FOOD & BIOBASED RESEARCH
WAGENINGEN UR

Packaging of Brussels Sprouts in different production and distribution chains

Maxence Paillart
Fátima Pereira da Silva

Report 1187

Colophon

Title	Packaging of Brussels Sprouts in different production and distribution chains
Author(s)	Maxence Paillart and Fátima Pereira da Silva
Number	1187
ISBN-number	ISBN number
Date of publication	November 2010
Confidentiality	yes
OPD code	OPD code
Approved by	Henry Boerigter

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

Content

1 Introduction

Just as other vegetables, the type of packaging has a large effect on the quality and shelf life of Brussels sprouts. The objective of this project was to evaluate a number of packaging types in three different distribution chains. The chains have been chosen to simulate possible and realistic chain conditions.

A single test has been carried out by FBR with a multiple number of variables and samples. The samples were evaluated at 4 different moments in the chain. An analysis of variance was applied to compare the performance of the different packaging types.

This report presents the results of this study. The set up of the test is described in the following chapter. Afterwards the results will be presented and discussed. Finally the main conclusions of the study will be drawn.

2 Test set up

The tested packaging variables were:

- Net bag (Net)
- Hot needle (HN)
- Modified atmosphere option 1 (MA 1) (Sylpaphane film: PA-200 530mm)
- Modified atmosphere option 2 (MA 2) (Amcor PA-160)

The simulated distribution chains were:

- Chain 1: Constant low temperature (best case scenario)
- Chain 2: Temperatures fluctuation with abuse temperature and ethylene (worst case scenario)
- Chains 3: Current situation (with temperature fluctuations)

The chains are described in detail in Annex 1. In total 12 variables have been studied.

The Brussels sprouts (variety B-Abbacus; all coming from the same grower and harvested on the same day: week 36-2010) were packed by Freshwell and cool transported to the facilities of FBR. Each package contains 750 g of Brussels sprouts. The product temperature at the packaging moment was 6°C. At FRB, they have been given a code and placed in the one of the 3 storage cells (3 cells were used, one for each chain). The respective temperature profile (chain simulation) was started (Annex 2). In the cell where chain 2 was simulated, a shot with ethylene was given (concentration ethylene 1 ppm). The first step in the simulation was the storage at the packaging house/grower.
After the chain simulation, all the samples were placed inside one cell to determine the shelf life period of the Brussels sprouts. The shelf life simulation occurred at 20°C and 60% relative humidity with day/night period of 12 hours.

In order to establish the quality and shelf life of the package types, the samples were measured at 4 different moments:

- at the beginning (day 0)
- at the moment the packages are displayed at the retailer (day 2);
- half way the expected shelf-life (day 6);
- 1 week after the first display day at the retailer (day 9).

At each of these evaluation moments the following was measured:

1. Weight losses

The weight loss was measured in 3 samples/packages for each variable. The same 3 packages were used in all evaluation moments.

2. Sensorial judgement

The sensorial evaluation is based on 5 samples for each variable. After opening the packages, 20 Brussels sprouts (half of the content) were randomly taken to score individually the colour of the leaves and the cut surface. The evaluation of the other parameters was applied on the whole sample. The following parameters were evaluated:

- Colour of the leaves (Annex 3)
- Browning of the cut surface (Annex 4)
- Smell by opening
- Firmness
- Condensation
- Rot

3. Gas composition of the head-space

The gas composition was measured with DanSensor Checkmate II O_2/CO_2. For each variable, 5 samples/packages were used to assess the composition of the head space.

4. Photos

Photos have also been taken, under the same light conditions, to have a visual impression of the results.

3 Results and discussion

For all results presented here below, the following codes have been used:

- Net bag = Net
- Hot needle = HN
- Modified atmosphere option 1 = MA 1
- Modified atmosphere option 2 = MA 2
- Chain 1 = K1
- Chain 2 = K2
- Chains 3 = K3

3.1 Weight losses

The weight loss is strongly depending on the package type (Figure 1). As expected the net bag has the highest weight loss (in average 133g per package on day 9 for the 3 chains), followed by the hot needle package and finally the MA packages where no weight loss has taken place. Next to the package type, there is also an effect of the kind of distribution chain. Between Chain 1 (optimal) and 3 (current) there is no significant difference. Chain 2 however shows significantly more weight loss then the other 2 chains. This is valid both for the net bag as for the hot needle (for the MA packages there is no weight losses).

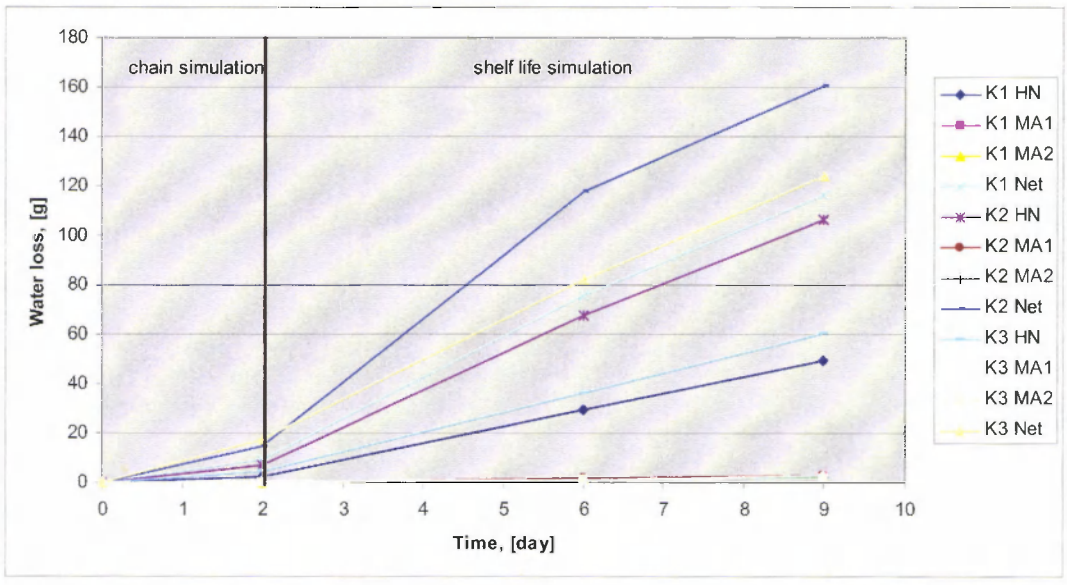


Figure 1: Water loss of the Brussels sprouts packages during transport and shelf life simulation (versus time)

3.2 Sensorial analysis

3.2.1 Colour of the leaves

This parameter is scored between 1 (green, fresh leaves) and 5 (much yellow, bruin leaves) and the acceptance limit is 2,5. Figure 2 shows the average colour of the leaves.

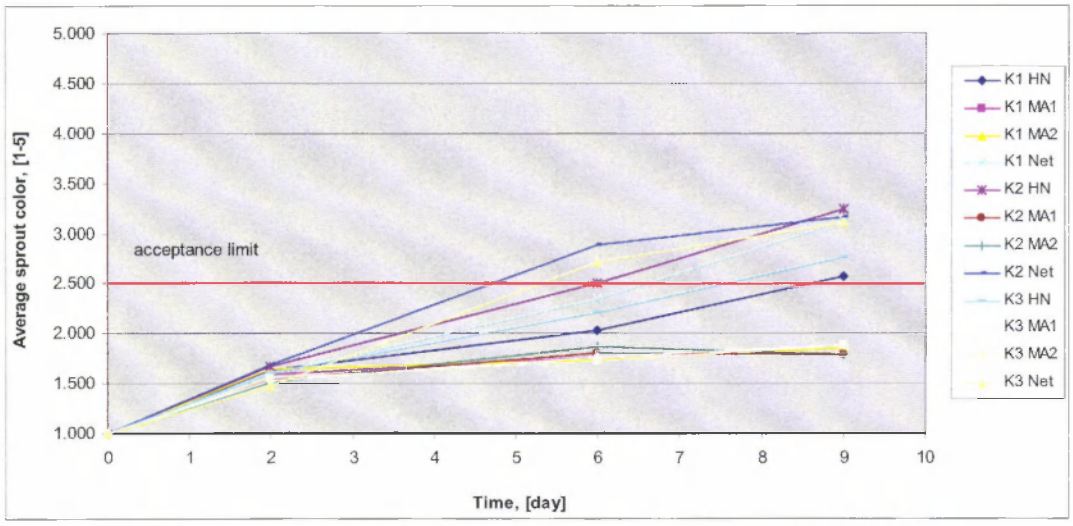


Figure 2: Color of the Brussels sprouts leaves during the chain and the shelf life simulation. (Acceptance limit fixed on score 2.5 (=light yellow color of the outside leaves))

There is a strong significant difference in the colour of the sprouts packed in MA relatively to the other 2 concepts. The sprouts packed in MA show greener leaves and the average colour remains almost constant whereas in the other concepts the colour clearly increases (to yellow). The sprouts in the net bags have the highest scores (more yellow) and the results of Hot needle packages are in between. In the last 2 evaluation moments, the average colour of the net bag is significantly higher than the Hot needle (with the exception of chain 2).

One expects that the effect of the temperature (and ethylene) on the quality decay is larger in the unprotected package. When comparing the effect of the chains, for the MA packages there is no difference between the chains. For the Hot needle packages, chain 2 (worst case) shows higher average colour than chains 1 and 3. Chain 1 and 3 are not significant different. On the other hand for the net bags, there are no significant differences (with exception of day 6, where chain 1 – best case scenario -is better than 2 and 3).

3.2.2 *Browning of the cut surface*

This parameter is scored between 1 (white surface) and 5 (dark brown) and the acceptance limit is 3. Figure 3 shows the average amount of browning of the cut surface.

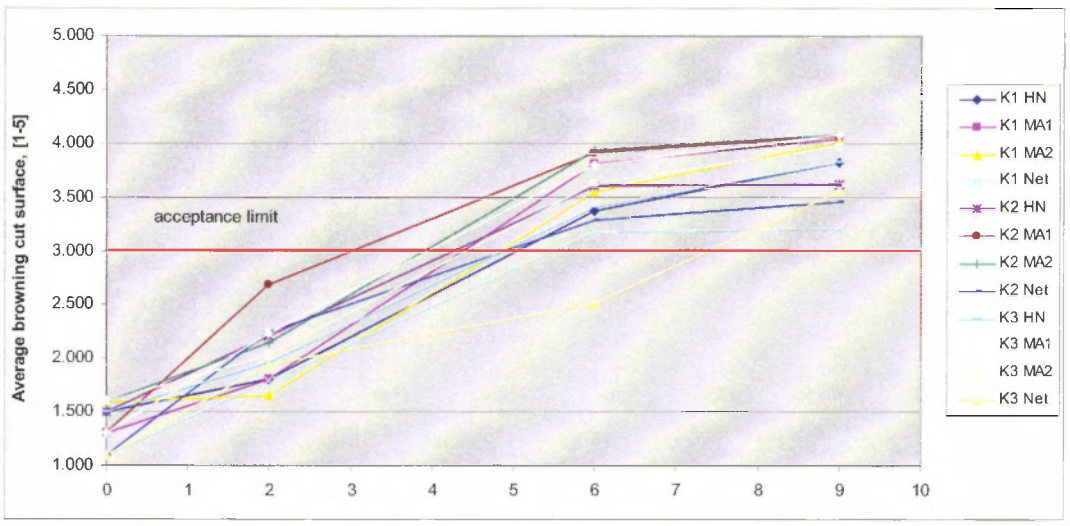


Figure 3: Cut surface of Brussels sprouts during chain and shelf life simulations (Acceptance limit fixed on score 3 (=yellow with circle))

With the exception of the Net bag package in chain 3, after 6 days none of the packages are still acceptable.

The sprouts packed in the net bag show in average less browning, the MA packages the most browning and consequently the Hot needle scores in between. In the last 2 evaluation days the difference between the net and Hot needle is significant.

For the same packaging treatment, no significant difference between the 3 chain simulations has been observed. The potential effect of the chain simulation is negligible on the color of the cut surface compared to the one resulting of the shelf life simulation conditions.

3.2.3 *Smell by opening*

The smell when opening the packages was scored between 0 and 3. If no odor was detected the score 0 was given. Packages where the typical and acceptable cabbage odor was present were scored with 1. Packages with off-odors where scored 2 or 3 (3 for a very strong off-odor).

Figure 4 shows the average scores for the smell by opening. According to the statistical analysis there was no significant difference between the 3 chain conditions. On the other hand there are differences between the packages. Due to the open structure of the net bags there was no odor detected in these packages (exception was the first day when the smell of the fresh Brussels sprouts was still perceptible). The Hot needle package is also rather open therefore the odor intensity is significantly lower than in the MAP packages and is always acceptable (loses its fresh odor on the last days of the shelf life simulation). The difference between the 2 MA packages is not consistent. Both in evaluation 2 and 6, the odour intensity was significantly higher in MA2 than MA1. However in the last day there is no difference between the samples. For the 2 MA packages, the off-odor is directly related to the presence or not of rotten sprouts inside the package. This should be taken into account when analysing the difference between the 2 Ma packages.

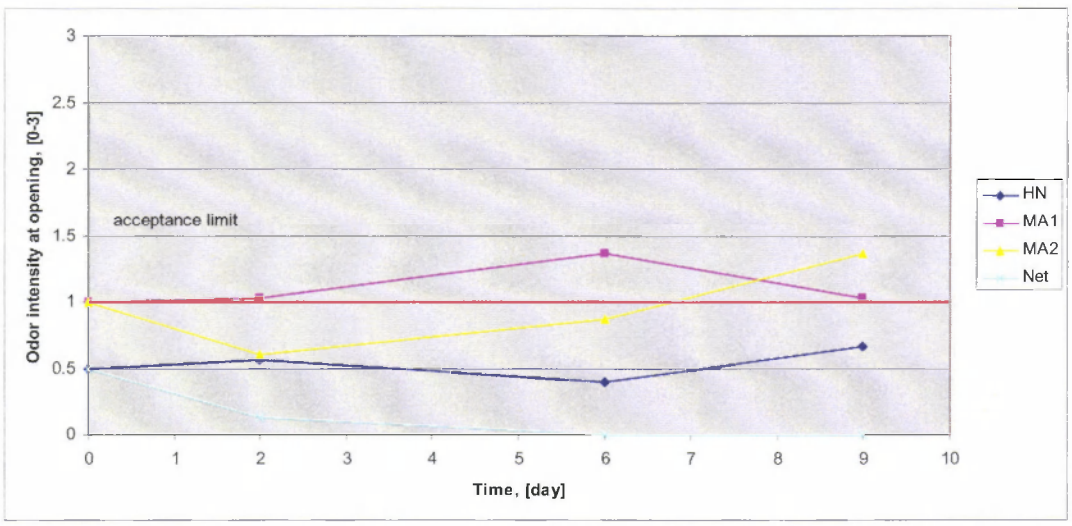


Figure 4: Odor of the Brussels sprouts just after opening the samples. (Acceptance limit fixed on score 1.5 (=light of odor detected))

3.2.4 Firmness

This parameter is scored between 1 (fresh, firm sprouts) and 3 (soft sprouts). Figure 5 presents the average firmness score in time. There is no statistic significant difference between the chains. However there are differences between the package types. As expected the sprouts packed in the net bags lose their firmness significantly faster than the other packaging types. After 5-6 days these sprouts are no longer acceptable. The sprouts packed under MA remain the most firm and are acceptable until the end of the shelf life. The results of the Hot needle are as expected in

between. The difference between the MA en Hot needle packages is however only significant in the last evaluation day (Hot needle less firm). Between the 2 MA packages there are no significant differences.
A direct relationship can be found between the quantity of water loss during the chain and the shelf life simulations and the lost of firmness. Due to the loss of water in the cells, (loss of turgidity) the leaves undergo a process called plasmolysis. When this happens, the cells are no longer rigid and therefore lose their structure and thus firmness. This process can also be induced by ethyleen.

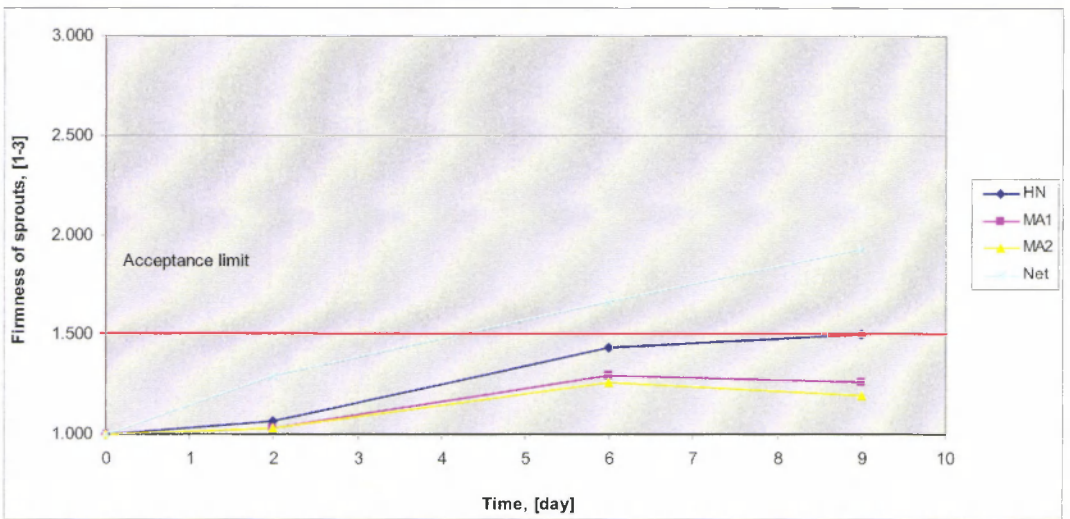


Figure 5: Firmness of the Brussels sprouts at opening of the packages. (Acceptance limit fixed at 1.5 (= first outside leaves are wilted))

3.2.5 Condensation

The condensation at the package is scored as follows:
0 = no condensation
1 = some condensation
2 = much condensation; the product is not visible

The results are presented in Figure 6. There are no differences between the 3 chains. This is to be expected because the different temperature profiles have only been applied in the first days of the chain. The net bag has hardly any condensation, the Hot needle some and the MA packages the most. The average scores of the different types of packages are significant different. In addition there are no significant differences between the 2 MA packages. In the last evaluation day the amount of moisture in the MA packages was close to be unacceptable.

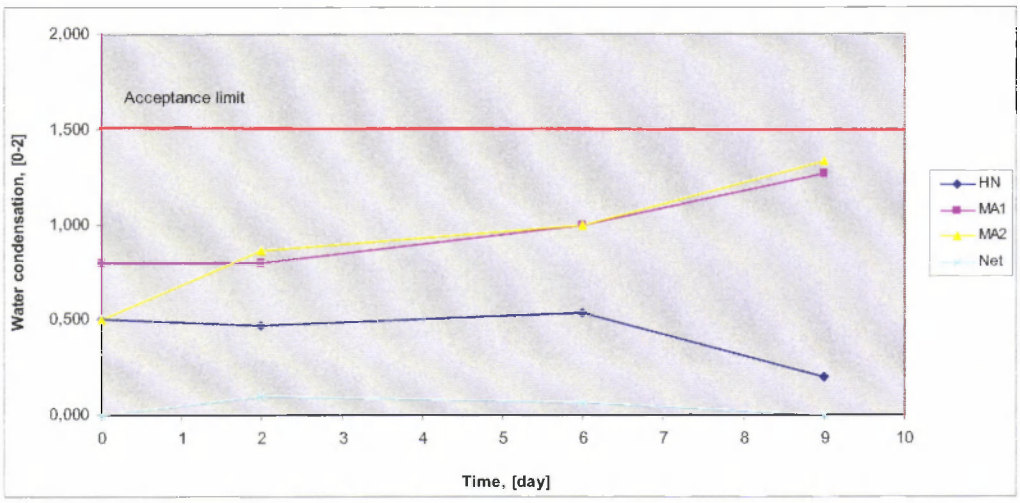


Figure 6: Condensation observed on the packaging before opening the samples. (Acceptance limit fixed at 1.5 (= lot of water condensed on the package))

3.2.6 Rot

This parameter is measured just by counting the number of rotten sprouts (visible from outside) in a package. The amount of rotten sprouts increases in time as it can been seen in Figure 7. This is particularly clear for the MA packages. Due to the high relative humidity(RH)/moisture level in these packages, the amount of decay can increase more easily. Taking into account the lower moisture/RH in the Hot needle packages the amount of decay is also less. In the net bag there is no increase of the moisture content on the package therefore the amount of rotten sprouts is also much smaller. In addition these rotten spots dry out and therefore they do not increase and the chance of contaminating other sprouts is also lower.
This test is performed with young sprouts from the beginning of the season. The sprouts that are harvested in the beginning of the season have weak inner leaves that easily decay and lead to rotten spots. This parameter depends on the quality of the raw material and the kind of packages can have an influence on the development of the fungi present on the weak sprouts (the high moisture increases the fungi growth).

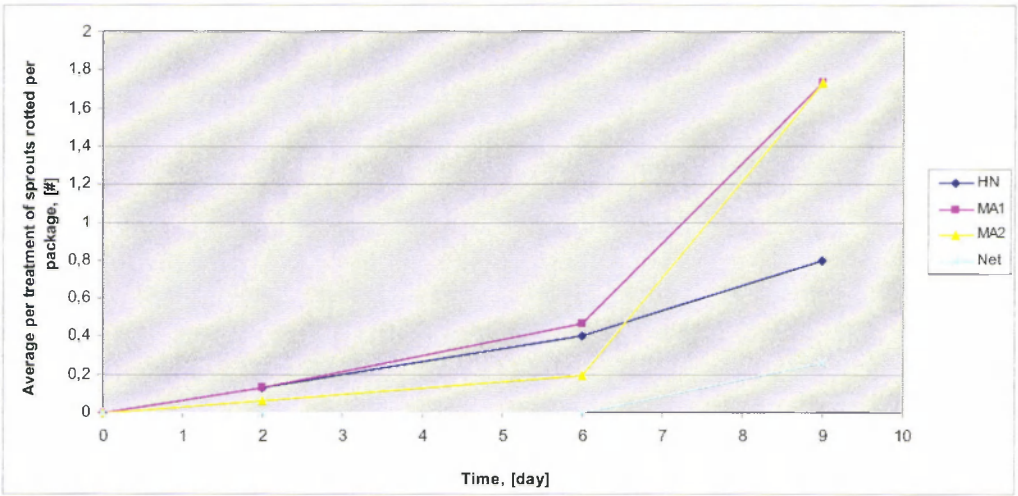


Figure 7: Average of sprouts rotted per package and per chain treatment

3.3 Gas composition of the head-space

Figure 8 and Figure 9 show respectively the percentage of oxygen and carbon dioxide in the head space. Since the other packages are open, the gas composition is only measured in both MA packages. Due to the respiration of the Brussels sprouts the concentration of oxygen in the head space decreases and the concentration of carbon dioxide increases in time. The difference between the 2 MA packages and the different chains is not significant. There are also no significant differences in the head-space composition in the beginning. between the packaging treatments.

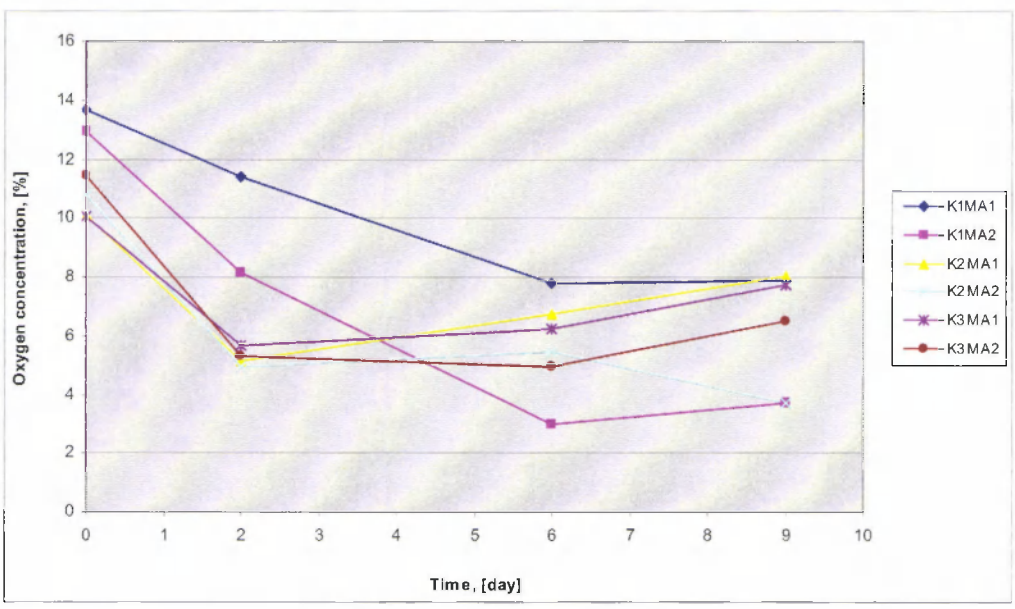


Figure 8: Oxygen concentration of the two MA packaging treatments

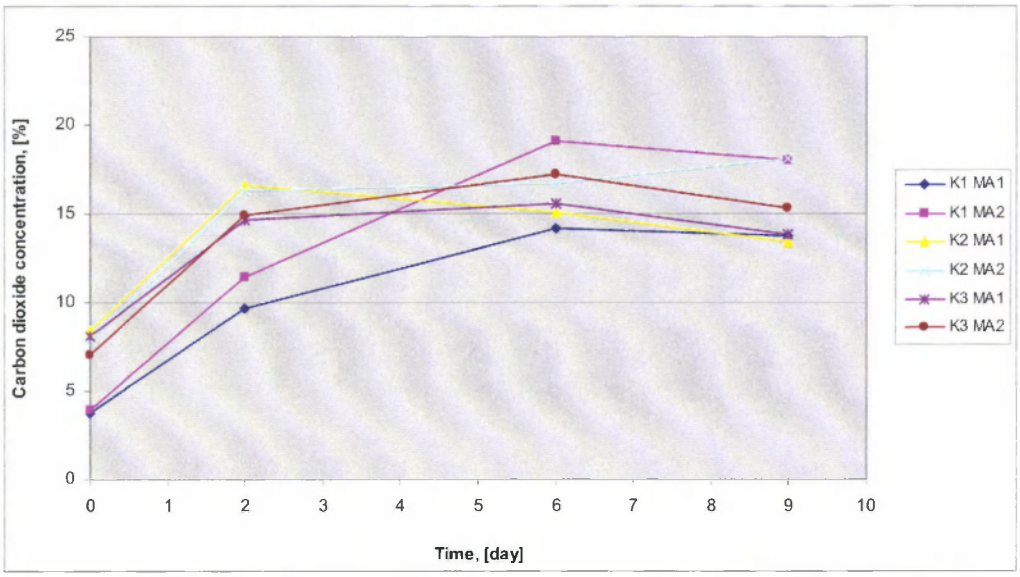


Figure 9: Carbon dioxide concentration of the two MA packaging treatments

The head space composition of the net bag and Hot needle packages is the same as the air (21% oxygen and 78% nitrogen). Oxygen levels around 2-3 % or below and carbon dioxide between 15-20% or higher can lead to anaerobic respiration. This needs to be avoided since it will lead to off-odors.

3.4 Photos

On each evaluation day, photos of the samples were taken. These photos are summarized in the Annex 5 for the evaluation made after the chain simulation, in the Annex 6 for quality evaluation processed on day 6 and in the Annex 7 for the evaluation at the end of the shelf life period.

4 Conclusions

There is a clear difference between the package. The sprouts packed in MA packages do not lose weight, remain firm and the colour of the leaves is green. However the cut surface is rather brown. On the other hand the sprouts packed in the net bags lose weight (17%), become soft and the leaves yellow. But the cut surface is less brown than in the MA packages. The Hot Needle package is in between. The weight loss for example is 9%. When the quality parameters green colour, firmness and no weight loss are considered the most important, the MA packaging is the best type of packaging. In the test however we conclude that the high relative humidity (RH) in the MA packaging causes two negative effects. First of all the high RH increases the development of rot in the sprouts. And in addition the browning of the cut surface is more intense in the MA packaging than in for example the net bags.

There is not a clear difference in the effect of the chains on the quality. For some parameters there are no difference and in some cases there are differences between one package type but not for others. In addition the variations in temperature occur only in the first 2 days. For the rest of the period (7 days) the temperature and Relative Humidity is the same, so it can be expected that the effect of the chain is less visible.

In the presence of rotten sprouts, the MA packages show off-odors. These packages have a high relative humidity, thus the amount of rotten spouts increases in time. Because the sprouts dry out in the net bags, the rotten spots also dry and thus do not infect other sprouts.
In young sprouts the inner leaves are still fragile and weak, thus more sensitive to rotten. This test was done with young sprouts (beginning of the season). Therefore the results regarding the odor by opening and the amount of rotten sprouts can be different when the test is repeated later in the season.

Recommendations

Raw material
It should be stressed that a certain package type does not cause rotten spots. The sprouts will only decay if they have been infected and are sensitive to rot, thus depends on the quality of the raw material. For the early harvest in the season, it is recommended to select a variety of Brussels sprouts resistant against the development of rot.

Temperature at the retailer
The simulated temperature in the retailer shelf is rather high. Therefore the quality of the product after 9 days is quite poor. Based on these results, it is advisable to display the Brussels sprouts at low temperature. The shelf life of Brussels sprouts depends directly on the storage temperature.

For each increase of 10°C above the optimal temperature (2°C), the rate of deterioration increases by two. Brussels sprouts packed within optimal packaging (MAP) and stored at 2°C can reach a shelf life period of 4 weeks. Lowering the storage temperature by the retailer to 7°C will increase significantly the shelf life of the product of at least one week extra.

Decreasing the temperature at the retailer will have a positive effect on the 3 types of packages studied. It can be expected that the profit of lowering the temperature will be the highest in the MA packages. This however requires further research.

Relative Humidity

The high moisture observed inside the MA packaging is a problem for the extension of the shelf life of Brussels sprouts. Indeed high moisture favors the development of rotten sprouts (infected before the packing process) and increases the activity of the phenol oxydase enzyme. Controlling the moisture content inside the packaging will help to extend the shelf life of the product. This can be achieved by:

- Drying correctly the sprouts after washing them and before packing them.
- Pre-cooling the sprouts to 2°C before packing permits also to reduce significantly the moisture inside the packaging.
- Using a packaging material more permeable to the water (PLA material for instance) can help also to control the moisture inside the bag.

Browning of the cut surface

The major problem of MA packages is the browning of the cut surface. This is the result of enzymatic activity in the presence of oxygen. Some sprouts varieties might be less sensitive for this problem, and thus make the MA package concept more feasible.

Applying directly on the sprouts before packing, a treatment with antioxidant additives can reduce the browning coloration of the cut surface. The addition of ascorbic acid in the washing water or/and drying the cut surface before packing can reduce significantly the enzymatic reaction that occurs on the cut surface of the sprouts.
The enzymatic activity is also slowed down if the product is stored at cold temperature. Applying MA packaging in combination with cold storage during the complete retail chain will increase the shelf life and improve the quality attributes of the product.

Appendices

Annex 1: Chains simulations (temperature fluctuations and ethylene injection for the second chain simulations)

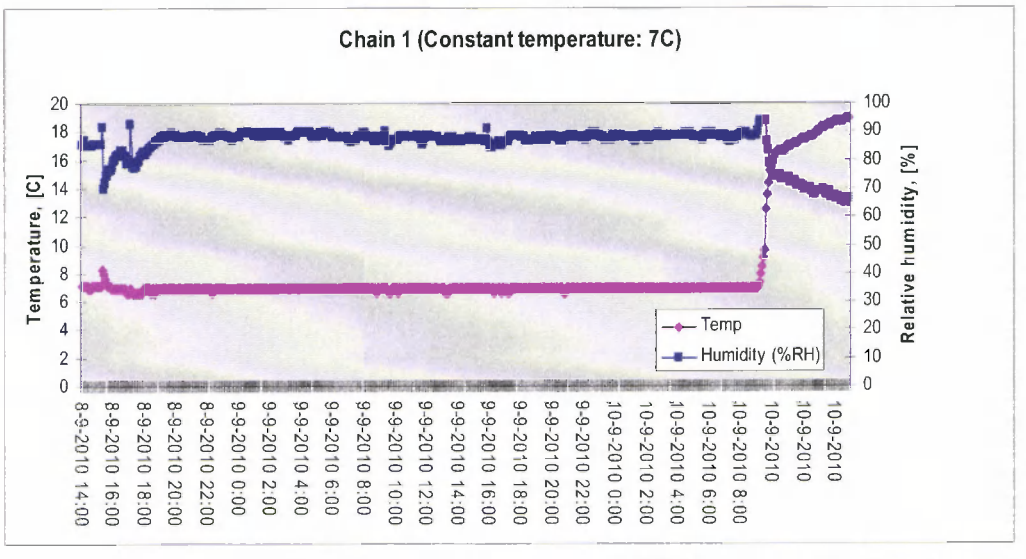
Chain 1	Time (hours)	Date	Start moment of the resp. chain step	Temperature (°C)	Beoordeling
opslag verpakker	4	Wo 8 sept.	14.00	7	Eerste beoordeling
transport	2	Wo 8 sept.	18.00	7	
op en overslag transporteur	3	Wo 8 sept.	20.00	7	
transport	6		23.00	7	
opslag DC	10	Do 9 sept.	05.00	7	
transport winkel	3		15.00	7	
opslag winkel	15		18.00	7	
uitstalling winkel	Begin uitstalling	Vr 10 sept.	09.00	20	Tweede beoordeling
uitstalling winkel	Na 4 dagen	Dinsdag 14 sept. om 9.00		20	Derde beoordeling
uitstalling winkel	Na 7 dagen	Vrijdag 17 sept. om 9.00		20	Vierde en einde beoordeling
Total aantal dagen	10.0				

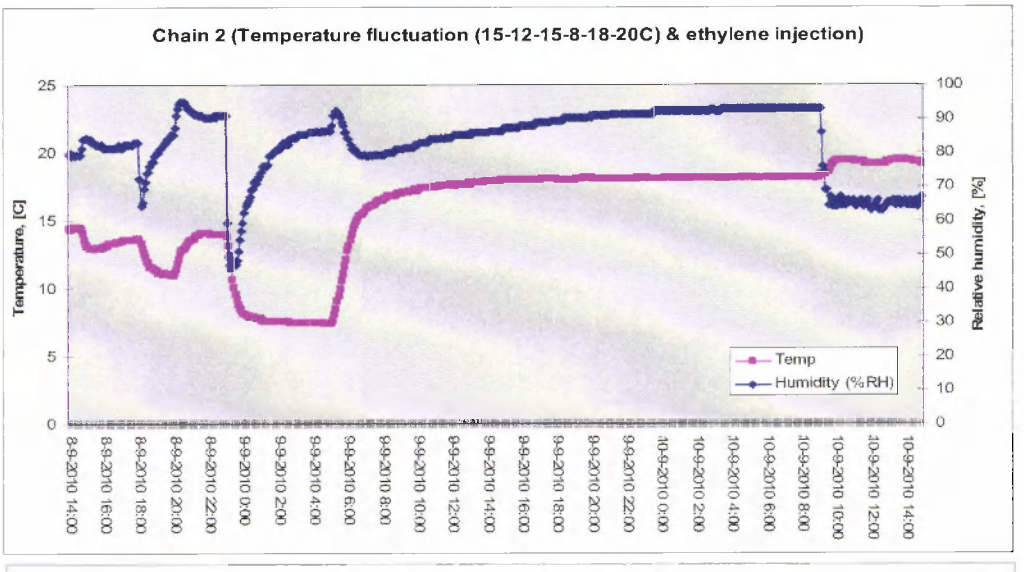
Chain 2 (with ethyleen shot)	Time (hours)	Date	Start moment of the resp. chain step	Temperature (°C)	Beoordeling
opslag verpakker	4	Wo 8 sept.	14.00	15	Eerste beoordeling
transport	2	Wo 8 sept.	18.00	12	
op en overslag transporteur	3	Wo 8 sept.	20.00	15	
transport	6		23.00	8	
opslag DC	10	Do 9 sept.	05.00	18	
transport winkel	3		15.00	18	

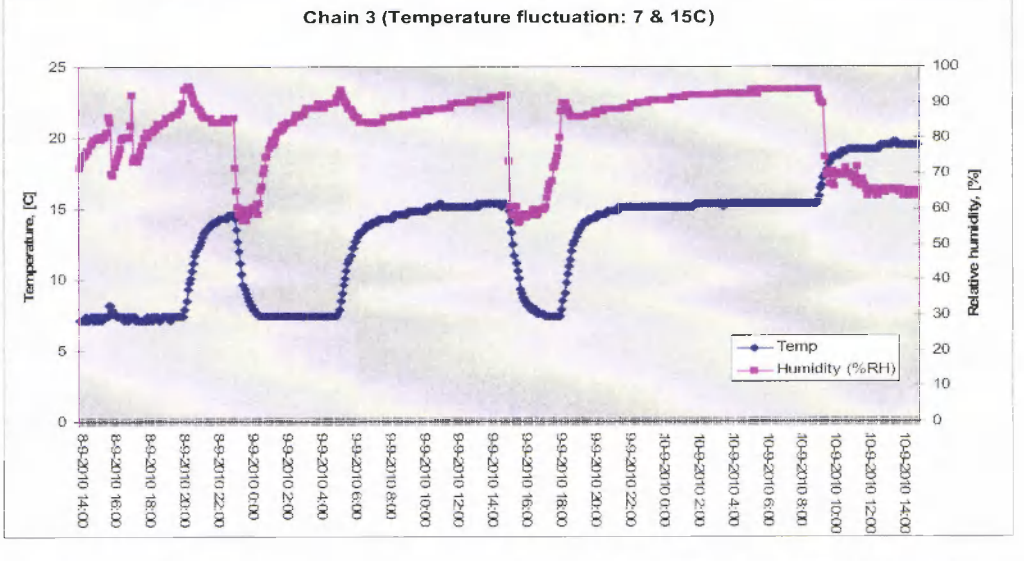
opslag winkel	15		18.00	18	
uitstalling winkel	Begin uitstalling	Vr 10 sept.	09.00	20	Tweede beoordeling
uitstalling winkel	Na 4 dagen	Dinsdag 14 sept. om 9.00		20	Derde beoordeling
uitstalling winkel	Na 7 dagen	Vrijdag 17 sept. om 9.00		20	Vierde en einde beoordeling
Total aantal dagen	10.0				

Chain 3	Time (hours)	Date	Start moment of the resp. chain step	Temperature (°C)	Beoordeling
opslag verpakker	4	Wo 8 sept.	14.00	7	Eerste beoordeling
transport	2	Wo 8 sept.	18.00	7	
op en overslag transporteur	3	Wo 8 sept.	20.00	15	
transport	6		23.00	7	
opslag DC	10	Do 9 sept.	05.00	15	
transport winkel	3		15.00	7	
opslag winkel	15		18.00	15	
uitstalling winkel	Begin uitstalling	Vr 10 sept.	09.00	20	Tweede beoordeling
uitstalling winkel	Na 4 dagen	Dinsdag 14 sept. om 9.00		20	Derde beoordeling
uitstalling winkel	Na 7 dagen	Vrijdag 17 sept. om 9.00		20	Vierde en einde beoordeling
Total aantal dagen	10.0				

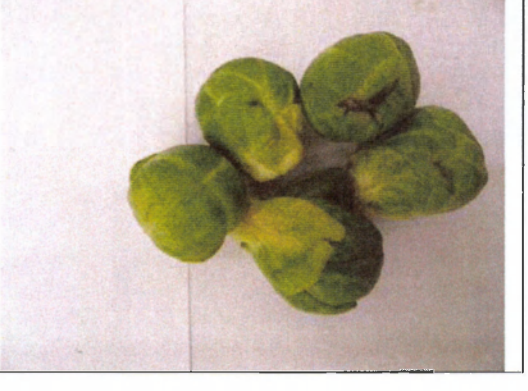
Annex 2: Temperature and relative humidity profiles of the 3 chain simulations







Annex 3: Color of the leaves scale

1= fresh green	
2= poor green/nerves visible	
3= poor green with yellow color	

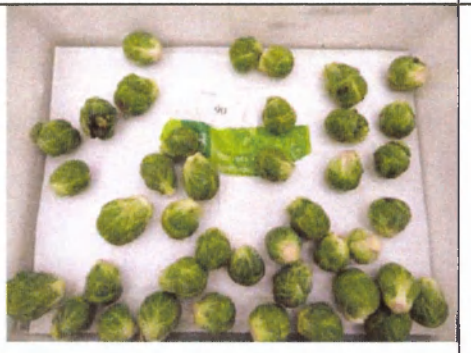
4= yellow	
5= brown	

Annex 4: Color of cut surface scale

1= white	
2= white with circle visible	
3= yellow with circle	
4= grey circle inside	

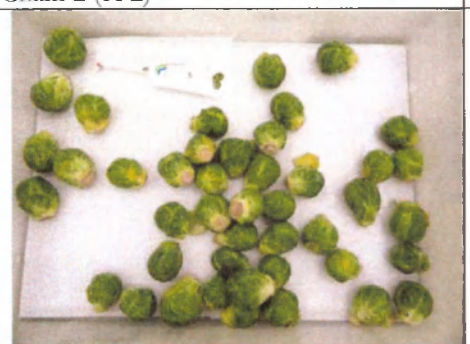
5= grey/black color	

Annex 5: Overview of the Brussels sprouts after chain simulation (day 2)

Day 2	Chain1 (K1)	Chain 2 (K 2)	Chain 3 (K3)
Net			
HN			

MA1			
MA2			

Annex 6: Overview of the Brussels sprouts on half way of shelf life simulation (day 6)

Day 6	Chain1 (K1)	Chain 2 (K 2)	Chain 3 (K3)
Net			
HN			

MA1			
MA2			

Annex 7: Overview of the Brussels sprouts at the end of the shelf life simulation (day 9)

Day 9	Chain1 (K1)	Chain 2 (K 2)	Chain 3 (K3)
Net			
HN			

MA1			
MA2