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Market possibilities for using new films for MA Packaging

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The parties joining the research project are:

Kureha Chemical Industry Co., Ltd.
Japan

and

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the Netherlands.

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1. Summary

This report consists of a market research on the possibilities of using films developed by Kureha Chemical Industries Co. for MA packaging. The study is restricted to packaging materials with O_2-permeability between 5,000 $cm^3/(day\ atm.\ m^2)$ and 15,000 $cm^3/(day\ atm.\ m^2)$. Furthermore, it is assumed that the ratio of O_2-permeability and CO_2-permeability is approximately 1:15. To our knowledge these kind of films are not commercially available yet.

There are several ways to extend the shelf life of perishable products, like Controlled Atmosphere (CA) storage, Modified Atmosphere (MA) packaging and gas packaging. The advantages and disadvantages of MA packaging will be compared to CA storage and gas packaging. Market possibilities of MA packaging have been evaluated.

A more detailed research has been done on five products which will probably benefit from an MA package made of films developed by Kureha. The products are pear, potato, onion, lettuce and chrysanthemum cutting. Information has been collected on the production, import and export data for the most important European countries, the USA and Japan. The general structure of the different distribution chains has been traced and, finally, inventories were made of the current packaging materials and possible MA advantages for the products.

Furthermore, a list is given of other interesting products to pack in the new films. This list includes products that have a high profit margin at the retail outlet.

Finally, some general comments are included on the possible extension of modified atmosphere packages to transport packages.

2. Packaging of perishable products

2.1 Introduction

The storage time and shelf life of a perishable product represents the time span of maintaining a minimal quality of the harvested product. The minimal quality of a product is not determined by a single aspect, but rather reflects a large number of different aspects, like colour, firmness, rot and shrivelling. The importance of individual aspects strongly depends on the nature of the product. In general the shelf life of the product is limited by the first observed quality problem.

It is well known that shelf life extension is achieved by decreasing the temperature and/or changing the gas composition around the product. Low temperatures (above 0°C.) are effective for products of moderate climates. The storage at low temperatures of fruits and vegetables, from tropical or subtropical origin may be limited by *chilling injury*, a disorder induced by low temperatures (0-12°C.). Obviously, each product requires a specific temperature and gas composition for an optimal protection against quality decay. The most important gasses influencing the product quality are: oxygen (O_2), carbon dioxide (CO_2), water vapour (H_2O) and ethylene (C_2H_4). These gasses influence the metabolic activity of the living products, such as respiration, ripening and senescence. For dead products (fish, meat, etc.) these gasses may reduce the microbial growth and oxidation processes.

Packaging of a product fulfils several important functions. For instance, it protects the product against mechanical damage and makes it transportable. Furthermore, the package is applied as a tool in the logistics and may be used as a marketing tool for selling the product to a consumer. The package of perishable products may also allow the incorporation of special mechanisms, in order to enhance the shelf life and to increase the quality of the product delivered to the consumer. Some important mechanisms by which a package may influence the product quality are:

- protection against dehydration ;
- slowing down the biological deterioration of perishable products by reducing the overall biophysical activity, this can be obtained by changing the gas composition inside the package;
- reducing microbial growth and oxidation processes;
- protection against undesired light;
- protection against sudden (unwanted) temperature changes in the climate outside the package.

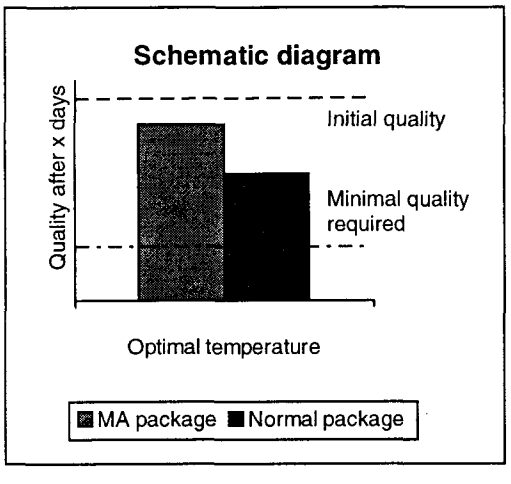
In this report we will mainly focus on slowing down the biological deterioration by changing the gas composition around the product. Hence, in most cases we restrict ourselves to living products (e.g. fruits and vegetables). Roughly speaking the three most important ways to change the gas composition around the product are Controlled Atmosphere storage (CA), Modified Atmosphere packaging (MA) and gas packaging. In the next sections CA storage, MA packaging and gas packaging will be described in more detail.

2.2 CA storage

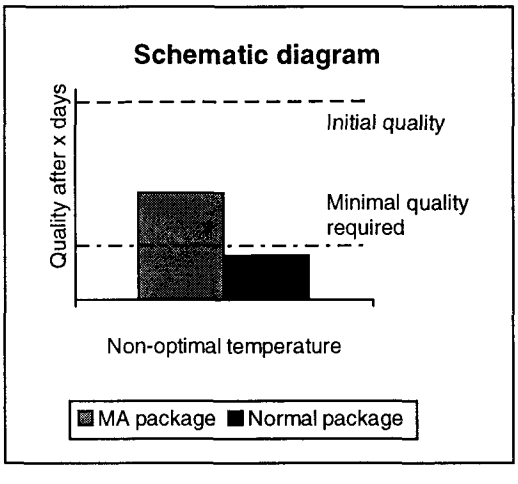
In CA storage, concentrations of oxygen, carbon dioxide, water vapour and ethylene are actively regulated by specific equipment in cooling facilities. In practice, CA storage is used for large volumes of products (> 50 tons) that are stored for longer periods (up to nine months). In the Netherlands CA storage is performed at specific cooling buildings located at the auction and less frequent at growers. Thus, storage under controlled atmosphere requires high investments in buildings, equipment and energy.

2.3 MA packaging

Storage time and shelf life of living respiring products can also be affected in a passive manner by applying packaging films with a specific gas barrier. At the moment of packaging, normal air is around the product inside the package. Driven by the respiration of the product (it consumes oxygen and produces carbon dioxide) the gas composition inside the package will change. The oxygen concentration decreases, while the carbon dioxide concentration increases. The newly formed modified atmosphere reduces the degradation of the perishable product. The appropriate MA conditions will be specific for each product and depend on the gas condition demands set by the product. Investments are low, since no investments in special equipment is necessary. In most cases products are MA packed at the wholesaler or export traders.



Quality under optimal temperature.



Quality under non optimal temperature.

The two figures above schematically show the general advantage of MA packaging. The figure on the left compares the quality of MA packed product to ordinary packed product under optimal temperature conditions. Due to the changed atmosphere inside the MA package, the quality of the MA packed products is higher. For non optimal temperature conditions, the MA advantage (relative to the normal packed product) is even larger. This is schematically shown in the figure at the right. Hence, the MA advantage is relatively large under non optimal temperature conditions. Therefore, the added value of an MA package is the largest in insufficiently controlled distribution chains.

2.4 Gas packaging

Similar to MA packaging, gas packaging involves a film package which reduces the degradation of the product. Unlike MA packaging, the initial gas condition is not the normal atmosphere, but an actively created gas condition. Hence, air is actively removed by a new mix of gasses that is advantageous for the packed product. The major advantage of gas packaging is the rapid and active establishment of the appropriate gas condition for the packed product. This advantage is especially interesting for products that perish rapidly. Gas packaging is complicated since every product needs a specific gas mixture which has to be added to the package. Hence, especially the gas packaging of different products in a relatively short time is rather expensive. The initial gas condition is maintained for a period up to one or two weeks, depending on the product activity and the gas diffusion characteristics of the high barrier film.

Contrary to MA packaging both respiring and non respiring (like for example fish and meat) products are packed in gas filled packages. In general packaging is performed at the producers (processed foods), specialised wholesalers or at the export traders (living products). Gas packaging requires investments in gas packaging machines and packaging material.

3. Some market possibilities for MA packaging

3.1 Consumer trends in food

Recent marketing research shows several interesting trends in preferences of the Dutch consumer. Contrary to the past, consumers don't automatically buy their products in the supermarket nearest by[1]. The consumer chooses its supermarket because of the high quality it delivers, its nice design and the large choice of products (especially of meat, vegetables and fruits) that is offered[2]. Remarkably, low prices are less important. In the Netherlands seventy percent of the total fruits and vegetables is sold at the supermarkets, where the consumer buys his fresh products more and more pre-packed at the self service counter (68%).

Quality directed consumers pay attention to several aspects concerning the quality of products. For instance, the freshness of a product is very important for the consumer. By freshness is meant both fresh from the field and fresh-made products. Recently, the popularity of products like fresh-made juices and salads has increased very fast. On the other hand products like canned food, that have no fresh image, are losing popularity. Another aspect which is important for the consumer is ease. Less consumers are willing to buy a product that is difficult to prepare. Therefore convenient food like ready-to-eat meals and cooled pizzas is a fast growing market[3]. Taste is another interesting aspect. Consumers prefer to eat prepared meals that taste as well as their home made meals. Also, products have to contain ingredients with a healthy and safe image. Obviously the latter aspect is strongly coupled to freshness. The last aspect related to quality is the quest for a bigger variety of products.

3.2 General market possibilities for MA packaging

The consumer trends mentioned above are strongly related to MA packaging. It is therefore not surprising that MA packaging is a fast growing market[4]. Quality decay of perishable products is delayed by MA packaging. Therefore the general quality and thus aspects like freshness and taste of MA packed products is better than that of normal packed products. Another important MA advantage is the longer storage time. Due to this longer storage time, perishable products can be transported over longer distances. In this way new markets can be created and consumers may profit of a more varied supply of fruits and vegetables. A second advantage of longer storage time is that distribution chains become more flexible. To a certain extend, growers and wholesalers can decide on what moment they want to sell and

[1] 'Bouwen marktgerichte ketens': Nehem Consulting Group, 's Hertogenbosch, 1996.
[2] 'CBL Consumententrends 1996': Centraal Bureau levensmiddelen, Leidschendam, 1996.
[3] A. C. Nielsen; market researchers, 1996.
[4] Day, B.P.F., Gorris, L.G.M.: Packaging of fresh produce on the West-European market, ZFL 44 nr. 1/2, Campden, UK, Wageningen, the Netherlands, 1993.

buy their products. Finally, fruits and vegetables can be offered to the client during a longer period.

In the past MA packaging has been successfully introduced for many products. Tomatoes, cut lettuce, apples, mushroom, broccoli and chicory are packed in MA retail packages.

3.3 Specific MA advantages for the Kureha film

Since there is a great market potential, why aren't all fruits and vegetables packed in MA packages yet? As mentioned before, essential in any MA package is the permeation of oxygen in and carbon dioxide out of the package. Among others, this permeation avoids very low oxygen concentrations. Very low oxygen concentrations will cause anaerobic respiration and may result in the deviation of taste and the occurrence of various side effects. The balance between the respiration of the product and the gas transport through the film makes the development of an optimal MA package rather complex. The key point in MA packaging is to pack the perishable product in the appropriate film. Naturally, in practice a film with certain properties is rather suitable for a group of products instead of one product only. The reason that not all products are packed in MA packages yet, is partially caused by the absence of films with the appropriate permeability. Common films under average atmosphere reach ratios of the order of 1:3. Since there is a great market potential, we believe that newly developed films which create good MA conditions for certain products, are very interesting from a commercial point of view. For this reason Kureha Chemical Industry Co. should develop a film for which the ratio of O_2-permeability and CO_2-permeability lies between 1:15 and 1:20.

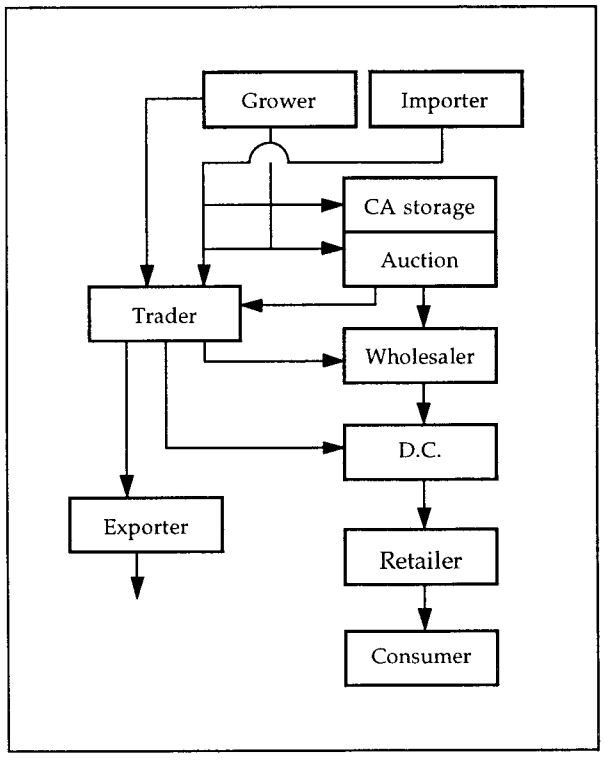
In general, MA films try to increase the CO_2 concentration and decrease the O_2 concentration inside the package. Increasing the CO_2 level results in a decrease in the respiring rate of plant material and in this way the shelf life of MA packed fruits and vegetables is prolonged. Products like strawberries and broccoli benefit from this increased CO_2 level. Yet, it has to be noticed that there is a limit to the level of CO_2 exposed to the product. All products start producing off-flavours when they are exposed to approximately 40% of CO_2. However, several products, like pears, potatoes, onions, lettuce and chrysanthemum cuttings, are much more sensitive to carbon dioxide and start developing physiological disorders at very low levels of CO_2. For these products an increased carbon dioxide level can have several harmful effects. For instance changes in the sugar contents can take place, off-flavours can be produced and finally an exposure to too high levels of carbon dioxide can even be toxic.

For these products the currently available MA films are not suitable, since the CO_2-permeability is too low. Increasing the ratio of O_2 to CO_2 creates a low level of CO_2 inside an MA package and can give a benefit on the storage time of these products. In order to avoid anaerobic respiration the O_2 permeability should lie between 5,000 $cm^3/(day\ atm.\ m^2)$ and 15,000 $cm^3/(day\ atm.\ m^2)$. Anaerobic respiration yields undesirable off-odours and flavours and therefore product quality is lost.

4. Product specific information

In this chapter we present product specific information. For each product we will give some information concerning growing, post harvesting and consuming. Data of production, import and export are presented for the most important European countries. Detailed tables containing all producing, exporting and importing countries in the EU are presented in the appendix. Remarks on the distribution chain and the current packaging material are in most cases only relevant for the Netherlands. We emphasise that the information is presented in order to introduce the European and Dutch fruit and vegetable market to Kureha and to support our statement that this market is interesting for Kureha Chemical Industry Co. Finally, some MA possibilities concerning the specific product are presented.

Some remarks have to be made on the numbers presented in this chapter. Unfortunately it is impossible to get all information from one origin and therefore described years, currency and numbers may differ a little bit from one source to another. Furthermore, some numbers were not available. In the figures some abbreviations are used. UK stands for United Kingdom, Be./Lux. means Belgium and Luxembourg, EU is the abbreviation of European Union and Czech. Rep. means Czechoslovakian Republic. The currency used in the figures concerning Europe is ECU. The import and export values for the Netherlands are presented in Dutch guilders (dfl). At the moment one ECU is about 2 Dutch guilder.



General lay-out of the Dutch distribution chain for fruits and vegetables.

In the figure above the general lay-out of the distribution chain for fruits and vegetables in the Netherlands is shown. The sale of fruits and vegetables is in most cases performed at the auction. The products are sold to wholesalers, who distribute the products further to, for example, a distribution centre (DC) or an exporter. Recently some retail chains tend to eliminate the auction and order their products at a trader. The trader buys his products directly from the growers.

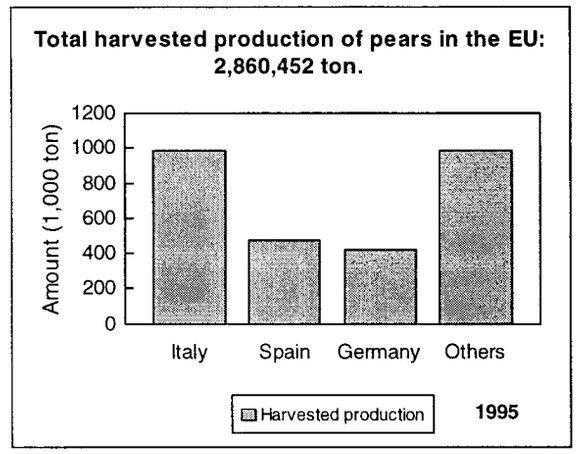
4.1 Pear

The first product we will describe in this chapter is the pear. Most pears are grown in a mild climate. Cold nights and especially night frost may result in a bad forming process of the fruit. Therefore pears are mostly produced in South European countries like Italy and Spain. The Dutch pear cultivation is located in the Southwest of the Netherlands. In this area the climate is the mildest. Eating-pears are eaten raw or can be used in a fruit salad. Cooking-pears are cooked and, subsequently, eaten as a vegetable or a desert.

Concerning the MA packaging of pears, the CO_2 concentration inside a package is very important. If the CO_2 concentration is too high it causes a physiological disease; the centre of the pear turns brown and in the end, scattered in the fruit, holes develop. This disease is called *brown heart*.

4.1.1 Production volume

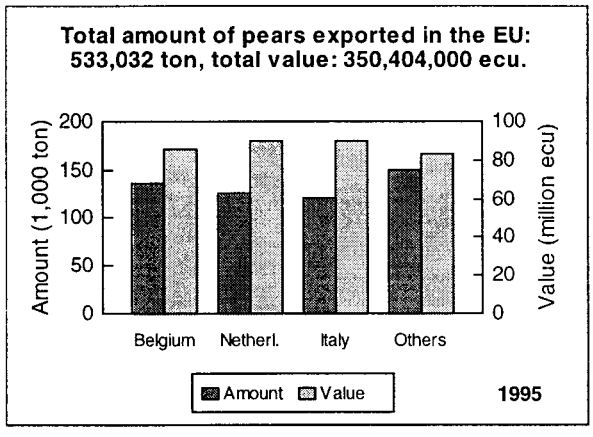
In the figure below we present the production of pears harvested by the three most important pear producers in the EU. To give you an impression of the amount we're dealing with in Europe compared to other countries; in 1993 the USA produced 848,000 ton of pears and in the same year Japan produced 396,000 ton according to the FAO.

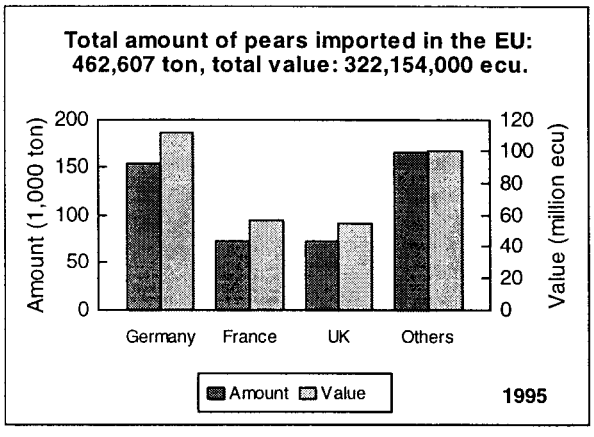


Harvested production of pears by the most important pear producers in the EU.

4.1.2 Import and export numbers

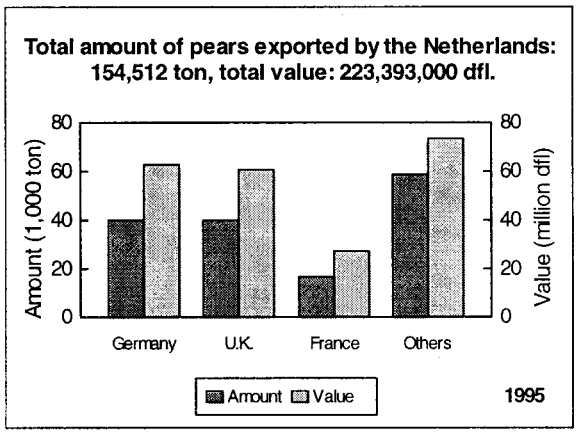
The figures below present import and export numbers of the three most important pear importers and exporters in the EU. As you can see in the figure below Belgium is the major exporter of pears and Germany is the major importer in Europe. The value of the imported and exported volumes is presented as well.

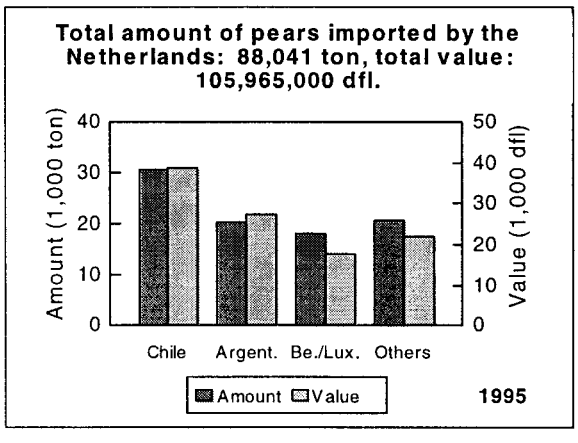




Export and import numbers of the most important European countries.

In the figures below numbers of the Netherlands are presented. Unlike the figures above, the numbers consider non EU members as well. During the season the Dutch pear experiences competition by pears from Belgium/Luxembourg and France. From April to July the Dutch supply is replenished by pears from Chile and Argentina.





Pear-export and import numbers of the Netherlands.

4.1.3 Distribution chain in the Netherlands

Pears can be stored for several months in mechanically cooled cells or CA cells. After storage the pears are being transported by truck to a wholesale trade (wholesaler) or directly to the distribution centre of a retail chain. Storage at the wholesaler and at the DC is relatively short (one day) and is cooled at 4 °C. Finally the pears are being delivered by cooled trucks at the retailer together with other fruits and vegetables. Pears are displayed non cooled at the retailer (generally at 18 °C.).

Pears from Chile and Argentina are being imported by ship. The duration of this transport is about twenty days. Storage on board is conditioned. The pears are packed in boxes and stored on pallets that are stacked into the hold of the ship. Dunnage or inflatable bags may

be placed between the pallets to improve air circulation and temperature control. All holds have their own temperature and relative humidity control. Transport of pears may also take place in 'reefers'. Reefers are insulated containers which have their own individual refrigeration units.

4.1.4 Current packaging material and possibilities for MA packaging

Pears are presented at the retailer in three ways:

- unpacked, in one way or re-usable crates;
- packed in PE bags filled with approximately one kilo of pears;
- on a Polystyrene tray covered with a PVC film or sometimes a PVDC film.

The foamed PS tray protects the pears from mechanical damage (e.g. bruises) and serves the consumer well on the aspect of ease. The pears are not presented in the cooled area of the fruit and vegetables department of a store. The packed pears can be preserved cooled for another five to ten days and non cooled for a maximum of four days.

MA packaging for pears can be interesting for small (one or two persons) families who visit the supermarket only a few times a week. Pears can be packed with six per package to suit the wishes of these families. The amount packed is small in order to guarantee a bigger variety and the quality decay of the product is delayed by the modified atmosphere package.

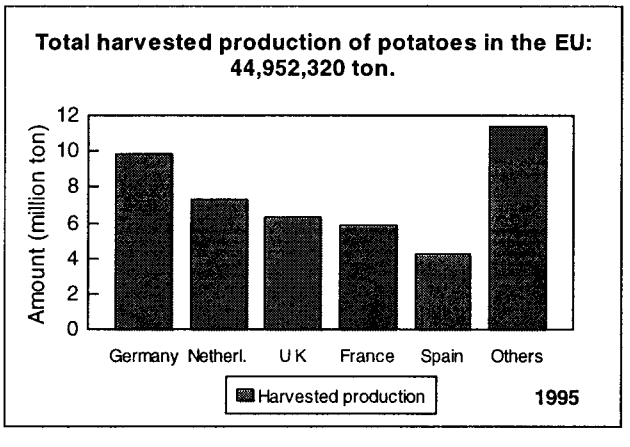
4.2 Potato

Potatoes are, unlike the other products mentioned in this report, an agricultural product. The scale of agriculture is very big compared to horticulture. The production of potatoes is divided in two major groups; consumption potatoes and seed potatoes. The Netherlands are a major producer of seed potatoes in Europe. Potatoes are grown in temperate zones. Extensive production and consumption areas are situated in Europe and the former Russian Federation. Another extensive area is the USA.

Potatoes can be eaten cooked, baked and fried. Concerning the MA package, especially the CO_2 concentration is very important. If the CO_2 concentration is too high, the potato can get *blackheart*, i.e. the potato turns dark inside. Thus, special attention has to be paid on the packaging of potatoes.

4.2.1 Production, import and export numbers

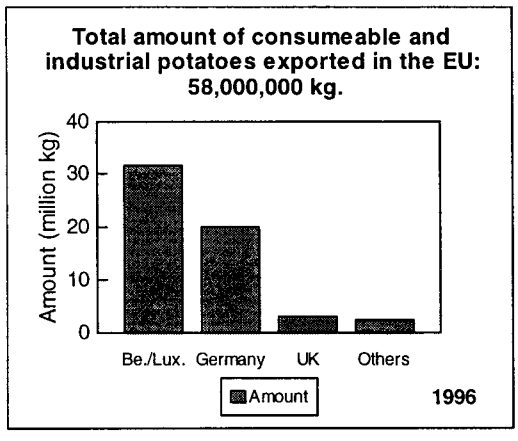
In the figure below we present the production volumes of potatoes in the European Union. As you can see Germany is the biggest producer followed by the Netherlands. In 1995 Japan produced 3,800 ton of potatoes, while the USA produced 19,024 ton. Another important producer of potatoes in Europe is Poland producing about twice the amount of Germany. Unfortunately, information on import and export of potatoes by the EU members is not available.



Production volumes of potatoes by the most important potato producing countries.

The figure below presents the export of potatoes performed by the Netherlands. Unfortunately, as far as we know, no information is available on the value of exported potatoes. Most potatoes are grown in the west and north of the Netherlands. The area where potatoes are grown is slowly becoming smaller. Due to the increasing popularity of pastas and rice the consumption of potatoes, and also the production, decreases. In general, the import and export volumes of potatoes are not very big compared to the production volume since the greater part of the potatoes is consumed in the country of origin itself. For example, the Netherlands produced 7,340,430 ton potatoes and imported only 292,000 ton

(including 50,500 ton starch potatoes) in 1995. Detailed numbers about the import of potatoes by the Netherlands are not available.



Volumes of potatoes exported by the Netherlands.

4.2.2 Distribution chain in the Netherlands

Potatoes are stored at 2-3°C in mechanically cooled stores between four and nine months. Potatoes are being transported in 1.000 dm^3 boxes. Due to the long tenability and the relative low value of potatoes, long distances are covered by ship. Short distances are covered by truck. Depending on the destination in Europe transport by boat takes about three days. During transport the potatoes are not cooled. After packing at the wholesaler the potatoes are distributed to the distribution centre of the retail chain. Potatoes are stored here at 4 °C for a relative short time (one day). Subsequently, potatoes are transported in a cooled truck, together with other fruits and vegetables, to the retailer. At the retailer potatoes are displayed in a non cooled area (18°C.).

4.2.3 Current packaging material and possibilities for MA packaging

The present retail package for potatoes in the supermarket has a weight between two and five kilos. A perforated LDPE bag is used as a package. The perforations in the bag have a diameter of about ten millimetre. These perforations are necessary, since otherwise the moisture production of the potatoes will cause a high humidity inside the package and subsequently the potatoes start rotting. A disadvantage of the perforations is that clay particles leave the package through the holes, causing dirt in the supermarket. Therefore retailers prefer closed bags.

Although in general profit margins of potatoes are rather small, we see also trends to better packaging. The first trend is towards smaller quantities packed. Instead of large volumes, six to ten potatoes are packed in small retail packages. In this way the traders of potatoes hope to increase the added value of potatoes and create a more competitive position with respect to pastas and rice. Due to this trend the percentage of the costs, caused by the package, may increase to 30% of the total costs. The second trend is towards peeled potatoes and pre-cooked potatoes. Quantities of 500 gram are packed in an evacuated or gas-packed

film. The products are presented at the cooling unit of the fruits and vegetables-unit. These products cost about ten times the price of plain potatoes.

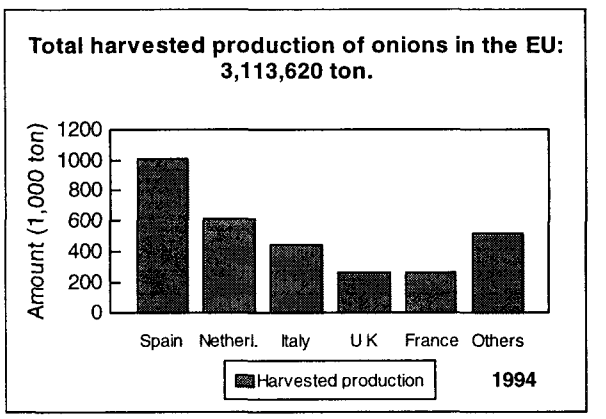
MA packaging supports the above mentioned trends towards smaller packaging units. Small quantities of potatoes can be packed in an MA bag, which may be supported by a carton box.

4.3 Onion

The onion we consume originally comes from Central Asia. Via Egypt, Greece and the Roman Empire the onion was introduced in Europe. During the past years the consumption of onions has been quite constant. Onions are eaten both raw and cooked or baked. Concerning the gas composition inside the package in case of MA packaging, once again the CO_2 concentration is of major importance, since onions become glassy when exposed to a too high level of CO_2.

4.3.1 Production volume

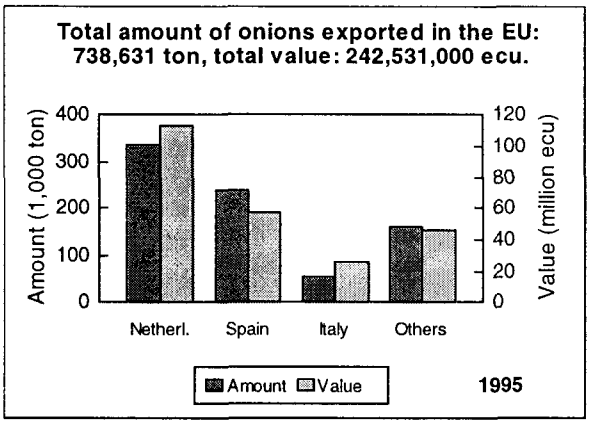
The figure below presents the production of onions for the most important European countries. Besides these numbers it has to be mentioned that the USA produces the biggest amount of onions in the world, namely 2,400,000 ton and that Japan is the second biggest producer with 1,350, 000 ton (source: FAO). Unlike the rest of the numbers, the numbers presented below concern 1994.

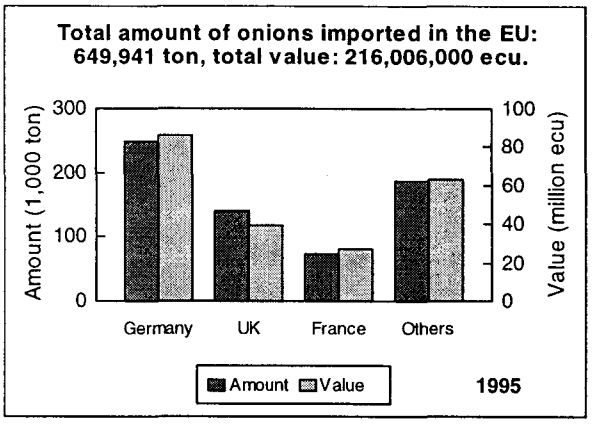


Total harvested production of onions in the European Union.

4.3.2 Export and import numbers

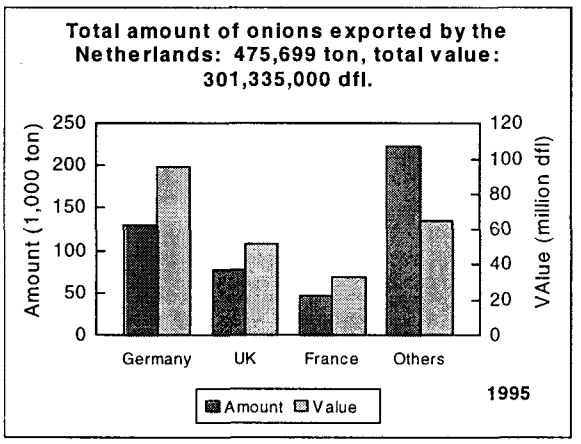
In the figures below we present the export and import numbers of the members of the EU. It is clearly shown that the Netherlands export a considerable amount of their production. Germany is the major importer of onions in the EU. Finally, it has to be mentioned that the former Russian Federation imports large amounts of onions of a relative low value. This is not displayed in the figure.

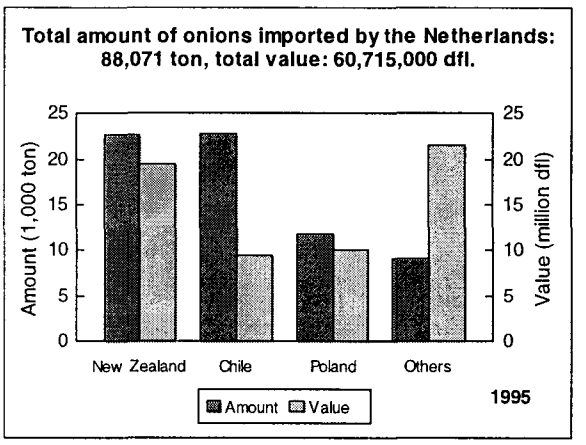




Numbers of onions exported and imported by EU members.

Detailed import and export numbers of the Netherlands are presented in the figure below. Export of onions is of vital interest for the Dutch onion cultivation. The Netherlands are the biggest exporter of onions in the world. For the Netherlands the most important export countries in Europe are Germany, UK, France and Belgium. In Africa, Dutch onions are exported to Senegal and Ivory Coast. Onions imported by the Netherlands merely come from New Zealand and Chile.





Numbers of onions exported and imported by the Netherlands.

4.3.3 Distribution chain in the Netherlands

Onions can be stored, at low temperatures, for about two to ten months. The onions are dried first. The onions are packed in reusable plastic crates by the grower and transported to the auction or directly to specialised onion industries. About 20 kilos of onions fit in one crate. Transport from overseas, for example from New Zealand to the Netherlands, is usually not cooled but only ventilated to keep the onions dry. This transport takes about three weeks. The onions are packed in nets of about 25 kilos. Subsequently one thousand kilos of packed onions are placed on one pallet. In Europe onions are being transported by truck. At the retailer the onions are presented in the non cooled part of the fruits and vegetables department. The onions can be stored at home for another one to two months.

4.3.4 Current packaging material and possible MA advantage

In general twenty kilos of onions is offered at the auction. Specialised onion industries pack the onions in PE nets of one or one and a half kilo. The usage of nets prevents moisturising of the onions. Similar to potatoes onions are very sensitive to water vapour. Onions give much dirt at the retailer and at the consumer. The dried parts crack and drop on the floor in small parts. Due to this problem supermarkets prefer to sell onions packed in closed bags, which offers great opportunities for MA packaging.

More and more cut onions are presented in the refrigerated part of the fruits and vegetables-unit. 250 Gram of onion cuttings are put in a plastic tray and covered with a stretchfilm. The price of this convenience package is about four times higher compared to the raw product.

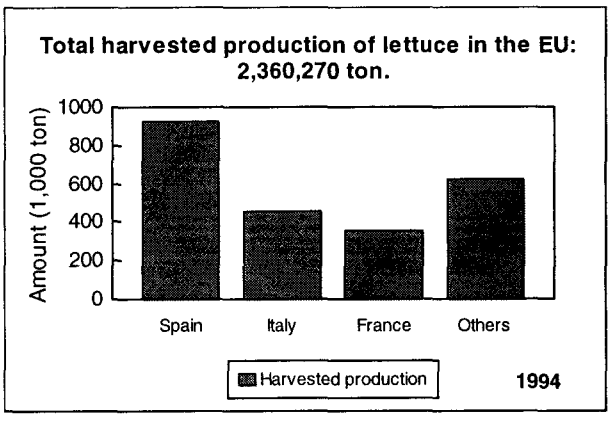
From ATO-DLO research it appears that dry onions can be well packed under MA conditions. By combining a low oxygen concentration with a not too high carbon dioxide concentration the sprout growth is slowed down. Care has to be taken of storage conditions. Onions will rot when exposed to a high concentration of water vapour.

4.4 Lettuce

Lettuce is grown as a vegetable. It is most of the time eaten raw in a salad but the leaves are sometimes eaten stewed. When lettuce is exposed to too high levels of oxygen the outer parts of the leaves turn brown. This physiological disorder is called *brown stain*. Thus, CO_2 permeability of a package for lettuce should be high.

4.4.1 Production volumes

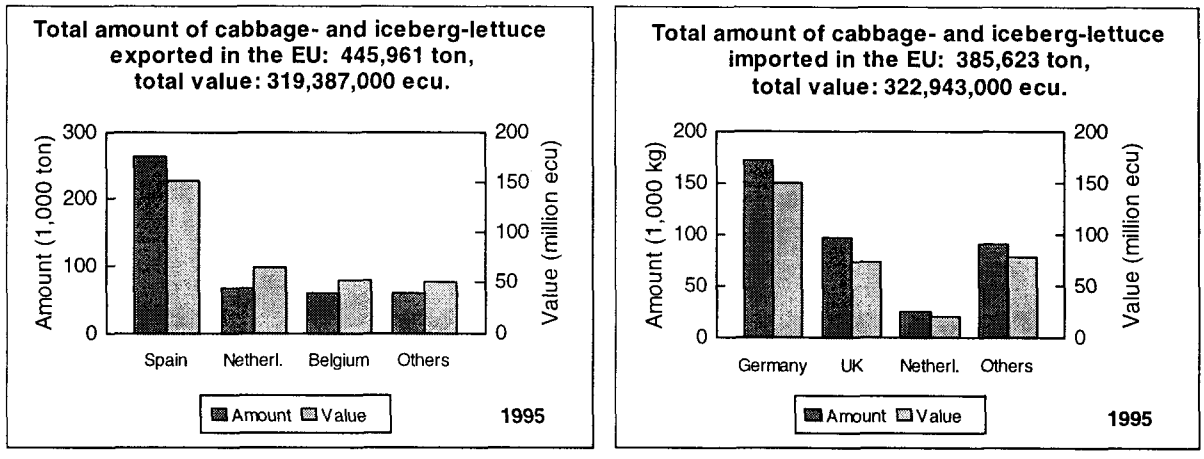
The figure below presents the production volumes of the most important lettuce producing countries in the European Union. As you can see, Spain is the biggest producer of lettuce. Similar to the production numbers of onions, the production numbers of lettuce concern 1994.



Production of lettuce in the EU.

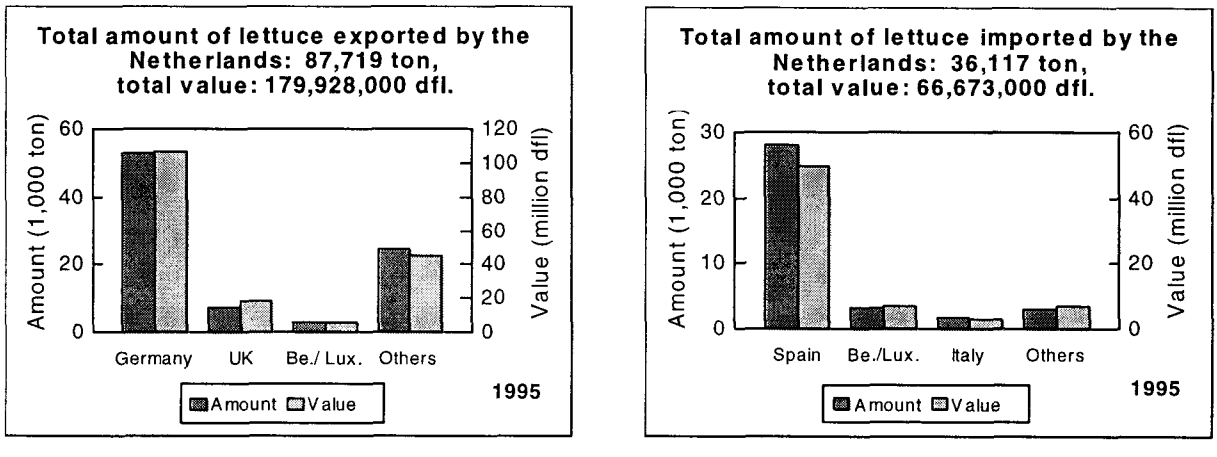
4.4.2 Import and export numbers

Two kinds of lettuce are popular in Europe, cabbage-lettuce and iceberg-lettuce. Cabbage-lettuce has a loose structure, while iceberg-lettuce is a firm ball of crackling leaves. Lettuce is available year-round in the Netherlands. During the season lettuce is grown outside on the field. From October until May lettuce is grown under glass or sometimes it is imported. The figures above present export and import numbers of cabbage-lettuce and iceberg-lettuce in the European Union. Spain, being the major producer of lettuce in the European Union, of course exports the biggest amount of cabbage-lettuce and iceberg-lettuce in the EU. The Netherlands is the second biggest producer and delivers a relative high quality compared to Spain.



Export and import numbers in the EU.

The two figures below present detailed numbers about the Dutch export and import of lettuce. The Netherlands import their lettuce mainly from Spain. The price of this lettuce is relatively low, because of the quality and the fact that almost all lettuce is offered in a relative short time span. The Netherlands mainly export their lettuce to Germany.



Import and export numbers of lettuce in the Netherlands.

4.4.3 Distribution chain in the Netherlands

Lettuce cannot be preserved for a longer period. It is directly transported by a truck. Lettuce from Spain can be transported within two days to the Netherlands. In general, lettuce is presented in the supermarket in a non cooled area. At home packed cabbage-lettuce can be stored cooled for a maximum of one week. Iceberg-lettuce can be stored a little longer.

4.4.4 Current packaging material and possible MA advantages

Cabbage-lettuce is packed in an open LDPE bag directly after harvesting. Packaging is performed by the grower. Lettuce grown on the full ground is not packed. Cabbage is presented non cooled at the retailer. Iceberg-lettuce is packed directly after harvesting. The

lettuce is wrapped in a PE or PVC bag or put into a perforated PE bag. At the retailer the packed product is presented in the cooling unit.

Recently more and more cut iceberg lettuce and lettuce-mixes are being sold. At the moment cuttings are gaspacked in quantities of 250 gram. A high barrier film is used and a mix of nitrogen and carbon dioxide is added. At the inside of the package moisture can often be seen on the film. The price per kilo of these products can be up to ten times the price of plain lettuce.

Since the convenient food market in Europe is growing fast, cut lettuce is commercially very interesting for MA packaging. Needed is an appropriate film that fits the respiration of cut lettuce.

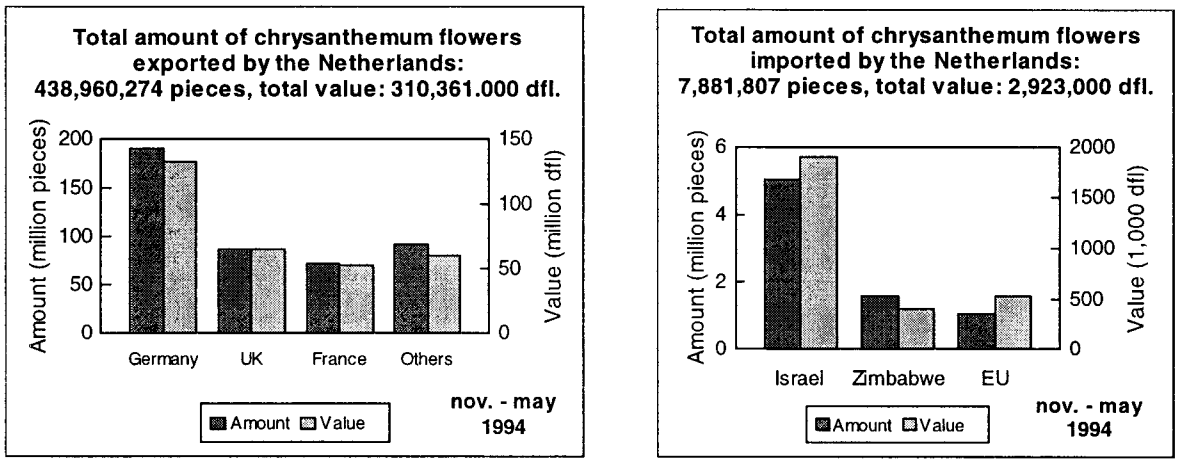
4.5 Chrysanthemum cutting

Chrysanthemum cuttings are cultivated in the Netherlands at specialised cutting industries. Cuttings are twigs that have been cut off from the parent plant. Cutting industries have branches in countries like Costa Rica, South-Africa and Brasilia. Cutting industries provide their cuttings to growers who grow flowers from them. Approximately every cutting is cultivated into one flower.

Chrysanthemum cuttings are sensitive to CO_2. Too high concentrations of the gas makes the plant material turn slushy. Therefore attention has to be paid to the development of an appropriate MA package for chrysanthemum cuttings.

4.5.1 Production, import and export numbers

In the figure below we present numbers of cut chrysanthemum flowers imported and exported by the Netherlands.



Import and export numbers of chrysanthemum flowers in the Netherlands.

It is very hard to find detailed numbers on chrysanthemum cuttings. Therefore detailed numbers of production, export and import concerning chrysanthemum cuttings can not be presented in this report. Because approximately every cutting becomes a flower, numbers of imported and exported chrysanthemum flowers may be a good indicator for the amount of chrysanthemum cuttings produced, imported and/or exported by the Netherlands. It has to be noticed that, unlike all other numbers the figure above concerns a half a year only. With a yield of *f* 543,045,000 chrysanthemum is one of the most sold flowers in the Netherlands. The figure at the left shows that quite an amount of the Dutch chrysanthemum flowers is exported. An estimate of cuttings produced in the Netherlands is 1,4 milliard pieces with a selling price of approximately 4 cents per piece.

4.5.2 Distribution chain in the Netherlands

Chrysanthemum cuttings are stored in mechanically cooled cells. In Europe cuttings are transported in cooled trucks. Cuttings from Costa Rica, South Africa and Brazil are transported by plane. Transport to the airport is in a cooled truck or a non cooled truck. The cuttings are stored up to several hours at the airport without cooling facilities. Due to high temperatures and temperature fluctuations in this distribution chain, about 10% of these cuttings is rejected.

4.5.3 Current packaging material and possible MA advantage

In the Netherlands fifty chrysanthemum cuttings are packed in a small plastic bag. The only function of the plastic bag is to keep the cuttings together. In general, the storage time is not enhanced by the bag. Forty plastic bags are put together in a plastic crate. The crates are used as transport packages. The cuttings from overseas are transported in corrugated paperboard boxes.

Research at ATO-DLO shows that an MA package has advantages for the chrysanthemum cutting quality. Also quality of cuttings from overseas areas can be improved. In these chains where temperature isn't regulated, MA shows in general very big advantages.

5. Other products

Not only the five products mentioned in this report can benefit of the packaging material to be developed. Several other products have similar respiring characteristics and may benefit from the new packaging material as well. In the table below, a list is given of the most sold products to the Dutch households in 1994. We recall that we restrict ourselves to films with the following properties: the ratio of O_2-permeability and CO_2-permeability lies between 1:10 and 1:20 and the O_2-permeability lies between 5,000 and 15,000 cm^3 /(day atm. m^2). As you can see, the new MA film, we discuss in this study is suitable for many products.

Top 20 (1994)	Amount purchased (kg)	Price per kilo (dfl)	Suitable for Kureha film
Apple	31.4	1.85	–
Orange	28.8	1.91	+
Banana	13.7	2.90	–
Mandarin	9.1	2.78	–
Cauliflower	8.7	7.03	–
Pear	7.1	1.88	+
Onion	7.0	3.37	+
Cucumber	6.8	6.97	+
Carrot	6.6	2.05	–
Tomato	6.2	2.57	+
Chicory	5.8	2.88	–
Lettuce	4.7	3.47	+
Mixed vegetables	3.9	2.06	depends on the mixture
Melon	3.8	2.78	–
Leek	3.7	6.14	–
Grape	3.7	3.17	+
Endive	3.4	3.77	–
Grapefruit	3.3	2.37	–
Kiwi	2.6	3.59	+
Strawberries	2.5	6.33	–

Top 20 of fruits and vegetables purchased by Dutch households in 1994.

Besides the products presented above, several other products can benefit from the film to be developed by Kureha. A list of these products is presented below (included are fruits and vegetables with a high profit margin).

Cranberry	Olive
Chilli pepper	Peach
Egg plant	Plum/prune
Nashi pear	Sweet potato
Nectarine	

List of products with more or less similar respiring characteristics.

6. Possible extension to transport packaging

Until now we mainly considered retail packages. Retail packages are designed to optimally serve the consumer, the end user in the distribution chain. To deliver the retail package at the retailer, in most cases a transport package is needed to protect the retail package and the product against mechanical damage and to realise trading units. Thus, a transport package contains in general much more product than a retail package. Therefore transport packages are usually firm plastic crates or board boxes.

MA shows some interesting advantages in transport packaging as well. While the packages are applied directly after harvesting, a modified atmosphere will be established early in the distribution chain. As illustrated in chapter 2, quality decay in normal packages is higher than in MA packages when exposed to non optimal temperatures. Thus, especially not well conditioned distribution chains are interesting for MA transport packages. These chains are merely found in the eastern part of Europe and in some intercontinental transport. An MA transport package can considerably slow down the quality decay of fruits and vegetables and thus increase the value of these products.

Onions and potatoes seem to be interesting products to pack in an MA transport package. When the MA transport package is used during storage in the cooling cells the product quality may be enhanced. The products have a very long storage time and may therefore profit the most of a modified atmosphere package. Actually, by using an MA transport package in cooling facilities a cheaper and more flexible way of CA storage is developed. The transport package may be designed as a bag in box system or for example, the MA film may be put around the box as a cover.

We have to emphasise that a reliable MA transport package is not obtained by simply enlarging a retail package. The optimal MA transport package is only obtained when the combination of the packed product and the specific package is considered. Because of the nature of each product it has to be examined individually in combination with the MA package. The amount of product, the temperature profile in the distribution chain and finally the storage time all influence the behaviour of the MA package and thus the optimal package design.

7. General remarks and continuation of the research

MA packaging has a general advantage on the storage of fruits and vegetables. Delay of quality decay depends on the specific activity of the product, the characteristics of the used films the package design and the circumstances in the distribution chain. Especially a film with an O_2-permeability of at least 5,000 $cm^3/(day\ atm.\ m^2)$ and an O_2 to CO_2 permeability of the order 1:15 is commercially very interesting. These products form a first selection of products that may benefit from MA packaging and are all representatives of a larger group.of products. All of these products show some commercially interesting aspects and especially cut lettuce is interesting to pack in an MA retail package since convenient food is a fast growing market.

Again it must be emphasised that because of the different nature of each product further research has to be done on the interaction between product, MA film and package design. For example in case of cut lettuce, special attention has to be paid on the cutting of the lettuce as well. Cutting damages the surface of the product and subsequently introduces another factor in quality decay. Badly designed packages may lead to anaerobic respiration causing off-flavours and odours. furthermore, an optimal package concept has to be developed taking into account the distribution chain and all kind of marketing aspects

A meeting between Kureha Chemical Industry and ATO-DLO should be arranged to discuss the results and a possible continuation of the cooperation. If Kureha Chemical Industry has successfully developed the new films or believes that the new films will be developed in the near future, we think it is very interesting to start the general framework project as described in the project proposal 'developing new films for MA packaging' (number OPD 96/032). Roughly speaking the general framework more or less consists of the following studies:

- studying the packaging material;
- choosing one or more products to focus the research on;
- choosing a test market and determining in detail the circumstances within the specific distribution chain;
- quantifying the film in a realistic MA experiment.

ATO-DLO can develop a package concept that will be the optimal compromise between the demands set by the product, the distribution chain and the market. Naturally, ATO-DLO can also support and advise you in developing and successfully marketing the new film for packaging fruits, vegetables and special plant materials.

8. Appendix

In this appendix tables are presented that contain more numbers about the products evaluated in chapter four. The tables contain exact numbers and per table the used source is mentioned.

Table of contents

A.1 Pears European Union

Pears EU	Harvested production 1995 (ton)
Italy	986,800
Spain	469,000
Germany	422,934
France	335,154
Netherlands	181,000
Belgium	156,335
Austria	123,679
Portugal	87,000
Greece	60,000
UK	37,600
Luxembourg	950
Total	2,860,452

Source: Eurostat

Pears EU	Export 1995 (ton)	Value (1,000 ecu)
Belgium	136,600	86,275
Netherlands	126,031	90,431
Italy	120,538	90,295
France	72,332	35,885
Spain	60,173	37,876
Portugal	6,072	4,084
Germany	5,299	3,486
UK	3,431	1,591
Austria	2,270	308
Sweden	125	74
Denmark	107	46
Greece	30	34
Ireland	24	19
Total	533,032	350,404

Source: Eurostat

Pears EU	Import 1995 (ton)	Value (1,000 ecu)
Germany	152,701	111,095
France	72,817	56,227
UK	71,335	54,520
Italy	42,006	25,598
Netherlands	31,803	15,378
Austria	17,309	12,971
Sweden	15,899	8,561
Belgium	15,139	7,982
Spain	14,415	9,296
Denmark	8,746	5,784
Ireland	7,711	5,109
Finland	5,214	4,116
Greece	4,974	3,727
Portugal	2,538	1,790
Total	462,607	322,154

Source: Eurostat

A.2 Pears Netherlands

Pears Netherlands	export 1995 (ton)	value (1,000 dfl)
Germany	39,756.00	62,338.00
UK	39,641.00	60,671.00
France	16,828.00	27,113.00
Russia	16,360.00	18,245.00
Denmark	6,796.00	10,429.00
Spain	6,516.00	8,842.00
Sweden	7,789.00	8,127.00
Be./Lux.	5,678.00	7,384.00
Norway	2,831.00	4,046.00
Italy	1,604.00	2,463.00
Other	10,713.00	13,735.00
Total	154,512.00	223,393.00

Source: CBS

Pears Netherlands	import 1995 (ton)	value (1,000 dfl)
Chile	30,515.00	38,761.00
Argentina	20,515.00	27,257.00
Be./Lux.	18,335.00	17,820.00
France	8,945.00	8,687.00
USA	3,050.00	5,051.00
Spain	3,032.00	3,288.00
Germany	1,157.00	1,499.00
Italy	665.00	1,189.00
Other	1,827.00	2,413.00
Total	88,041.00	105,965.00

Source: CBS

B.1 Potatoes European Union/Netherlands

Potatoes EU	Harvested production 1995 (ton)
Germany	9,898,280
Netherlands	7,340.430
UK	6,297,000
France	5,839,000
Spain	4,193,900
Belgium	2,117,000
Italy	2,107660
Portugal	1451,000
Denmark	1,441,000
Sweden	1,073,800
Greece	1,006,000
Finland	798,000
Austria	724,400
Ireland	642,000
Luxembourg	22,860
Total	44,952,320

Source: Eurostat

Potatoes Netherlands	Export consumption & industrial potatoes 1996 (ton)
Be.\Lux.	31,500
Germany	20,000
Denmark	500
France	1,000
Italy	500
Spain	500
UK	3,000
Sweden	1,000
Total EU	58,000.00

Source: Bedrijfschap voor de groothandel en de tussenpersonen in aardappelen

Unfortunately no detailed information is available on the export and import of potatoes by the Netherlands (especially values are not available).

C.1 Onions European Union

Onions EU	Harvested production 1994 (ton)
Spain	1,008,600
Netherlands	611,020
Italy	445,240
UK	268,600
France	264,010
Germany	216,950
Greece	185,010
Austria	61,520
Sweden	24,000
Finland	14,730
Belgium	13,870
Luxembourg	80
Total	3,113,620

Source: Eurostat

Onions EU	Export 1995 (ton)	Value (1,000 ecu)
Netherlands	336,198	113,606
Spain	237,812	57,098
Italy	55,531	25,900
Belgium	45,235	20,126
France	31,039	12,798
Austria	13,288	5,558
Germany	12,202	4,170
UK	4,761	1,886
Denmark	1,558	594
Sweden	439	343
Ireland	384	279
Portugal	99	147
Greece	80	25
Finland	5	1
Total	738,631	242,531

Source: Eurostat

Onions EU	Import 1995 (ton)	Value (1,000 ecu)
Germany	248,165	85,961
UK	139,133	39,464
France	75,377	27,401
Belgium	74,663	20,280
Spain	19,915	8,718
Netherlands	17,533	5,674
Ireland	16,517	6,001
Sweden	14,374	5,245
Portugal	11,450	4,192
Austria	9,222	4,264
Italy	8,532	3,001
Denmark	8,390	3,086
Finland	3,893	1,434
Greece	2,777	1,285
Total	649,941	216,006

Source: Eurostat

C.2 Onions Netherlands

Onions Netherlands	Export 1995 (ton)	Value (1,000dfl)
Germany	129,937	95,685
UK	77,513	51,863
France	45,948	33,029
Be./Lux.	34,938	21,823
Spain	14,155	12,789
Sweden	10,385	7,061
Russia	12,433	6,677
Czech. Rep.	12,004	6,132
Senegal	12,621	5,302
Poland	23,977	5,149
Other	101,788	55,825
Total	475,699	301,335

Source: CBS

Onions Netherlands	Import 1995 (ton)	Value (1,000 dfl)
New Zealand	22,644	19,548
Chile	11,846	10,077
Poland	22,774	9,474
Spain	6,887	4,030
Argentina	5,635	3,793
Australia	3,603	3,053
Germany	3,593	2,732
Italy	2,136	2,126
Be./Lux.	2,070	1,551
France	2,525	1,223
Other	4,358	3,108
Total	88,071	60,715

Source: CBS

D.1 Lettuce European Union

Lettuce EU	Harvested production 1994 (1,000 ton)
Spain	924.26
Italy	456.15
France	356.00
UK	212.80
Germany	124.30
Belgium	84.67
Netherlands	84.27
Greece	75.90
Austria	28.07
Sweden	10.07
Finland	3.48
Luxembourg	0.30
Total	2,360.27

Source: Eurostat

Cabbage- and Iceberg-lettuce EU	Export 1995 (ton)	Value (1,000 ecu)
Spain	261,979	151,504
Netherlands	67,468	64,420
Belgium	58,312	52,862
France	32,308	32,351
Italy	20,255	13,757
UK	3,292	2,329
Germany	987	653
Austria	474	260
Portugal	377	355
Ireland	195	463
Denmark	143	271
Sweden	102	111
Greece	55	40
Finland	14	11
Total	445,961	319,387

Source: Eurostat

Cabbage- and Iceberg-lettuce EU	Import 1995 (ton)	Value (1,000 ecu)
Germany	171,989	149,608
UK	97,477	73,004
Netherlands	24,992	21,502
Sweden	24,842	19,799
France	19,055	12,931
Austria	16,819	20,547
Denmark	7,569	6,740
Italy	5,872	4,251
Finland	5,456	5,532
Ireland	3,270	3,687
Spain	3,143	2,206
Belgium	2,575	2,622
Greece	2,357	322
Portugal	207	192
Total	385,623	322,943

Source: Eurostat

D.2 Lettuce Netherlands

Lettuce Netherlands	export 1995 (ton)	value (1,000 dfl)
Germany	52,880	106,933
UK	7,337	17,945
Be./ Lux.	2,685	5,572
Sweden	5,633	10,446
Spain	4,652	6,529
Denmark	3,639	6,801
Austria	1,995	5,128
Italy	1,630	3,019
Finland	1,393	3,151
France	1,141	1,986
Other	4,734	12,418
Total	87,719	179,928

Source: CBS

Lettuce Netherlands	import 1995 (ton)	value (1,000 dfl)
Spain	27,979	49,685
Be./Lux.	3,334	7,076
Italy	1,846	3,165
France	1,480	4,025
Germany	540	910
UK	431	550
Turkey	266	844
Other	241	418
Total	36,117	66,673

Source: CBS

E.1 Chrysanthemum flowers Netherlands

chrysanthemum cut, fresh Netherlands	export 1/11-31/5 1994 (pieces)	value (1,000 dfl)
EU.	414.847.931	293.932
Germany	189.973.183	132.614
UK	86.410.060	64.537
France	71.617.379	52.38
Italy	24.412.820	13.522
Be./Lux.	11.690.214	7.945
Spain	8.821.796	4.557
Denmark	7.604.270	4.304
Ireland	7.092.264	8.823
Greece	5.240.657	3.952
Total	438.960.274	310.361

Source: CBS

chrysanthemum, cut, fresh Netherlands	import 1/11-31/5 1994 (pieces)	value (1,000 dfl)
Israel	5,039,960	1,903
Zimbabwe	1,591,652	402
EU.	1,041,490	526
Germany	914,180	462
Total	7,881,807	2,923

Source: CBS

Unfortunately detailed information about chrysanthemum cuttings is not available. The numbers displayed concern the total of cut chrysanthemum flowers during only a half of a year.