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New Developments and Trends in Food Processing and Packaging in Europe

Invited paper for the 7th annual Conference of the Society of Packaging Science and Technology, Tokyo, Japan, June 10th, 1998.

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This review of developments and trends will reflect the present state of the art in Europe, including some interesting ongoing research and development, with main emphasis on food processing, which is the author's personal field of expertise. These developments may not necessarily be novel in Japan, which is very much in the forefront in food packaging development and in commercialising new food technology.

The overriding trends in the European food field today concern consumers demand for fresh-like, minimally processed foods, emphasis on consumer safety, nutrition and convenience and demand for minimal negative effects on the environment and on energy resources. In the paper, these trends, as well as some secondary trends, will be discussed and commented on with regard to actual developments, industrial or on the R&D level.

Keywords : European food field trends, Food processing, Food sterilisation and pasteurisation, Food packaging, Minimal processing, Non-thermal processing, Environmental issues, Reuse and recycling of packaging, Biodegradable packaging, Life Cycle Analysis

Introduction

The most important European trends can be listed as follows :

- Consumers demand for fresh-like, minimally processed foods without artificial additives and without unnaturally long shelf lives.
- Emphasis on consumer safety, nutrition and convenience
- Demand for minimal negative effects on the environment and on energy resources over the entire life cycle of food and food packaging.

Secondary trends, as a result of these, are :

- Emphasis on mild processing methods and combinations of such processes and measures (hurdle technology), including both thermal and non-thermal methods and compositional changes to achieve "minimal processing".

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- Preventive on-line process-and product control (HACCP etc.) and official certification of company programmes for production monitoring and environment.
- Extensive application of process modelling and simulation, including predictive microbiology
- Conspicuous growth in chilled foods and MAP-products (including sous-vide products) with limited shelf life.
- Growing market in health foods and in functional foods.
- Consumer directed product development
- Demands for reuse and recycling of packaging, and packaging solutions well adapted to reuse, recycling and minimal land and air pollution, including minimal use of packaging (no over-packaging).

In the following I will deal with some of these trends, mainly with regard to developments in processing and, to a somewhat lesser extent, in packaging.

Minimal processing.

Mild methods and a minimum level of processing are required for optimal retention of freshness as well as minimum use of artificial additives. To make the resulting products safe to consume, a combination of measures will often be needed, such as combining processes with modifications in pH, water activity, natural preservatives, MA-or Sous-Vide packaging etc. This whole trend in food processing is termed "minimal processing" and is dominating European product and process development today.

In traditional food processing, thermal methods of preservation (pasteurisation or sterilisation) dominate. The need for milder treatments in preservation has, however, lead to the development of a number of non-thermal methods, both physical, chemical and microbiological, which have come to dominate as themes for European conferences and workshops on minimal processing.

Thermal minimal processing.

Developments in thermal processing can be listed under the following main headings :

In-package processing :

- High Temperature Short Time (HTST)
- Microwaves and High Frequency
- Sous-Vide processing

- Infrared heating

Aseptic processing :

- Single flow or separate flow liquid/solids
- Electrical resistance heating (Ohmic heating)
- Microwave and High Frequency heating

Other thermal processes :

- Steam injection+evaporative cooling
- Processing under CO_2 pressure
- Ultrasound (thermosonication)

In-package thermal processing.

A target for minimal thermal processing is to approach a true HTST process. (High Temperature Short Time). When you go up to temperatures in the range 125-135°C the rate of inactivation of bacterial spores is much higher than that for the deterioration of sensory properties or nutritional values. You can achieve a safe process with minimal loss of quality. Limiting factors for in-package HTST treatment are heat transfer properties and product or package thickness. If heat transfer is slow and product thickness high, high temperatures will lead to overheating of outer food layers.

Large scale processing in aluminium foil laminated plastic pouches has been very successful in Japan, allowing near HTST processes at sterilisation temperatures up to 128°C and processing times around 20 minutes. It is interesting to recall, that the pouch was first commercialised in Europe but did not succeed because the process was far from optimised. The pouch is now slowly coming back in Europe, applying the standing pouch for higher consumer convenience, and finally taking advantage of the potential for product improvement inherent in the small product thickness.

Today, retorting is done batchwise or continuously, using hot water or steam as the heating medium and sophisticated process control of time-temperature, pressure and F-or C-value development. Sometimes this is also coupled to on-line process simulation for optimal retention of quality and inactivation of bacteria and enzymes.

A HTST-like processing method, introduced fairly recently in France, is to can vegetables immersed in water, with only partial sealing prior to processing. Inside the retort, the water is
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drained from the can by food grade steam, which heats the food in direct contact very

rapidly. Cans are then fully sealed within the pressurised retort before cooling, which creates a partial vacuum inside (sous-vide). The process is claimed to result in substantially improved quality retention.

There is, at present, certain growth in retortable plastic containers with barner materials other than aluminium foil. Because of the new environmental directives on re-use and re-cycling, there is also re-awakened interest in glass and metal packaging with reduced material thickness and improved graphics. One interesting new package is the Hexcan (Thomassen & Driver), which has been given a beehive pattern of buckles, which increase the mechanical strength of the can body and make the can easier to grip.

Within one of the research programs of the European Union three different kinds of *time-temperature indicators* have been developed to monitor the safety of the sterilisation and pasteurisation processes. These devices are now slowly coming into practical use in process development work in the food industry.

- An enzyme based system for evaluating the safety of pasteurisation systems, demonstrating a z-value of 6-12°C.
- A chemical system based on the hydrolysis of nitrophenol glucoside, useful for evaluating quality change during pasteurisation processes, with a z-value between 23 and 27°C.
- A microbial system for evaluating sterilisation processes, based on Bacillus *sterothermophylus* spores, immobilised in alginate beads.

The first two devices are enclosed in glass capillaries, which are inserted into the food. In the last one, the spores are enclosed in small alginate beads, which are permeable to the chemical environment in the food but not to micro-organisms. All three devices performed well both in water retorts and in microwave- and Ohmic heating systems.

Microwaves offer a possibility to approach more closely true HTST processing by direct heating of both surface and interior of the food, with a penetration depth in the order of 2-3 cm, with limited spread in temperature. Over the last ten years or so, dozens of continuous microwave tunnels have been installed in Europe for pasteurising packaged foods, mostly tray packed pasta dishes or fresh pasta of fairly low water activity.
At least one sterilisation plant, manufactured by Italian OMAC, is in operation in Belgium at a capacity of about 1 ton/hr, producing a line of ready to heat and eat dishes in their "Top Cuisine" line. A shelf life of 9 months at ambient temperature and a fresher taste than for

conventional processing are claimed. Preformed trays of seven-ply coextruded structure are used, incorporating a top layer of PET and two PP layers, sandwiching an EVOH barrier. The lidstock is PP/EVOH/PP.

Elaborate process control and quality assurance programs are essential features of this process, having a come-up time to 125-128°C around 7-8 minutes and a total processing time about 20 minutes. This is not notably shorter than the processing times possible with steam processing in pouches, and quality advantage over pouch processing is not very apparent. An advantage is, however, that foods such as entr★es can be tray packed with a slight MA headspace to avoid the deformation of product surface appearance often resulting from vacuum packaging.

In comparison, the former Alfa-Star microwave process, now the property of Tetra Pak, achieved processing time of 5-6 minutes at 130-135°C, but is not a commercial system today. It indicates, however, that there is a clear possibility of future improvements. This is also supported by modelling and simulation of field distribution and heating patterns in microwave tunnels, made at SIK within a European Union sponsored project. This simulation software proved to be a very important tool in the evaluation and optimisation of commercial microwave systems.

When microwave pasteurising or sterilising packaged foods, hot spots may occur at corner and edges, for which reason overriding gas pressure will be needed. A limitation in packaging is that foil laminated packaging cannot be used, at least not in the lids of trays. This limitation in barrier properties can now be overcome by the advent of high barrier plastic films, applying EVOH or SiO_x surface coatings. An additional possibility may become the use of LCP (Liquid Crystal Polymers) to create barrier properties comparable to aluminium foil laminates.

Long wave *infrared heating* at wavelengths around 30 μm has long been in use for industrial cooking and drying applications, achieving shorter processing times than by convective heating. With the advent of short wave (1 μm) and intermediate (about 5 μm) quartz tubes, IR heating has gained wider acceptance and use for rapid baking, drying and cooking of foods of even geometry and low thickness. The short-wave IR has a penetration depth of several mm in many foods and can therefore be used to about the same effect as microwaves for thin materials. In addition, it is not absorbed by transparent plastic packaging and is being successfully applied for the surface pasteurisation of packaged bakery products both in France and in Sweden. IR is also easy to control and relatively inexpensive, with a high degree of energy utilisation.

Aseptic processing

Aseptic processing means sterilising (or pasteurising) pumpable foods on line, followed by packaging under sterile conditions in pre-sterilised packaging material. Continuous heat processing in combination with aseptic processing is in world-wide use for free-flowing liquids, such as milk (50% of total market) and juices. In western Europe the consumption of these products amount to 1 litre per person and week. Carton systems dominate by 70% of the market (mainly Tetra Pak and PKL).
More than 1600 aseptic packaging systems are said to be available in Western Europe, from more than 30 manufacturers. A number of systems have been introduced for true HTST treatment, using two or more steps of heating, applying steam injection or infusion for the final split-second temperature rise to around 150°C, followed by very rapid evaporative and heat exchanger cooling.

Large numbers of new packages for aseptic or hot fill are presented with their respective filling machinery, often disappearing quietly after a while. It seems that the manufacturers supplying cardboard beverage packaging are becoming increasingly interested in plastic packaging in the form of jugs, pouches and bottles or packages of PET. One interesting example is the Tetra Max package, which was test marketed a few years ago, and which is not yet in commercial production. It is based on continuously thermoforming bottle halves from roll material of chalk filled polypropylene. These halves are sealed together, filled and capped. An LCA analysis by the PIRA Institute demonstrated 40% less environment impact than from traditional plastic bottles. One other interesting development is the "world's first" aseptic PET line (ASIS=Aseptic Integrated System) for fruit juices and tea in Italy, in co-operation between SIPA, Procomac and Del Monte.

Environmental issues ,however, also speak for paper board packages, one interesting and fairly novel entry being the Carto Can Aseptic Paperboard and package system for beverages (Walki Can), which has also been introduced into Japan.

The real challenge today, however, is how to successfully process low acid viscous foods with a high proportion of solid particles of above 20-25 mm diameter. The mayor problem is to assure overall sterility without heat damage to slower moving material or mechanical damage to particles. Attempts to reduce this problem by separate processing of liquid (continuously) and solids(batchwise) has not met with much commercial success. The ingenious and simple Rotahold (Stork company) design, by which liquid and particles are moved through the same heating zone at different speeds by paddles is also in little use. Contributing is the fact, that filling and sealing systems which can effectively handle large particles seem to be lacking. Important is also, of course, that no apparent consumer demand has developed for these products as yet !

A clear possibility to achieve more uniform heating, even at particle sizes of several cm, is by using direct electrical resistance heating or microwave and high frequency heating.
The best known electric resistance heating system is the APV Ohmic heating column, where electrodes for main frequency current are in direct contact with the food, which is transported in a vertical concentric tube. These electrodes are constructed of noble metal-coated titanium to avoid any electrochemical reactions and dissolution of metal ions into the food.

The electrical conductivity of the food determines the rate of heating, and extremely high heating rates are possible. If solids and liquids have the same conductivity, they will, in principle, heat at the same rate, irrespective of particle size. The Ohmic system demonstrates excellent retention of particle integrity up to several cm diameters, due to the absence of the mechanical agitation typical for scraped surface heat exchangers. The first known installation, in Britain, produced foods with 25mm particulates both for the institutional market (bag-in-box) and entrée meals for the retail market (packed in form-fill-seal trays). A recent installation in Germany with the Lübecker Ersaco GmbH processes entrée dishes with a 50% proportion of particles of dimensions in length up to 5cm for their new line of pre-cooked dishes and soups. It seems, however, that commercial application of ohmic heating is more successful in Japan than in Europe at the present time.

Tubular heaters suitable for continuous aseptic processing have been designed both for microwave heating at 2450 MHz and High frequency heating at 27 MHz. A commercial French plant for microwave cooking and pasteurisation of meat emulsions, vegetable stews etc. is based on what is called a hybrid mode applicator. It is claimed that the temperature variation up to 85°C can be kept within +3°C, and that thermal efficiencies around 70% can be reached. Another more efficient tubular microwave system is under development at the SIK research institute in Sweden.

No doubt aseptic packaging will also have to adapt to consumer demands for easy reheating in the microwave oven. This then asks for microwave transparent packaging and food and packaging shapes giving an even distribution of the microwave energy in the food. It should also be tolerant to temperatures up to 130°C, which can occur during re-heating, especially if so called susceptors or metal foil patterns are used on the package for browning effects or for better field distribution.
For the sterilisation of packaging materials for aseptic packaging, novel alternatives are the UV Eximer cold laser presented by Elopak and the Intensive Light Pulses, commented on elsewhere in my presentation.

In France a couple of interesting new thermal processes have been introduced to meet increasing demands on the consumer market for high-quality ready-to-use chilled shredded vegetables and fruits with sufficient shelf life. One applies vacuum steam followed by evaporative cooling and packaging under modified atmosphere, containing at least 2% oxygen, in a refrigerated clean room. It is claimed that tastier and crisper products are obtained with better retention of solubles and lower energy consumption. Fig. 1 (See appendix).
In the other process, thermal treatment is done under CO_2 pressures up to 6 bars. It is claimed that pasteurisation temperature can be reduced by as much as 10°C and processing time by almost 50% compared to treatment at atmospheric pressure without CO_2.

Non-thermal, physical processes

Noteworthy developments in Europe in this field of processing concern :

- High pressure
- Pulsed electric field

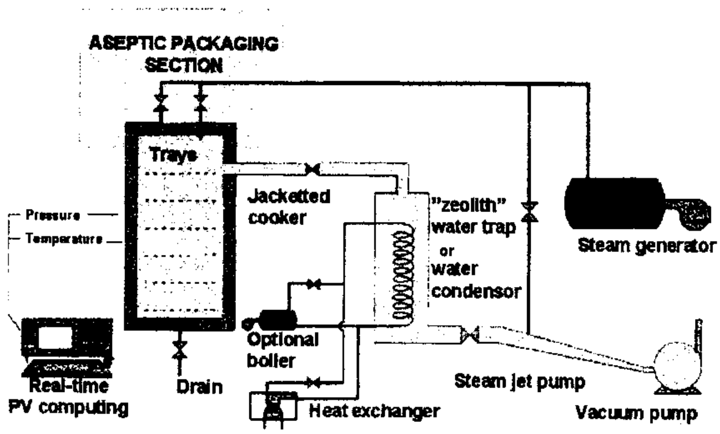

Fig. 1. French vacuum processing of fruit and vegetables developed by INRA.

- Pulsed light
- Air ion bombardment

None of these food applications originated in Europe, but in Japan (high pressure) and USA, even if Sweden and France have traditionally had leading equipment manufacturers in high-pressure technology for non-food uses.

High pressure

Commercial development in Europe for food applications has been slow, even if equipment manufacturers like ABB, National Forge and Stansted quickly were able to offer equipment with high volume capacity (1000 litres and pressures up to 600 MPa). More recent is the development of a semi-automatic, horizontal pressure vessel with a double set of pistons for loading and unloading in a straight line from French ACB and equipment with an external high-pressure intensifier from ABB which will lower costs and increase equipment life-length Fig2(appendix).

On the other hand, co-operative research within the European Union framework has been very intense, covering all aspects of high pressure phenomena and potential applications, including the use of high pressure supercritical CO_2 for the inactivation of micro-organisms and enzymes.

Interest within the food industry has been considerable, but high investment costs and uncertainty of the consumer reactions have restrained development. So far there are only two large scale installations in Europe, one in Spain for the processing of meat products and one in France for the processing of orange juice.

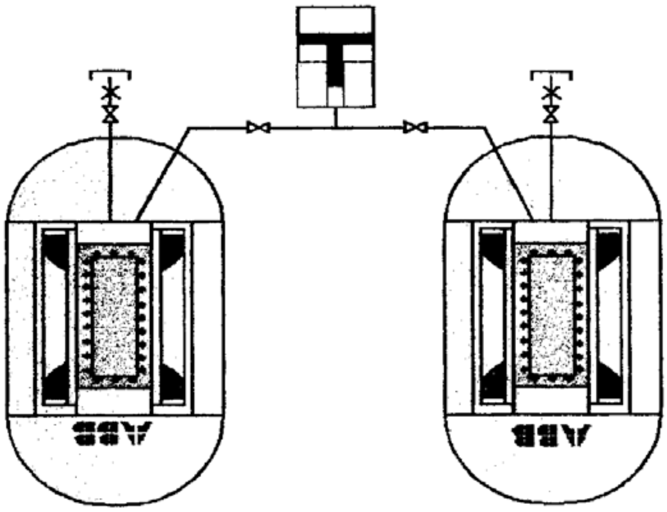

Fig. 2. ABB high pressure vessels with common hydraulic system.

Pulsed electric field (PEF)

The concept of applying very intensive electric field pulses to inactivate micro-organisms was patented by the Maxwell Labs in the US in the mid-80-ies and developed to pilot plant scale in co-operation with Tetra Pak, the US Army Natick Research and others. The principle is that liquid foods are passed through a narrow channel. Over this channel, high voltage micro-or millisecond pulses are passed, discharging an electrical condensor. At field strengths in the order of 15-30 kV/cm micro-organisms suffer membrane damage which will kill the cells. As in the case of high pressure processing, sensory and nutritional properties are very little affected.

This is a very actively researched process at present and subject of much international co-operation, such as between a European network of research groups and enterprises and a corresponding group in the US. The experience of Tetra Pak development with pulsed electric field for food pasteurisation and extraction was recently presented at a conference at SIK. It is deemed a viable pasteurisation method for pumpable foods, but not sufficiently lethal to micro-organisms for sterilisation purposes. They expect treatment costs to be about double that for thermal processing, but still within a reasonable cost range, considering its benefits. Time until commercial application was estimated at 3-7 years, including time for regulatory approval and scale up to industrial capacity.

Intensive light pulses

This is another method, patented by Maxwell labs and further developed in co-operation with the same industry group as mentioned for electric field pulses. It is based on charging a powerful condensator and discharging it in milliseconds over a flashlight, producing light flashes in the order of 10^{13} watts ! As a rule, just one or two flashes will be sufficient for the surface pasteurisation of packaging material (for aseptic packaging) or foods (such as bakery products), or transparent liquids such as bottled beer or on-line pasteurisation of drinking water. In Europe the process is now near commercial application for packaging and water purification, after the process has been approved by FDA in the US.

Air ion bombardment

Researchers in UK have demonstrated that a direct stream of negative air ions kills food-born pathogens, plated on agar substrate. Determining factors are exposure time, distance from emitter, ion charge and rate of ion flow. The main components (Fig.3, appendix) are a high-voltage generator, a sharply pointed emitter of negative ions and an earthed conducting surface on which the food to be treated is positioned. The main microbiocidal effect is

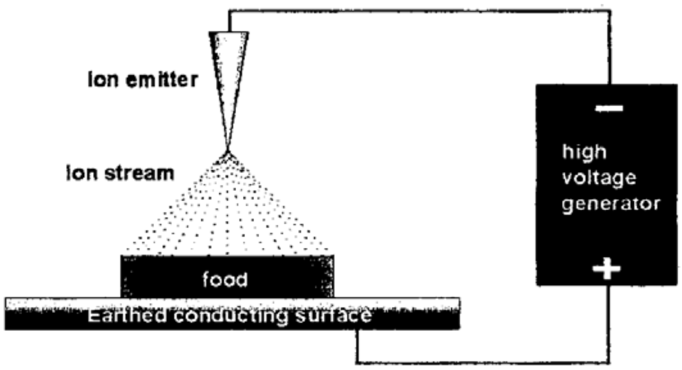

Fig. 3. The principle of air ion bombardment processing. Sutherland and Copus.

probably caused by the superoxide radical anion damaging the microbial cell membrane. Preliminary work demonstrated that a few minutes treatment effectively killed both yeasts and Gram negative as well as Gram positive bacteria, including spore formers. Work continues within a British Government sponsored R&D program.

Non-thermal "chemical" processes

Modified atmosphere

Refrigerated foods, pre-cooked or minimally thermally processed, represent the fastest growing food segment in Europe today, due to their image of freshness, high quality and convenience. The consumer no longer deems limited shelf life as a negative, but rather a sign of the natural property of non-manipulated food. For economical and practical reasons, however, it is desirable that shelf life can be sufficiently prolonged for distribution and a reasonable time of storage in the home refrigerator. One important factor to this end is MA-packaging, which is in rapid increase in Europe, and usually based on headspace combinations of nitrogen, carbon dioxide and oxygen in flexible packaging in high barrier laminates. In another joint European research effort MAP studies include the use of high level oxygen, nitrous oxide and argon as headspace gas components. The very positive results with argon, recently reported by the Air Liquid company have, so far, not been confirmed, while very high oxygen levels appear to have some beneficial effect for certain foods but not for all. For non-respiring foods, a good barrier property is a packaging requirement, but also convenience and microwaveability are important.

Active or smart packaging

Closely related to MA-packaging is the use of so called active packaging, a field fairly dominated up to the present by Japan, best known application being oxygen absorbers.

Interest in this field is now considerable in Europe, judging from ongoing R&D and testing of commercial devices. The Finnish company Bioka Ltd produces enzyme based oxygen absorbers, which will reduce oxygen levels in an oxygen impermeable package to below 0.01%. Using such devices, the retention of sensory quality in products such as ham sausage and rye bread was clearly better than in gas-flushed packages, and packaging with higher gas permeability could be used and total packaging costs reduced.

Studies of *consumer attitudes towards active packaging devices* in Finland, demonstrated that the use of absorbers was well accepted for foods like pizza and rye bread but not for fresh meat packages. 40% of consumers were actually willing to pay about 2 US cents more for products with an oxygen absorber to get food of high quality without the use of food additives.

At SIK work with antioxidant containing packaging material, comparing the use of α-tocopherol and BHT as stabilizers has demonstrated that BHT migrates too fast and completely into the packaged food, while α-tocopherol gives a good balance of protecting both packaging material and food against oxidative reactions.

Unfortunately, very strict European regulations do not allow many of these innovative active packaging concepts to be used.

Time-Temperature-Integrators tagged to the outside of food packages for the control of chilled food handling can also be regarded as active packaging, especially types now under development in Sweden which are directly integrated with the package and automatically activated in the course of the packaging operation. The system consists of two mini-pouches, one containing an enzyme and the other its substrate and a pH indicator. It is activated by breaking the barrier between the two pouches. The enzyme reaction proceeds at a pace which is logarithmically dependent on temperature in the same way as the rate of deterioration of the packaged food. Colour change from green to yellow in a little observation window indicates that the food quality can no longer be guaranteed.

Environmental issues in food processing and packaging.

Just about all leading food companies in Western Europe have, or are in the process of implementing, an internal environmental program, since environmental effects have become a very important issue with consumers and government agencies alike. Consent to use "green" symbols on the food package is important not only to company image and sales but often also to processing efficiency and product cost.

A powerful tool in the continuing work in these programmes is the use of Life Cycle Analysis (LCA), covering the interaction with the environment, including energy utilisation, over the entire life cycle of food products, packaging, process machinery etc. It has, for example, become very important in identifying critical points in the food chain with regard to the environment and in choice situations between different alternatives, for example for the packaging of a new product, or the choice between several alternative processes.

While food waste is equivalent to some economical loss and can mean short range pollution of the environment, even if composted or used as animal feed, it is 100% biodegradable and a renewable resource. The situation for food packaging is different, and demands are getting stricter all the time from government agencies and consumers for reuse, recirculation, minimising the use of packaging and "overpackaging" and designing packaging for easy separation of materials for reuse.

By the year 2001 at the latest, all packaging on the EU market should be manufactured according to the European Parliament and Council Directive 94/62/EC on packaging and packaging waste. The demands on packaging are the following :

- Preventing the production of packaging waste
- Reusing packaging
- Recycling and other forms of recovering packaging waste
- The safe final disposal of packaging waste
- Minimise the amount of packaging
- Reduce landfill to the absolute minimum

Reuse and recycling

Within the EU research programmes a great amount of joint research has been devoted to problems in reuse and recycling of packaging, of importance to consumers safety and product quality. The reuse of PET bottles for beverages is very high, but cleaning has been problematic because water temperatures above 70°C cannot be used. Flavour carry over can be considerable, since the commercial type of washing operation does not remove more than 20-50% of sorbed volatiles from the previously packed product. Misuse by consumers, storing non-food liquids in the bottles prior to recirculation, is another problem, because of which standardised inertness and contamination tests have been developed. Applying a protective layer of new PET on recycled PET proved to be an effective measure against carry over of volatiles.

It was also demonstrated, that PET and PC bottles showed no thermal or chemical degradation and no change in barrier properties after 15 use cycles.
Lately, there has been fairly strong pressure from governments and ecologist groups to recycle packaging back into food contact use, rather than for odd uses or incineration. One interesting project of this kind is presently being commercialised in Sweden in co-operation with Dow Chemical. Polyester or paperboard waste is mixed with food grade clay, latex and carbon black, formed into food serving trays and dried to physical stability and strength in a 200 kW microwave plant.

Edible and biodegradable packaging

There is a marked interested in Europe today in edible and biodegradable packaging and coating of foods and a great many research groups are involved in this area of packaging. As is well known, Japan already has developed a number of commercial edible film materials, both carbohydrate- and protein based. In Europe, where research interest seems to be focused on protein based and starch derivative-based films, there is so far very little commercial application as film materials Their excellent oxygen barrier properties first have to be combined with good machineability and mechanical strength and acceptable moisture barrier properties. Preliminary results indicate that applying a SiO_x coating on edible films may lead to a solution. The European market leader in fresh dairy products, Danone, recently decided to use yoghurt cups made of polylactic acid, which is fully degradable, after development work in co-operation with Dow Chemical and Cargill.
Walki Lamicoat in co-operation with British Zeneca have developed a biodegradable packaging material consisting of paper or board laminated with the ICI Biopol material, which is made from sugar by bacterial fermentation.

Convenience

While environmental aspects are becoming increasingly important, convenience and novelty factors will sometimes be at least equally important. A good example is the coffee preparation package and server, now under introduction in Sweden. A rectangular paperboard package (Fig.4,appendix) contains a closed PE capsule of instant coffee, surrounded

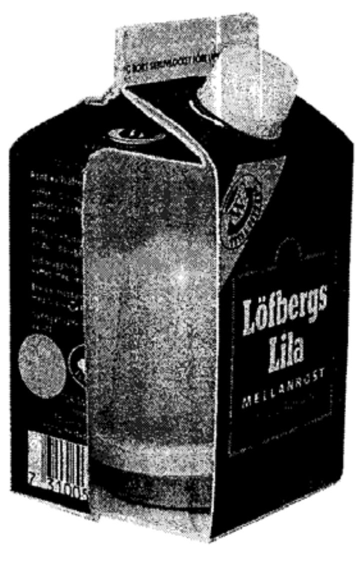

Fig. 4. Smartpack hot beverage system.
CD Food Technology AB.

by pure spring water. It is heated in a specially designed microwave oven. Correct final temperature is assured within 1°C by a liquid crystal tag, which changes colour. An optical sensor reacts on the colour change to shut off microwave power. At this temperature the capsule releases and mixes the coffee powder into the hot water, and fresh coffee can be served through the convenient pouring device.

Summing up

It is of course impossible to give, within a few pages, a complete picture of current trends and developments in food processing and packaging in Europe, or Western Europe, with its wide variation in language, culture, food habits and customs and degree of technical development. In addition, what is new or novel in Europe may well originate from other continents, where it may already be established.

With these reservations, I still hope that I have given a reasonably accurate picture of developments in European food processing and packaging, which, after all, may not be very different from what is going on in the United States, Japan and Australia.

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(原稿受付1998年8月18日)