PACKAGING TECHNOLOGY AND SCIENCE
Packag. Technol. Sci. (in press)
Published online in Wiley InterScience (www.interscience.wiley.com). **DOI**: 10.1002/pts.776

Modified Atmosphere Packaging of Fresh Meats – Sudden Partial Adaptation Caused an Increase in Sustainability of Dutch Supply Chains of Fresh Meats

By Dr. E. U. Thoden van Velzen[1] and Dr. A.R. Linnemann[2]*

[1] Wageningen UR Agrotechnology & Food Sciences Group, PO Box 17, 6700 AA Wageningen, The Netherlands
[2] Wageningen UR Product Design and Quality Management Group, PO Box 8129, 6700 EV Wageningen, The Netherlands

In the past decade, a major transition evolved in the Dutch fresh meat industry with ramifications for the entire meat business. In 1995, more than 95% of all fresh meat products for consumers were either sold loose or packed in the traditional way, i.e. on a white styrofoam tray with stretch wrap. Almost a decade later, about half of the meat industry has adapted the modified atmosphere packaging (MAP) technology. Strikingly, the first trials with this technology had already been conducted in The Netherlands in 1964, but it took four decades for the technology to conquer the Dutch meat industry. This paper argued that the partial adaptation of MAP diminished the product losses in fresh meat sales and hence the environmental impact of meat production and consumption. Copyright © 2007 John Wiley & Sons, Ltd.

Received 21 September 2006; Revised 5 March 2007; Accepted 5 March 2007

KEY WORDS: fresh meats; modified atmosphere packaging; case-ready packaging; high oxygen packaging; implementation; environmental impact

INTRODUCTION

The packaging methods for fresh meats have changed greatly in the last decade in The Netherlands. In 1995, more than 95% of all fresh meat products for consumers were sold either without packaging or packed in the traditional way, i.e. on a white styrofoam tray with polyvinyl chloride (PVC) stretch wrap. Nowadays, about half of the consumer packed fresh meat products are packed in modified atmospheres. This involves packing fresh beef, pork and veal in atmospheres that are enriched in oxygen and carbon dioxide (typical: 60–70% oxygen, 25–35% carbon dioxide and nitrogen as ballast) in top-sealed trays with barrier trays and top lids. Some entrepreneurs use the same gas mixture for poultry meats; others use mixtures with less oxygen. Various packaging styles are being used, ranging from transparent thermoformed amorphous polyethylene terephthalate (APET) trays with APET or APET–polyamide lids to coloured barrier foam trays [usually expanded

*Correspondence to: Dr. E. U. Thoden van Velzen, Wageningen UR Agrotechnology & Food Sciences Group, Bornsesteeg 59, Wageningen, 6708 PD, The Netherlands.
E-mail: ulphard.thodenvanvelzen@wur.nl

polystyrene–polyethylene (PE)–polyethylene-*co*-vinyl alcohol (EVOH)] with transparent PE–EVOH–PE top films. Strikingly, the modified atmosphere packaging (MAP) technology for fresh meat has already been developed in the 1960s. Hence, it has taken four decades for the MAP technology to conquer the Dutch meat industry. This paper reflects on this major change and discusses the effects it has on meat processing and retail with respect to business costs, product losses[i] and environmental impact.

THE TRADITIONAL WAY OF PACKING FRESH MEAT IN SUPERMARKETS

When supermarkets expanded in The Netherlands in the 1960s, they initially adopted a very traditional manner of dealing with fresh meat products. They invited a butcher inside their store, who had his own chilled display cabinet, cooler and cutting devices. Meat companies (often just slaughterhouses in those days) directly supplied the in-store butcher with carcasses and wholesale cuts. The butcher portioned the parts to consumer-ready meat products on the site and wrapped them in plastic sheets or paper bags.

This method was labour intensive and resulted in queues in front of the meat department during peak hours. To resolve this, pre-packed meat products were introduced in the 1970s. The butcher still ordered his carcasses at the meat company, but would pre-pack meat products during the slow hours to have a buffer during peak hours. New chilled display cabinets for meat products were introduced, and the consumer could pick the products of his choice without direct interaction with the butcher. A new standard in meat packaging emerged; white styrofoam trays with PVC stretch wrap. The transparent stretch wrap allowed the meat product to sell itself based on its visual qualities. The trays were (and are) relatively cheap and gave the product a clean, hygienic and modern appearance. Moreover, the PVC stretch film was easily wrapped around the product and offered a better protection against contaminants like sand, dust and dirt than open bags and sheets did previously. Additionally, the flexible nature of the stretch wrap assured that even large and bulky meat products could be easily packed and remained visible.[1]

During the 1980s and 1990s, the market share of pre-packed fresh meats grew steadily,[2] and supermarket butchers gradually vanished from sight. In some supermarkets, a small butcher counter remained besides the much larger display cabinets for pre-packed meats. In other chains, the butcher remained barely visible on site and had no customer contact any more. And in other supermarket chains, the butcher disappeared completely. In the latter chains, all meats were pre-packed at a centralized meat processing plant and were distributed fresh every business day to all outlets. The last (centralized meat pre-packing) operations steadily became dominant. Although this resulted in major cost savings for retailers, it also intensified existing problems and created a new problem. A new issue that had to be dealt with was order policy, which was tightly related to the existing problems of preventing product losses and out-of-stocks. The shelf life of fresh meat products in normal air is short, and the centralized pre-packing system shortened the effective display time in the shops, and hence made the efforts to prevent product losses and out-of-stocks more important. The tools that retailers used initially were order systems based on sales forecasts; the MAP technology was implemented much later.

MEAT QUALITY AND MEAT BUSINESS

Fresh meat is highly perishable. It needs to be chilled (preferably below 4°C) and even then, two quality aspects limit the shelf life to a few days in air: microbial growth and discolouration. Microbial growth is the predominant factor limiting shelf life, and in a limited amount of cases, bone discolourations are the limiting factor. Freshly cut chilled meat is cherry red and this colour fades within a few days to brown – greyish. Freshly cut chilled meats at the point of packaging usually

[i] Product losses are defined as the percentage of fresh meats that does not reach consumers because the expiration date has been exceeded in the supermarket.

DOI: 10.1002/pts

Packaging Technology and Science

have microbial loads of 10^4–10^5 CFU/g[ii] in The Netherlands, and this exceeds 10^7–10^8 CFU/g within 2–4 days.[iii] Dutch consumers in supermarkets predominantly judge the visual qualities of pre-packed meat products, price and shelf life. The fleshy parts should have a bright red colour and a low visible fat content.[iv] Meat products that show discolourations (brown, grey, green, etc.) or possess a putrefying odour will obviously not be bought. The relevant Dutch law (Warenwet) does not specify quantified acceptation limits for fresh meat; it just mentions that fresh meat should be inspected by an official meat inspector who should declare that such meat does not appear or smell decayed. This legal vagueness causes every meat company to develop its own meat quality parameters and acceptation limits. For instance, the acceptation limit for total aerobic mesophile count varies from 5.10^6, 1.10^7 to even 1.10^8 CFU/g at various meat companies.[v] Hence, whenever new meat products were introduced in the market, shelf life tests were conducted to determine the 'best before date'; for traditionally packed meats, this was usually the packaging date +2, +3 or +4 days. Hence, freshly produced and traditionally packed meat products that were distributed either via a distribution centre or directly to the shops had effective display times of 1–3 days.

Besides the short effective shelf life of traditionally packed meat products (1–3 days), retailers also experienced long response times to standard orders of 1–2 days. Meat managers in supermarkets often determined the stock levels in the shop as one of the first tasks in the morning; they filled in an order form and had it phoned or faxed to the meat company. The meat company would combine these orders in a production plan for the next day, produce and distribute it. Hence, it would normally take about 1.5–2.0 days for ordered meat products to arrive in the shop. Hence, supermarkets that started with centralized pre-packed meats soon discovered themselves to be vulnerable to losses due to product losses and out-of-stocks.

In order to minimize these losses, retailers and meat companies mutually developed sales forecast tools, which used as input: realized sales of the previous years per outlet per day, the weather forecast, holidays, etc. These tools became more reliable with the years, and some actually worked reasonably good, being able to reduce the product losses to less than 5%. However, not all employees of retailers and meat companies had full confidence in these prognosis tools. Some individuals considered it their own responsibility to make the correct orders and did not use them. Others felt that the prognosis tools did not consider all relevant factors and hence felt obliged to modify the prognosis, etc. Therefore, in most supply chains that worked with centralized pre-packed meat products, the product losses remained high (8–12%). In these supply chains, additional ordering was frequent; meat companies had hectic productions, often experienced acceleration effects[vi] and sometimes haphazardly had to operate night shifts.

EARLY ADAPTERS

Already prior to the Second World War, various new distribution technologies for fresh meat were being developed in New Zealand and Australia, all of which relied on low temperatures and carbon dioxide-rich atmospheres. Only after 1960 plastic barrier packaging materials became available that enabled commercial implementation of packaging fresh meats under modified atmospheres for consumers.[3] The first known experiments in The Netherlands were performed in 1964.[vii] The first experiments gave appallingly bad results. Tradi-

[ii] Total aerobic mesophile count in colony forming units per gram.

[iii] These numbers are based on more than 400 measurements performed from 1998 to 2003 at our facility with meats originating from various local suppliers.

[iv] Dutch consumers do not appreciate fresh meats to be marbled in the manner British consumers do.

[v] Many Dutch meat companies would prefer clearer meat quality standards, but at the same time think that it will be technically difficult to achieve one standard for the various types of meat.

[vi] Acceleration effects in supply chains are sudden increases in order quantities followed by a few days with very low order quantities. This effect causes high inventory levels and often results in high levels of product losses. Furthermore, it causes economic damage for the producers, which have to cope with peak demands and subsequent very low demands.

[vii] Personal communication with Mr Geert Pepping, former chief meat purchaser of Makro BV.

DOI: 10.1002/pts

tional butchers tested the packaging machine. In the opinion of these butchers, meat should only be packed when it could not be sold directly. They bought several carcasses on Monday, hung them in a cool cell, cut these down during the week and the parts that were not sold by Friday were vacuum-packed. Hence, this new packaging machine was also used on Fridays with highly contaminated leftovers. So these butchers packed meat products which were near the end of their shelf lives in modified atmospheres and discovered that this technology did not extend the shelf life. This poorly conducted experiment reconfirmed their belief that butchery is an art and that new machines had no added value. The new technology had quite a bad reputation in the next decade.[vii]

Wagemans (predecessor of Promessa BV, Deventer, Netherlands) was the only meat company that remained interested in new meat packaging technologies. It was the preferred supplier of retailer Makro BV, Diemen, Netherlands. Both companies wanted to position themselves in the market as quality meat suppliers. Through trial and error, Promessa mastered the MAP technology in 1975 and started to supply fresh meats in transparent gas barrier packages with 5–8 days of shelf life. One of the technical aspects that required research and development (R&D) work was optimizing several production parameters including gas composition in such a way that the meat was kept bright red, without creating bone marrow discolourations[4] or lipid oxidation off tastes.[5,6] Another aspect that needed research was the minimal product-to-headspace ratio, which was found to be 1:2 v/v. Promessa converted its complete production to MAP. They named this technology 'Atmos'. For two decades, Promessa remained the only meat company in The Netherlands that used the MAP technology. Promessa also created a new business model to take advantage of the longer shelf life, using a buffered production system. This meant that they became able to supply from the buffer and maintain a much more steady production with fewer shifts. A complete analysis of this business model with actual ordering, production and delivery data for over 3 months was made within the Foundation Agricultural Chain Knowledge (AKK) project 'Tomorrow's Meat Demand'.[7] The analysis revealed that the direct additional cost for Promessa were €0.07 per pack due to the use of more and more expensive packaging materials, and that the revenue was €0.10 per pack due to lower indirect costs of product losses in the Promessa–Makro supply chain.

In 1995, Van der Pelt BV and Verba Vlees BV also started a few production lines with MAP technology. They offered meat products packed in modified atmospheres to retailers on demand. This retail demand for modified atmosphere (MA)-packed meat products remained low, because retailers directly noticed the higher direct cost of about €0.07–0.11 per pack, but were unable to grasp the benefits due to the lower indirect costs caused by reduced product losses. Moreover, people within the meat business debated that MA-packed meat with such a long shelf life could never be 'fresh'. This 'fresh meat' discussion had a strong traditional, cultural element. Some retailers and consumers argued that meat could only be fresh when it was directly cut. The fact that a wholesale cut from which a butcher makes the individual cuts had already been underway for several days in the supply chain was not realized. Hence, the word 'fresh' is slowly losing its original (time-related) meaning. Nowadays, fresh starts to be associated with unprocessed and low microbial loads. Nevertheless, retailers were (and some still are) convinced that conventional meat packages yielded more sales in their shops than MAP. Hence, the largest meat companies continued to use the traditional packaging method, and this method remained dominant up to the turn of the century.

LARGE-SCALE TRANSITION

Just before the turn of the century, Albert Heijn (market leader in Dutch retail) started to demand that fresh pork and beef products should be packed under modified atmospheres. Its meat suppliers (at that time, Dumeco and Hilton) were forced to implement the MAP technology. Albert Heijn's rationale is not documented, but based on its distribution system and policies, it is likely that it had three motives.

First, Albert Heijn's distribution involves distribution centres, which reduces the effective shelf life in the display and hence contributes to the problem of product losses in the shops. After the

DOI: 10.1002/pts

Packaging Technology and Science

bovine spongiform encephalopathy crisis (1999), new legislation was enforced (2000/418/EC) that commanded the execution of existing legislation and to incinerate spoilt meat. Since incineration is relatively expensive, the spoilage problem became more apparent as a financial problem.

Second, this retailer likes to position itself as a quality supplier on the Dutch market. During the 1970–1990s, scientific work had clearly proven the benefits of the MAP technology over traditional packaging technology.[8–10] It was no longer possible for Albert Heijn to continue packaging meat traditionally and to remain credible as quality supplier.

Third, retailers received consumer complaints relating to the traditional meat packages that leaked meat juices onto other items in their shopping bags. Since MA packages have the additional advantage of being leak proof, this undoubtedly formed a side argument.

Albert Heijn chose barrier foam trays and not transparent thermoformed MA packages. Although the former is more expensive, they felt that consumers would accept the transition better when the package appearance remained similar. They also continued working with coloured trays to indicate the type of meat, namely, green for beef, pink for pork, grey for lamb, yellow for poultry, orange for turkey and blue for fish. Hence, the added costs for the suppliers of Albert Heijn would have amounted to about €0.11 per pack. They also needed to change their production plants, build large warehouses for all the different sizes of pre-formed coloured barrier foam trays and to expand their distribution capacity (less MA-packed meat products fit in a truck as compared to traditionally packed meat products).

In the same period, the company Laurus intended to become the market leader in Dutch retail, and the rivalry with Albert Heijn was (and is) large. When Albert Heijn introduced MA-packed meat products in its shops, Laurus decided to follow. Laurus and the Hendrix Meat Group implemented a transparent MA package for fresh meats, which was more similar to the Promessa package. The added cost for this thermoformed package was roughly €0.07–0.08 per pack.

Later, several smaller retailers also implemented MAP for fresh meats, either for their full portfolio of meat products or only for several slow movers. Often they sourced meat from the same meat companies as the larger retailers and were offered to implement these products as well. Based on the market share of the supermarkets that have implemented MA packaging for fresh meats and on the level of implementation, we estimate that about half of the case-ready meat products (i.e. beef, veal, pork and poultry) are currently (i.e. 2005) sold in modified atmospheres in The Netherlands.

SLOW IMPLEMENTATION

The main reason for the impeded implementation of MAP technology in the Dutch meat supply chains was that the added costs were crystal clear for the entrepreneurs, but the benefits were intangible. Prior to 2000, all retailers lacked sufficient business administration systems. Most of the retail managers only received aggregated loss numbers (including theft, promotional discounts and last day of shelf life discounts) and were insufficiently aware of the losses due to product losses. Moreover, these managers were less concerned with losses. They felt that they could control losses sufficiently with improved sales prognosis tools and better order systems. Additionally, their main focus was on promotions and volume growth strategies. Only after business administration systems had improved and generated accurate product loss numbers was the problem recognized at the retail headquarters, and it was realized that the indirect cost of product losses was much higher than the direct packaging costs.

A second reason for slow implementation was the unequal division of costs and benefits between suppliers and retailers; the majority of the costs were for the meat packers, while the major benefits were for the retailers. Around the turn of the century, most retailers had reorganized their supply of fresh meats to one preferred partner. This meat company was fully dependent on the retailer, and this facilitated the implementation of MAP.

COST-BENEFIT OF THE TRANSITION

The main benefit of the MAP technology is reduction of indirect costs due to a lower percentage of

DOI: 10.1002/pts

product losses. Once the retailers understood the financial losses caused by losses of fresh meats and the cost-saving effect of MA packages, they strived for implementation. This required mostly dependent meat companies on which the transition could be enforced and to a lesser extent creative meat companies that developed their own financial benefits from MA packages.

MA packages have major benefits for consumers. MA packages do not leak meat juices in shopping bags. The shelf life in their home refrigerators is greatly enhanced and allows consumers to shop less frequently. Additionally, meat products packed in modified atmospheres stabilize the bright red meat colour for a longer time, keeping it attractive for consumers for a longer period. Moreover, this new package appears to reduce the risk of food infections with microbial pathogens as compared to standard packages.[viii] These consumer benefits were primary considerations for Makro and Promessa to start with this technology, but have presumably played a limited role during the large-scale transition with Albert Heijn and Laurus.

MA packages have potentially major benefits for meat companies as well, provided they are able to redesign their production processes. Promessa clearly changed its business model, is now less affected by acceleration effects and works with fewer shifts.

Although meat entrepreneurs did not aim to reduce the environmental impact of fresh meat chains, this actually seems to have happened; the overall environmental impact appears to be lowered due to a reduction of the amount of spoilt meat that is discarded at the supermarkets. This is quite remarkable since with this transition, the amount of packaging materials used has increased, whereas the focus of the European and Dutch legislation is on packaging material reduction as a measure to reduce the environmental impact of food production.

It is difficult to give an accurate figure for the observed effect because most data on environmental impacts required for such a calculation are not readily available, and those data that can be traced are subject to large variations depending on, for instance, the system boundaries that were used for the particular environmental assessment. Data on total energy requirements for meat production, e.g. vary from 30 to 70 MJ/kg.[11] Important factors that cause variations include the type of meat. Besides feed conversion and growth rate, the life span of an animal also influences the total energy requirement. Animals with a longer life span like beef animals require more energy for the meat they produce than e.g. chickens. However, vegetable produce that is cultivated for the sole purpose of animal feed (tapioca, maize and grains) contribute more to the energy requirements of meat production than feed that is readily available as pasture. To illustrate our case, we chose to use an energy requirement of 70 MJ/kg meat. This figure is recent and was calculated for pork production in The Netherlands.[12]

As an indicative figure for the total energy requirement for the production of packaging materials, we used 90 MJ/kg as an average of values for different packaging materials like low-density polyethylene (LDPE) resin, 78 MJ/kg; LDPE film, 89 MJ/kg; polyethylene terephthalate (PET) resin, 81; PET film, 109; polypropylene (PP) resin, 73; PP film, 99; and PP tray, 115.[13] From this figure, we deducted 45 MJ/kg to account for the recovery potential, i.e. the amount of energy that is regained in the form of generated electricity when the materials are incinerated with energy recovery at waste disposal plants.[11]

According to experimental measurements at our institute, MAP increases the weight of packing materials for an individual product by 0.01 kg, namely, from 0.01 kg for a tray and 0.001 kg for stretch film in conventional packaging to 0.02 kg for a tray and 0.001 kg for top film in MAP. Assuming that the average meat content of a package is 0.350 kg, the additional energy requirement for more than 50 MA packages equals the energy requirement of an average meat product of 0.350 kg. In other words, an avoided loss of 0.350 kg of meat compensates for the extra energy require-

[viii] We made this observation during our work with pork. Three times we received pork shipments that happened to be contaminated with indigenous *Salmonella.* This meat was used in comparative packaging tests, and qualitatively, *Salmonella* tests were always included. In all traditional packages, *Salmonella* remained present up to the end of the shelf life (5 days), whereas in MA packages, the percentage of *Salmonella*-positive packages gradually dropped during storage at 4–7°C. Near the end of the shelf life (7–8 days), all MA packages were *Salmonella* negative.

DOI: 10.1002/pts

Packaging Technology and Science

Table 1. Estimated environmental impact of the partial market adaptation of MAP for fresh red meats in The Netherlands between 1994 and 2005

	1994 (5% MAP)	2005 (50% MAP)	Difference
Meat losses at the supermarkets per annum			
Weight (1000 tons/year)	40.7	29.4	−11.3
Value (million Euro/year)	285.2	205.8	−79.4
Energy content (PJ/year)*,‡	2.85	2.06	−0.79
Packaging used per annum			
Weight (1000 tons/year)	13.8	19.2	+5.4
Costs (million Euro/year)	37.0	78.6	+41.6
Energy content (PJ/year)†,‡	0.62	0.86	+0.24

*Based on a value of 70 MJ/kg pork meat as produced in The Netherlands.[12]
†Estimated as an average of 90 MJ/kg for various packaging materials (Association of Plastics Manufacturers) *minus* a recovery potential for plastics of 45 MJ/kg.[11]
‡Unit for annual energy use is PetaJoule per year, or 10^{15} J/year.

ments needed to replace more than 50 conventional packages by MA packages.

In the 10 years from 1995 to 2005, the amount of meat spoilt in the supermarkets decreased with 11 000 tons annually, which represents a cost saving of about €79 million and an amount of energy of 0.79 PJ (PJ = 10^{15} J, see Table 1). The transition also implies an increase in the weight of meat trays and top film being used (in total, 5000 tons extra). The enormous amount of energy that is no longer being lost (0.79 PJ/year) compares favourably to the energy content of the increased amount of packaging materials used (0.24 PJ/year).

Obviously, this is only an indicative calculation of the environmental impact, which reveals that packaging technologies that prolong the shelf life of perishable products can have positive environmental impacts by reducing the product losses. Moreover, it also shows that the environmental impact of product losses is larger than the increased use of packaging materials. This effect is corroborated by the outcome of a study on other packaging materials for perishable products.[14] In order to make the environmental impact assessment more precise, other factors will need to be considered as well. One such aspect is the amount of truck transports. However, this effect is supply chain specific and cannot be generalized. In some supply chains, MA packages will cause more transports because fewer packages fit in one truck; in other supply chains, the delivery frequency will be lowered, and the amount of truck transports will be reduced. Therefore, it was not considered in this indicative calculation. Furthermore, the environmental impact of transports in food supply chains is usually relatively small compared to the impacts of food production and home preparation.[11]

FUTURE OUTLOOK

There is still room for technological improvements in (Dutch) meat supply chains. First of all, the performance of refrigeration equipment at retailers and consumers can be improved, yielding longer shelf life with MA packages and hence, possibly, an even better quality at the point of consumption. Chilled display cabinets at retailers show large temperature fluctuations with often high peak temperatures (6–9°C), low temperatures of –4 to +2°C) and frequencies of 0.5–2.0 h, caused by the defrost cycles of refrigeration units. The opportunistic growth behaviour of most spoilage organisms therefore causes a much larger growth than what would be expected based on the average tem-

DOI: 10.1002/pts

peratures (2–4°C). Furthermore, more than 40% of all home refrigerators are insufficiently chilled in Great Britain,[15] and there is no reason to assume that this situation is different in The Netherlands. Both cooling systems can easily be modified with a minimal investment to yield better performing refrigerating devices.

Furthermore, major improvements are possible in the slaughter process. As previously mentioned, the initial load on European meat at the moment of packaging is relatively high: approximately 10^4–10^5 CFU/g, which is predominantly caused by the extended carcass chilling times of 24–36 h. All this time, the carcass resides in a carcass cooler in which chilled air is forced to circulate along the carcasses, which results in high initial loads. This can be avoided using new, much faster chilling technologies in which carcasses are chilled inside vacuum bags within 2 h time. The shorter time and vacuum bag greatly reduce the initial load on the carcass and hence extend the shelf life of the meat products cut from these carcasses. First experiments with these new chilling technologies even indicated that the time-consuming process of beef aging is no longer required.

Alternatively, carcasses and wholesale cuts can be decontaminated with various techniques. It is expected that in the near future, disinfection of carcasses and meat parts with lactic acid and other chemicals will be allowed in the European Union. This technology reduces the initial microbial loads (usually a log 1–2 reduction). New electrochemical methods, Electric Thermal Bacteriolysis (ETB) rely on very short treatments with steam and high voltages. These are reported to lower the initial load much further to about 10 CFU/g. Both techniques can greatly contribute to a further extension of the shelf life of meats packed in modified atmospheres in comparison to traditionally packed meats.

Additionally, recent research has shown that bacteriophages are able to control the growth of specific food pathogens in packed meat products.[16] Furthermore, peptides such as lysozyme and nisin are able to reduce the growth of spoilage organisms in general in packed meat products.[17] These technologies appear promising in combination with MAP technology.

Major improvements are expected in advanced stock management systems, including a faster exchange of sales data between retailers and meat companies and the implementation of vendor-managed inventory systems. New internet solutions will make counter sales data available for meat suppliers. Furthermore, combinations of new interactive packages and internet solutions will also yield real-time quality differentiated stock-level information for the retailer's headquarters and the meat company. When wisely used, these systems will be able to reduce meat spoilage and concomitant financial losses greatly.

Although all these new technologies can contribute to better quality of fresh meat products for consumers and can also possibly lower the overall business cost, their implementation is uncertain. As the implementation of MA packages took four decades, this can also happen to these techniques. Especially, new slaughter and carcass chilling technologies are likely to be implemented slowly, since the investments will have to be done by slaughterhouses, and the benefits will be predominantly for the retailers.

PACKAGING INNOVATION IN PERSPECTIVE

Many innovative packaging systems for fresh foods have been developed in R&D centres, and a few have actually been implemented in the market. Recent examples of technologies that have been applied to a limited extent in Europe include oxygen absorbers for cooked meat products, nuts, coffee, etc.,[18] and equilibrium MAP for fruit and vegetables.[19] These technologies have clear benefits for products and raise the general question why these protective packaging technologies are implemented to a limited extent. Besides the unique mix of technical and financial limitations unique to every technology, several general lessons can be learned from the Dutch fresh meat example.

Packaging innovation is more likely to happen in supply chains with long-lasting business relationships than in loose free-trading networks. A solid business relation will allow food industries to invest in packaging machines more easily and depreciate them over a few years. Furthermore, those companies will be more inclined to share costs and profits originating from packaging innovation.

DOI: 10.1002/pts

Packaging Technology and Science

The majority of innovative packaging concepts will raise the costs of packaging. Protective packaging will raise the shelf life of products and hence reduce the indirect costs of product losses. This new package will only be implemented when it can be proven beyond reasonable doubt that the total business costs of packaging purchasing, machine investment and product losses are lower for such a protective package as compared with the traditional package. In order to make these calculations and to prove this as packaging companies, the retail company needs to possess and to be willing to share detailed business information.

Packaging innovation usually involves many partners (machine builder, material supplier, designer, gas supplier, etc.) and usually also has implications for various business aspects (production, logistics, marketing, quality control, purchase, etc.), making it inherently complex and time consuming. Furthermore, within most food companies and retailers, these packaging aspects are not dealt with in an integrated manner, but rather by several different managers with different opinions and responsibilities, and hence usually a fair amount of time is necessary to convince all those involved. Often food retailers work with 3 month periods to launch new products, and therefore the implementation of protective packaging technologies hardly ever fit in this time frame, making it troublesome in advance.

CONCLUSIONS

In the past decade, a major transition has occurred in the packaging method for fresh meat products in The Netherlands. About half of the market has implemented the MAP technology. In hindsight, retailers and consumers benefited the most from this transition. Strikingly, the environment also appears to have benefited from this transition, although more packaging materials are now being used. The implementation took four decades (1964–2005), largely because the benefits were not understood in precise financial terms. Furthermore, the investments had to be made by meat companies, and the revenues were almost exclusively for the retailers.

ACKNOWLEDGEMENTS

Mr Ronald Koenders, Mr Geert Pepping and Mr Paul Dielen are thanked for the open, interesting and inspiring discussions, and the improvement suggestions that were made. Mr Nico Bolder of Wageningen-UR Animal Sciences Group performed all the microbiological work and is thanked for his all his work and enthusiasm. Furthermore, we are grateful for the financial support given by AKK and the Dutch Ministry of Agriculture, Nature and Food Quality (LNV).

REFERENCES

1. Boehme F. Frischfleischportionen optimal verpacken. *Verpackungsrundschau* 1971; **22**: 594–606.
2. Westra P. De markt voor voorverpakt vlees. *NVC conference "Verpakken van Vlees"*: Gouda, 4 November 1999. Translated statement: From 1990 to 1998 the market share of Dutch supermarkets in meat sales grew from 61 to 76%, at the same time the percentage pre-packed meats grew from 41 to 63% (the largest in Europe).
3. Brody AL. Modified atmosphere/vacuum packaging of meat. In *Controlled/Modified Atmosphere/ Vacuum Packaging of Foods*, Brody AL (ed.). Food. & Nutrition Press, Inc.: Trumbull, CT, 1989; 17–38.
4. Grobbel JP, Dikeman ME, Smith JS, Kropf DH, Milliken GA. Effects of polyvinyl chloride overwrap film, high-oxygen modified atmosphere packaging, or ultra-low-oxygen modified packaging on bone marrow discoloration in beef humerus, rib, thoriac vertebra and scapula. *J. Anim. Sci.* 2006; **84**: 694–701.
5. Zhang M, Sundar S. Effect of oxygen concentration on the shelf-life of pork packed in a modified atmosphere. *Packag. Technol. Sci.* 2005; **18**: 217–222. DOI: 10.1002/PTS.693.
6. Houben JH, Dijk van A, Eikelenboom G, Hoving-Bolink AH. Effect of dietary vitamine E supplementation, fat level and packaging on colour stability and lipid oxidation in minced beef. *Meat Sci.* 2000; **55**: 331–336. DOI: 10.1016/S0309-1740(99)00161-8.
7. Thoden van Velzen EU, van Dijke I, Bolder N, Snels J, Thors M. Vleesvraag voor morgen – kwaliteitsverhoging in de vleesketen door point-of-sale ketensturing en kwaliteitsborging tot point of consumption. *AKK Public Final Reports* 2003; 1–12. http://www.akk.nl/database.html. Last accessed Apr 2007.
8. Benedict RC, Strange ED, Palumbo S, *et al.* Use of in-package controlled atmospheres for extending the shelf life of meat products. *J. Agric. Food Chem.* 1975; **23**: 1208–1212. DOI: 10.1021/jf60202a029.
9. Gill CO, Tan KH. Effect of carbon dioxide on growth of meat spoilage bacteria. *Appl. Environ. Microbiol.* 1980; **39**: 317.

10. Young LL, Riviere RO, Cole AB. Fresh red meats. A place to apply modified atmospheres. *Food Technol.* 1988; **42**: 65–69.
11. Dutilh CE, Linnemann AR. Food system, energy use. In *Encyclopedia of Energy*, Volume 2. C. J. Cleveland (ed.), Elsevier: Oxford, UK, 2004; 719–726.
12. Zhu X, van Ierland CE. Protein chains and environmental pressures: a comparison of pork and novel protein foods. *Environ. Sci.* 2004; **1**: 254–276.
13. Association of Plastics Manufacturers, 2006. http://www.plasticseurope.org [accessed 4 September 2006].
14. Bergsma GC, Sevenster MN, Vroonhof JTW, *et al.* Verkenning van een nieuwe milieumethodiek voor verpakkingen en integratie met productbeleid. CE rapport 04.5971.32. CE, Delft, 2004.
15. Worsfold D, Griffith CJ. Assessment of the standard of consumer food safety behaviour. *J. Food Prot.* 1997; **60**: 399–406.
16. Greer GG. Bacteriophage control of foodborne bacteria. *J. Food Prot.* 2005; **68**: 1102–1111.
17. Nattress FM, Yost CK, Baker LP. Evaluation of the ability of lysozyme and nisin to control meat spoilage bacteria. *Int. J. Food Microbiol.* 2001; **70**: 111–119. DOI: 10.1016/S0168-1605(01)00531-1.
18. Flodberg G. Determination of oxygen and water vapour in modified atmosphere packages for meat sausages with and without an oxygen absorber. *Packag. Technol. Sci.* 1997; **10**: 1–13. DOI: 10.1002/(SICI)1099-1522(199701/02)10:1<1::AID-PTS379>3.0.CO;2-G.
19. Lee LZ, Arul J, Lencki R, Castaigne F. Methodology for determining the appropriate selectivity of mass transfer devices for modified atmosphere packaging of fresh produce. *Packag. Technol. Sci* 1996; **9**: 55–72. DOI: 10.1002/(SICI)1099-1522(199603)9:2<55::AID-PTS357>3.0.CO;2-8.

DOI: 10.1002/pts