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Test shipment of broccoli from La Hoya (Spain) to Boston (U.K.)

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CONFIDENTIAL

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By order of:
KAPPA PACKAGING

Confidential

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Summary

In close co-operation Kappa Packaging and ATO-DLO have developed a new fully recyclable Modified Atmosphere transport package for broccoli. In many practical laboratory experiments performed during the last year, this so-called MA-box has proven to have a positive effect on the keeping quality of Dutch broccoli (especially with respect to colour and firmness).

The main goal of the pilot test described in this report was to study whether the MA-box could achieve a similar positive effect on the keeping quality of Spanish broccoli during an actual transport from Spain to Great Britain. In order to be able to quantify the possible quality improvements, broccoli in the newly developed MA-box was compared to broccoli in the currently used box.

During the pilot test broccoli was transported from Sacoje (a Spanish horticultural co-operation) situated in La Hoya, Spain to Univeg (a British co-operation that produces and imports vegetables) in Boston, Great Britain. During the test all relevant parameters were studied. First of all the temperature and, O_2 - and CO_2 concentration in the MA-box and control box were monitored and compared with computer simulations. The latter values were computed by the ATO-DLO MAP-model, an advanced simulation tool developed by ATO-DLO during the last 3 years. The quality of the product was monitored during storage and transportation. Finally, after arrival in Boston (UK) the quality decay of the broccoli was determined.

Conclusions

The effect of the new MA-box *on the quality of Spanish broccoli is the same as on the Dutch broccoli. The O_2 - and CO_2 concentration in the MA-box and the firmness and colour of the broccoli developed as expected. There were no differences in taste between broccoli from MA-boxes and control boxes.*

Sainsbury judged the discoloration of the stalk end unacceptable for use in the supermarket. In the near future, further investigations will be carried out to prevent the discoloration of the stalk end in order to make the MA-box *more suitable for the British market.*

1. Introduction and goals

A Modified Atmosphere box (MA-box) for broccoli has been developed by ATO-DLO in close co-operation with KAPPA PACKAGING. Modified Atmosphere Packaging (MAP) of fruits and vegetables is widely used as an inexpensive method to preserve quality during distribution. Respiring produce (like broccoli) in an MA-package will create altered gas conditions in the immediate vicinity of the produce. Metabolic processes as ripening, respiration and senescence will decrease and therefore the keepability of the product will be enhanced. Hence, in the new MA-box filled with broccoli, the atmosphere is created by the interaction between the respiration of the broccoli (O_2 uptake and CO_2 production) and the permeation of the respiratory gases through the paperboard box. The elevation of CO_2 and moisture and reduction of O_2 have an inhibitory effect on product deterioration.

So the MA-box has a positive effect on the keeping quality of Dutch broccoli (inhibition of yellowing, better retention of green colour and reduction of weight loss). Obviously, one of the most important advantages of this new MA-box occurs when broccoli is stored after packing and/or transported over relatively long distances. It is well known that Spain is an important producer of broccoli within Europe. An important destination market for Spanish broccoli is Britain. Great Britain may be described as a relatively critical market with rather high quality requirements. At the moment the quality level of the imported broccoli from Spain is not always sufficient to meet the high British standards. Hence, there is a need for an intelligent transport package that decreases the quality decay during transport and storage. In addition, the labour costs to supply the market at the right moment with the right amount of product are very high which might be another reason to apply the new MA-box in the near future.

The main goals of this test are to study:

- *the possibilities to enhance the storage time of broccoli directly after harvest in Spain in order to reduce the labour costs;*
- *the possibilities to increase the storage time inside the package (so-called packed shelf life [1]) and improve the quality of the Spanish broccoli at the moment of arrival in Britain.*

As mentioned above, the permeation of the respiratory gases (O_2 - and CO_2) through the paperboard package is an important property of an MA-package. Previous research has shown that dynamic forces, as occur during transport, have a significant effect on this gas permeation (see ATO-DLO report; Overview of the development of an MA box for broccoli & the results of dynamic and static tests of MA boxes with perforations and ritslines). Therefore, complementary goals were to get an impression of the performance of the MA-box regarding:

- *the mechanical properties (strength) of the box;*
- *the effect of dynamic forces (occurring during transport) on the permeation of the respiratory gases (O_2 - and CO_2).*

The supermarket chain Sainsbury has the intention to use the MA-box for broccoli in the near future. At this moment Sainsbury is being supplied with broccoli packed in open boxes topped with ice. In this test the quality of Spanish broccoli packed in the newly developed MA-box was compared with the quality of Spanish broccoli packed in ordinary boxes, after storage and transport to Britain.

The test was carried out in close co-operation with Univeg, a British importer and producer of vegetables (Boston). In Spain the broccoli was supplied by Sacoje, a Spanish horticultural co-operation situated in La Hoya.

[1] By *packed shelf life* is meant the time (in days in a storeroom of 18°C and 75% RH) during which the quality of the packed broccoli is acceptable (for selling).

2. Materials & Methods

2.1. Distribution

Product and Packing
Figure 1 shows the time schedule of the pilot test and the expected temperature at each stage of the test. The test was carried out with mature broccoli (cultivar *Marathon*). Members of Sacoje grew the broccoli. On each of the three packing days (25th, 28th and 30th of April) broccoli of three different members was packed. The broccoli had been harvested the day before packing and was subsequently precooled overnight.

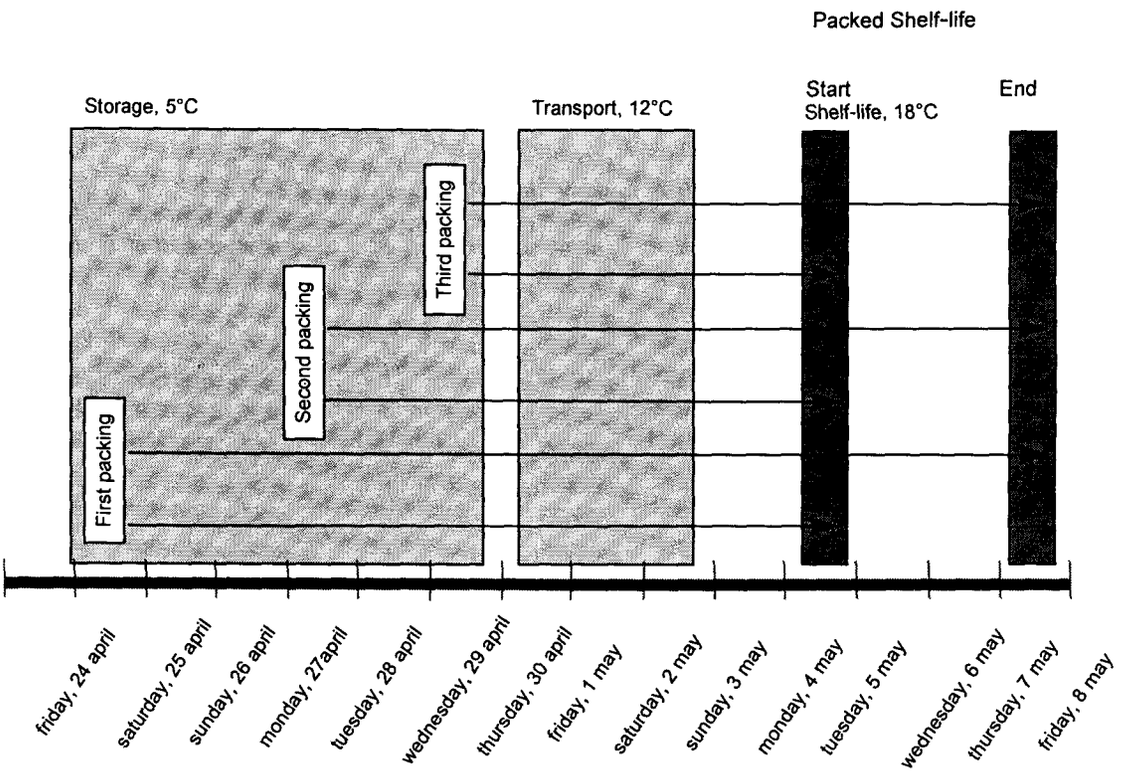

Figure 1. Time schedule, and storage conditions during the pilot test.

Broccoli with outstanding quality was selected and trimmed to the right weight before packing. Subsequently, the broccoli was packed in the new MA-box and in the control box with topped ice (1 kg). Finally, the two different box types were stacked on separate pallets.

The dimensions of the MA-box are 59 cm x 39 cm x 16 cm, with a content of 8 kg of broccoli. A full pallet has 13 layers with on each layer 5 boxes, leading to a total pallet load of 520-kg broccoli. The dimensions of the control box are 50 cm x 30 cm x 18 cm, with a content of 6 kg of broccoli and 1 kg ice. A full pallet has 11 layers with on each layer 8 boxes leading to a total pallet load of 528-kg broccoli and 88-kg ice.
It took approximately 4 hours to complete the two pallets (form 9:00 until 13:00 o'clock). Directly after the stacking, the pallets were tied up and put into a cold storeroom (2°C) until transportation to Britain. The above procedure was repeated each packing date.

Storage and Transportation
The pallets were placed in a cold storeroom at 2°C. All pallets from the three successive packing dates were loaded on a truck at 23:00 Thursday evening 30th of April. This truck arrived in Boston, Great Britain on Monday morning at 7:00 a.m. the 4th of May. Immediately after arrival the truck was unloaded and the pallets were placed in a cold storeroom (5°C). The next day samples were placed in the shelf life room. The surplus of the broccoli was sold.

2.2. Measurements

Temperature and relative Humidity
The temperature in the packinghouse and the temperature of the product were monitored during packing and storage. An Escort sensor data logger (temperature and relative humidity) with three external temperature sensors was placed in each pallet. Data were collected every 30 minutes from Saturday April 25th until Thursday May 7th.

Concentrations O_2 and CO_2
The O_2 - and CO_2 concentration in the MA-box were measured immediately after packing and during storage at Sacoje. At Univeg the O_2 - and CO_2 concentration in the MA-box were also measured daily during the packed shelf life period at 18°C. The O_2 - and CO_2 concentration were measured with a abissprint gas analyser. The O_2 - and CO_2 concentration in the MA-box were also computed with the ATO-DLO MAP-model. For these simulations all available input parameters were used. In Table 1 all input parameters and their values are shown.

Parameter	Value
respiration O_2	5,4 mmol / kg . hour
CO_2	1,4 mmol / kg . hour
permeation through the MA-box	50 ml/ (min. bar)
box dimensions	0.59 * 0.39 * 0.16 m (l * w * h)
broccoli per box	8,2 kg (average)
transportation	no effect on gas permeation
temperature	see measurements (figure 1)

Table 1. Input parameters and values for the ATO-DLO MAP-model.

By comparing the calculated values with the measured values the effect of the transportation on permeability can be estimated.

Product Quality
Firmness, colour, stalk end discoloration and other relevant quality aspects were judged by a product expert during the packed shelf life period at Univeg (starting at Tuesday 5th of May and ending Friday 8th of May). For the quality measurements 2 boxes of each treatment (packing date * grower * box type) were put in the shelf life room (18°C and 75% RH) and subsequently the packed shelf life was determined. As mentioned before the packed shelf life of the broccoli is defined as the time (days) during which the quality of the broccoli is acceptable (for selling).

External quality
- *Weightloss:* the weight of the broccoli was measured at Sacoje when the product was packed. At Univeg the weight of the broccoli was measured on Wednesday 6th of May.
- *The firmness:* is indicated with + when it is acceptable or +/- when it is just acceptable or - when it is not acceptable and it is no longer possible to sell the product.
- *Colour*: a mature green colour is valued with an 8, complete yellow broccoli is valued 0. When the first flowers start opening but are still green the colour is valued 6 and the broccoli can still be sold. When the first flowers are open and yellow the colour is < 6 and the product is unacceptable for sale.
- *Stalk end discoloration*: a 0 is no discoloration, 5 is completely black, a colour > 3 is unacceptable.

Internal quality

- *Taste*: in order to investigate the effect of the MA-box on the taste of the broccoli, the taste of broccoli transported in the MA-box was compared with the taste of broccoli transported in the control box. Each member of the taste panel had to judge three pairs of cooked broccoli (MA versus control). The members of the taste panel had to give for each pair a preference to the sample that was the firmest, the sweetest and the most tasteful. In total the MA-packed broccoli was compared 18 times with the broccoli packed in the control box. A panel of 6 persons, 4 female, and 2 male, aged from 24 to 50 including smokers and non-smokers carried out the comparison.

3. Results & Conclusions

3.1. Introduction

Since the test showed more or less similar results for all growers, below only the average values per packing data are presented.

3.2. Temperature and Relative Humidity

In Figure 2 the average temperature during storage and transport is shown. The figure shows temperature data of a) the storage room / truck, b) inside a MA-box and c) inside the control box.
The temperature in the MA-box differed from the temperature in the control box during the transportation from La Hoya to Boston. During this period the temperature in the MA-box was higher than in the control box. This difference was due to the presence of ice (1 kg) in the control box. After the boxes had been loaded on the truck the temperature of the product in the control boxes started to increase. On arrival at Univeg the ice in the control box was completely melted. At that moment the temperature of the product in the control boxes was comparable with the temperature of the product in the MA-box. Due to the changed logistic at Sacoje there was 1 kg ice added to the control box instead of the normal amount of, 0,5 - 0,3 kg. Hence, normally the MA-box and the control box will reach equal temperatures within a shorter period than in this test. As shown in Figure 2 the temperature of the storeroom was below zero during the first 2 days. This was caused by a defect in the cooling system. This low temperature could damage the product. At 2°C, which is usual, the ice in the control box will melt faster than at the lower temperatures during this test.

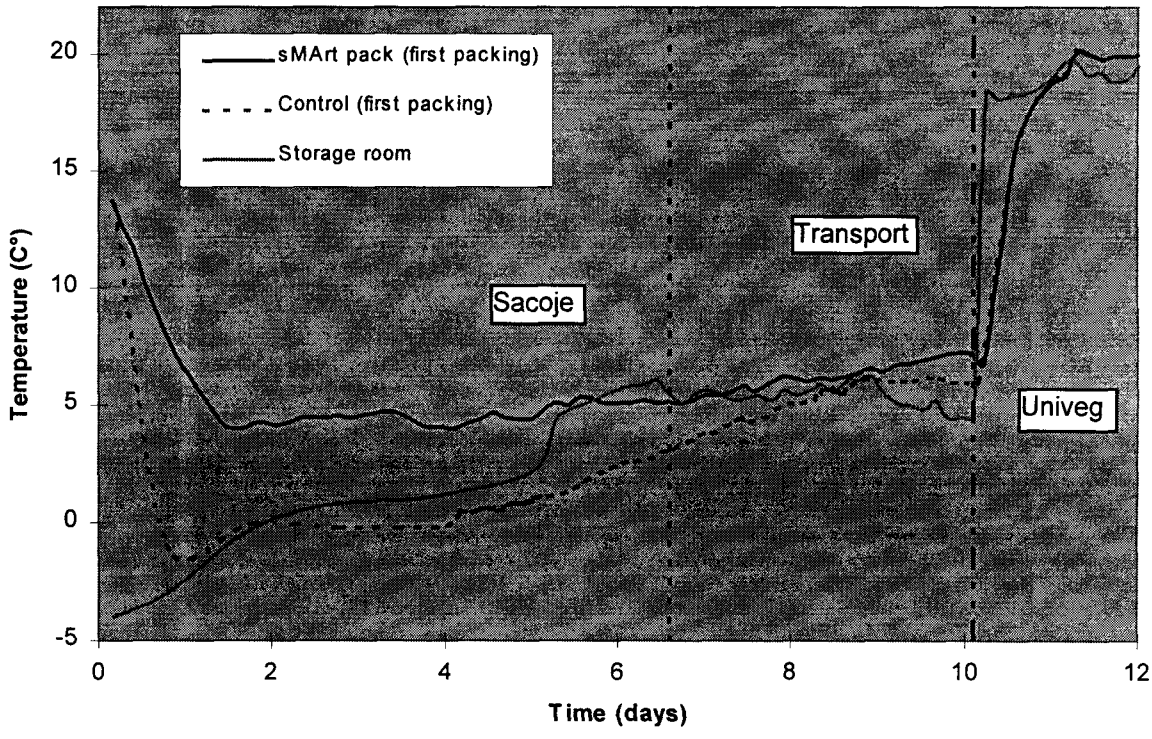

Figure 2. Temperature during transportation and storage

Conclusions
- *The average difference between the product temperature of the broccoli in the* MA-box *and the broccoli in the control box before the ice melts is 5°C.*
- *When the ice has completely melted the temperature is equal in both types of boxes.*

3.3. O_2 - and CO_2 concentration

During the test the O_2 - and CO_2 concentration were measured in 1 out of 3 boxes. Both the simulated and the measured O_2 - and CO_2 concentration are shown in figure 3. In the figure a deviation is shown between the calculated values with the measured concentrations on arrival at Univeg.

With closed ventilation hatches, the truck was more or less airtight and an increased CO_2 level and decreased O_2 level was expected. The truck was a kind of large MA-box. This assumption turns out to be correct when the O_2 - and CO_2 concentration in another truck loaded with 6 pallets of broccoli and 20 pallets of cabbage was measured at arrival at Univeg. The gas concentrations in this truck were indeed different from the normal concentrations (namely: 17,4% O_2 and 4,5 % CO_2). In a truck completely loaded with broccoli these concentrations will show an even larger deviation from the normal ambient O_2 - and CO_2 concentration.
Comparing the measured O_2 - and CO_2 concentration with the calculated O_2 - and CO_2 concentration there is no reason to suspect an effect of the transportation on the O_2 - and CO_2 concentration. Non of the measured boxes showed an additional leakage caused by dynamic effects (transport).

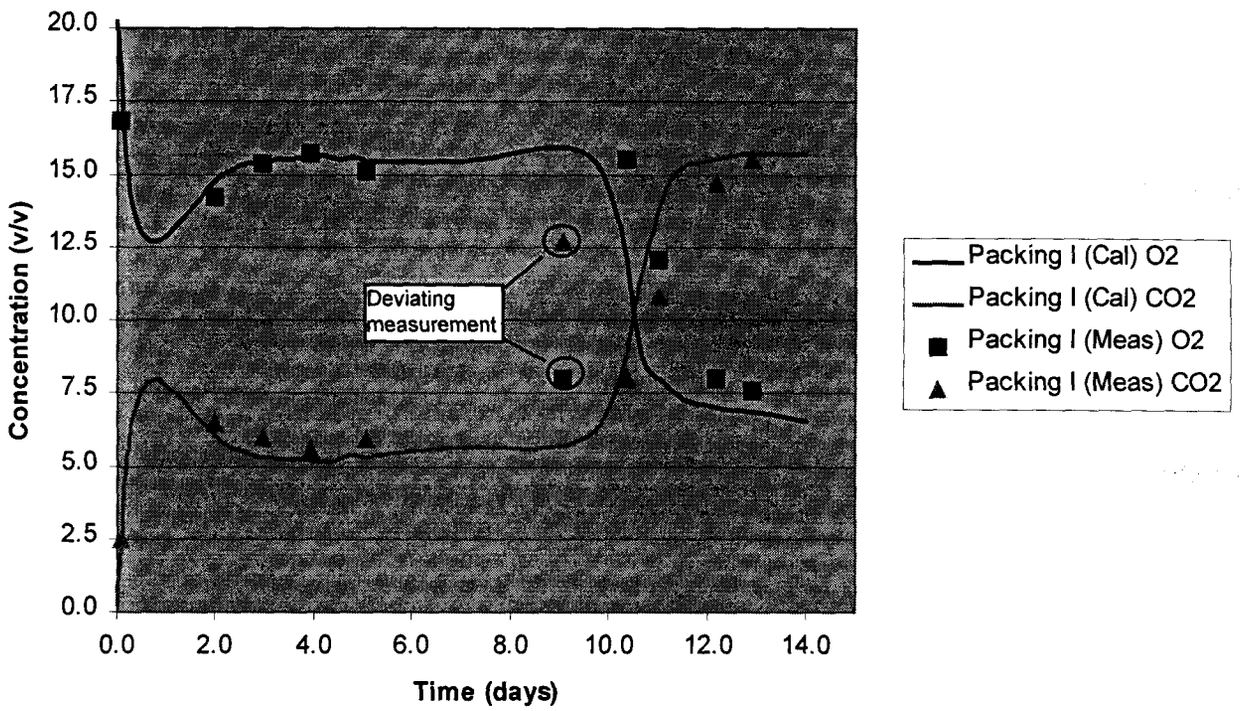

Figure 3. Calculated and measured concentration O_2 and CO_2 in MA-box.

Conclusions.
- *The O_2 and CO_2 concentrations in the* MA-box *developed as predicted with the ATO-DLO MAP-model.*
- *Closed ventilation hatches of a truck can have an effect on the concentrations O_2 and CO_2 in the truck.*
- *Transportation has less effect on the permeability than expected.*
- *All boxes have simular properties concerning gas permeation rate.*

3.4. Product Quality

Rot and Mould growth
No rot or mould growth was determined during this test.

Weightloss.
The summarised results are shown in table 2.

Packing	Control box	MA-box
I (5 days storage)	7,4 %	1,7 %
II (3 days storage)	5,3 %	1,4 %
III (no extra storage)	3,3 %	1,1 %

Table 2. Percentage of weightloss of broccoli after storage, transportation and 2 days of packed shelf life (18°C).

Conclusions.
Broccoli stored and transported in an MA-box *loses less weight than broccoli stored and transported in the control box. The reduction of weightloss will result in a firmer product.*

Firmness.
Table 3 shows the firmness of the broccoli during the shelf-life period. + indicates a saleable product and - an unsaleable product.

Packing	Control box		MA-box	
	Tuesday (5 may)	Friday (8 may)	Tuesday (5 may)	Friday (8 may)
I	-	-	+	+
II	-	-	+	+
III	+/-	-	+	+

Table 3. Firmness of broccoli during shelf life.

Conclusions.
Broccoli packed in the MA-box *was saleable during the whole test period regarding firmness. The broccoli packed in the control box was unsaleable at the beginning of the shelf life period (packing date II and I). The broccoli from packing III was not saleable after 3 days of storage in the shelf life room.*

Colour.
Table 4 shows the colour of the broccoli on arrival and at the end of the shelf life period at Univeg.

Packing	Control		MA-box	
	Tuesday (5 may)	Friday (8 may)	Tuesday (5 may)	Friday (8 may)
I	6	4,5	7	6
II	6	4,8	7	6
III	7	5	7	6

Table 4. Colour of broccoli during shelf life period at Univeg.

Upon arrival at Univeg the colour of broccoli packed in the MA-box was better than the colour of the broccoli packed in the control box (except broccoli from packing III). The broccoli packed in the control box was unsaleable after 3 days of packed shelf life. The colour of the broccoli packed in the MA-box was still acceptable after 3 days of shelf life (all 3 packing dates).

Conclusions
The colour of broccoli stored and transported in the MA-box *was better preserved than in the control box.*

Colour stalk end
In table 5 data on the stalk end discoloration are summarised. The broccoli packed in the MA-box was unsaleable regarding discoloration of the stalk end after one-day storage in the shelf life room. The broccoli packed in the control box stayed acceptable regarding stalk end discoloration.

Packing	Control		MA-box	
	Tuesday (5 may)	Friday (8 may)	Tuesday (5 may)	Friday (8 may)
I	1	1	3	3
II	2	2	3	3
III	1	1	3	3

Table 5. Colour of stalk end of broccoli during the shelf life period at Univeg.

In order to study a microbial infection as a possible cause off this discoloration samples were sent to Bertby analytical consultants (Burton upon Trent, Staffordshire). The results of these test indicate that the discoloration of the stalk end is most likely not due to microbiological infection although there are some kinds of micro organisms that show an increased growth in the MA-box compared with the control box. Obviously the discoloration is enzymatic and is stimulated by the increased moisture inside the MA-box. In addition the sensitivity will be of great influence whether or not the discoloration appears.To Sainsbury the discoloration was unacceptable. They will not use the box before this problem has been solved.

Conclusions
Discoloration of the stalk end is stimulated in MA-boxes. This is unacceptable for Sainsbury.

Packed Shelf-life.
In table 6 data on all quality aspects are summarised in the Packed shelf life. The broccoli packed in the MA-box was unsaleable because of discoloration of the stalk end after one-day in the shelf life room. All other quality aspects stayed acceptable for the whole period.
In the control box only broccoli from packing III stayed acceptable for 2 days after that all broccoli packed in the control box was unacceptable, the limiting quality aspects were firmness and colour.

Packing	Control	MA-box
I	0	1
II	0	1
III	2	1

Table 6. Packed shelf life in days.

Conclusions
In the MA-box discoloration of the stalk end is ithe limiting quality aspect. In the control box the firmness and color are the limiting quality aspects.

Taste.
Table 7 shows the summarised results of the taste test. Differences are only significant if a sample is preferred 14 times versus 4 times. No off flavours were found.

Taste attribute	Control	MA-box
Firmness	10	8
Sweetness	10	8
Taste	10	8

Table 7. Results of taste test.

Conclusions
*There is no significant effect on the taste of the broccoli caused by the way of packing (*MA *or control).*

Presentation
The MA-box had a better presentation than the control box, the box performed better and showed none of the deformations the control box did.

4. Discussion and Final Conclusions

The MA-box performed as expected during the test. The temperature, the relative humidity and the O_2 - and CO_2 concentration in the box developed as predicted. The influence of dynamic forces (transportation) on the total package performance was less than expected.

The MA-box had a positive influence on weightloss, firmness, and colour of broccoli. No effect (positive or negative) of the MA-box on the taste of the broccoli was found.

In general, Sainsbury was very positive about the effect of the MA-box on the colour, firmness and presentation.

A point of improvement was the discoloration of the stalk end occurring in the MA-box. For a successful introduction on the British market this problem has to be solved.