	17	80	75	4 ± 1
		HN + PerfoTec	0	1.3 ±0.3	58	0	58	100	100	2 ± 0
		Xtend	8	2.9 ±0.5	25	8	0	30	25	40 ± 4

2.4 Discussion and conclusion

The conditions of the supply chain from the producer in Brazil to Wageningen in the Netherlands were not optimal in this shipment. The severe break of the cold chain that occurred in the first week after harvest most likely seriously affected the results. MA packaging is expected to contribute to a better quality, but under the condition that temperature in the supply chain fluctuates less than during this trial. Indicatively, a temperature fluctuation of 4-5°C would be acceptable for the PerfoTec liner (Personal communication by PerfoTec, 2020). Another note for the realized supply chain is that the seven-day period between the reefer ready to be loaded and departure was unusually long (Personal communication by Agricola Famosa, 2020). It should ideally be a maximum of 3 days, although often difficult to realize in practice. Packing and loading depends on the vessel's schedule which is out of control of the producer. Although harvest is planned near shipping, sometimes the vessel is delayed due to unforeseen circumstances.

The measured CO_2 levels were higher than the target level. For papaya, the target is to stay below 8% CO_2 (Arpaia and Kader 1997, Martins, Resende et al. 2015, Zhou, Paull et al. 2016). At higher levels, development of bad odour and skin damage can occur. However, high CO_2 levels can inhibit mould growth. This trade-off between skin condition and mould growth inhibition should be carefully evaluated. In the present trial, brown spots observed on papayas from PerfoTec packages are probably caused by too high CO_2. Based on the results, the degree of perforation for the PerfoTec liner will be increased in the next trail (with an indicative 20% higher perforation).

During shelf-life, the papayas originating from the PerfoTec liners (exclusively or in combination with HN-bags) remained greener than the papayas from HN-bags and Xtend. This was the case both for the shelf-life without and with the bags. The greener colour is probably related to the higher CO_2 in the PerfoTec liners earlier in the chain, where 16-18% CO_2 was measured after arrival in the Netherlands. However, these CO_2 levels probably also explain the brown spots (discolouration) on the skin that were found in the PerfoTec liner and combined packaging.

The main conclusions are:

- The chain conditions showed a serious problem with an increase up to 26 °C around the loading of the reefer container in Brazil. Temperature control during the total chain is of course very important to reduce quality issues. For subsequent trials, it is necessary to prevent high temperatures in the chain in order to have a fair judgement on the performance of PerfoTec liners compared to the HN-bags.
- The PerfoTec liner led to CO_2 levels above the target level of 8%. The permeability of the liner should be increased in the next trial.
- Especially the Xtend liner led to pitting on the skin.
- The HN-bags performed best among the packages, although also here several quality issues were found.
- The method developed to analyse the % of yellow skin proved to be useful.
- The method used for firmness measurements was not suitable. Another method should be explored in the next trial.

3 Trial: MA packages (2020)

3.1 Introduction

As a follow-up to the earlier trial, a new test was set up in which 3 different bag types were compared: HN-bad, Perfotec biodegradable liner and Xtend liner. The PerfoTec biodegradable liner was adapted based on the previous results. Papayas were packed at Agricola Famosa in Brazil and transported to the Netherlands to the port of Rotterdam by sea reefer. Quality was assessed during a period of shelf-life in Wageningen.
This trial was also used to develop a method to analyse internal papaya colour. This flesh colour gives an indication of the ripening progress.

3.2 Methods/Design of the research

3.2.1 Materials

Boxes with papayas 'Tainung' were packed at Agricola Famosa in Brazil on March 13th 2020. The maturity was the Agricola Famosa's standard for export to Europe, i.e. with 1-2 yellow stripes. Boxes were randomized over the 3 different treatments (Table 8). Each box contained 7 fruits. Total fruit weight per box was around 8 kg.
Three temperature loggers (LogTag TRIX-8, LogTag Recorders Ltd) were added to the pallet with boxes.

Table 8 Overview of 3 treatments (bag types) of trial MA packages 2020

Treatment	**Bag**	**Way of packaging**	**# boxes**
1	HN-bag (Hot-needle) on individual fruit	Flowpack machine	8
2	Perfotec biodegradable liner	Manual	8
3	Xtend liner (Papaya, 815-PP64)	Manual	8

3.2.2 Realized chain conditions

After packing on March 13th 2020 at the Flamengo farm (near Mossoró), the pallet with boxes was transported on one of the following days to the farm in Inajá (Pernambuco State) where it was later added to a container with yellow honeydew melons for transport to the Netherlands. The realized timetable and temperature log data are given in respectively ***Table 9*** and ***Figure 8***. The realized chain conditions in this trial were problematic. In Brazil, the trial pallet had to undergo a detour of several days with high temperatures (between 25 – 30 °C) before reaching the cooled transport container.

Table 9 Realized timetable of trial MA packages 2020

Date	**Location**
13 March 2020	Packaging at Agricola Famosa, Flamengo farm Mossoró
13-17 March	From Flamengo farm to Inajá, Brazil
22 March	Departure Inajá, Brazil
4-5 April	Arrival Rotterdam, the Netherlands
6 April	Arrival at Frankort & Koning in Venlo, the Netherlands
7 April	Transport to WFBR Wageningen and placed at 10 °C, the Netherlands
8 April	Transfer to 20 °C to start shelf-life, the Netherlands

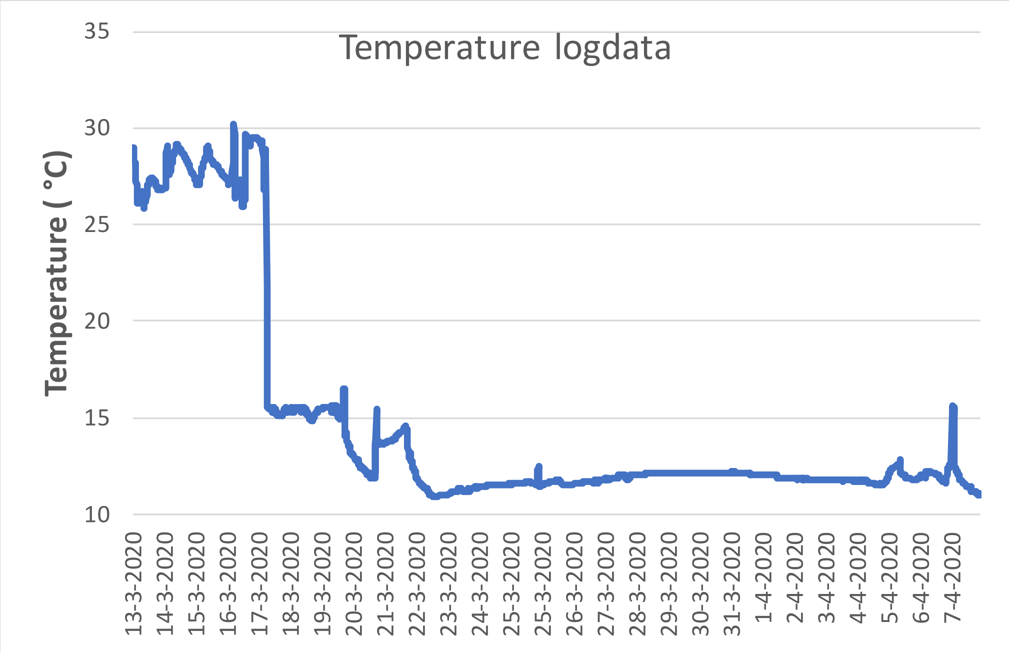


Figure 8 ***Temperature between packaging in Brazil and start of shelf-life in Wageningen of trial MA packages March-April 2020***

3.2.3 Quality assessments in the Netherlands, general information

After arrival in Wageningen on April 7th 2020, the boxes were stored at 10 °C for another day. On April 8th concentrations of O_2, CO_2 and ethylene were measured inside the bags. The bags were then removed and 6 boxes from each treatment were transferred to shelf-life conditions at 20 °C and 75 % RH. Quality assessments took place after 0, 2 and 6 days shelf-life on 2 boxes of each treatment.
The remaining two boxes of each treatment remained at 10 °C to perform an indicative taste test after 6 days. This was done because in the previous test there was a suspicion of off-taste when consuming directly at 10 °C.

3.2.4 Data analyses

Data are expressed in mean values per 2 boxes with 95% confidence interval error bars.

3.2.5 Measurements

The O_2, CO_2 and ethylene concentrations in the bags were measured as described for the previous trial 'MA packages (2019)'.
With the exception of the weight (per box), all papayas were scored individually on the parameters as stated in ***Table 10***. Based on experiences of the previous trial, quality assessments were adapted for shrivelling (4 instead of 2 classes) and firmness (make a longitudinal cut with a knife and score by feel, instead of using an automatic penetrometer).

Table 10 Measurement and methods used (trial MA packages 2020)

	Method / Classes
Weight loss (%)	Total fruit weight per box was measured with a balance (Mettler Toledo XS10001L/XS320001L)
Shrivelling	0 = no visible shrivelling, 1 = very slight, 2 = slight, 3 = clear shrivelling
Pitting of the skin	0: no pitting 1: up to 25% of skin surface shows pits 2: 26-50% of skin surface shows pits 3: 51-75% of skin surface shows pits 4: more than 75%
Sunken spots	Number of spots per fruit
Mould (fungus hyphae visible) on stem, crown or fruit belly	Yes/No. Resulting in % of fruits with mould.
Rot (fruit tissue affected) on stem-end, crown or fruit belly	Yes/No. Resulting in % of fruits with rot.
Lenticel browning (spots)	Yes/No. Resulting in % of fruits which show the disorder.
Brown spots on the skin	Yes/No. Resulting in % of fruits which show the disorder.
Bruising	0 = no bruising, 1 = some bruising (insignificant), 2 = clear bruising
Skin & internal colour	Image analysis with a RGB camera (MAKO G-192C POE, Allied Vision, Germany) positioned in a LED light cabinet (designed by WFBR and built by IPSS Engineering, the Netherlands). (Smart Colour Inspector). Analyses were done with the in-house software tool developed at WFBR (ColorAnalysis V3.40). For the skin this resulted in % yellow. For internal colour (from a slice in the middle) this resulted in % ripe flesh.
Firmness	Make a longitudinal cut with a knife and score by feel: 1 = Soft, 2 = Intermediate, 3 = Firm/hard
Other disorders (with description/photo)	Yes/No. Resulting in % of fruits which show the disorder.

3.3 Results

3.3.1 Realized gas conditions

A day after arrival in Wageningen, gas measurements were taken, still under cooled conditions. As is to be expected from its perforations, the HN-bags had gas concentrations similar to the surrounding air (***Table 8***). The PerfoTec liners had the lowest O_2 and the highest CO_2. The total O_2+CO_2 averaged 21.3% for PerfoTec and 22.6% for Xtend. The ethylene concentrations for PertoTec and Xtend were in a similar range.

Table 8 O_2, CO_2 and ethylene in packaging after arrival in Wageningen of trial MA packages 2020. Data represent means of 2 boxes ± standard error (s.e.)

	O_2 (%) mean ± s.e.	**CO_2 (%) mean ± s.e.**	**Ethylene (ppb) mean ± s.e.**
HN-bag (Hot-needle)	**20.8 ± 0.0**	**0.1 ± 0.0**	**0.0 ± 0.0**
PerfoTec	**13.1 ± 0.6**	**8.2 ± 0.4**	**360 ± 98**
Xtend	**17.1 ± 0.5**	**5.5 ± 0.7**	**234 ± 89**

3.3.2 Condensation

As soon as the papayas arrived in Wageningen, the status of the packages was inspected. No condensation was observed.

3.3.3 Weight loss

Weight loss in the 26-day period between packaging and start of shelf-life varied between the 3 types of packaging (***Table 9***). The papayas in HN-bags had lost 5.3% weight in average. The weight loss was slightly less for the Perfotec liners (4.8%) and lowest for Xtend (2.3%). In the subsequent shelf-life period without packaging, the weight loss was similar for the 3 treatments. Because the papayas from Xtend started with a lower weight loss %, they also ended with a lower weight loss % over the total transport + shelf-life.

Table 9 Weight loss (%) in the 26-days period (packaging) and with additional 2 and 6 days shelf-life (unpacked) of trial MA packages 2020. Data represent means of 2 boxes ± standard error

	26-day packaging	+ 2 days shelf-life	+ 6 days shelf-life
HN-bag (Hot-needle)	**5.3 ± 0.5**	**6.9 ± 1.0**	**12.1 ± 1.0**
PerfoTec	**4.8 ± 0.4**	**6.1 ± 1.4**	**11.5 ± 1.2**
XTend	**2.3 ± 0.3**	**3.8 ± 0.2**	**8.4 ± 0.5**

3.3.4 General appearance

Photos at different time points during the trial give an impression of the appearance and colour development of the fruits (***Figure 9***). Clearly the quality after 6 days of shelf-life was (too) poor. In order to compare the 3 treatments, the focus in the following paragraphs is therefore on the results of the quality assessments after 0 and 2 days shelf-life.

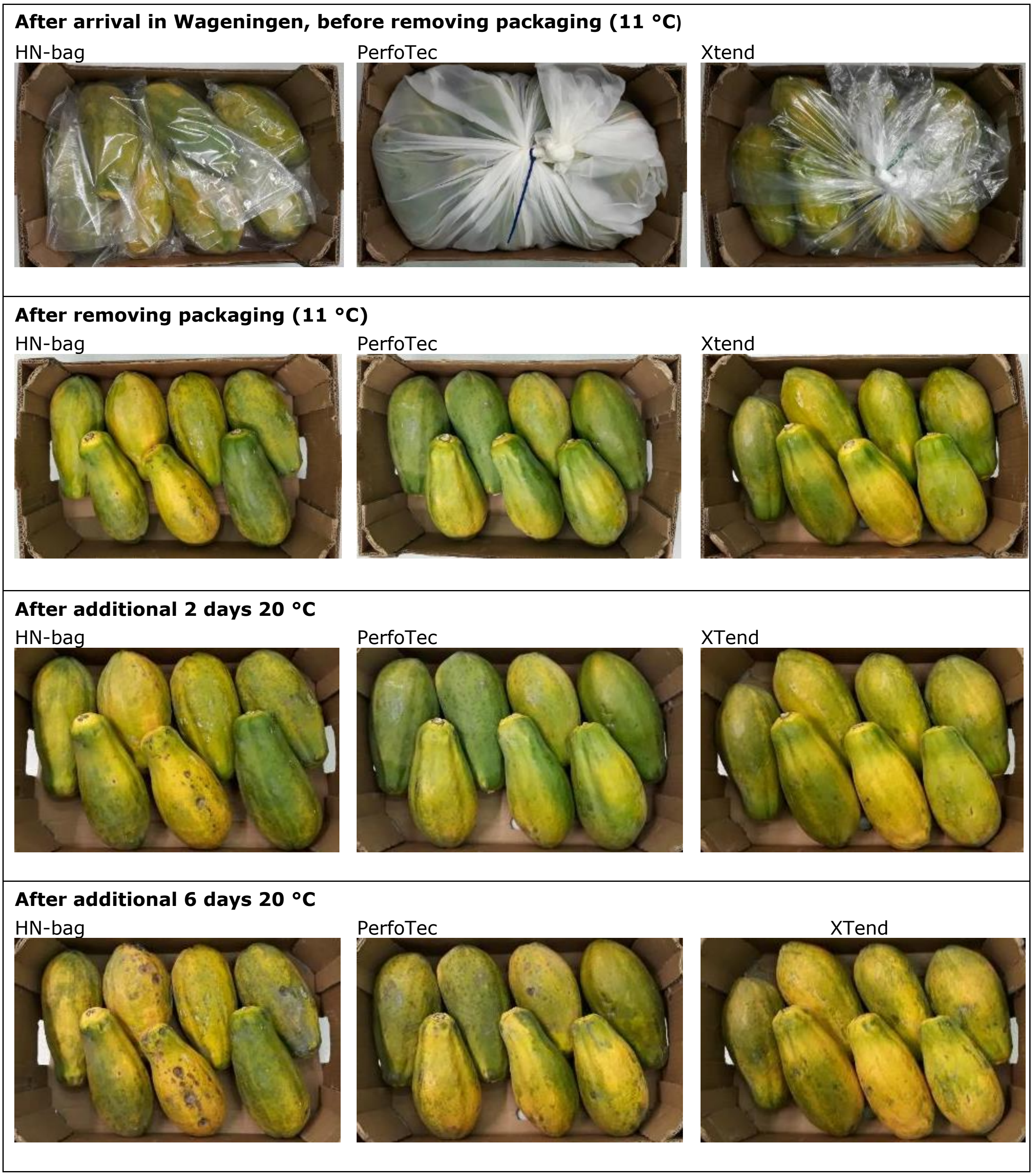


Figure 9 ***Photos taken at different timepoints during the trial give an impression of general fruit appearance of trial MA packages March-April 2020.***

3.3.5 Firmness

Already on the first assessment day, at the start of shelf-life, all fruits were rated as soft, indicating an advanced ripeness stage.

3.3.6 Disorders, diseases, and skin colour

The presence of disorders, diseases and the skin colour were evaluated. ***Table 10*** shows the results for different quality parameters of the papayas.

Initially, shrivelling symptoms were the highest for the HN-bags and lowest for the papayas from the Xtend bags. PerfoTec liners scored in between. This corresponds to the observed difference in weight loss. After 6 days of shelf-life, all papayas showed clear shrivelling.

On the day of arrival in Wageningen, only a slight pitting of the skin of some papayas was visible. The PerfoTec bags had the highest scores of pitting. The same was found after 2 days of shelf-life. After 6 days of shelf-life, other quality problems overshadowed the visibility of the pits.

There was no mould found on the stems. Before shelf-life, 29% of the papayas from HN-bags showed already some other form of mould and/or rot. Stem-end mould/rot was the most common problem here. Both PerfoTec and Xtend liners outperformed the HN-bags, with 0 and 7% total mould/rots, respectively. Stem-end mould/rot but also diseases on other fruit parts developed very quickly during shelf-life. After 2 days of shelf-life, Xtend performed best, although the total mould/rot was also very high. The variation between the boxes was high.

Fruits with bruises and brown spots were also seen, but very scarce and insignificant.

Table 10 Results of quality assessments for papayas from different packages after 0, 2 and 6 days shelf-life of trial MA packages March- April 2020. Data represent means of 2 boxes (±standard error)

	Days shelf-life	Treat-ment	Shrivelling (score 0-3) (mean ± st.error)	Pitting (score 0-4) (mean ± st.error)	Stem mould %	Stem-end mould/rot (%)	Crown mould + rot (%)	Belly mould +rot (%)	Total mould + rot (%)	% yellow skin (mean ± st. error)
Before shelf-life	0 days at 20 °C	HN-bag	0.7 ± 0.0	0.1 ± 0.1	0	29	0	7	29	43 ± 4
		PerfoTec	0.4 ± 0.1	0.4 ± 0.4	0	0	0	0	0	13 ± 9
		Xtend	0.0 ± 0.0	0.0 ± 0.0	0	0	0	7	7	33 ± 3
Shelf-life without bags	2 days at 20 °C	HN-bag	1.1 ± 0.0	0.1 ± 0.3	0	64	29	64	86	24 ± 5
		PerfoTec	0.4 ± 0.3	1.0 ± 0.8	0	36	29	36	79	5 ± 2
		Xtend	0.0 ± 0.0	0.4 ± 0.7	0	14	7	43	43	13 ± 7
	6 days at 20 °C	HN-bag	1.4 ± 0.0	-	0	93	100	43	100	-
		PerfoTec	1.5 ± 0.1	-	0	86	86	93	100	-
		Xtend	1.6 ± 0.3	-	0	100	100	86	100	-

Before the start of shelf-life conditions, the fruits from PerfoTec liners were greener (lower % yellow skin) than the other treatments. Also in the following period at 20 °C, the papayas from PerfoTec liners remained the greenest.
The % yellow as assessed by RGB camera and image analysis was lower after 2 days of shelf-life compared to 0-day shelf-life. The opposite would be expected when fruits ripen. It is likely that the deterioration of skin quality (more brownish) led to the apparent decrease in % yellow.

Two boxes of each treatment were not transferred to shelf-life conditions, but stayed at 10 °C. An indicative taste test after 6 days revealed no off-taste.

3.3.7 Method development for internal colour

In the course of this trial, a method was developed for objective analyses of flesh colour, expressed as % of ripe flesh. By using standardized RGB images of fruits, colour learning software (developed by WFBR) was taught to calculate the % ripe fruit flesh (orange/red coloured tissue).
It is based on the Hunter L, a, b color scale where:

- L scale indicates light vs. dark where a low number (0-50) indicates dark and a high number (51-100) indicates light.
- a scale indicates red vs. green where a positive number indicates red and a negative number indicates green.
- b scale indicates yellow vs. blue where a positive number indicates yellow and a negative number indicates blue.

So the L value indicates the level of light or dark, the a value redness or greenness, and the b value yellowness or blueness. All three values are required to fully describe the color of an object. The following figure shows an example of an image taken (left), after which the % of ripe fruit flesh (orange/ red coloured tissue) is calculated by the software (right). This method developed may be used in the next trial.

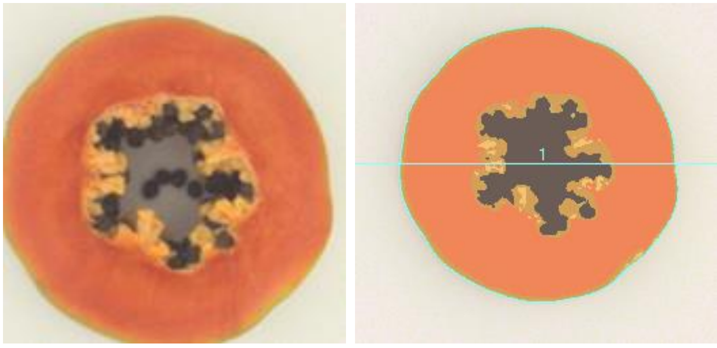


***Figure 10** Example of an image taken after which the % ripe fruit flesh is calculated by the software (85% in this example)*

3.4 Discussion and conclusion

Unfortunately, the realized chain conditions in this trial were problematic. In Brazil, there were 4 days where the papayas were exposed to high temperature before the start of cooling process. While quality was still acceptable at arrival, it decreased very fast during shelf-life.

Based on experiences from the previous trial (October 2019), the PerfoTec liner was modified with more perforations. Now the performance was better. CO_2 was around 8% on arrival in Wageningen, while in previous trial it reached much higher concentrations. Based on literature, this is an acceptable level at which positive quality effects can be expected (Arpaia and Kader 1997, Martins, Resende et al. 2015, Zhou, Paull et al. 2016).
Before the start of shelf-life conditions, the fruits of PerfoTec liners were greener (lower % yellow skin) than the other treatments. Also in the following period at 20 °C, the papayas of PerfoTec liners remained the greenest. Presumably this inhibition of yellowing is due to the realized CO_2 percentage.

In the previous trial, the Xtend liner led to clearly more pitting on the skin. In this present trial, more pitting was found on papaya packed in the PerfoTec liner, although not in a serious amount and of low commercial importance. In general, both the PerfoTec and the Xtend liner performed better than the HN-bags with benefits for (slightly) less weight loss, less shrivelling, reduced yellowing and less rots.

The main conclusions are:

- Temperature control during the total chain remains the most important point of attention.
- In general, both the PerfoTec and Xtend liner performed better than the HN-bags under the realized (unfavourable) circumstances.

4 Trial: RipeLocker (2020)

4.1 Introduction

In this trial, papayas were shipped in RipeLockers and compared to the current standard of individual papayas in HN-bags packed in cardboard boxes. The conditions in the RipeLocker pallet-sized hypobaric storage chambers were set and remotely-monitored by RipeLocker LLC.
Papayas were packed at Agricola Famosa in Brazil and transported to Rotterdam, the Netherlands, by sea reefer, after which the quality was assessed over a period of shelf-life in Wageningen.
This trial was also used to explore near-infrared spectroscopy (NIR) as a method to non-destructively indicate the ripeness stage of the fruit.

4.2 Methods/Design of the research

4.2.1 Materials

Papayas 'Tainung' of 3 maturity stages were harvested and selected at Agricola Famosa on September 4th 2020. Samples of 9 fruits were measured on pulp firmness (hand penetrometer with 1.0 cm^2 plunger) and °Brix (hand refractometer). ***Table 11*** provides an overview of the 3 maturity stages (Green, Standard, Ripe).

Table 11 Maturity stages before shipment to the Netherlands with initial quality parameters at start of the trial in Brazil of trial RipeLocker September 2020 (data: Agricola Famosa). Data represent means of 9 fruits (± standard error)

Maturity stage	**Identification**	**Firmness (kg/cm^2) and °Brix**	
Green	Green labels	16.1 ± 1.9 kg 13.0 ± 2.1 °Brix	
Standard (Agricola Famosa's standard for export to Europe, i.e. green with 1-2 yellow stripes)	Yellow labels	14.2 ± 3.0 kg 13.5 ± 3.2 °Brix	
Ripe (tree-ripe, 60% yellow)	Orange labels	1.2 ± 0.3 kg 13.3 ± 0.3 °Brix	

Agricola's normal practice for treatment against stem end mould was not applied, as this trial was packed separately from the normal procedures for commercial shipments.

All fruits were packed in foam nets and divided over 4 RipeLockers and cardboard boxes (controls). Part of the fruits were numbered, weighed and photographed (***Table 12***; ***Figure 11***). RipeLocker conditions (pressure, O_2, CO_2 concentrations) were set by RipeLocker LLC, with differences between the 4 RipeLockers. RipeLockers were numbered as RL1, RL2, RL3 and RL4.

Table 12 Overview of treatments of trial RipeLocker September 2020

Treatments (5)	**Maturity stages (3)**	**Recording initial weight + photos**
RipeLocker RL1	3 maturity stages x 30 fruits	3 maturity stages x 10 fruits
RipeLocker RL2	3 maturity stages x 30 fruits	3 maturity stages x 10 fruits
RipeLocker RL3	3 maturity stages x 30 fruits	3 maturity stages x 10 fruits
RipeLocker RL4	3 maturity stages x 30 fruits	3 maturity stages x 10 fruits
Control boxes	3 maturity stages x 6 boxes	3 maturity stages x 36 fruits

Figure 11 Start of the trial RipeLocker 2020 at Agricola Famosa (RipeLocker (left), Control boxes (center), initial quality assessment (right))

4.2.2 Realized chain conditions

Papayas were packed on September 4th 2020. The pallet was shipped from the Flamengo farm (near Mossoró) to Inajá (Pernambuco State) in Brazil. It was then shipped together in a reefer container full of yellow honeydew melon to the Netherlands. The reefer settings were 10 °C, 65% RH and closed circulation.

The transport from the farm in Brazil to the importer in the Netherlands lasted 3 weeks. Based on RipeLockers readings (provided by RipeLocker LCC), the reefer container had no power supply for at least 17 hours. This happened from Saturday, September 5th, 2020 11:15 PM to Sunday, September 6th, 2020 16:28 PM (Brazilian time). The RipeLockers have a power back up system for 12 hours. But after this period, the RipeLocker system stopped operating. After the power was restored, RipeLocker data showed that a high CO_2 build-up had occurred inside the RipeLockers. Data also indicated that the ambient temperature (in the reefer) during this period was between 14 °C and 20 °C (***Figure 12***). Air inside the reefer (background) was approximately 12% O_2 and above 5% CO_2 (above sensor's range) and was steady from September 6th to September 9th.

Data from Xsense loggers (Agricola Famosa) which were inserted in yellow melon boxes in the same reefer, showed a different temperature pattern (Figure 13). In any case, the cold chain was not maintained during the first days of the trial. Table 13 gives an overview of the timetable achieved.

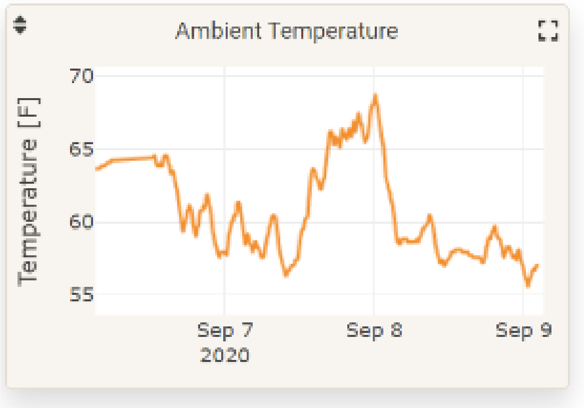


Figure 12 Temperature in the reefer between 6-9 September of trial RipeLocker September 2020. Source: RipeLocker LLC. (55-70 °F corresponds with 12.8-21.1 °C)

Figure 13 Data from Xsense temperature/RH logger of trial RipeLocker 2020 (placed in yellow melon boxes of the first pallet in the container). Source: Agricola Famosa.

Table 13 Realized timetable of trial RipeLocker 2020

Date	Location / activity
4 September 2020	Packing at Agricola Famosa (Brazil), start shipment via Hapag-Lloyd container
5-6 September	Power off, rise of temperature
6 or 9 September	Leaving port of Salvador
24 September	Arrival Rotterdam (the Netherlands)
25 September	Arrival at Frankort & Koning (Venlo, the Netherlands)
26 September	Decommission RipeLockers at Frankort & Koning
28 September	Transport to WFBR Wageningen (the Netherlands) and placed at 10 °C
29 September	Transfer to 18 °C to start shelf-life (assessments day 0)
2 October	Assessments 3 days shelf-life (day 3)
6 October	Assessments 7 days shelf-life (day 7)

4.2.3 Quality assessments in the Netherlands, general information

On September 28th 2020, the RipeLockers were delivered to Wageningen by truck with the RipeLocker lids slightly open (sufficient for fresh air exchange). The air temperature in the RipeLockers was measured immediately (11.7 °C). The RipeLockers and cardboard boxes were placed at 10 °C (65% RH) until the next morning.

All papayas were transferred from the RipeLockers and boxes into plastic crates (60x40x17cm) with labels. Foam nets were removed and the numbered papayas were weighed and photographed. A third of the load was then assessed for quality (0-day shelf-life). Two-thirds of the load was transferred to a room at 18 °C (65% RH) for later quality assessments after 3 and 7 days of shelf-life (the latter day included the numbered papayas).

4.2.4 Measurements

All papayas were scored individually on the parameters as stated in ***Table 14***. Based on experiences from the previous trial in April 2020, quality assessments were adjusted for firmness (score by feel when making a longitudinal cut). In addition, the measurements were extended with °Brix, internal colour and NIR.

Table 14 Measurement and methods used of trial RipeLocker September 2020

Measurement	Method / Classes
Weight loss (%) (numbered fruit)	Weight of numbered fruits was measured with a balance (Mettler Toledo 6002)
Shrivelling	0 = no visible shrivelling, 1 = very slight, 2 = slight, 3 = clear shrivelling
Sunken spots	Number of spots per fruit
Lenticel browning (spots)	Yes/No. Resulting in % of fruits which show the disorder.
Brown spots on the skin	Yes/No. Resulting in % of fruits which show the disorder.
Pitting of the skin	Yes/No. Resulting in % of fruits which show the disorder.
°Brix	Digital refractometer (Hi 96801 Hanna Instruments, Woonsocket, RI, USA; PHT0004)
Firmness	Make a longitudinal cut with a knife and score by feel: 1 = Soft, 2 = Intermediate, 3 = Firm/hard
Mould (fungus hyphae visible) on stem, crown or fruit belly	Yes/No. Resulting in % of fruits with mould.
Rot (fruit tissue affected) on stem-end, crown or fruit belly	Yes/No. Resulting in % of fruits with rot.
Skin colour	Image analysis with a RGB camera (MAKO G-192C POE, Allied Vision, Germany) positioned in a LED light cabinet (designed by WFBR and built by IPSS Engineering, the Netherlands). (Smart Colour Inspector). Analyses were done with the in-house software tool developed at WFBR (Color Analysis V3.40). Resulting in % yellow skin
Internal colour	Image analysis (see Skin colour) of longitudinal cut. Resulting in % ripe flesh
NIR (near-infrared spectroscopy)	Labspec Hi-Red spectrometer (350-2500 nm) with Hi-Brite probe (Malvern Panalytical). To study relation with internal colour.
Other disorders (with description/photo)	Yes/No. Resulting in % of fruits which show the disorder.

The location on the fruit where the NIR measurement was performed was marked (Figure 14). The longitudinal cross-section (for firmness and internal colour) was then made on this spot. The °Brix was measured on a piece of tissue from the marked spot after removing the skin.

Figure 14 ***NIR measurement on marked spots, and papayas with longitudinal cross-section through the marked spots***

4.2.5 Statistical analyses

The effect of treatment was analysed per assessment day and per maturity stage by analysis of variance as far as statistically justified (SPSS version 25.0.9.2). When significant differences were observed, comparisons among were made using Tukey's test for post-hoc analysis. The significance level used was 95%.
Standard errors for 95% confidence interval are shown when statistically appropriate (data normally distributed).

4.3 Results

4.3.1 Visual impression of papayas when still in the RipeLockers

The 'green' and 'standard' papayas in the RipeLockers looked very fresh, almost as if they had been just harvested. Some mould (no decay) was often visible on the stem. There were no signs of fruit dehydration (shrivelling), unlike the papayas in the control boxes.
Several 'ripe' papayas in all 4 RipeLockers showed signs of collapse. This was recognized as damage due to too fast release of the hypobaric condition. The observed internal (translucent) red coloration of the flesh may be the consequence of this collapsing, or could have been present already before in these very mature fruit (***Figure 15***). *Note: Due to poor quality of ripe (orange) papayas these were only assessed after 0 days shelf-life.*

Figure 15 ***Papayas in the RipeLockers at opening (trial RipeLocker September 2020)***
Left : General view with fresh looking 'green' and 'standard' papayas
Middle : Stem mould
Right : Longitudinal section of collapsed 'ripe' papaya

4.3.2 Weight loss

The weight loss of the papayas in the RipeLockers during transport was very low (***Figure 16*** top panel). The total weight loss remained lower after 7 day of shelf-life compared to papayas from control boxes. (***Figure 16*** bottom panel).

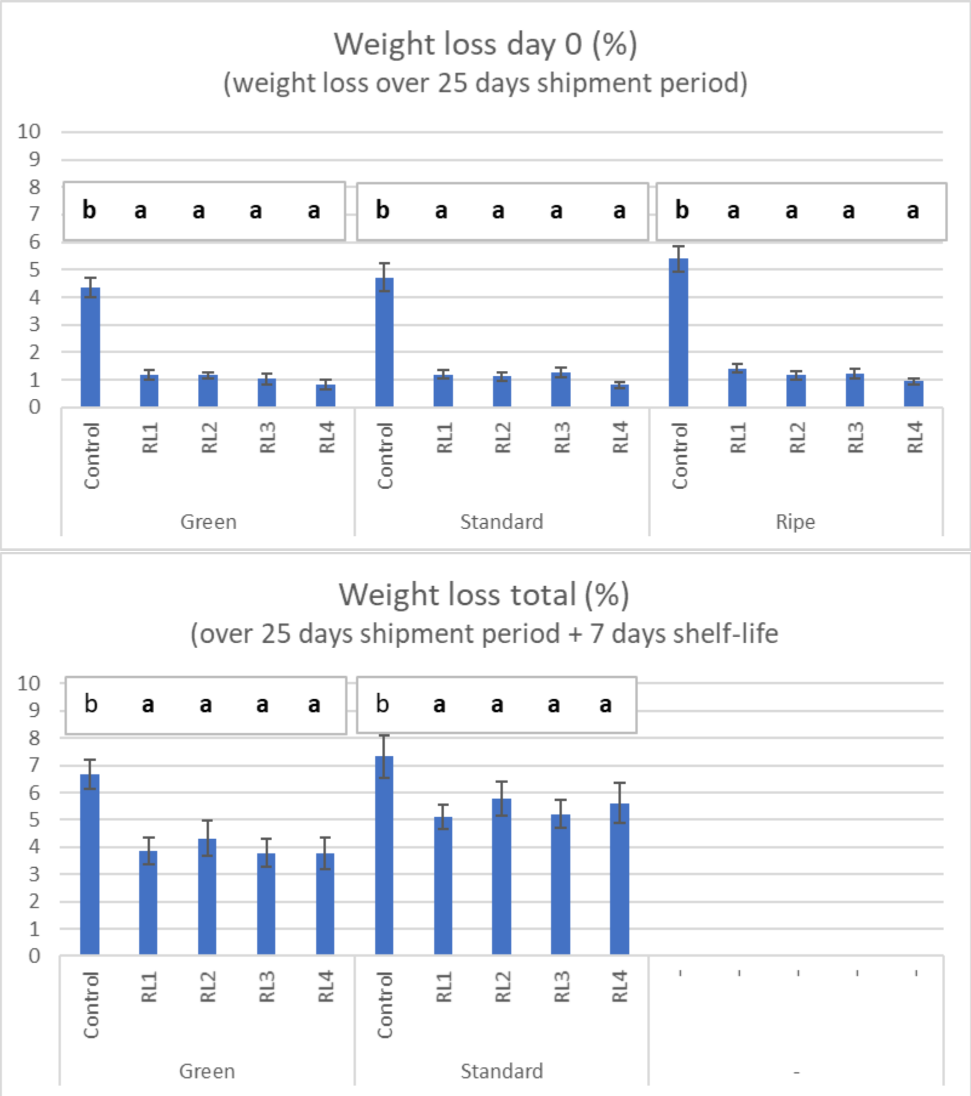


Figure 16 ***Weight loss (%) over the 25 days shipment period (upper panel), and including 7 days shelf-life (bottom panel) of trial RipeLocker September 2020. Data represent means with error bars representing 95%-confidence interval (n=10-12 fruits). Means with different letters are significantly different.***

4.3.3 General appearance

The following photos give an impression of the appearance of ‘green’ and ‘standard’ papayas (Figure 17 and Figure 18). Photos were selected of papayas which were free or low in decay. Especially the ‘standard’ papayas had a fresher, brighter look coming from RipeLockers compared to control boxes at arrival in Wageningen.

***Figure 17** Development of appearance of the same (numbered) ‘green’ papayas of trial RipeLocker September 2020*
Left: Control box (top: Brazil; middle: arrival Wageningen; bottom: 7 days shelf-life)
Right: RipeLocker 1 (top: Brazil; middle: arrival Wageningen; bottom: 7 days shelf-life)

Figure 18 ***Development of appearance of the same (numbered) 'standard' papayas of trial RipeLocker September 2020***
Left: Control box (top: Brazil; middle: arrival Wageningen; bottom: 7 days shelf-life)

4.3.4 Firmness, Brix, disorders and diseases, skin colour

Table 15 shows the results of the various quality assessments after 0, 3 and 7 days shelf-life. The scores on shrivelling were in line with the weight loss, fruits shipped in RipeLockers showed less shrivelling than fruits from control boxes. Moreover, sunken spots were mainly found on papayas from control boxes. The variation in lenticel spots was very high.

Table 15 Results of quality assessments for papayas harvested at different maturity stages followed by a 25-day shipment plus 0, 3 and 7 days shelf-life of trial RipeLocker September 2020. Data represent means of 10 to 12 fruits (± standard error)

Days shelf-life	Maturity stage at harvest	Treat-ment	Shrivel-ling (score)	Sunken spots (#)	Lenticel spots (%)	Brown spot (%)	Pitting (%)	° Brix	Firm-ness (score)	Stem mould (%)	Total mould (%)	Total rot (%)	% yellow skin
0 days	Green	Control	1.6±0.3	1.4±0.8	0	0	40	8.9±0.7	3.0±0.0	0	0	0	0.5
		RL1	0.1±0.2	0.0	10	0	0	7.8±0.7	3.0±0.0	70	80	0	0.5
		RL2	0.0	0.0	0	0	0	10.0±0.5	3.0±0.0	100	100	0	0.4
		RL3	0.1±0.2	0.0	0	0	0	8.9±0.9	3.0±0.0	40	60	10	0.9
		RL4	0.0	0.0	0	0	0	10.6±0.9	3.0±0.0	50	60	0	0.7
	Standard	Control	1.6±0.3	2.0±0.7	70	0	0	11.0±0.5	1.9±0.2	30	30	10	3.3
		RL1	0.0	0.0	20	0	0	11.8±0.7	2.8±0.2	80	90	0	1.1
		RL2	0.0	0.0	20	0	0	10.2±0.9	2.3±0.3	100	100	20	2.1
		RL3	0.0	0.0	30	0	0	12.0±0.8	2.4±0.3	80	80	0	2.5
		RL4	0.1±0.2	0.0	50	0	0	12.1±0.3	2.6±0.3	80	80	10	2.4
	Ripe	Control	1.9±0.3	0.1±0.2	0	0	0	12.5±0.5	1.0±0.0	90	100	0	32.2
		RL1	0.0	0.0	0	0	0	11.3±0.7	1.0±0.0	100	100	0	35.3
		RL2	0.0	0.2±0.3	0	0	0	11.1±0.4	1.2±0.3	100	100	0	31.1
		RL3	0.0	0.0	0	0	0	12.3±0.3	1.0±0.0	90	90	10	32.9
		RL4	0.0	0.0	0	0	0	11.9±0.3	1.0±0.0	90	90	0	35.9
3 days	Green	Control	2.8±0.4	1.9±1.4	30	0	0	9.9±0.7	2.3±0.3	30	30	0	1.6
		RL1	0.2±0.3	0.0	40	0	0	10.5±1.0	2.7±0.3	100	100	30	0.6
		RL2	0.2±0.3	0.5±0.6	0	0	10	8.4±1.0	3.0±0.0	90	90	50	0.5
		RL3	0.2±0.3	0.2±0.4	0	0	0	9.1±1.3	2.9±0.2	100	100	30	0.3
		RL4	0.2±0.3	0.0	10	10	0	10.0±0.5	3.0±0.0	90	90	60	0.7
	Standard	Control	2.3±0.5	4.8±1.6	90	0	0	11.1±0.6	1.8±0.3	70	70	20	4.3
		RL1	0.3±0.3	0.0	50	10	0	11.0±0.7	2.2±0.4	100	100	60	2.2
		RL2	0.7±0.3	0.7±0.8	30	0	0	11.8±0.7	2.2±0.5	100	100	100	4.6
		RL3	0.1±0.2	0.0±0.0	30	0	0	11.4±0.3	2.1±0.4	100	100	60	2.3
		RL4	0.5±0.3	0.1±0.2	70	0	0	11.3±0.8	2.5±0.3	100	100	70	1.1
7 days	Green	Control	2.4±0.4	3.3±1.3	80	10	0	9.2±0.6	2.5±0.4	30	30	30	1.4
		RL1	1.1±0.4	4.7±2.1	40	20	0	9.1±0.6	2.6±0.3	20	20	0	4.5
		RL2	1.4±0.4	3.0±1.6	50	10	0	9.7±0.7	2.9±0.2	80	80	70	0.5
		RL3	1.5±0.5	4.8±2.2	30	0	0	9.2±0.8	2.4±0.3	40	40	0	2.7
		RL4	1.3±0.3	4.0±1.7	10	10	0	10.1±1.2	2.0±0.0	90	90	50	6.2
	Standard	Control	3.0±0.0	10.3±2.2	100	0	0	11.7±0.6	1.3±0.3	60	60	60	7.1
		RL1	1.7±0.3	8.8±2.2	90	0	0	11.5±0.4	2.3±0.3	100	100	40	8.3
		RL2	0.9±0.6	3.1±1.2	50	50	0	11.5±0.5	2.4±0.4	100	100	100	2.1
		RL3	1.5±0.4	4.0±1.2	90	0	0	11.4±0.3	1.9±0.2	100	100	0	8.1
		RL4	1.4±0.4	2.0±1.3	50	40	0	11.0±0.4	1.9±0.5	100	100	100	7.9

Lenticel browning was mainly found on papayas from 'standard' maturity. The incidence was generally less for papayas stored in RipeLockers compared to control boxes. The lenticel spots seem to develop during shelf life.

Brown spots developed during shelf-life, with highest scores for standard maturity stage papayas of RipeLockers RL2 and RL4.

Pitting was barely observed. If so, it were just a few pits and mostly on green papayas from the control boxes after the 0-day shelf-life. Bruises were not observed.

The °Brix varied considerably between individual fruits. In general, the °Brix of 'standard' maturity was higher than for 'green' harvested papayas. There were no consistent differences between the treatments. The firmness of green papayas was initially high with an average score of 3.0 (= firm, hard). Many papayas of this group remained (too) firm during shelf-life. Papayas of 'standard' maturity stage were on average less firm. Although not always statistically significant, papayas of 'standard' maturity were on average firmer for the RipeLocker treatments compared to the control boxes.

Stem mould was already present after 0 days shelf-life. For both the 'green' and 'standard' papayas, the stem mould was clearly more present on papayas of the RipeLockers treatments than of the control boxes. The stem mould increased between day 0 and day 3. On day 7, the stem mould seemed to have decreased

compared to day 3 for the green papayas. Probably the drier shelf-life conditions (65% RH) led to drying of the white fungus hyphae and thus to less visible mould.
The total % of fruits with signs of mould (either stem and/or crown and/or fruit belly) was very similar to the data for stem mould only, indeed this was the predominant mould type.
The % fruit with signs of rot (either stem-end and/or crown-end and/or belly) was generally lower in RL1 and RL3 compared to RL2 and RL4.

The % yellow colour of the skin did not increase much during shelf-life and there were no clear differences between the treatments.

We did not detect any off-flavour when tasting.

4.3.5 Flesh colour

Table 16 shows examples for the colour imaging of the fruit flesh and the associated software calculations of % ripe, half-ripe und unripe tissue. This shows that the objective analysis of the flesh colour of longitudinal sections of papaya fruits has yielded good estimates of the % ripe (orange/red coloured tissue), % half ripe and % unripe (green/white) tissue.

Table 16 Examples of colour imaging for the 3 maturity stages

Original image	Image analysed by software	Fractions calculated by software

Green stage:

	Nr.1	Nr.2	Nr.3
Ripe (%)	44	0	0
Half ripe (%)	43	0	0
Unripe (%)	13	100	100

Standard:

	Nr.1	Nr.2	Nr.3
Ripe (%)	71	66	69
Half ripe (%)	28	31	29
Unripe (%)	2	3	2

Ripe:

	Nr.1	Nr.2	Nr.3
Ripe (%)	90	90	88
Half ripe (%)	10	10	12
Unripe (%)	0	0	0

The external colour did not always correlate with the internal colour: 'Green' maturity papayas which had a similar external colour did differ in internal colour. An example is given in ***Figure 19***.

Figure 19 Example of 'Green' papayas where the external colour does not correlate with the internal colour (photos taken after 7 days shelf-life)

Papayas of 'green' maturity kept a large fraction unripe tissue, even after 7 days shelf-life (***Figure 20***).

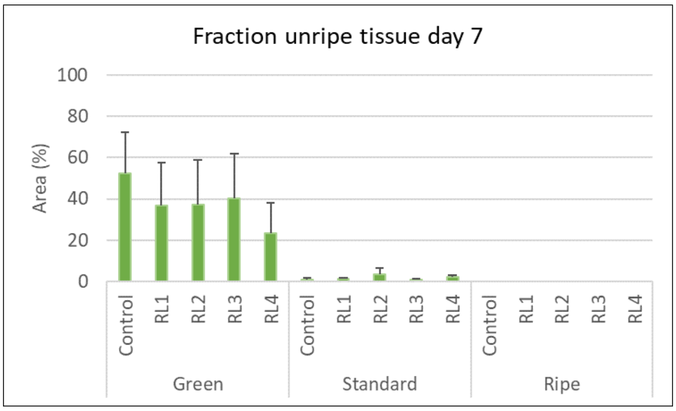


Figure 20 Fraction unripe (green/white) tissue after 0, 3 and 7 days shelf-life. Data represent means with error bars representing 95%-confidence interval (n=10-12 fruits).

4.3.6 NIR

The % of ripe tissue (inside) was used to calibrate NIR measurements performed on the outside of the papayas. This resulted in a good correlation between the two (R^2 = 0.787). The prediction of °Brix with NIR could unfortunately not be done with very high accuracy (R^2 = 0.54) (***Figure 21***).

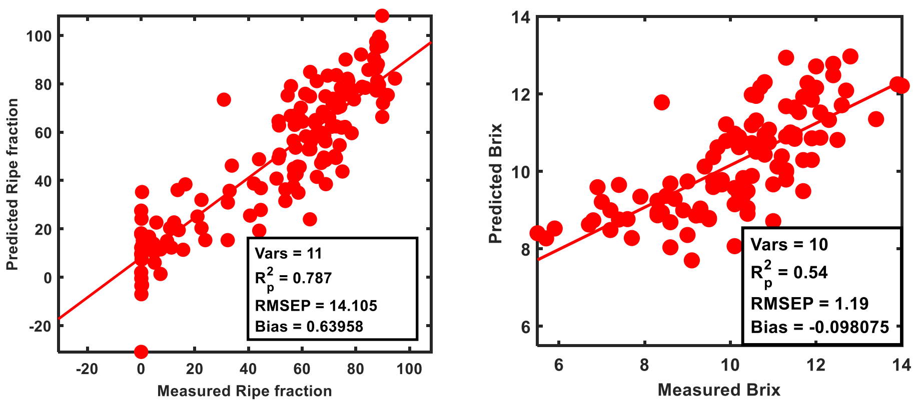


Figure 21 Measured Ripe fraction inside the fruit and measured °Brix ***compared to the predicted ripe fraction (left) and predicted*** °Brix ***(right) with the NIR technology***

4.4 Discussion and conclusion

Overall, compared to control boxes, papayas from the RipeLockers scored well for overall appearance, less weight loss, less shrivelling, less lenticel browning and higher firmness (for 'standard' harvest maturity). The incidence of stem mould was a problem for the papayas in the RipeLockers. However, the incidence of stem mould could have come from the fact that the Agricola's normal practice for treatment against stem end mould was not applied, as the trial was packaged separately from the normal procedure for commercial shipments. This means that a possible solution to this problem might be available. In general, RipeLockers RL1 and RL3 papayas had a better overall appearance after 7 days shelf-life, compared to RL2 and RL4. Information received from RipeLocker LLC after the trial indicated that the O_2 and CO_2 levels were (too) low in RipeLockers #2 and #4. This will be anticipated on in next trials.

Scientific progress was made for colour imaging and NIR. NIR measurements were performed non-destructively from the external of the papayas, after which the % of ripe tissue was assessed through colour imaging and used to calibrate NIR measurements. This resulted in a good correlation of the two. This is interesting because the external colour (that is visible to humans) does not correlate well with the internal colour. Interestingly, the internal colour can give an indication of flesh firmness (see 'Trial MA Packages 2019').

The batch of 'green' maturity stage papayas included fruits that did not reach an acceptable quality during the shelf-life, as evidenced by low °Brix, insufficient softening, and white flesh colour. Therefore, a much earlier harvest stage than current practice (1-2 stripes of yellow) is not advisable.

In conclusion, this first trial with RipeLockers shows potential for a better papaya quality, knowing that improvements can be made in decommission of RipeLockers at arrival (slow vacuum release), mould control, and fine-tuning RipeLocker conditions.
The rest of this project will take into account the following points of attention.

General (all trials):

- Prevent the break of cold chain in supply chain as much as possible.
- Include Agricola's normal practice for treatment against stem mould.
- The developed NIR model needs validation with a new set of research data.

Specific for trials with RipeLockers:

- Follow the correct procedure for slow vacuum release of the RipeLockers.
- Fine-tuning of RipeLocker conditions, based on the observed quality differences between the RipeLockers with different conditions.

5 Trials MA packages and RipeLocker (2021)

5.1 Introduction

As a follow-up to the earlier trials, new tests were conducted with both PerfoTec MA packages and RipeLockers. Treatments were:
- HN-bags (Hot-needle) in boxes, which is the current standard.
- PerfoTec's consumer pack in boxes. PerfoTec's high precision laser perforation system was used, based on previous data from the PerfoTec's respiration meter.
- RipeLockers with different parameters with the aim of reducing senescence, combined with/without natural oil with the goal of reducing moulds/rots.

Papayas were packed at Agricola Famosa in Brazil and transported to Rotterdam, the Netherlands by sea reefer. The quality was assessed over a period of shelf-life in Wageningen, the Netherlands.

For the interpretation of the results, it is important to consider that the trials were dominated by an internal disorder in all treatments (***Figure 22***). Many fruits were found with a greyish discolouration of the tissue around the seeds (seed list). The symptoms progressed during shelf-life and extended into the flesh. It was not visible from the outside which fruits were affected. This disorder is most likely a chilling injury. Taste of the fruits, both with and without symptoms, was not good as confirmed during a visit by our project partner Frankort & Koning. Cold temperature may have negatively affected the taste.

This chilling injury is also likely to interfere with other quality parameters, so the interpretation of all other results should be done carefully.

***Figure 22** Photos of the internal disorder found in the trial 2021. In the initial phase, a greyish discolouration of the seed list is visible (1st photo), later expanding with greyish discolouration into the flesh (2nd and 3rd photo). The tissue near the seed list separates easily (4th photo).*

5.2 Methods/Design of the research

5.2.1 Materials

Papayas 'Tainung' of 2 maturity stages ('standard 'and 'ripe') were harvested on March 16th 2021 at Agricola Famosa in Brazil. Agricola's normal procedure for treatment against stem-end mould was applied. The papayas were then all stored in a storage room (10-11 °C) until they were loaded into a reefer container on March 23th for transport to the Netherlands. In this intermediate period, the initial quality was measured and the various treatments were prepared. On March 18th samples of 8 fruits were measured on pulp firmness (hand penetrometer with 1.0 cm^2 plunger) and °Brix (hand refractometer). ***Table 17*** gives an overview of the 2 maturity stages. Note that the ripe papayas showed lenticel spots.

Table 17 ***Maturity stages before shipment to the Netherlands with initial quality parameters at start of the trial March 2021 in Brazil. Data represent means of 8 fruits (± standard error).***

Maturity stage	Firmness (kg/cm^2) and °Brix	
Standard (Agricola Famosa's standard for export to Europe i.e. green with 1-2 yellow stripes)	10.6 ± 3.3 kg 13.0 ± 0.7 °Brix	 
Ripe (tree-ripe, 60% yellow)	3.5 ± 1.2 kg 14.1 ± 0.8 °Brix	 

Table 18 and ***Table 19*** give an overview of the different treatments. On March 18th 2021, packing in HN-bag and PerfoTec (consumer bags '302') took place. The fruits were then placed in cardboard boxes. Because the arrival of RipeLockers was delayed, the loading and sealing took place on March 22th. All fruits were packed in foam nets and divided over 8 RipeLockers. Some of the fruits were numbered, weighed and photographed. To fill the RipeLockers, buffer fruits were added to reach a total of 90 fruits per RipeLocker. RipeLocker conditions (pressure, O_2, CO_2) were set by RipeLocker LLC.

Table 18 ***Overview of treatments with MA packages of trial 2021, started on March 18th***

Treatments (2)	Maturity stages (2)	Recording initial weight
Boxes control (HN-bags)	2 maturity stages x 6 boxes	Total weight per box
Boxes PerfoTec consumer bags	2 maturity stages x 6 boxes	Total weight per box

Table 19 ***Overview of treatments with RipeLockersof trial 2021, started on March 22nd***

Treatments (9)	Maturity stages (2)	Recording initial weight and photos
Boxes control (HN-bags)	2 maturity stages x 6 boxes	
RipeLocker RL1, settings 1	2 maturity stages x 30 fruits	2 maturity stages x 10 fruits
RipeLocker RL2, settings 2 *	2 maturity stages x 30 fruits	2 maturity stages x 10 fruits
RipeLocker RL3, settings 3	2 maturity stages x 30 fruits	2 maturity stages x 10 fruits
RipeLocker RL4, settings 3	2 maturity stages x 30 fruits	2 maturity stages x 10 fruits
RipeLocker RL5, settings 1 combined with natural oil	2 maturity stages x 30 fruits	2 maturity stages x 10 fruits
RipeLocker RL6, settings 2 combined with natural oil	2 maturity stages x 30 fruits	2 maturity stages x 10 fruits
RipeLocker RL7, settings 3 combined with natural oil	2 maturity stages x 30 fruits	2 maturity stages x 10 fruits
RipeLocker RL8, settings 4 combined with natural oil	2 maturity stages x 30 fruits	2 maturity stages x 10 fruits

***** RipeLocker nr 2. was lidded but not vacuum sealed, gas conditions have probably been similar to ambient.

5.2.2 Realized chain conditions

After loading the test objects into the reefer container, it was transported to the farm in Inajá (Pernambuco State in Brazil) where commercial cargo of honeydew melons was added for sea transport to the Netherlands. Unlike normal commercial cargo, this reefer with trials was only partially filled (***Figure 23***).

Figure 23 Reefer unloading in the Netherlands, showing placement of trial boxes and RipeLockers (in front of pallets with melons)

The realized timetable and the recorded temperature are shown in ***Table 20*** and ***Figure 24*** respectively. While the intended transport temperature was 10 °C, the realized temperature was in fact below 10 °C for 20 days including a period of 16 days between 8.2 and 8.5 °C. The cause of this deviation has not been determined.

Table 20 Realized timetable of trial March 2021

Date	Location / activity
16 March 2021	Harvest at Agricola Famosa, start shipment via Hapag-Lloyd container
18 March	Weight and quality measurements and packing of PerfoTec bags and HN-bags as controls
22 March	Loading and sealing of RipeLockers, and packing of HN-bags as controls. Reefer loaded and leaving to Inajá farm to add commercial load of melons.
24 March	Leaving port of Salvador
16 April	Arrival at Frankort & Koning; transport to Wageningen and placed at 10 °C. Packages: first observations RipeLockers: connected and operating again
19 April	Packages: all packages removed RipeLockers: decommission and first observations
20, 22, 26 April	Transfer to 18 °C and quality assessments after 0, 2 and 6-day shelf-life

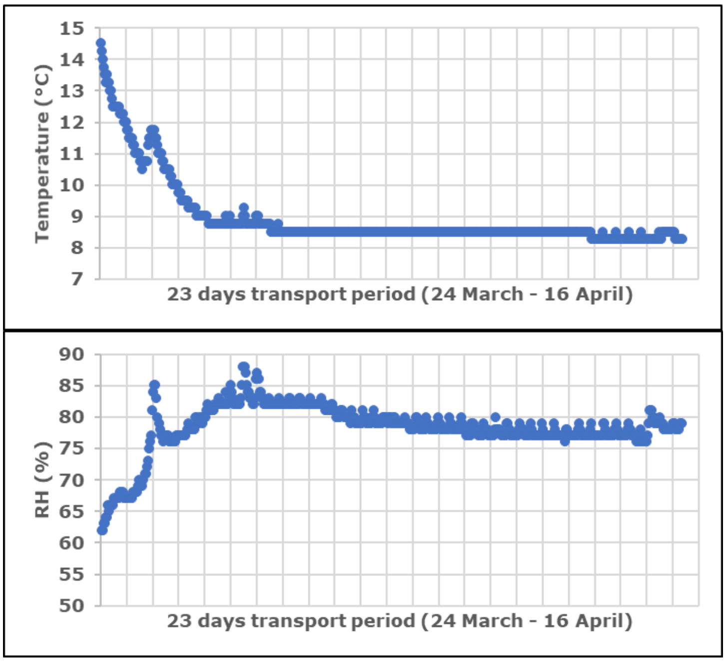


Figure 24 ***Recorded temperature (°C) and Relative Humidity (%) in the reefer during 23 days of transport from port of Salvador in Brazil to Venlo in the Netherlands of trial 2021 Source: Agricola Famosa (reefer data Hapag Lloyd)***

5.2.3 Netherlands, general information

On April 16th 2021, the boxes and RipeLockers were delivered by truck to Wageningen and placed at 10 °C. The boxes were weighed and photographed. The individual bags in the boxes were sampled for O_2 and CO_2 concentrations.
The RipeLockers were reconnected to electricity and internet. Vacuum from the RipeLockers was slowly released 2-3 days later (on-line by RipeLocker LCC) before the lids were removed on April 19th.
On April 19th MA bags were sampled for O_2, CO_2 and ethylene concentrations. Then all the papayas were transferred from the RipeLockers and boxes to crates with labels. Foam nets (RipeLockers) and MA bags were removed and the numbered papayas were weighed and photographed. A third of the load was then assessed for quality (0 days shelf-life). Two-thirds of the load was transferred to a room at 18 °C (65% RH) for later quality assessments after 2 and 6 days shelf-life (the latter included the numbered papayas).

5.2.4 Data analyses

Data are expressed in mean values per 2 boxes (MA packages) or 10 fruits (RipeLocker) or otherwise if indicated. Standard errors are displayed if relevant.

5.2.5 Measurements

The O_2, CO_2 and ethylene concentrations in the bags were measured as described for the trial 'MA packages (2019)'.
With the exception of the weight (per box), all papayas were scored individually on the parameters as stated in ***Table 21***.

Table 21 Measurement and methods used of trial March – April 2021

Measurement	Method / Classes
Weight loss (%)	Total fruit weight per box (MA trial) was measured with a balance (Mettler Toledo XS10001L/XS320001L). Weight of numbered fruits (RipeLocker trial) was measured with a balance (Mettler Toledo 6002).
Shrivelling	0 = no visible shrivelling, 1 = very slight, 2 = slight, 3 = clear shrivelling
Sunken spots	Number of spots per fruit
Lenticel browning (spots)	Yes/No. Resulting in % of fruits which show the disorder.
Brown spots on the skin	Yes/No. Resulting in % of fruits which show the disorder.
Pitting of the skin	Yes/No. Resulting in % of fruits which show the disorder.
°Brix	Digital refractometer (Hi 96801 Hanna Instruments, Woonsocket, RI, USA; PHT0004). Selective samples.
Firmness	Impression when making longitudinal cut with a knife by hand: 1 = Soft, 2 = Intermediate, 3 = Firm/hard
Mould (fungus hyphae visible) on stem, crown or fruit belly	Yes/No. Resulting in % of fruits with mould.
Rot (fruit tissue affected) on stem-end, crown or fruit belly	Yes/No. Resulting in % of fruits with rot.
Skin colour	Image analysis with a RGB camera (MAKO G-192C POE, Allied Vision, Germany) positioned in a LED light cabinet (designed by WFBR and built by IPSS Engineering, the Netherlands). (Smart Colour Inspector) Analyses were done with the in-house software tool developed at WFBR (ColorAnalysis V3.40).
Internal colour	Image analysis (see Skin colour) of longitudinal cut.
NIR (near-infrared spectroscopy)	Labspec Hi-Red spectrometer (350-2500 nm) with Hi-Brite probe (Malvern Panalytical). To study relation with internal colour.
Other disorders (with description/photo)	Yes/No. Resulting in % of fruits which show the disorder.

5.3 Results MA packages

5.3.1 Realized gas conditions

The measured gas conditions in the packages at 10 °C are shown in ***Table 22***. The % O_2 and % CO_2 in the HN-bags were similar to the environment (measured: 20.6% O_2, 0.1% CO_2). The PerfoTec bags had averages of 18.5% O_2 and 2.6% CO_2 for standard papayas, and about 18.1% O_2 and 3.0% CO_2 for ripe papayas. Ethylene concentrations varied widely between the individual PerfoTec bags.

Table 22 Concentrations of O2, CO2 and ethylene in packages of trial March-April 2021 after arrival in Wageningen

Packages	**Harvest maturity**	**Day (at 10 °C)**	**# bags analyzed**	**O_2 (%) mean ± std error**	**CO_2 (%) mean ± std error**	**Ethylene (ppb) mean ± std error**
HN-bag	**Standard**	**Arrival**	2	20.6 ± 0.1	0.1 ± 0.0	
		+ 3 days	2	20.5 ± 0.1	0.1 ± 0.0	< 30 ppb
	Ripe	**Arrival**	2	20.6 ± 0.1	0.1 ± 0.0	
		+ 3 days	2	20.5 ± 0.1	0.1 ± 0.0	< 30 ppb
PerfoTec	**Standard**	**Arrival**	46 *	18.5 ± 0.1	2.6 ± 0.2	262 ± 111
		+ 3 days	46	18.5 ± 0.2	2.6 ± 0.2	328 ± 103
	Ripe	**Arrival**	48	18.2 ± 0.2	2.9 ± 0.2	407 ± 186
		+ 3 days	48	18.0 ± 0.2	3.1 ± 0.2	448 ± 76

***** 2 out of 48 packages had less than 1% O_2 and appeared to lack perforations. These data are not included.

5.3.2 Condensation

As soon as the papayas arrived in Wageningen, the status of the packages was inspected. No condensation was observed.

5.3.3 Weight loss

Weight loss during the 32 days of storage plus transport period in cooled conditions (bagged fruits) was slightly lower for PerfoTec than for HN-bags (***Table 23***). It was similar in the next shelf-life period without bags.

Table 23 Weight loss (%) during 32 days of storage plus transport period (cooled, with bags) and during subsequent 3 days shelf-life (18 °C, without bags) of trial March-April 2021. Data represent means ± standard error with 95%-confidence interval

Harvest maturity	Packages	32 days period cooled, with bags (mean ± std, n=6)	2 days period at 18 °C, without bags (mean ± std, n=2)
Standard	**HN-bag**	4.9 ± 0.1	2.0 ± 0.3
	PerfoTec	4.1 ± 0.5	2.1 ± 0.3
Ripe	**HN-bag**	4.8 ± 0.6	2.0 ± 0.0
	PerfoTec	4.1 ± 0.1	2.1 ± 0.2

5.3.4 General appearance

Upon arrival in Wageningen, the general appearance of the papayas in the packages was good. After 2 days of shelf-life, the freshness and shine was clearly less. ***Figure 25*** gives an impression.

5.3.5 Disorders and diseases, brix, firmness, skin colour

The internal disorder (see '5.1 Introduction') was found after 0 days shelf-life for a high percentage of fruits. This internal disorder, together with the unusual transport conditions (long time and too cold temperature), makes the comparison of PerfoTec MA package with the control HN-bags of little relevance for practice. However, results can still provide useful insights for future trials.

Taking into account the variation between individual fruits, there were no clear differences between PerfoTec and the HN-bag for the observed disorders and diseases, brix, firmness and skin colour (***Table 24***).

Pitting was not observed. Flesh colour data and NIR measurements were not analysed because the flesh colour of many papayas was affected by the internal disorder.

'standard' maturity at arrival in Wageningen, HN-bags (upper 3 boxes) and PerfoTec (lower 3)

'ripe' maturity at arrival in Wageningen, HN-bags (upper 3 boxes) and PerfoTec (lower 3)

'standard' maturity after 3 days 18 °C. Upper 2 crates from HN-bags, lower 2 from PerfoTec

'ripe' maturity after 3 days 18 °C. Upper 2 crates from HN-bags, lower 2 from PerfoTec

Figure 25 ***Impression of papaya appearance of trial March-April 2021 upon arrival in Wageningen and after 2 days shelf-life at 18 °C for 'standard' maturity (left) and 'ripe' (right)***

Table 24 ***Results of quality assessments for papayas harvested at different maturities followed by 32 days storage + shipment plus 0, 2 and 6 days shelf-life. Data represent means of 10 fruits (mean ± standard error) or % of 10 fruits with the disorder/disease***

Days shelf-life	Maturity stage at harvest	Treatment	Shrivelling (score 0-3)	Sunken spots (#)	Lenticel spots (score 0-3)	Brown spot (%)	° Brix	Firm-ness (score 1-3)	Total mould/ rot (%)	Disorder internal (%)	% yellow skin
0 days	**Standard**	**HN-bag**	0.3 ± 0.3	0.7 ± 0.8	1.3 ± 0.7	0	10.8 ± 0.6	2.3 ± 0.5	0	60	21 ± 9
		PerfoTec	0.1 ± 0.2	0.3 ± 0.4	0.9 ± 0.6	0	10.9 ± 0.4	2.3 ± 0.5	0	90	11 ± 5
	Ripe	**HN-bag**	0.6 ± 0.5	0.4 ± 0.4	1.9 ± 0.7	0	11.8 ± 0.5	2.1 ± 0.5	0	80	33 ± 7
		PerfoTec	1.3 ± 0.7	0.2 ± 0.3	1.4 ± 0.7	0	10.9 ± 0.6	1.4 ± 0.3	40	70	33 ± 8
2 days	**Standard**	**HN-bag**	0.0 ± 0.0	0.1 ± 0.2	1.0 ± 0.4	0		2.8 ± 0.3	0	90	10 ± 4
		PerfoTec	0.9 ± 0.7	0.4 ± 0.6	1.3 ± 0.5	0		1.8 ± 0.5	20	90	21 ± 5
	Ripe	**HN-bag**	1.4 ± 0.5	0.3 ± 0.4	2.0 ± 0.5	0		1.7 ± 0.5	10	100	26 ± 5
		PerfoTec	1.3 ± 0.7	0.2 ± 0.3	2.0 ± 0.5	0		1.3 ± 0.3	70	100	30 ± 8
6 days	**Standard**	**HN-bag**	0.9 ± 0.5	1.1 ± 0.8	1.2 ± 0.6	0	10.9 ± 0.5	2.4 ± 0.5	20	70	25 ± 10
		PerfoTec	1.3 ± 0.6	2.5 ± 1.1	1.9 ± 0.5	10	10.9 ± 0.2	2.1 ± 0.4	10	90	26 ± 9
	Ripe	**HN-bag**	2.9 ± 0.2	3.6 ± 1.3	2.5 ± 0.4	0	11.2 ± 0.3	1.0 ± 0.0	60	100	51 ± 11
		PerfoTec	2.2 ± 0.4	3.7 ± 1.4	2.3 ± 0.4	0	11.0 ± 0.3	1.2 ± 0.3	20	90	34 ± 9

5.4 Results RipeLockers

5.4.1 Impression at opening of the RipeLockers

Papayas were carefully observed after opening of the RipeLockers. The fruits were free of condensation. Several fruits with abrasion damage were found. This mechanical damage was caused by sliding of the fruit during sea transport.
Four RipeLockers were combined with a natural oil. However, this essential oil did not vaporize due to its experimental formulation. Instead, it caused oil to stick to some of the fruits. These fruits were discarded and therefore there were not enough fruits of RipeLockers RL5 to RL8 for quality assessments after 6 days of shelf-life.
As known beforehand, one of the RipeLockers (RL2) was not vacuum sealed before arrival.

5.4.2 Weight loss

When interpreting the weight loss data, it should be kept in mind that after weighing at the beginning of the trial there was a period of 4 days in the storage room when the papayas were still unpacked and still outside the RipeLockers.

The weight loss of papayas in the 32-day period until opening of the RipeLockers was lower compared to the papayas in HN-bags in the control boxes, with the exception of the unsealed RipeLocker RL2 (***Table 25***). In the next shelf-life period, the papayas that came out of the RipeLockers lost less or the same weight than the papayas that came out of the HN-bags.

Table 25 Weight loss (%) during 32 days storage and transport period (cooled) and during subsequent 3 days shelf-life (18 °C) of trial 2021. Data represent means ± standard error (n=10).

Harvest maturity	**Treatment** *(all treatments include a 4 days period unpacked in storage room at start of the trial)*	**32 days period cooled**	**3 days period at 18 °C, unpacked**
Standard	**HN-bag**	4.4 ± 0.7	2.4 ± 0.8
	RipeLocker RL1	3.8 ± 1.0	1.8 ± 0.1
	RipeLocker RL2 *(not sealed!)*	6.4 ± 0.7	1.6 ± 0.2
	RipeLocker RL3	4.1 ± 0.2	2.3 ± 0.4
	RipeLocker RL4	3.3 ± 0.9	2.3 ± 0.4
Ripe	**HN-bag**	4.5 ± 0.4	2.1 ± 0.5
	RipeLocker RL1	3.3 ± 0.1	1.5 ± 0.2
	RipeLocker RL2 *(not sealed!)*	6.9 ± 1.0	1.5 ± 0.1
	RipeLocker RL3	3.1 ± 0.2	1.8 ± 0.3
	RipeLocker RL4	2.5 ± 0.2	2.3 ± 0.4

5.4.3 General appearance

Upon arrival in Wageningen, several fruits with abrasion damage were found. This mechanical damage was caused by sliding of the fruit prior sea transport, due to loose packing. It is preventable, but unfortunately it clearly had a negative impact on the general appearance of the fruits in this trial. ***Figure 26*** gives an impression.

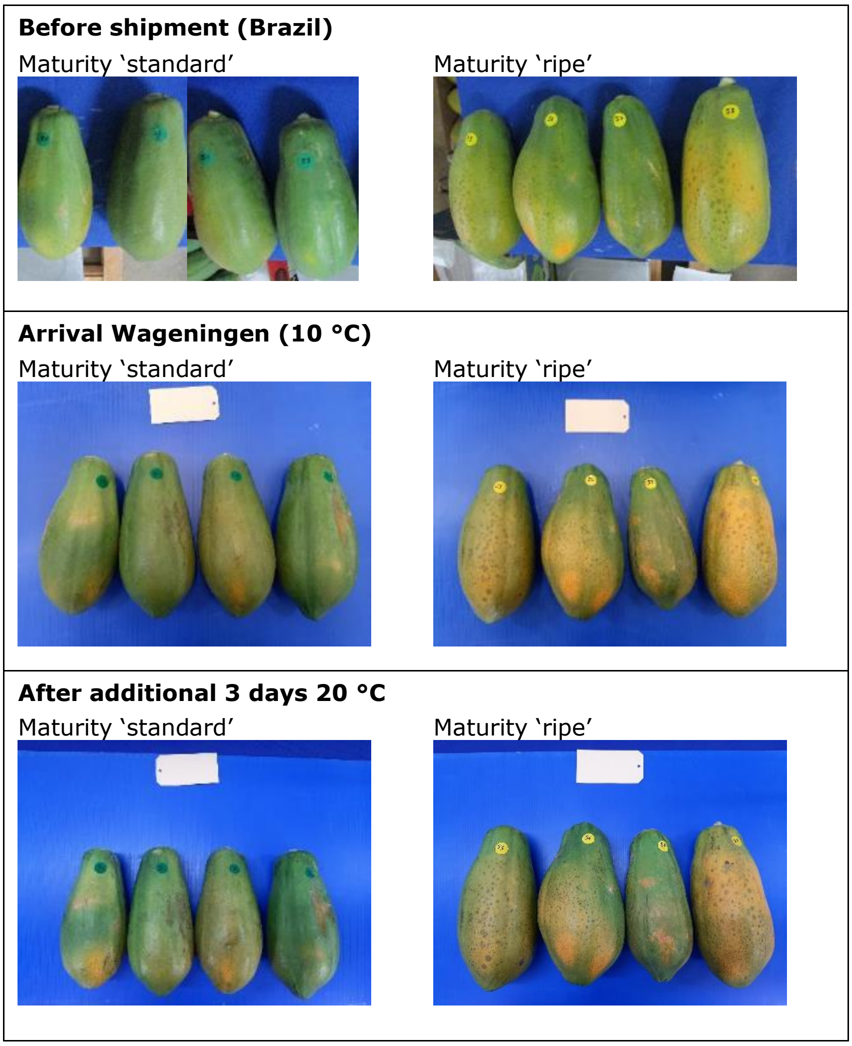


Figure 26 Development of appearance of the same (numbered) papayas of maturity ‘standard’ (photos left) and maturity ‘ripe’ (photos right)of trial March-April 2021. Photos were selected of papayas which were free or low in decay, out of RipeLocker no. 3.

5.4.4 Disorders and diseases, firmness, brix, skin colour

The internal disorder (see '5.1 Introduction') was found after 0 days shelf-life for a high percentage of fruits. This internal disorder, together with the unusual transport conditions (long time and too cold temperature), makes the comparison of RipeLocker with the control HN-bags of little relevance for practice. However, results can still provide useful insights for future trials.

The internal disorder increased rapidly during shelf-life. After 0 day shelf-life, 28% and 22% of all assessed 'standard' and 'ripe' fruit, respectively, had visible symptoms. After 2 days of shelf-life, this had increased to respectively 61% and 45%. (Table 26).
In general, after 0 days shelf-life, the % of fruits with symptoms was less for the papaya stored in RipeLockers compared to the control HN-bags. The unsealed Ripelocker (RL2) showed a high percentage of the disorder. Ripelocker RL1 had a remarkably low percentage of 'ripe' fruit with the disorder throughout the 6 days shelf-life. The same was true for RipeLocker RL5, which, however, was only assessed up to 2 days of shelf-life.

Shrivelling symptoms were often less for the papayas from the RipeLockers compared to HN-bags.

Brown spots were not always clearly distinguishable from the abrasion damage that had occurred during sea transport. However, it was clear that fruits from RipeLockers RL4 and RL5 had the most brown spots. Taking into account the variation between individual fruits, there were no clear and consistent differences between the treatments for sunken spots, lenticel spots, brix, firmness, and skin colour. The same can be concluded for moulds and rots, although RipeLocker RL3 may be the one that performed best overall. Lenticel spots were observed more for 'ripe' than for 'standard' papayas. It should be noted that lenticel spots for 'ripe' papayas were already visible at harvest.

Pitting was not observed. Flesh colour data and NIR measurements were not analysed because the flesh colour of many papayas was affected by the internal disorder.

In this trial, the oil treatment of RipeLocker RL5 to RL8 can be considered as not applied. Quality of papayas of RipeLockers RL5-RL8 was in any case not better than Ripelockers RL1-RL4.

Table 26 Results of quality assessments of trial March- April 2021 for papayas harvested at different maturities followed by 32 days storage + shipment plus 0, 3 and 6 days shelf-life. Data represent means of 10 fruits (mean ± standard error) or % of 10 fruits with the disorder/disease.

Days shelf-life	Maturity stage at harvest	Treatment	Shrivel-ling (score 0-3)	Sunken spots (#)	Lenticel spots (score 0-3)	Brown spot (%)	° Brix	Firm-ness (score 1-3)	Total mould/ rot (%)	Disorder internal (%)	% yellow skin
0 days	Standard	**HN-bag**	0.6 ± 0.5	0.6 ± 0.7	1.8 ± 0.5	0	11.4 ± 0.5	2.3 ± 0.3	10	100	16 ± 4
		RL1	0.0	0.0	1.1 ± 0.5	10		2.5 ± 0.3	0	0	11 ± 6
		RL2 not sealed!	0.0	0.0	0.8 ± 0.5	10		2.6 ± 0.3	0	60	11 ± 5
		RL3	0.0	0.1 ± 0.2	0.9 ± 0.5	0	11.1 ± 0.6	2.9 ± 0.2	0	10	10 ± 5
		RL4	0.0	0.0	1.6 ± 0.8	80		1.7 ± 0.4	0	0	14 ± 9
		RL5	0.0	0.3 ± 0.4	1.1 ± 0.7	20		2.1 ± 0.4	10	0	13 ± 5
		RL6	0.0	0.2 ± 0.4	1.0 ± 0.5	0		2.5 ± 0.3	10	10	11 ± 5
		RL7	0.0	0.0	1.0 ± 0.7	10		2.5 ± 0.4	10	30	10 ± 3
		RL8	0.0	0.1 ± 0.2	0.7 ± 0.7	0	10.4 ± 0.4	2.6 ± 0.5	0	40	3 ± 2
	Ripe	**HN-bag**	1.3 ± 0.8	0.9 ± 0.7	1.8 ± 0.6	0	11.8 ± 0.2	1.7 ± 0.4	30	90	30 ± 7
		RL1	0.0	0.0	1.5 ± 0.4	0		1.7 ± 0.3	0	0	18 ± 5
		RL2 not sealed!	0.0	0.0	2.6 ± 0.3	0		1.7 ± 0.4	10	70	28 ± 7
		RL3	0.2 ± 0.4	0.1 ± 0.2	1.6 ± 0.7	0	10.8 ± 0.6	1.8 ± 0.6	20	0	15 ± 4
		RL4	0.0	0.5 ± 0.7	2.1 ± 0.7	80		1.3 ± 0.3	10	0	22 ± 5
		RL5	0.0	0.0	1.8 ± 0.7	50		1.9 ± 0.5	0	0	12 ± 4
		RL6	0.0	0.4 ± 0.4	1.7 ± 0.4	0		1.4 ± 0.3	20	0	24 ± 5
		RL7	0.2 ± 0.4	0.0	2.4 ± 0.3	10		2.0 ± 0.6	40	0	16 ± 10
		RL8	0.0	0.0	1.6 ± 0.8	0	11.7 ± 0.1	1.6 ± 0.4	10	40	28 ± 8
3 days	Standard	**HN-bag**	0.2 ± 0.3	0.3 ± 0.4	1.5 ± 0.3	0		2.5 ± 0.4	0	90	13 ± 4
		RL1	0.7 ± 0.5	0.3 ± 0.4	1.1 ± 0.7	0		2.1 ± 0.5	30	50	6 ± 3
		RL2 not sealed!	0.0	0.0	1.2 ± 0.4	0		2.0 ± 0.4	30	90	13 ± 4
		RL3	0.1 ± 0.2	0.2 ± 0.4	1.2 ± 0.5	0		3.0 ± 0.0	0	50	9 ± 4
		RL4	0.2 ± 0.3	0.3 ± 0.3	1.1 ± 0.6	10		2.5 ± 0.4	10	30	8 ± 3
		RL5	0.4 ± 0.4	0.3 ± 0.4	1.4 ± 0.4	20		2.3 ± 0.4	40	50	7 ± 3
		RL6	0.1 ± 0.2	0.5 ± 0.4	1.2 ± 0.6	0		2.4 ± 0.4	10	40	9 ± 4
		RL7	0.1 ± 0.2	0.4 ± 0.4	1.0 ± 0.7	0		2.5 ± 0.3	10	70	8 ± 3
		RL8	0.5 ± 0.4	0.1 ± 0.2	1.3 ± 0.6	0		2.0 ± 0.5	0	80	4 ± 2
	Ripe	**HN-bag**	1.3 ± 0.8	1.7 ± 1.9	2.3 ± 0.5	0		1.8 ± 0.5	50	100	25 ± 5
		RL1	1.0 ± 0.3	0.6 ± 0.5	2.4 ± 0.4	0		1.3 ± 0.3	20	0	21 ± 7
		RL2 not sealed!	0.3 ± 0.3	0.4 ± 0.4	1.2 ± 0.6	0		1.8 ± 0.4	30	100	26 ± 8
		RL3	0.3 ± 0.4	0.6 ± 1.0	1.5 ± 0.5	10		1.9 ± 0.5	0	50	15 ± 5
		RL4	0.1 ± 0.2	0.0	1.6 ± 0.7	0		1.6 ± 0.5	80	10	16 ± 5
		RL5	0.9 ± 0.4	0.2 ± 0.4	1.9 ± 0.5	0		1.8 ± 0.4	90	0	17 ± 7
		RL6	0.7 ± 0.4	0.6 ± 0.5	1.9 ± 0.6	0		1.7 ± 0.4	20	40	25 ± 10
		RL7	1.1 ± 0.7	1.1 ± 0.7	2.3 ± 0.6	0		1.6 ± 0.4	90	13	16 ± 5
		RL8	1.2 ± 0.5	0.3 ± 0.4	1.7 ± 0.3	0		1.5 ± 0.4	30	90	16 ± 5
6 days	Standard	**HN-bag**	1.5 ± 0.4	2.0 ± 1.5	1.8 ± 0.4	0	10.7 ± 0.4	1.4 ± 0.7	30	100	36 ± 9
		RL1	0.9 ± 0.2	1.3 ± 0.8	0.9 ± 0.7	0	10.5 ± 0.3	2.4 ± 0.3	40	100	16 ± 8
		RL2 not sealed!	1.0 ± 0.5	2.2 ± 1.2	1.5 ± 0.6	0	10.1 ± 0.9	2.1 ± 0.5	0	80	24 ± 9
		RL3	1.0 ± 0.5	1.6 ± 1.1	1.6 ± 0.5	0	10.8 ± 0.4	2.3 ± 0.4	20	70	25 ± 8
		RL4	1.0 ± 0.4	1.7 ± 1.1	1.7 ± 0.5	0	10.8 ± 0.3	1.6 ± 0.4	20	90	24 ± 8
	Ripe	**HN-bag**	2.0 ± 0.6	1.3 ± 1.3	2.3 ± 0.6	0	11.5 ± 0.4	1.4 ± 0.3	80	100	45 ± 6
		RL1	2.3 ± 0.5	3.1 ± 1.2	2.8 ± 0.3	0	11.3 ± 0.3	1.0 ± 0.0	100	10	52 ± 9
		RL2 not sealed!	2.5 ± 0.4	4.6 ± 1.6	2.5 ± 0.4	0	11.1 ± 0.6	1.2 ± 0.3	50	90	48 ± 6
		RL3	2.1 ± 0.5	2.0 ± 0.7	2.6 ± 0.3	0	11.1 ± 0.5	1.2 ± 0.3	50	80	41 ± 12
		RL4	1.7 ± 0.4	2.5 ± 0.8	2.2 ± 0.5	0	11.8 ± 0.3	1.2 ± 0.3	50	70	39 ± 6

5.5 Discussion and conclusion

The internal disorder, together with the unusual transport conditions (long time and too cold temperature), makes the comparison of PerfoTec MA package and Ripelockers with the control HN-bags of little relevance for practice. Nevertheless, the trials contributed to useful insights for future trials and adaptations in the technology.

Some issues with RipeLockers have been identified. The movement of fruits during sea transport caused abrasion damage, and there was an error in the application of the natural oil. Both problems can be avoided in future trials. Two PerfoTec bags were found that did not appear to have perforations. This is an important point of attention for the packhouse.

The symptoms of the internal disorder are similar to those found in a previous experiment at WFBR where it was identified as chilling injury due to temperature temporary below 10 °C (Brouwer, Nijenhuis-de Vries et al. 2019). Reefer data from the trial confirmed a temperature that was too cold during the long period of 20 days, even down to 8.5 °C. Furthermore, several observations are in line with the typical symptom development for chilling injury, namely an increase after transfer to warmer conditions, more pronounced symptoms for less mature fruits and an off-taste. Skin pitting, which is sometimes attributed to chilling, were not found.
Overall, the percentage of fruits with chilling symptoms after 0 days of shelf-life was less for the RipeLockers compared to the control HN-bag. It is not clear whether this can be attributed to the imposed gas conditions. Perhaps a slightly higher temperature in the RipeLockers contributed to this difference. It is striking though that the unsealed (though lidded) RipeLocker (RL2) also had a high incidence.

The conditions in the PerfoTec bags on arrival were about 18% of O_2 and 3% of CO_2 at 10 °C. The bags were removed after arrival, before the start of the shelf-life period. It should be discussed whether this protocol should be amended in a future trial. Keeping the bags also during shelf-life can be beneficial for maintaining quality up to the supermarket shelf.

The brown spots on the skin, most found in RL4 and RL5, were associated with high CO_2 levels in a previous trial ('Trial MA packages 2019'). RipeLocker LCC indeed confirmed that this makes sense given the applied gas conditions in these two RipeLockers.

In summary, PerfoTec and HN-bags both scored well on external fruit appearance. PerfoTec performed better than HN-bag with respect to less weight loss. The modified O_2 and CO_2 concentrations did not affect the quality in this trial, but have potential to do so in a realistic supply chain, perhaps including a storage buffer period or retail phase after arrival in the Netherlands.

Papayas from the RipeLockers showed less weight loss, and therefore less shrivelling, than the control boxes with HN-bags. It should be kept in mind that the recorded weight loss included a period of 4 days before loading the RipeLockers. The weight loss in this initial period could have contributed to a large extent to the total weight loss. In the previous trial, the % of weight loss over 25 days in RipeLockers was only approximately 1%. Differences in performance between the individual RipeLockers with different gas conditions can help to refine the search for the optimal conditions.

Based on the course of this trial and repeating temperature issues during transport, it was decided with all project partners to carry out the next trial on site in Brazil under controlled conditions in order to make fair comparisons between the new technologies and current practice with HN-bags.

6 General discussion and conclusion

The trials done in the first three years within the four-year program Fresh on Demand, lead to very useful information about the papaya supply chain and postharvest technologies. However, the overall quality of the papaya after transport (and shelf-life) in these trials was disappointing for several reasons. The main conclusions are:

- The quality at harvest (ripeness stage) and a good control of temperature during loading and transport is of high importance to fulfil consumer demands and avoid product waste. Obviously, limiting the time between harvest and retail phase as much as possible contributes to a better result.
- Both MA packaging (PerfoTec) and the use of dynamic-atmosphere chambers (RipeLocker) showed positive results. Both technologies will be further fine-tuned in next trials.
- Based on the course of the trials and repeating temperature issues during transport, it was decided with all project partners to carry out the next trial on site in Brazil under controlled conditions, in order to make fair comparisons between the new technologies and current practice with HN-bags. The next trials (year 2022), will be described in a separate report.

7 References

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