New processes and products
An updated guide for people active in food processing, product development and marketing

by
Nils Bengtsson

SIK-Rapport 1994 No. 606
SIK, P.O. Box 5401, S-402 29 Göteborg, Sweden
New processes and products
by Nils Bengtsson

Table of contents

Objectives
Summary
What characterizes food process and product development in today’s food industry?
New developments in food processing
  Food preservation
    Pasteurization, sterilization
    Drying and extrusion
    Deepfreezing
    Chilling – Cold storage
  Food preparation
Other special processes
  Biotechnology – Gene technology
New food products
  Raw materials, ingredients additives
  Trend products
Packaging
Future development
How to use this overview in your own development work
Appendix: Tabulation of new processes and products
New processes and products
by Nils Bengtsson

Objectives
The objectives of the present study were to present an overview of new developments in processing techniques and food products or product types, to provide impulses for applications and further development within the reader’s own business, and to give some idea of the competitive situation in the future.

Summary
This overview is based on a study of the literature from 1989 and onwards, including abstracts and proceedings from conferences within the subject area, and on contacts and discussions with food technologists and research workers.

New food product development is likely to reflect new trends in consumer attitudes and food consumption, and developments in process technology reflect an ambition to meet consumer demands as effectively and economically as possible. Only rarely has a new technology provided the impulse and prerequisites for an entirely new product.

After some introductory views on the characteristics of today’s process and product development, new developments in process technology are presented, grouped into preservation processes and other special processes.

The review of new food products begins by covering new trends in raw materials, ingredients and additives. Present consumer trends are then used as a basis for grouping new products and product categories.

Finally, there are some comments on ongoing and expected future developments.

Each section is followed by a brief bibliography.

New developments are listed in the appendix, with space for the reader’s own notes.
What characterizes the food process and product development of today?

Process development

Traditionally, the food industry has been fairly passive in its process development, largely leaving the initiative to the equipment and packaging manufacturers. Not infrequently, moreover, new technology has been transferred from other branches of industry rather than being developed for food processing from the outset.

The food industry's outlook on processing has always been conservative. It has been a tool with which to produce the products and the quality to meet current market demand at a profit, rather than a possible means of producing entirely new products. The main objective of technological improvements and innovations has therefore been to raise yields and improve process reliability, while lowering production costs and product quality variation on existing production lines.

There are, however, a few examples where process development has been a more direct result of product development demanding the capability to manufacture an entirely new product.

The transfer of "new" technology and "new" processes from other industries or from ongoing R&D from outside the food industry, in principle, follow one of two pathways in the form of a conscious search either for the technology to solve a given problem or for possible applications for an interesting technology which already exists. An example of the former might be drying and freezing in fluidized beds; and example of the latter might be heat processing by microwaves or short-wave infrared. Equipment and packaging companies which serve many branches of industry often function as catalysts in such technology transfer, as do applied research institutes.

Normally, product development (and marketing) determine process development demands and objectives. Once in a while, however, the process technology is the directing factor, for example when a new process makes it possible to manufacture products in an entirely new way and with new and interesting properties. Extrusion technology provides one example; high-pressure technology may be another one.

Technical developments in processing and packaging — as in the development of continuous, aseptic processing systems — are often closely inter-related with one another.

Product development

The product development of today is hectic, especially in countries like the USA, Britain and Japan, and the majority of new products also have a short life expectancy. Over 3,000 new food products were introduced on the British market during 1991, for example, most of them with an expected life cycle of less than a year. Of these "new" products, the majority required nothing more than simple modifications or additions to existing product lines.

Product development is directed by the demands and wishes expressed by marketing departments — ultimately by the demands of the market. The needs and attitudes of the consumers and shifts in trends and lifestyles play an important role. Important trends during the late 1980s which are still in vogue — as demonstrated by various consumer studies — include the following (the ranking varies somewhat from one study to the other):
• healthy, natural
• tasty
• safe
• convenient
• fresh
• environmental, ethical

Alongside all the new products, there are a number of traditional brand products for which demand remains stable, irrespective of the trend of the day. These are subject to process optimization, but only with great caution to product development.

While product development is usually the driving force behind new processes, examples of the contrary can also be found — the intense product and packaging development caused by the breakthrough of the domestic microwave oven, for instance.

What do we actually put into the notion of "newness" when it comes to processes and products? In this paper at least, new technology is taken to mean a) technology already in use in branches other than food; b) technology previously tried and discarded as impractical for foods, but which has taken on renewed interest as a result of changed circumstances; c) entirely new ideas and innovations.

The notion of a "new" product does not include simple modifications or extensions to products and product lines already on the market. It is more a matter of new product types or concepts with differing composition and properties which perhaps also cater to new consumer target groups.
New developments in food processing

Food preservation

Sterilization and pasteurization

Heat treatment
Heat processing by steam or hot water is the main sterilization method. Processing of packaged foods using HTST (High Temperature Short Time) principles for improved product quality has become feasible by reducing package thickness and optimizing the sterilization value (F-value) and cook value (C-value), which has in turn become possible as a result of better knowledge of processing principles and modern process control.

Process equipment is now being launched that permits steam processing under pressure inside partially closed containers without any brine being present. Sealing and cooling are completed under pressure in the autoclave. This method, which has previously been proposed for flame sterilization, is claimed to result in substantially improved quality and shorter processing times for vegetables.

As will be seen in the chapter on microwaves (page 19), there are already about a dozen working installations in Europe for the pasteurization or sterilization of foods in plastic trays by a combination of microwaves and hot air or steam. It has been claimed that rapid heating to sterilization temperature by microwaves promotes a more HTST-like process than that which is possible using heat conduction and convection alone.

During the 1980s, there was considerable interest in continuous sterilization of pumpable solids containing foods with aseptic packaging, as manifested by impressive R&D programmes on process and packaging systems. Almost a hundred different packaging systems were developed. A limited number of products have been launched, primarily soups and sauces, so far mostly with fairly limited success. One important reason has been the difficulty of giving both liquid and particulates the same degree of heat processing, to assure product safety without quality loss. Particulates are easily damaged mechanically by the pumping, as well as by the heat treatment (in heat exchangers) and the filling operation.

A recently “re-invented” partial solution to the problem is to heat process the solid and liquid phases separately and remix them again before the filling operation, as in the Alfa Laval Twintherm system or the Stork FSTP system (Fig 1). More lenient pumps and fillers have also been introduced.

Electrical resistance heating offers a new means of very rapid and mild heat treatment, with equally rapid heating of liquids and solids, provided electrical conductivity is about equal and in an intermediate range in which neither the necessary voltage nor the electrical current are excessively high. The Ohmic heater introduced by APV is the first commercial version of this technology in continuous processing (cooking, pasteurization and sterilization) in combination with aseptic processing. Several production lines are already said to be in commercial operation for mild aseptic sterilization of products such as pre-cooked foods (in competition with cook-chill products), dog food (packaged in Tetra Brik), cherries and strawberries, etc. Claims include notable quality advantages in terms of flavour, colour, appearance and mechanical integrity compared with previous systems based on scraped surface heat exchangers.

Microwaves and high frequency may offer viable alternatives to electrical resistance heating in the future. Tubular fixed-mode microwave applicators are already in use for
In France, two novel blanching and pasteurization processes for vegetables have recently been introduced to increase the safety and shelf life of MA-packed products. One is based on heat processing under CO₂ up to a pressure of 3 MPa, permitting blanching and pasteurization in one step at temperatures below 60°C (not suitable for green vegetables). The other process combines bulk steam blanching and pasteurization with vacuum cooling and packaging in a clean-room.

Another system for continuous pasteurization in combination with aseptic packaging is the Thermoval system, which is currently being used to extend the shelf life of liquid eggs.

Finally, a novel process claimed to be effective in reducing bacteria levels in foods uses shell freezing, followed by a thermal shock.

**Literature:**

**Additional literature:**
Varoquax, P. Recent developments in the processing of fruit and vegetables in France. The European FOOD and DRINK Review Autumn 1993.
Non-thermal
The search for milder methods of inactivating micro-organisms with better retention of sensory and nutritional properties has recently led to a number of new methods which are not based on heat processing. The working mechanism consists of damaging the cell membrane of the micro-organism, making it more permeable, and thus destroying its reproductive ability.

High pressure.
The treatment of foods under very high pressures has many potential applications in freezing technology and gel technology, for instance, but interest has focused on the possibility of inactivating bacteria and enzymes at low temperature for pasteurization and sterilization. The technology is already in commercial use in Japan for the sterilization of acid foods such as marmalade, fruit jellies, citrus juice and fruit yoghurts. Intensive R&D is under way in Europe and the USA.

The process is non-thermal in principle, although the pressure increase in itself causes a certain rise in temperature. The pressure range of interest lies between 4,000 and 6,000 kg/cm², a range which has long been used in the commercial production of quartz crystals and ceramics. For food processing, equipment is presently available only for volumes of around 50 litres for solid foods and a couple of hundred litres for liquids. It is claimed, however, that fairly high capacities can be obtained at reasonable cost by using several overlapping batch units (Fig 2). For liquids, continuous equipment is also said to be in use in Japan.

In principle, high pressure affects all reactions and structural changes where a change in volume is involved, as in the gelation of proteins or starch. The mechanisms behind the killing of micro-organisms consist of a combination of such reactions and the puncturing or permeabilization of the cell membranes. Vegetative cells are inactivated at about 3000 kg/cm² and ambient temperature, while spore inactivation requires much higher pressures (above 6000 kg/cm² in combination with a raise in temperature to 50-70°C. Certain enzymes are already inactivated at 3000 kg/cm², while others may be very difficult to inactivate at all within the pressure range which is practicable today. Moisture level is extremely important in this context.

The main advantages of high-pressure treatment are that sensory and nutritional quality are retained better than by other methods, partly because of the low temperatures used and partly because the pressure is evenly distributed throughout the food material, irrespective of its volume and shape. The processing time is short, moreover, between 2 and 30 minutes. The high pressure may also result in new functional properties (texture and consistency, etc.) which may involve advantages or disadvantages, depending on the product.

A number of combinations of high pressure and heat, electrical resistance heating, ultrasound, additives, etc., are also being studied (for "hurdle effects").

Other interesting application areas than sterilization/pasteurization include the following:
- gelatinization of starches and proteins
- tempering of chocolate
- blanching of vegetables
- tenderization of meats
- coagulation of fish and meat minces
- surface coating and agglomerizing
- freezing and thawing

An interesting recent finding at more moderate pressures is that heat inactivation of bacteria can be considerably accelerated in the presence of CO₂ and N₂O at pressures below 6 bars, the effect increasing with pressure.
Fig. 2. Layout of a high-pressure processing plant. (Ref. 8)

Literature:


Additional literature:


Intensive light pulses.

A method patented by the Maxwell labs and developed by an industry group for the US Department of Defense is based on the charging of a condensator and discharging it in milliseconds over a flashlight, producing light flashes of extremely high power (in the order of 1013 watt!). As a rule, just one flash will be sufficient for the surface sterilization of a packaging material or food.

For the sterilization of food surfaces, the UV content of the flash is filtered off. What probably happens is that there is an extremely rapid surface heat shock, despite the fact that no temperature rise can be measured. For the surface sterilization of packaging material, the UV content of the light is about 30%, which means that one is in fact using a combination of photothermic and photochemical sterilization. Commercial application is said to be imminent (Fig 3).
**High electric field pulses.**

Pulsed electric fields (PEF) for the sterilization of liquid or pumpable foods without solids have been the subject of parallel developments in the USA and Germany. The Krupp Elcrack process is in commercial use for the treatment of meat and fish offals for fat separation, while food applications are still in the laboratory stage.

Development work in the USA is being supported by large grants from the Department of Defense.

The principle is that liquid foods are passed through a narrow channel over which high voltage micro- or millisecond pulses are passed, discharging an electrical condensor over two electrodes. At field strengths in the order of 15-30 kV/cm the micro-organisms are so effected by voltage differences over their membranes that the permeability increases to allow free passage of cell contents, thus killing the cells. The electrical pulses lead to some heat generation that can easily be removed by water cooling. As in the case of high-pressure sterilization, sensory and nutritional properties are very little affected, and at least some enzyme systems are not inactivated.

So far, the equipment has not been successfully scaled up to pilot and commercial size, but there is hope that some time in the future the process will be applicable for the "cold" sterilization of not only liquid but also of solid foods.

**Oscillating magnetic fields.**

Another patented method is also based on charging a condensor and momentarily discharging it in order to sterilize liquid foods. In this case, however, it is discharged across an induction coil which is helium-cooled for superconductivity. The resulting magnetic field of between 5 and 50 tesla is believed to release so much energy that covalent bonds are broken and micro-organisms killed in milliseconds, without any temperature rise. There is, however, some doubt as to whether equipment which generates such enormous magnetic fields would be manageable in a food production plant. So far reported inactivation has been limited to two log cycles.

**Ionizing radiation.**

This technology has been very thoroughly researched and equipment has long been available for the processing of foods on an industrial scale. It is permitted in several countries today for food pasteurization, but the development of applications is slow because of negative attitudes among the general public. Should consumer resistance to its application subside in the future, of which there are present indications in the USA, the preferred source of energy is likely to be electron accelerators rather than radioactive isotopes.

**Hyperbaric oxygen.**

In 1992, Food Technology Intelligence Inc. in the USA presented a process for the pasteurization of foods by active oxygen. First, oxygen already dissolved in the food is
removed under vacuum. Then the food is saturated with active oxygen under pressure and then vacuumized, after which the vacuum is broken using inert gas. It has been claimed that this process is particularly suitable for products where heat treatment cannot be used, such as raw egg products.

**Preservation by combination processes**
Various modified recipes (salt, sugar, pH, aw, etc.) and antimicrobial additives, preferably of "natural" origin, can be added to the battery of novel thermal and non-thermal methods of inactivating micro-organisms. An intensive search for such substances is under way and can be exemplified by new bacteriocines (similar to Nisin and Tylosin), substances of poly-cationic character such as chitosan and antimicrobial enzymes such as lysozyme, each with a fairly limited range of activity.

With ever louder demands being voiced by consumers for "natural" foods with a minimum of processing, the search for combination methods of preservation to minimize quality change, while retaining food safety is intensifying. A "hurdle effect" is generally recognized, implying that a certain synergistic effect is to be expected when combining "hurdles" to combat microbial development.

**Literature:**

**Additional literature:**
Castro, A. J. et al. Microbial inactivation by pulsed electric field. A review. J. Food Processing and Preservation, 17 (1), 1993, 47-73.
Leistner, L. Food preservation by combined methods. Food Research International 25, 1992, 151-158.
Drying and extrusion

Drying

Drying with microwave and high-frequency heating in combination with air or vacuum drying and drying by IR (infrared) are also dealt with in separate chapters.

Accelerated air drying can be achieved also by using the Jet-Sweep technique and various new versions of fluidized beds and combinations with spray drying, for example.

Air impingement, or Jet-Sweep, by which air is blown through orifices towards the food material at velocities towards 20 m/s or more, breaks up the layer of laminar flow near the food surface and thus strongly increases heat and mass transfer. This technique is best suited for drying thin or single layers of food pieces (Fig 4).

Some new versions of the fluidized bed are the vibrating bed, for “sticky” materials, the “sprouted bed” for liquids and the “toroidal bed”. It is claimed that a combination of spray drying and sprouted bed will result in an evaporative capacity which is 5-10 times as high as in spray drying alone. A series of fluidized beds is claimed to be seven times more effective than conventional drying methods.

For foods sensitive to oxidation, drying in an inert atmosphere may be of interest (CO₂, N₂ elimination of pollution, while also having a sterilizing effect. The prospects are also claimed to be promising for drying fish mince, citrus fruits and apple sauce.

Zwaag AG in Switzerland have developed the SDT-process (Super Dry Technology) for drying slices of fruits with a combination of air drying and a series of pressure-and vacuum steps.

The ILV-Institute in Munich has developed the MIVACO process for drying piece shaped foods with vacuum air convection at 100-200 mbar in combination with microwaves.

Another combination method, for baking, uses air impingement and microwaves and reduces the baking time for loaves by 75% compared with conventional ovens. It is suggested that this technique might make small, local bakeries competitive with large, centralized ones.

In Japan, Akahoshi has reported successful pilot work on the drying of slices of potato and chicken meat, with a combination of cold air and microwaves, with resultant quality close to that of freeze-dried material.

The CSIRO in Australia has developed freeze drying of foods at atmospheric pressure, using new absorbents for the water vapour. Quality is claimed to be equal to that obtained by freeze drying, although the drying time is much longer.
**Osmotic preconcentration of solid foods for dehydration** (or freezing or canning) is gaining new attention in R&D, although the commercial application is as yet unclear.

Basic knowledge of the dehydration process has improved, along with models of heat and mass transfer, allowing them to be utilized for process optimization combined with better methods of process control. One good example consists of the development of **HTST drying of pasta**. This technique promises to reduce drying times for pasta from the present 7-8 hours to a couple of hours, resulting in improved quality in sensory and hygienic terms alike. The advantages envisaged for combined hot-air and microwave drying may thus be matched or exceeded.

Microwave technology is of greater interest in the finish drying and volume expansion of starch films and potato slices for snacks products, since it is founded on the unique properties of the microwaves.

---

**Extrusion**

New knowledge in the field of twin-screw extrusion has been developing strongly since the 1980s. This has led to technical improvements and new methods of process simulation and control (fuzzy logic, neural networks). Process equipment has become increasingly versatile and flexible. At the same time, the product range has widened considerably to cover much more than snacks, petfoods and Danish biscuits. The general direction of product development is either to duplicate or improve existing products using cheaper and more effective techniques or to develop entirely new products.

Today's extruders can mix, shear, cook, process and shape a multitude of products of different shapes (also 3-dimensional), texture and composition. Some examples of new technical possibilities include **co-extrusion** (e.g. the outer shell of cereals with a soft stuffing), **co-expansion** (two extruders with a common die) and **extruders with split flow** for separate modification of the pre-die flows.

Twin-screw extrusion of food mixes with up to 80% water content using long cooling nozzles offers new possibilities for emulsifying fats, sterilizing spices, etc., for microparticulating proteins and restructuring and shaping meat and fish mince.

An extruded crab analogue on a surimi base with a fine fibre structure is already on the market in Japan. Cheese analogues and fat analogues (microparticulated β-lactoglobulin), encapsulation in protein gel and thin, edible protein films are other product possibilities under development for extrusion at high water content. The **modification of raw materials for industrial use**, such as extrusion as a pre-treatment for pressing oil from soybeans, extrusion of malt for producing beer with improved aroma and for modifying starches is of particular interest.

The combination of high shear and temperature can achieve a **real bactericidal effect and inactivate enzymes**. The Danish Technological
Institute sterilized black pepper and paprika by extrusion down to below 10000 microorganisms/g, without any noticeable loss of flavour. The process has been commercialized by Lucas Ingredients (Masterspice), who mix in cereals for sufficient shear force and temperature rise. Good results have also been reported for the sterilization and “deodorization” of crushed cocoa beans for chocolate production.

An American patent describes a process in which supercritical CO₂ is injected under pressure in ready “cooked” dough in an extruder, dissolving in the water phase. After extrusion, the CO₂ is liberated under expansion to the volume desired. The technique permits up to 35% moisture content in the dough and gives an extrudate with a smooth surface, more uniform microstructure and lower water solubility index.

One type of low-pressure extrusion is represented by the Japanese Twin-equipment that is increasingly often being installed for the manufacture of various filled products, such as German Knödel, Russian pastry, croustades, stuffed potato dumplings and pies, etc.

**Literature:**


**Additional literature:**


**Deep freezing**

Developments in freezing technology in recent years have been characterized by mechanical and process control improvements and by the tailoring of freezers and combination freezers to specific needs. Examples of the latter include Frigoscandia’s Crust o Freeze and L’Air Liquid’s Crust Flow, combining shell-freezing of wet or sticky foods using liquid nitrogen followed by final freezing on a conveyor freezer or in a fluidized bed.

The rate of freezing in a fluidized bed has been raised considerably in experiments using a combination of cold air jets through special nozzles, giving extremely high air velocity while modifying the product flow through the bed appropriately.

It has been claimed that the cost of cryogenic freezing can be substantially reduced in a new system which is based on on-site production of liquid air.

More fundamental research in freezing technology, i.e. research that might lead to more radical improvement in product quality...
and storage stability, especially for products that do not freeze well using the techniques currently available, has however been quite limited. Such research is now becoming increasingly active and is uncovering a number of interesting new possibilities based on control of ice crystallization and growth and “manipulation” of the phase states of frozen water.

Ice crystallization can be affected by the use of Ice Nucleating Agents (INA). It is common knowledge that micro-organisms like *Psuedomonas syringae* are being used as an additive in the water feeding artificial snow machines on the ski slopes. In principle, the mechanism is that cell membrane structures act as starting points for ice nucleation and crystallization, which can then be initiated at a higher temperature and a lower degree of supercooling than normal. Many have believed that the addition of INA, or the transfer of the gene responsible for the ice nucleating effect, would make it possible to raise the freezing temperature and rate of freezing of foods, with positive effects on quality and economy. So far this hope has not been convincingly substantiated. It is quite clear, however, that INA addition has given positive results in reported research on freeze concentration, lowering the degree of supercooling and leading to larger and more easily separated ice crystals.

Ice crystallization can also be initiated at lower degree of supercooling by treatment with ultrasound according to a British patent by Cell System, who claim to have obtained considerable quality improvements in difficult-to-freeze foods by individually optimizing the time-temperature programming for each particular food, in combination with ultrasound exposure. There is plenty of evidence from other research that proper time-temperature programming of cooling, freezing and re-heating may result in quality improvements. The positive effect of ultrasound treatment in this context has, however, not been convincingly demonstrated so far.

**Fig. 6. Phase diagram for the freezing of a water solution.** (Ref. 26)
Great expectations have also been raised by the application of antifreeze proteins (AFP) for blocking undesirable nucleation and ice-crystal growth.

Promising results have been reported on the transfer of the antifreeze gene from an Arctic fish to tomatoes and yeast cells, and from applying purified AFP as an additive in ice cream to prevent ice-crystal growth and grainy texture (Fig 5).

*High-pressure technology* offers additional means of controlling the freezing and thawing of foods. At a pressure of 2000 kg/cm² the freezing point of foods lies at around -20°C. This means that foods can be "frozen-stored" without any actual ice crystallization. When lowering the pressure under well-controlled conditions, the food will freeze very rapidly. Since the pressure is even throughout the food volume, the freezing rate will be the same in the food centre as well as at the surface — which can offer unique possibilities compared with cryogenic methods. This has been shown in experiments on the freezing of tofu in Japan. Correspondingly, it should be possible to thaw the frozen food with an even temperature rise throughout the food sample.

"Glassy state" technology. When freezing foods, an increasing proportion of the freezeable water crystallizes as ice as temperature falls, until it approaches the eutectic temperature. At a certain temperature, Tg', a phase change occurs in the still unfrozen phase into an amorphous or glassy state. In this state, diffusion and reaction rates are very restricted because of the dense structure, and thus the storage life should be considerably increased (Fig 6).

Unfortunately, for most foods Tg' lies below commercial storage temperatures and considerable research efforts are under way to raise Tg' by changes in composition without negatively affecting quality. For certain foods, such as bakery products and confectioneries with low water content and high carbohydrate content, Tg' may already be high, sometimes even above room temperature. Using extremely high freezing rates it may be possible, at least in theory, to go directly into the glassy state region even from high levels of unfrozen water.

**Literature:**


**Additional literature:**

Recent investigations have shown that quality retention in fish, especially fatty species, can be considerably improved by lowering storage temperatures from those in normal commercial practice, -20 to -30°C, down to -40 to -60°C, which is known as “Super-freezing”. In Japan, tuna fish may be stored at as low as -60 to -70°C commercially. The additional investment and storage costs may be economically feasible for special high-quality products. Glassy state conditions would probably be part of the explanation for the improved quality retention.

A recently introduced Japanese process for the thawing of meat and fish at -3°C under a high voltage electrostatic field will probably have to be classed as humbug, although an electrostatic field has been shown to give a slight increase in the heat transfer coefficient at the air-food interface.

Over the last five-year period or so, research interest in osmotic concentration for dehydro-freezing has reawakened, although no commercial application is known as yet. Several groups have demonstrated that fruits, berries and vegetables that are partially dehydrated by osmosis in concentrated solutions of sugars or salts prior to freezing will show some improvement in quality and shelf life.

The reduced water activity resulting from the combination of water loss and sugar uptake is likely to raise Tg' considerably, which should have a positive impact on shelf life.

---

**Chilling — Cold storage**

Over the past few years, chilled foods have experienced very rapid development on the European markets, especially in Britain. A major part of this development concerns MA-technology (packaging in Modified Atmosphere), using headspace volumes, gas compositions and packaging properties adapted to the specific product. The thing that is new from a technical point of view is the tailoring of a combination of preservative measures, from recipe and pre-treatment (pH, aw, additives), choice of packaging (material properties, headspace composition), pasteurization (by heat, high pressure, radiation) to chilled storage conditions (time-temperature). Such combinations of protective measures create a series of hurdles against microbial growth, hopefully with synergistic effects. As a system, this technology has been termed “hurdle technology”.

One old technology made new is called “super chilling” or “deep chilling”. This signifies rapid cooling to and storage within a temperature range of between 0°C and -5°C. For the majority of foods, good temperature control is a prerequisite, in order to avoid any appreciable formation and growth of ice crystals. In the USA, chilled chicken is distributed at -2°C in “Crystal Pack”, and good results have been reported in the literature for a number of foods. There is, however, hardly any cold chain available for super chilling today and it is hard to say if the costs involved in creating such a distribution chain could be justified by the expected doubling or trebling of high-quality life.

A special case of superchilling is the Japanese “controlled freezing point” technology. The concept means that the optimal cooling rate and cold storage temperature (often equivalent to the lowest temperature where no ice formation occurs) is determined for each food material. It is claimed that temperature fluctuations can be kept within 0.5°C, resulting in a shelf life of several months. It must, however, be considered doubtful whether this
can really be achieved in a practical distribution chain at a reasonable cost.

In institutional catering, different modifications of cook-chill systems (as an alternative to cook-freeze) are being used to rationalize food production, especially in hospital kitchens. This technique has come into increasing use in catering and, recently, also on the consumer market. In principle, the food is cooked, packed under vacuum or modified atmosphere (MA) and rapidly chilled, with or without a preceding pasteurization step, depending on the shelf life desired.

A new variation on this theme consists of the "sous vide" system, which was first introduced by a French gourmet chef in the late 1970s. The principle consists of preparing the food inside a closed vacuum pack under rigorously controlled time and temperature conditions, followed by rapid cooling and brief storage at between 0°C and +3°C before reheating inside the closed vacuum pack. For products like meat and fish, this technique is claimed to give markedly higher quality than is possible with cook-chill. On the other hand, much more stringent demand must be imposed on the entire process. It has been considered necessary to introduce some form of HACCP-system (Hazard Analysis Critical Control Point). Sovico, a company in Paris which prepares both cook chill and sous-vide meals for Paris schools, has adopted a very rigorous HACCP-based control system which also employs clean-room technology. This is probably the first time this technology has been adopted by a food company.

A couple of systems for liquid foods, combining heat pasteurization and an aseptic system, were demonstrated at the DGL Food Tec-fair in Frankfurt in November 1992. Using a system of this sort, shelf life can be prolonged to 1-2 months. (Alfa Laval’s "Thermoval" and Elopac’s "Protected Freshness").

According to a report by Food Technology Intelligence Inc., a "thermal shock" by combining shell freezing and rapid thawing with steam, will provide a sharp reduction in the microflora in vacuum-packed, chilled luncheon meats.

<table>
<thead>
<tr>
<th>Literature:</th>
</tr>
</thead>
</table>

<table>
<thead>
<tr>
<th>Additional literature:</th>
</tr>
</thead>
</table>
Food preparation

There are few really new techniques in industrial food preparation. Double-sided or single-sided grilling on Teflon belts, with or without microwave, continuous hot-air/steam convection cookers, combined microwave and hot air/steam cookers — all these techniques have been in use for a long time.

Infra-red grilling (and drying) is old technology with regard to long wave radiators (Calrods) and ceramic, gas heated radiators. Short-wave and intermediate wave IR radiators, with their superior speed and flexibility, have also been introduced for industrial grilling, but the application cannot as yet be regarded as finally developed.

The Jet-Sweep (air impingement) technology has been in use for several years for baking and dehydration of foods. Today, it is also being used commercially for the grilling and cooking of foods with hot air, steam or combinations of the two. (See also separate section on Jet-Sweep on page 10). The very rapid heat transfer which is made possible by this technique makes it an alternative to deep fat frying, markedly reducing the fat content without impeding sensory quality. This is taken advantage of in the USA, both in institutional equipment and in food vending machines (in combination with microwaves).

Scraped surface heat exchangers (SSHE) have long been in use for the cooking of pumpable foods such as stews and porridge. They are now facing competition from spiral tube heat exchangers, electrical resistance heating, HF and microwave heating.

Electrical resistance heating at mains frequency, between metal or carbon electrodes, was test marketed in Sweden in the 1970s for the cooking of potatoes in restaurant kitchens. In Israel the technique was developed for industrial blanching and pre-cooking of vegetables. Recently, it has been further developed by the APV company and launched as the “Ohmic heater”. This is already being used industrially for the cooking and sterilization of pumpable foods containing solid pieces of up to two cm in diameter.

As already indicated under the heading of pasteurization and sterilization, microwave heating in tubular “single mode” or “fixed mode” applicators may develop into a real challenge to the resistance heater. Successful development work has also been carried out in Denmark and Britain on the heat processing of sausages and minced meat by high-frequency heating (HF) at 27 MHz in tubular heaters of up to 30 cm diameter. In Britain, a combination of HF and hot air has also been in use for the continuous grilling of chicken.

Induction hotplates, which apply a strong rotating magnetic field for generating heat directly in metal cooking utensils, have been in use in Japan and France for several years. The rotating magnetic field creates eddy currents in magnetic metals and the temperature development can be precisely controlled so that the temperature can be maintained a few degrees below the boiling point of water, for example.

For industrial heating purposes, the technique is being used in Japan for the heating of deep fat fryers. It has been claimed that advantages include extended frying-oil life, higher product quality and increased safety and hygiene. The technique could possibly also be applied for heating metal-coated spheres in a fluidized bed for contact grilling of food particles. In France, several new techniques for large-scale institutional processing of foods have been proposed recently; the cooking of
pouched or unpacked food by vacuum steam, and the processing of CO2-packed foods or processing of unpacked food under pressurized CO2 in combination with aseptic packaging or sealing. It has been claimed that processing under CO2 will result in better quality retention and extended shelf life.

Treatment using very high pressures (See section on high-pressure technology) can gelatinize proteins and starches in a similar way as in heat processing at atmospheric pressure, but with far less change in food colour and flavour. In other words, it is possible to “cook” fish or egg by high pressure instead of by heat.

Literature:


Additional literature:

Other special processes

Microwaves

Microwave technology as such is well known and needs no general presentation here. It is a technique for very rapid in-depth heating that has been described as new and very promising for almost half a century and which has achieved its real breakthrough in domestic food preparation.

What is new today is that components, processing equipment and process control devices have been improved and further developed, and that reliability has reached the level required in the food industry. At the same time, the need in industry for continuous, fast processes has increased. As a result, old and once promising applications have been resurrected and, finally, begun to mature into practical use, when the particular advantages in processing and product quality can be economically justified. Processing economy will, as a rule, require that microwaves are combined with cheaper, conventional heating methods (hot air, steam, IR) and the microwaves reserved for the heating step in which the unique properties of microwaves can best be utilized.

The table below lists some successful industrial applications and pilot plant applications of current interest.

Typical advantages inherent in microwave heating are:

- Much reduced processing time, up to a power of ten
- Much improved in-depth heating

In order to really gain the benefit of these advantages, it will as a rule be necessary to have tailored processing equipment and to set stringent requirements in terms of raw material composition and quality, geometry, packaging and temperature evenness.

The following developments are considered to be of particular interest to the food industry:

<table>
<thead>
<tr>
<th>Food applications of microwaves, claimed to be successful</th>
<th>Product</th>
</tr>
</thead>
<tbody>
<tr>
<td>Application</td>
<td></td>
</tr>
<tr>
<td>Tempering, thawing, Melting, rendering, Blanching, Drying, Expansion, puffing, Baking, Roasting, Insect desinfestation, Preconditioning, Cooking, coagulation, Pasteurization, sterilization</td>
<td>Meat, fish, butter, berries, Fat, chocolate, Corn on the cob, potato, etc., Pasta, onions, juice, Potato chips, starch-based snacks, Dough raising, finish baking, Coffee and cocoa beans, peanuts, Cereals, müsli, Fish feed, grain, Beef, chicken, sliced bacon, fish, Bread, pre-cooked foods, yoghurt</td>
</tr>
</tbody>
</table>

More than a dozen processing lines for the pasteurization (and sterilization) of portion packed meals, produced by 5-6 equipment manufacturers, have gone into operation in Europe. The foods of prime interest have been those with reduced water activity, such as pasta dishes and breads, but even patés and other pre-cooked foods have been involved. It has become possible to reduce the tendency towards corner and edge overheating by various means, such as by
combining the frequencies of 915 and 2450 MHz and by taking advantage of the latest available research findings about mode types and field distribution in microwave cavities. All processing lines are based on some kind of combination with conventional techniques — hot air, water, steam or IR (Fig 7).

For the cooking and pasteurization of solids containing pumpable foods, new findings at SIK indicate that tubular single mode applicators with controlled field distribution (fixed mode) may develop into a very strong competitor to electrical resistance heating for the same purpose. In such an applicator, field distribution can be adapted to the velocity profile in order to achieve as even rate of temperature rise as possible all the way from tube wall to tube centre.

The drying of separate pieces of foods is without doubt the most promising application area for microwaves. By suitable combinations with hot air, for example, water transport towards the surface can be controlled in balance with surface evaporation, for accelerated dehydration with less volume change.

In microwave drying at low moisture levels, the inner parts of the product can be heated so rapidly that almost “instant” evaporation will result in volume expansion or puffing. Microwave heating will also level out temperature and moisture level through selective absorption during the final stages of drying. Usually, it can also be successfully combined with most other dehydration methods, such as vacuum drying of juice concentrates or drying in a fluidized bed. Finish drying with microwaves under strong volume expansion has recently been introduced by APV as an industrial process for the production of a new type of fat-free snacks. In the process, thinly extruded starch films are formed and expanded by microwaves of very high field density. A commercial plant of about 300 kW should already have been installed at an American snacks manufacturer. A similar approach is used in a 200 kW microwave plant of other manufacture for producing fat-free or low-fat potato chips.

The largest commercial food application so far is for the tempering (to temperatures just below the ice melting temperature) of frozen meat, fruits and berries in regularly-shaped heat-insulated packages of moderate thickness. In the future, a combination of air tempering at low temperature and low microwave field strength may become interesting for reducing the time required for tempering of whole and half carcasses, reducing tempering times from 2-3 days to 5-6 hours.

High-frequency heating (HF)

During the past 4-5 years, the heating of foods at a lower frequency of 27 MHz has experienced something of a come-back. New research findings have broadened fundamental knowledge and led to improved processing equipment. Mathematical models and computer simulation programs have been developed both for the calculation of optimal generator-applicator combinations and heat development in foods during HF heating. The basic technology is simpler than for microwaves and permits considerably larger dimensions in the material to be heated. At the same time, however, HF equipment is more
bulky, less flexible and frequency-stable than for microwave equipment. As for microwaves, HF processing must, for reasons of economy, be combined with conventional techniques. The ARFA-process (Air Radio Frequency Assisted) either combines HF with hot air jets, or sucks hot air through the drying bed for granular material.

The most common industrial food applications of HF are finish drying of extruded pet foods, post baking of biscuits (the probably largest food application of dielectric heating overall), the baking of bread and the tempering and thawing of frozen foods.

In Italy, a pasteurization process for packaged food products has been developed in pilot plant scale, using a combination of high frequency and hot air.

Recently, very promising results have also been reported for the coagulation and pasteurization of sausage and the grilling of chicken (ARFA). (Previously, several other kinds of continuous process have been launched for the production of sausages in a “natural” skin, such as the Swift process for high-frequency coagulation of a collagen surface film. APV Baker recently presented their “Sinteromatic” process, in which sausage mince is cast in moulds of sintered metal at very high temperature, followed by surface coagulation by weak acetic acid which is injected into the mould.)

Literature:

49. Ohlsson, T. Microwave Processing in the Food Industry. European Food & Drink Review, Spring 1991, 7-.

Additional literature:

Pavan, G., Zanetti, E. Pasteurization of packaged fresh food products with the combined technology of radio-frequency and hot air (In Italian). Technica molitoria, April 1993, 273-284.
Electrical resistance heating

Electrical resistance heating was already being considered in the 1880s. The principle is very simple, in that the food material is placed in or pumped through a space between two electrodes, and alternating current from the mains is passed through.

However, it was not until the 1970s that the method found limited industrial application for HTST-pasteurization of milk and ice cream mixes, etc. A serious attempt was made in Sweden to develop equipment for boiling potatoes in restaurants by electrical resistance heating, reducing cooking times to about 10 minutes. In Israel, the technique was used on a pilot scale for the blanching of vegetables. In the 1980s, the EA Technology institute in Britain completed a comprehensive R&D programme on electrical resistance heating, resulting in a patented process. This was followed by fundamental work at research institutes and engineering development by APV. The result was the Ohmic heater for on-line heat processing of pumpable foods, containing particulates of up to two cm diameter.

Primary applications include continuous cooking, pasteurization and sterilization in combination with aseptic packaging. The main advantages being claimed include superior particle integrity, even temperature distribution in liquids and solids (volumetric heating), very rapid temperature rise and absence of overheating at the tube walls.

With the present level of knowledge on electrode materials and reactions and on how the distribution of electrical field and current depends on different process and raw-material variables, the outlook for developing new applications should be good. Rates of heating can be expected which are at least comparable with those obtained using microwave heating, with better in-depth heating and superior energy efficiency. Available mathematical models and computer simulation programmes will facilitate process optimization.

This process should definitely have a future in industrial food processing. A dozen installations for pasteurization and sterilization are already claimed to be in use.

Limiting factors include electrode design and reactions, and the magnitude and variation of electrical conductivity in food particles and liquid (very low conductivity will require excessive voltage, and very high conductivity will result in excessive electrical currents). For vegetables, some kind of preliminary blanching may be required prior to resistance heating. Electrical fields can also cause electro-osmosis and increased leakage of cell liquids. Finally, for viscous foods, the flow rate near tube walls will be considerably less than in the tube centre, which may cause a temperature differential in between.

![Fig. 8. Flow chart for an Ohmic processing line. (Ref. 55)](image)

**Literature:**

Other processes based on electromagnetic fields

Exposure of juices to a magnetic field prior to concentration has been shown to accelerate cloud sedimentation and rate of water removal.

Similarly, dielectric or electrical resistance heating has been observed to enhance diffusion during extraction and to improve yield during the pressing of oil from seeds.

Exposure of bread dough for 20 minutes to an electrostatic field of 50 kV resulted in significantly lowered water loss and prolonged softness (less staling) after baking.

The positive effects claimed from electrostatic field treatment in some US bakeries, would probably, if real, be due to the proven positive effect from such fields on the surface heat transfer coefficient.

---

**Literature:**


Malcchev, E. M. *et al.* Effect of the magnetic field on the rate of moisture removal during the concentration of cloudy juices. Flüss. Obst, 1992, 59 (9), 537-539.

---

Infrared (IR) heating

In IR heating, heat is transferred by radiation, the wavelength of which is determined by the temperature of the radiating body — the higher the temperature, the shorter the wavelength. Present interest in industrial heating applications centres on shortwave IR (wavelengths of around 1 μm) and intermediate IR (around 10 μm), since these wavelengths make it possible to start up and reach working temperature in seconds, while also offering rapid transfer of high amounts of energy and excellent process control. In some food materials, moreover, short-wave IR demonstrates a penetration depth of up to 5 mm.

The best-known industrial applications (for non-food uses) are in the rapid drying of automobile paint and the drying of paper in the pulp and paper industry. For paper drying, IR has superseded microwaves because it offers superior process control and economy.

IR technology has long been under-estimated in the food field, despite its great potential. Its process fundamentals and application possibilities have been thoroughly studied at SIK in Sweden, and models and computer process simulation have been developed. IR is highly adaptable for combination with other forms of heating such as microwaves and high frequency. Efficiency is high, and heating rates comparable with those obtained with microwave heating are possible for thinner food material.

Since energy is transferred directly into the product surface, the surrounding air temperature can be kept moderate, requiring less heat insulation and thinner materials in processing tunnels. Rapid start-up and cool-down will be of particular importance in conjunction with unscheduled production stops.

IR heating should be particularly useful for continuous baking, drying and grilling, as well as for surface pasteurization. One negative aspect may be the need to illuminate or irradiate all product surfaces evenly, especially in foods of irregular shape, and to protect the food from possible breakage of quartz tubes.

The use of IR technology in the food industry is quite limited today, and the available equipment is not optimized for the various heating operations along processing lines for baking, drying and chocolate production, etc. Its application is certain to grow, as food equipment manufacturers begin to realize its full potential.
Ultrasound

Ultrasound at high energy levels (up to 10 w/cm²) and frequencies above those which can be perceived by the human ear has been attracting interest for a number of applications over the last few years. As a rule, the mechanism involved is considered to be cavitation and the substantial energy released when cavitation bubbles burst. In these bubbles and their interfaces with surrounding materials, very high pressures, electrical potentials and temperatures of several hundred degrees Celsius can momentarily occur during the formation of free radicals. This may then lead to both chemical and physical changes (for better or for worse) that can be put to good advantage for different purposes.

Oxidation reactions and enzymatic reactions can thus be accelerated (for rapid ageing of wine or whisky or tenderizing meat, for example). Catalytic reactions can be accelerated, as in the hydration of fats. Ultrasound has also been shown to induce the crystallization of ice, fat and sugar, etc., and to lower polymer viscosity (to ease pumping). Furthermore, it can facilitate dewatering and drying of foods, in the latter case by increasing heat-and mass transfer by up to 40-60%, so that dehydration can be carried out at a lower temperature. It has also been claimed that ultrasound achieves good results in the stabilization of emulsions, degassing of beer and phase separation.
According to a British patent application (2:261:807), ultrasound can be applied to thaw frozen blocks of food in a water bath, while a European patent application (0:543:628 A1) advocates its use for cutting foodstuffs.

A recent German publication claims successful sterilization of moistened spices using a combination of ultrasound and microwaves. According to Schramm, high power levels of ultrasound at 20 kHz have a poor sterilization effect in liquids, while low power levels of ultrasound in the MHz frequency range demonstrate a clear bactericidal effect. A probable mechanism is that cavitation waves cause the cell membranes of bacteria to collapse. The greatest potential in food applications for high-frequency ultrasonics (near microwave frequency) are, according to Shukla: phase transition, protein microparticulation, polymerization and depolymerization and the production of stable emulsions.

Membrane technology

Membrane filtration by microfiltration (MF), ultrafiltration (UF) and reverse osmosis (RO) has become a standard operation in the food industry for the concentration, fractionation, purification and cold sterilization of liquid foods, especially in the dairy industry. Milk and whey, for example, are concentrated by membrane technology in the manufacture of both traditional and novel products (such as fruit juices and feta cheese).

The main advantages over other separation techniques, according to Cuperus and Nijhuis, are that membranes:

- help to separate molecules and micro-organisms
- minimize thermal damage of products (and micro-organisms)
- require only moderate energy consumption

Interesting new applications include the reduction of alcohol content in beer and wine and the extraction of natural substances, such as colours and aroma substances, for industrial use. “Pervaporation” is a new technique, by which the permeate (filtrate) directly evaporates on the other side of the membrane, followed by condensation in a low temperature condensor. Aroma distillates can, by pervaporation, be concentrated by up to a hundredfold at low temperature.

In electrodialysis (ED), charged membranes are used to separate molecules or ions in an electric field on the basis of differences in charge and transport velocity through the membrane. A current application example is the desalination of whey for use in ice cream, bread, sauces and baby foods.

The trend today is for more specialized membranes to be tailored to one particular process and even one particular product, requiring close co-operation between membrane developers and users. In the future development of membrane processing, we will

### Literature:


### Additional literature:

Shukla, T. P. Microwave ultrasonics in food processing. Cereal Foods World, 37 (4), 1992, 332-
be seeing new membrane materials, such as ceramic materials that can withstand high temperatures and organic solvents and that can work over a wide pH range.

since its supercritical pressure lies little above ambient temperature and it is fully acceptable in direct contact with foods.

Lately, SE is also gaining ground in the extraction of aroma substances from spices, hops (for beer production) and pigments from citrus peel.

When it comes to spice extracts based on SE, opinions vary somewhat with regard to their deviation in aroma profile from the natural spice, from no difference to a certain deviation.

Although much has been done to optimize SE, it seems unlikely that the expense involved will permit its application in low-cost products in the foreseeable future, despite the optimistic articles that appear now and then on its use for defatting potato chips, beef, dairy products and eggs, etc.

Another interesting application of supercritical liquids is as a medium for enzymatic reactions, for example, to prepare “tailored” lipids.

---

**Supercritical extraction (SE)**

The extraction of foods by supercritical carbon dioxide was first heard of in food circles as a method for decaffeinating coffee beans. A couple of commercial installations have been in operation for several years, competing with cheaper conventional techniques. In SE, the solubility of different food components can easily be altered by changing pressure, temperature and the composition of the supercritical gas being used.

For food materials, carbon dioxide is especially interesting as an extraction medium,

---

**Literature:**


71. Hierio, M. T. G., Santa-Maria, G. Food Chem. 92, 45 (3), 189-


“Traditional” biotechnology includes selective breeding, complemented more recently by tissue and cell culture, somaclonal variation and undirected mutagenesis, as well as fermentation (beer, wine, cheese, salami) and enzyme processing.

Enzymes, both natural and “tailored” by genetic engineering, are enjoying broader application in the food industry in the production of flavours and control of colour, texture, appearance and nutritional value. Their use as processing aids and in the development of new products and ingredients, as well as in overcoming process limitations and as substitutes for chemical additives, is likely to increase considerably in the future.

Some examples include genetically engineered chymosine as a substitute for rennet in cheese production, the production of corn syrup on-line with bound enzymes, the use of lipases to modify the physiological properties of lipids, lactase for production of milk low in lactose and the use of lactoperoxidase, lysozyme and lactoferrine as preservatives.

The transfer of an antifreeze gene from Arctic fish to other fish species and to tomato was mentioned in the section on deep freezing. Additional examples are given on page 29 of what modern biotechnology can achieve in genetic engineering and antisense technology to inactivate specific genes.

Fermentation, a process that dates back thousands of years, is undergoing steady development from craftsmanship into engineering technology, as exemplified by solid state fermentation of vegetables and enzymatical decomposition of carrots into juices. Solid state fermentation with a starter culture is claimed to be a potential substitute for the blanching of vegetables. The nitrate content of vegetables can be reduced prior to fermentation with the aid of certain bacteria.

In the beer industry, a continuous process has been reported for the production of alcohol-free beer, using yeast immobilised on sintered glass.

Literature:
New food products

Each year, an immense number of new products are launched all over the world, the majority of which are simply additions of new sizes and packages, etc. to existing product lines. According to Campden Food and Drink Research Association, not less than 3,233 “new” products were introduced on the market in Britain during 1991, the corresponding figure for the USA in 1990 being 3,477.

The objective of this chapter is not to attempt to present any comprehensive picture of all this product development, but rather to highlight developments that involve new or substantially modified (improved) raw materials, product lines or individual products. Governing factors for such development are consumer attitudes and consumption trends that developed during the 1980s and which are likely to dominate for many years to come. It seems reasonable, therefore, to classify new product development in terms of these trends and attitudes:

- Fresh, natural
- Quality and value for money
- Health, nutrition, safety
- Convenience

Literature:

Raw materials, ingredients and additives

If product development and production are to succeed better in meeting the needs, demands and attitudes inherent in these trends, continued development will also be necessary when it comes to raw materials, ingredients and additives. Some examples of interesting developments in these areas are given below:

Foods produced by biotechnology/gene technology

The extension of traditional genetics to modern genetic engineering or gene “manipulation” to transfer hereditary characters, independently of species and relationship, signifies an entirely novel and very rapid means of developing raw materials with “tailored” properties. Whether this technology will be a success or not will depend on how well it is presented to the general public and the authorities. This has evidently been done well enough in the USA, judging from the fact that some applications are already being commercialized and a great many others are in progress.

- A tomato with firmer texture and delayed skin maturation has already been approved for commercial use. It will permit shipping of vine-ripened tomatoes with improved quality and shelf life and improved food processing quality.
- A genetically engineered yeast is claimed to give a richer beer aroma and facilitate filtering.
- The transfer of a gene from calf stomach to a yeast has already resulted in large-scale production and use of a chymosine identical to that in rennet.
- A potato with 30% higher solids content, which absorbs considerably less fat in deep fat frying, is under development.
- By the application of antisense technology, selective inactivation of specific genes can be achieved, including the genes responsible for the production of natural toxicants such as caffeine.
- As already mentioned on page 14, successful transfer of an AFP (antifreeze protein) gene from an Arctic fish species to other species of fish, tomato and potato has been achieved.
- Trehalose, which is a naturally occurring sugar of moderate sweetness, has the ability to retain the viability of desert plants in a state of almost complete dehydration. Purified trehalose as an additive in foods will significantly improve reconstitution ability and quality in dehydrated foods and prevent ice crystal growth in frozen foods such as ice cream. Its current price is, however, prohibitive for a food additive. Experiments are therefore under way to transfer the gene responsible for trehalose production to food plants, to achieve natural protection against quality loss during dehydration. Work is in progress to transfer the trehalose gene to sugar beet. This will hopefully make a 100-fold price reduction for trehalose possible in the future.
- It is also claimed that gene technology can be applied to make oil crops produce fats of the same fatty acid composition as in cocoa fat, thus rendering a cheap alternative to cocoa butter for the chocolate industry.
- Work is also under way to control the balance between amylose and amylopectine in potato starch.

The 1993 January issue of Food Processing (p 55) includes a table showing genetically modified foods.
Irradiated foods

Irradiation is without doubt the most carefully investigated of all our food preservation methods. FAO and WHO have expressed their acceptance of a number of common foods, within given dose limits. Several countries have issued limited permits, primarily for spices. However, negative consumer attitudes towards food irradiation, which tends to be associated with nuclear power, have raised doubts in the industry as to whether commercial applications will be at all possible within the foreseeable future.

It is rather surprising, therefore that irradiated foods are being successfully sold as quality products in a retail grocery in Illinois, USA, displaying a special symbol for irradiation. Because of the high quality of these products, the symbol is, apparently, associated with quality. Does the resistance against irradiated foods in fact emanate from small “pressure groups” and from media, while people in general would buy high-quality irradiated foods if given the chance? An important factor in the continued debate on food irradiation may be that it is now possible to determine whether or not foods have been irradiated.

Attitudes may change more rapidly than is generally expected, and the food industry would be wise to maintain a certain preparedness, should the process suddenly become commes il faut. Irradiation could serve as an important safety factor for chilled foods (MAP, sous-vide, etc.), in the absence of any heat processing or chemical additives.

Modified raw materials

The basis of the well-known Japanese surimi technology is that unwanted components of minced fish meats are removed by washing to give a matrix which can easily be structured and shaped into analogues of different foods, or used as a functional additive.

This technology is now being introduced to utilize and upgrade waste from meat and poultry, including beef, pork and mutton, to produce high-grade functional ingredients for various meat products. In this way, fat content can be reduced and binding properties improved.
Substitutes for fat and sugar

Extensive fundamental research on the relationships between process, composition and ultra-structure, texture, mouth feel and taste has revealed means of modifying biological macromolecules to provide fat simulation or other desirable functional properties in formulated foods. Several traditional food macromolecules, and some recently synthesized ones, have already won acceptance as low calorie substitutes for fat and sugar in food products. Such macromolecules include carbohydrates such as polydextrose, maltodextrine, modified starches, fibres and hydrocolloids, and fat analogues can also be based on proteins or lipids.

Microparticulated milk or egg protein is being used commercially (Simplesse) as a fat substitute in foods that are not subjected to temperatures above the coagulation temperature of the protein.

Substances such as sucrose polyesters with natural fatty acids (e.g. Olestra) have fat-like properties over the entire temperature range, and are not absorbed in the digestive system. Because of this, it is questionable whether they will ever be accepted as a food ingredients for environmental reasons (what might their impact be in sewage treatment and streams?).

A process developed by the French company Bioveccteurs imitates natural fat globules, substituting the fat “kernel” by a matrix of polysaccharides, while maintaining the “shell” of phospholipids and proteins.

The choice of fat or sugar substitutes must be tailored to the specific application, since different foods and food uses will differ in terms of the functional properties required.

Literature:

Additives

Pea protein and potato protein have been added to the already considerable list of functional protein isolates. New fibre materials, both water soluble and insoluble, complement beet fibre, potato fibre, pea fibre and oat fibre, etc.

Novelties in the field of spices include extrusion-sterilized spices and encapsulated spices with “controlled release”, the latter developed for use in foods for reheating in microwave ovens. Encapsulated aroma substances are being developed for the same type of use.

Naturally occurring substances like lysozyme (from eggs), ovotransferrine (from milk) and bacteriocins (from lactobacille fermentation) are being promoted as food preservatives. During 1991 an EC programme worth GBP1 million was initiated to map out naturally occurring antimicrobial systems.

The addition of trehalose (see biotechnology section) is claimed to improve reconstitution and quality of dehydrated foods and prevent ice crystal growth in frozen foods.

The addition of INA = Ice Nucleating Agents, such as bacteria or chemical compounds, represents an alternative to the transfer of INA
genes directly into the living food raw material.

The same can be said of antifreeze protein, AFP. According to Lillford, synthetic AFP is already in use commercially for protecting fruits, vegetables and formulated foods against changes caused by freezing.

Heme iron as an active food additive (giving higher retention of iron in the human body than by conventional iron enrichment of foods) is now being used in Japan in a number of “functional foods”: drinks, sweets, cakes, etc.

**Literature:**

Trend products

Fresh, natural foods

Chilled foods.
Market development in chilled foods has been very strong in Europe, particularly in Britain. MA-packaging dominates. In 1986, Britain represented more than 70% of the market total for MA-packs, out of a total volume of 650 million packs. In 1990, the European market had already reached 2 billion packs; the British share was “only” 40%.

It is not easy to identify any truly new products. Fresh pasta products in MA-packaging belong to this category, especially those pasteurized or sterilized by microwave technology.

Cook-chill products are enjoying continued growth in catering, as are sous-vide products, albeit to a lesser extent. To reach acceptable shelf life and safety for sous vide in the present chilled food chain, it has been necessary to use combination treatments, “hurdles”, such as pasteurization or freezing, before entering the consumer market. Such sous vide products are being marketed today in France and, on a very limited scale, in the USA.

Products based on some kind of “superchilling” are being sold in the USA (Crystal Pack) and in Japan (controlled freezing point technology), but it is doubtful if a cold chain is available with sufficient temperature control to really do credit to these methods.

On the producer’s side, there should be no real difficulty in arranging storage at 0 to +2°C. Modern home refrigerators have a special compartment for this temperature. The “missing link” lies in the distribution from producer to the home refrigerator.

Literature:


High quality, fresh-looking foods
This category includes high-quality products based on freezing preparation, HTST-pasteurization/sterilization and high-pressure processing.

Methods which are likely to provide additional enhancement of the quality of frozen foods, especially in foods which are still considered less suitable for freezing, include:

Programming/optimization of time-temperature development in cooling, freezing and defrosting, modifying food composition to obtain a glassy state already at normal tempe-
ratures of frozen storage, together with the application of freeze protective agents or genetically improved freeze protection.

On a limited scale, these options are already being taken advantage of, intentionally or unintentionally. AFP (antifreeze protein) is coming into use to obtain hardier tomatoes, higher survival of yeast in frozen doughs and to protect ice cream and other frozen dessert products against ice-crystal growth. (See biotechnology section).

Through osmotic concentration of cut fruits and vegetables, the water and dry solid contents are altered so that the glassy state is reached at a higher temperature than normal in the subsequent freezing operation (dehydro freezing), possibly well within normal frozen storage temperatures. Improved quality retention has been observed in several fruits, berries and vegetables, compared with freezing without osmotic preconcentration. So far, commercial application is very limited, if not non-existent. However, judging from the increasing number of publications on the subject in fruit-producing countries, interest in applications is on the increase.

By combining the freezing of an outer shell by cryogenic methods and continued freezing on band freezers or in fluidized beds, the assortment of IQF (individually quick frozen) products has grown considerably.

A Japanese research group used freeze concentration to produce a marmalade without heat processing, with superior fruit aroma. Freeze-concentrated strawberry juice was mixed with the previously separated pulp, adding sugar and high molecular pectine and citric acid to yield a ready, cold prepared marmalade. Alternatively, freeze concentration was combined with high-pressure sterilization.

There is an interesting new frozen food line under introduction in the USA for frozen baby foods.

Truly commercial HTST-pasteurization and sterilization has so far only been achieved for free-flowing liquids. For solid foods, the Japanese food industry has probably come closest to this goal, sterilizing in thin flexible pouches at 128°C.

The products containing solid pieces which have been processed by microwave heating or in continuous aseptic systems so far have not proved to be noticeably superior to conventional processing, mainly because of the difficulty in obtaining a very rapid temperature rise with sufficiently small spread in temperature and residence time. It has been claimed that Ohmic heating gives less spread in F- and C-values (sterilization and cook values) and that it has more of an HTST character. It should prove possible to obtain similar improvements using the new tubular microwave and HF applicators mentioned in previous sections.

In the dehydrated food sector, the new high temperature-short time dehydration process for pasta is claimed to give a substantial quality improvement. The novel drying processes Super-Dry Technology and microwave vacuum dehydration should make a new line of high-quality products possible, comparable to freeze dried foods.

Osmotic preconcentration and the use of trehalose promise to result in dried foods with considerably improved reconstitution ability and quality.
High-pressure technology in combination with limited heat treatment or other preservation treatment (pH, aw, etc.) has already resulted in a number of new products on the Japanese market — mainly marmalades, fruit juices and yoghurt with more natural aroma and colour. The ability of proteins and starches to gel at high pressures is expected to lead to new products, such as fish products and egg products, in the near future.

Fig. 10. Japanese consumer products produced using high-pressure technology. (Ref. 111)

Literature (in addition to that listed under the different processing methods):

Health foods, nutritional foods

"Functional" foods
The concept of "functional" foods was created in Japan 4-5 years ago to represent foods intended as part of the daily diet that actively supports specific bodily functions and/or counteracts certain diseases. In most countries where legislation and regulatory agencies permit health claims in advertising, such claims must be documented with reliable proof, whether the food is classified as a drug or a food. Alternative names for functional foods are medical foods, medicinal foods or nutraceuticals, especially when directed against a very specific bodily disorder.

The market for this category of foods has already grown to more than GBP500 million in Japan, and interest is growing globally.

A functional food can be something as "trivial" as a vitamin or iron-enriched food, something that has been on the market for a very long time. The fibre craze also belongs in this category. However, the chances have previously been slim when it comes to getting permission to market foods under claims that they:

- Prevent the development of diseases by stimulating the body's own defence mechanisms
- Slow down ageing
- Stimulate sex life
- Prevent the development of cancer or cardiovascular disease
- Stimulate metabolism and body weight reduction

Such claims have appeared on the Japanese functional foods market, even for products like iron-enriched candy!

In the USA, the Cancer Foundation has launched a major research programme around anticarcinogenic natural foods and additives. A preliminary list of foods that may contain active phytochemicals which possess such effects includes garlic, cabbage, liquorice, soybeans, ginger, carrots and celery. Very recently, it was found that apples contain a strongly anticarcinogenic substance, granatine. Antioxidants have long been regarded as having a protective effect against oxidation reactions in the human body, counteracting the development of cancer.

Fig. 11. Foods believed to contain anticarcinogenic substances. (Ref. 114)
The objective of the Cancer Foundation's programme is to establish a platform for the development of "designed foods", enriched with naturally-occurring active phytochemicals, somewhere in between food and medicine.

Fermented foods should also fit under the label "functional foods", since they have been shown to provide special nutritional functions, such as a positive effect on the uptake of iron in the diet. Solid-phase fermented vegetables were launched in Sweden and Hungary some years ago, but failed to gain consumer acceptance.

Health claims and more active marketing might very well pave the way for such products both on the institutional and consumer markets, however. It has been claimed in several countries that the launch of fermented vegetable drinks is imminent after research in Hungary, Sweden, France and Spain.

On the beverage side, isotonic sports drinks have already enjoyed a worldwide breakthrough. In Japan there is apparently also a market for "stamina drinks", claimed to cure hangovers and stimulate virility!

Products such as certain yoghurts, which contain live bacteria of a suitable strain, "probiotics" are claimed to support the normal bacterial flora in the intestinal tract and thus prevent infections and digestive problems. These products are now enjoying strong market development all over the world. The mechanisms are, however, only partially known. Yoghurt analogues based on soy meal and oat meal have been introduced.

The addition of micro-encapsulated Omega-3-fatty acids in dough is being used in the baking of Omega bread, which is sold by a Danish company.

**Literature:**


**Additional literature:**


**Light (lite) products**

"Light" products are almost flooding today’s markets, offering the consumer an easy, tasty and almost imperceptible way of reducing harmful over-consumption of calories, fat, saturated fat, cholesterol, sugar and salt. Taking advantage of the various substitutes, natural or synthetic, for fat, sugars and salt that are available today, a substantial part of the original content in formulated foods can be replaced in a low or zero alternative (see the section on page 31 about fat and sugar substitutes).

In the USA, consumers have developed something resembling a compulsion concerning fat and cholesterol, paving the way for more and more substitutes.
Even alcoholic beverages have been affected by the light and health trends, leading to wines and beers almost strained of alcohol using membrane techniques.

An interesting example of a product for which very low fat content has been achieved without changing the sensory quality is the low-fat hamburger introduced by McDonald.

This product contains almost 60% less fat and 40% fewer calories than a regular hamburger. The fat has been replaced by hydrolysed iota-carrageenan of a certain particle size, water and an aroma-enhancing additive. (A complication in formulating low-fat foods with replacers is that solubility relationships and the release of aroma substances differ from the natural fat systems).

An important question is, of course, if all these "light" products will really lead to lower overall intake of fat, calories, etc., or if the consumer will compensate by just eating more. Lower fat content can also be achieved by using less or no fat during preparation and cooking of the food. Examples of this include the no-fat process mentioned previously for expanding snacks and grilling by hot air Jet-Sweep instead of deep fat frying.

Fat can also be removed from fatty foods, such as chips, by extraction using supercritical carbon dioxide. Such applications are described in the literature, but it is doubtful, at least for the present, if they can be economically feasible.

### Literature:


123. O'Sullivan, M. O., Jones, S. A. Low-calorie foods and options for product development. Food Techn. Intern. Europe, 1991, 151-


### Convenience foods

The consumer desire for convenience will, in principle, be independent of other trends. There is no good reason why natural, fresh, healthy, etc. raw materials and products should not be convenient to use at the same time. Among the novel, convenient foods that have not already been discussed, the following deserve mention:

Chilled; Cook-chill, sous-vide and superchill in semi-prepared and fully prepared condition, with a growing variety of combination or “hurdle” techniques for sufficient shelf life.

Foods pasteurized or sterilized by ultrahigh pressure, also belonging to the chilled food sector, presently limited to marmalades, jams, juices and yoghurt.

“Shelf stable”; Produced by HTST-processing and aseptic techniques. Here too, hurdle techniques are being sought for — for the bread with meat filling that has been developed by the US Army, for instance. With the right combination of recipe, special baking method,
encapsulation technique, antioxidants, oxygen-removing agents and a high-quality MA-package, a six-month shelf life at +30°C can be obtained without any extra heat treatment.

Dehydrated products: The line of extruded semi-processed products, snacks, sweets, etc. is steadily growing in pace with the ongoing development of extruder technology (new shapes, fillings and combinations).

Expanded products such as snacks, based on extruded starch film or on sliced potato, are produced by microwave heating in combination with hot air convection and/or vacuum.

New kinds of pasta — for “instant” reconstituting “cup-noodle”-snacks and pasta yarns, for example.

Frozen products: The IQF line of products is being extended with the aid of novel combination freezers. With time, we may see freeze soft products, using AFP, or homogeneously quick-frozen foods using high-pressure techniques.

“Soft freezing” by replacing water with sugar solids, was much publicized some years ago, meeting with little real market success. Now the process seems to have found a more promising market niche for frozen desserts.

The most important event in convenience foods at present is, without doubt, the ongoing development of foods suited for microwave cooking or re-heating. This is a development where recipe, pre-treatment, positioning, packaging and preservative treatment must be integrated with microwave technology. In a nutshell, the problem is to bring about in a minute or two in a microwave field the same culinary result as in 20-30 minutes of conventional food preparation! Current development of special interest includes sandwiches, pies and pizzas, where reasonable solutions (by no means perfect) have been obtained with the help of susceptors, moisture barriers, reformulation with special ingredients and additives and special pretreatments.

**Fig. 12. Snacks produced by the APV “microwave dry frying” process. (From an APV brochure)**

Literature:


Additional literature:

Packaging

Packaging is of decisive importance to shelf life, quality, function and sales appeal of just about any food product. This is particularly evident in convenience foods, which are intended for microwave reheating in the package. The objective of this chapter is simply to highlight a number of interesting packaging novelties, without any claim to complete coverage of packaging development:

Active packaging

The notion of “active packaging” refers to packages that in themselves supply chemical or physical mechanisms which actively protect their food content. Alternatively, the function can be contained in a small bag inside the food package, a “magic bag”. The function can be to absorb undesirable substances or to release substances that will provide protection against oxidation or inactivate enzymes or micro-organisms, etc.

Oxygen absorbers in the form of small pouches containing reducing iron are being used worldwide to protect dry or semi-dry products. Development work is in progress on more sophisticated ways of eliminating oxygen, for example by a built-in electrochemical oxygen cell system.

Packaging films with a built-in layer which absorbs ethylene, ammonia and odorous substances are being used commercially in Japan.

For MAP packaging, films have been developed which have holes of about 1 μm in diameter made mechanically for the controlled release of CO₂, without permitting entry of bacteria (P-Plus film). Packages with built-in one-way valves offer similar facilities.

A sophisticated packaging development for the storage of respiring food material is based on a very special temperature switching “smart” polymer. At a given temperature rise, the gas permeability increases by jumps as the respiration of the plant material increases.

A French cook-in-pack system is based on a package with a one-way valve for releasing over-pressure during heating (on a continuous spiral steam heater, followed by a spiral air cooler).

An antimicrobial effect can be produced on the packaged food surface by a small pouch inside the package that releases ethanol vapour. Another such system is based on zeolites (an aluminium silicate) in combination with metallic silver or copper as filler in the inner film.

New materials

It has been claimed that the Japanese development of a silicon outer layer on transparent packaging films results in gas permeability which is as low as for Al-foil laminates. For one thing, this means that an increasing proportion of shelf-stable convenience foods can

Fig. 13. “Smart” packaging film. Principle. (Ref. 135)
be reheated in their packages in the microwave oven in the future. A new type of tin can with a plastic lid, suitable for re-heating in the microwave oven, is similar in orientation.

Another interesting development concerns rapid ultrasonic welding of the double seam of multi-layered cans with metal lids, rendering special sealing materials unnecessary.

**Environment, ecology**

Because public interest in packaging tends to focus on its environmental impact, its primary role — to protect the food — tends to fade into the background. Much of what has been said about active packaging may therefore be difficult to reconcile with the ever-growing environmental demands.

When recycling is not a reasonable alternative, biological degradability may be. The interest in using biopolymers as protective coating or as a packaging film material has, consequently, increased over the last few years. The USDA is running a special R&D programme on edible films.

Packaging films based on cellulose, starch, dextrine, gelatine, gluten, casein, chitosan, etc., can be given suitable mechanical and sensory properties, while wax or lipid-based coatings can supply the necessary water barrier. The technology for producing films and packages using biopolymers and for modifying their properties is in steady progress. Biopolymers have also been used with some success as a barrier material between components or layers in formulated foods.

A biopolymer based on corn starch is being launched for tray packages and as a water-soluble film in laminates, to enable simple water separation of the other plastic films for recirculation. Several companies are selling starch-based beakers and plates made by some kind of wafer technique.
Encapsulation

Macro-encapsulation (≥5000μ) and micro-encapsulation (<500μ) of liquid droplets, solid particles or gas can be regarded as a kind of packaging to protect food additives against oxidation, for example, or loss of aroma substances, etc. The objective might also be to make a certain ingredient easier to handle.

The use of micro encapsulation with “controlled release” properties, such as release during re-heating or in the digestive tract, is of particular interest. Controlled release is of special interest in the development of microwaveable foods and “functional” foods such as the Danish Omega-3-bread mentioned previously.

<table>
<thead>
<tr>
<th>Literature:</th>
</tr>
</thead>
</table>
Future development

Entirely new processes, either on their own or in combination with conventional ones, may have a decisive role to play in raising product quality, production reliability and safety and in lowering production costs. Sometimes they may also make it possible to develop entirely new types of product.

It is even more important, however, to acquire more in-depth knowledge of the properties of foods and how they are affected by different factors, as well as of the processes in use and opportunities for technical and economic optimization. This characterizes current developments in the food industry.

Computerized systems for operation analysis, process surveillance, simulation and control, new on-line sensors and methods of "at line" analysis are being introduced in combination with more effective staff organization and utilization through "expert systems". By applying "fuzzy logic", experimental results, although they may be inconsistent to a certain degree, can be utilized directly without statistical treatment in order to increase reasoning power in process sensing and control systems. This results in more flexible production in pace with market demand (just-in-time production) and implementation of quality control directly rather than after production.

Dull or heavy labour-intensive jobs (sorting, lifting, etc.) will be replaced by computerized technology/automation such as image analysis systems, industrial robots, etc. Clean-room technology is being introduced, along with HACCP and ISO 9000.

All this represents new technology, although the processes on which they are applied are not new.

The present course of developments appears to be to tailor processes for specific purposes on the basis of market studies of needs and requirements, translated into product definitions by product development. This may result in an improved or modified version of a previous processing line, a new combination of traditional techniques with new ones, or an entirely new process — to produce the desired product in the best possible manner.

Fig. 14. ABB palletizing robot. (ABB)
Fig. 15. Automated sorting of potatoes by image analysis (Silsoe Institute).

Literature:

158. Wilson, M. Real Future for Robots. Food Proc., Dec. 1992, 26-
How to use this overview in your own development work

The prime objective of this overview is to provide the technical and marketing staff of the reader’s company with a broad orientation in the possibilities available, either now or in the near future, which may be worth closer study in the light both of their own continued R&D work and of the expected competition. The list can be extended by the reader as new methods and products appear in the literature or on the market.

To provide a quick overview, new processes and products are listed in an appendix. Space is provided for the readers own notes and conclusions.

Processes and products which the author considers to be of special interest include the following:

- Combination processes involving microwaves and conventional heat processing
- High-pressure technology
- Jet-Sweep and IR-technology for dehydration and food preparation
- Antifreeze proteins and “glassy state” to facelift freezing technology
- Sterilization of spices by extrusion or ozone
- Surface sterilization by intense light pulses
- New membrane technology
- New raw materials based on genetic engineering
- Light products based on fat-and sugar replacers
- Natural preservatives
- Cook-chill and sous-vide with MAP
- Functional foods
- Products for the microwave oven
- Active and biologically degradable packaging

Gothenburg, Sweden, March 1994

Nils Bengtsson
Appendix to

New processes and products

<table>
<thead>
<tr>
<th>Processes</th>
<th>See page</th>
<th>Reader´s notations</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Sterilization and pasteurization:</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Vacuum-steam sterilization in partially sealed packages and closure under pressure</td>
<td>4</td>
<td></td>
</tr>
<tr>
<td>Microwave sterilization and pasteurization</td>
<td>4, 19</td>
<td></td>
</tr>
<tr>
<td>Aseptic system with separate sterilization of solid and liquid phase</td>
<td>4</td>
<td></td>
</tr>
<tr>
<td>Ohmic heating for pumpable foods containing solids</td>
<td>4</td>
<td></td>
</tr>
<tr>
<td>Tubular microwave and HF systems for pumpable liquids containing solids</td>
<td>4-5, 20</td>
<td></td>
</tr>
<tr>
<td>Ultrasound sterilization of liquids</td>
<td>5</td>
<td></td>
</tr>
<tr>
<td>Sterilization of spices and cocoa with extrusion</td>
<td>5, 11</td>
<td></td>
</tr>
<tr>
<td>Processing under CO₂ pressure</td>
<td>5</td>
<td></td>
</tr>
<tr>
<td><strong>Sterilization with:</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>High pressure</td>
<td>6</td>
<td></td>
</tr>
<tr>
<td>Intensive light pulses</td>
<td>7</td>
<td></td>
</tr>
<tr>
<td>High electric voltage pulses</td>
<td>8</td>
<td></td>
</tr>
<tr>
<td>Oscillating magnetic fields</td>
<td>8</td>
<td></td>
</tr>
<tr>
<td>Ionizing radiation</td>
<td>8</td>
<td></td>
</tr>
<tr>
<td>Hyperbaric oxygen</td>
<td>8</td>
<td></td>
</tr>
<tr>
<td>Hurdle technology</td>
<td>9</td>
<td></td>
</tr>
<tr>
<td>Processes, cont.</td>
<td>See page</td>
<td>Reader's notations</td>
</tr>
<tr>
<td>-----------------</td>
<td>----------</td>
<td>-------------------</td>
</tr>
</tbody>
</table>

**Drying and extrusion:**

**Drying:**
- Microwaves and hot air, cold air, vacuum convection 10
- Microwave expansion of snacks 10
- High frequency and hot air 10
- Jet-Sweep = Air impingement 10
- New types of fluidized beds 10
- SDT-drying 10
- MIVACO-process 10
- Inert gas drying 10
- Superheated steam 10
- Atmospheric freeze-drying 10
- HTST drying of pasta 11
- Drying by combination methods 11

**Extrusion:**
- Coextrusion 11
- Twin-extrusion at high moisture content 11
- 3-dimensional shapes 11
- With injection of supercritical CO₂ 12
- Low pressure extrusion of filled products 12
- Extrusion of malt for beer production 12
<table>
<thead>
<tr>
<th>Processes, cont.</th>
<th>See page</th>
<th>Reader’s notations</th>
</tr>
</thead>
<tbody>
<tr>
<td>Deepfreezing:</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Shell freezing with liquid nitrogen + convection freezing</td>
<td>12</td>
<td></td>
</tr>
<tr>
<td>Fluidization with Jet Sweep</td>
<td>12</td>
<td></td>
</tr>
<tr>
<td>Tempering with microwaves and HF</td>
<td>12</td>
<td></td>
</tr>
<tr>
<td>Cryogenic freezing with liquid air produced on site</td>
<td>12</td>
<td></td>
</tr>
<tr>
<td>Adding of Ice Nucleating Agents and Antifreeze Proteins</td>
<td>13-14</td>
<td></td>
</tr>
<tr>
<td>Freezing and thawing with high pressure technique</td>
<td>14</td>
<td></td>
</tr>
<tr>
<td>“Glassy state”-technology for prolonged shelf-life</td>
<td>14</td>
<td></td>
</tr>
<tr>
<td>Osmotic concentration for dehydro-freezing</td>
<td>15</td>
<td></td>
</tr>
<tr>
<td>Superfreezing</td>
<td>15</td>
<td></td>
</tr>
<tr>
<td><strong>Chilling and chilled storage (with or without MAP):</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Hurdle technology for increased shelf-life and safety</td>
<td>15</td>
<td></td>
</tr>
<tr>
<td>Superchilling</td>
<td>15</td>
<td></td>
</tr>
<tr>
<td>“Controlled freezing point” technology</td>
<td>15</td>
<td></td>
</tr>
<tr>
<td>Cook-chill and “sous-vide” with MA</td>
<td>16</td>
<td></td>
</tr>
<tr>
<td>HACCP and clean room technology</td>
<td>16</td>
<td></td>
</tr>
<tr>
<td>Thermal shock</td>
<td>16</td>
<td></td>
</tr>
<tr>
<td>Processes, cont.</td>
<td>See page</td>
<td>Reader’s notations</td>
</tr>
<tr>
<td>-----------------</td>
<td>----------</td>
<td>-------------------</td>
</tr>
<tr>
<td><strong>Food preparation:</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Short and medium wave IR</td>
<td>17</td>
<td></td>
</tr>
<tr>
<td>Jet-Sweep alone or in combination with microwaves</td>
<td>17</td>
<td></td>
</tr>
<tr>
<td>Spiral tube heat exchangers</td>
<td>17</td>
<td></td>
</tr>
<tr>
<td>Electrical resistance heating</td>
<td>17</td>
<td></td>
</tr>
<tr>
<td>Cooking in tubular HF</td>
<td>17</td>
<td></td>
</tr>
<tr>
<td>Induction heating</td>
<td>17</td>
<td></td>
</tr>
<tr>
<td>Grilling of chicken by HF + hot air</td>
<td>17</td>
<td></td>
</tr>
<tr>
<td>Gelatinizing at high pressure</td>
<td>17</td>
<td></td>
</tr>
<tr>
<td>Cooking by vacuum steam or under CO₂ pressure</td>
<td>18</td>
<td></td>
</tr>
<tr>
<td><strong>Other special processes:</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Microwaves for sterilization, pasteurization, drying and expansion</td>
<td>19</td>
<td></td>
</tr>
<tr>
<td>HF for drying of pet-foods, baking, tempering, thawing, sausage production and combined with hot air for grilling of chicken</td>
<td>20</td>
<td></td>
</tr>
<tr>
<td>Sinteromatic for “moulding” of sausages</td>
<td>21</td>
<td></td>
</tr>
<tr>
<td>Electrical resistance heating for sterilization, pasteurization and cooking of liquids containing solids</td>
<td>22</td>
<td></td>
</tr>
<tr>
<td>Exposure to magnetic fields, electric current, electrostatic fields to affect water removal, oil extracting, baking and heat transfer</td>
<td>23</td>
<td></td>
</tr>
<tr>
<td>Processes, cont.</td>
<td>See page</td>
<td>Reader’s notations</td>
</tr>
<tr>
<td>-----------------</td>
<td>----------</td>
<td>-------------------</td>
</tr>
<tr>
<td><strong>Other special processes, cont.</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>IR-heating for rapid dehydration, baking, grilling and surface pasteurization</td>
<td>23</td>
<td></td>
</tr>
<tr>
<td>Ultrasonics to accelerate reactions, induce crystallisation, lower the viscosity of liquids, dewater and dry, stabilize emulsions, sterilize spices (in combination with microwaves)</td>
<td>24</td>
<td></td>
</tr>
<tr>
<td>Membrane technology to lower alcohol content in wine and beer, sterile filtration, extraction and pervaporation</td>
<td>25</td>
<td></td>
</tr>
<tr>
<td>Supercritical extraction</td>
<td>26</td>
<td></td>
</tr>
<tr>
<td><strong>Biotechnology – gene technology:</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Processes with bound enzymes and tailor made enzymes</td>
<td>27</td>
<td></td>
</tr>
<tr>
<td>Production of alcohol free (low) beer</td>
<td>27</td>
<td></td>
</tr>
<tr>
<td>Transfer of antifreeze gene from fish to vegetables</td>
<td>27</td>
<td></td>
</tr>
<tr>
<td>Nitrate reduction in vegetables</td>
<td>27</td>
<td></td>
</tr>
</tbody>
</table>
**Products**

See page  Reader's notations

**Raw materials, ingredients, additives:**

**Biotechnology – gene technology:**

- Tomatoes with firmer texture and delayed maturation
- Yeast giving richer beer aroma and facilitated filtering
- Genetically produced chymosine
- Vegetables freeze protected by AFP gene
- Trehalose producing genes for protection of dehydrated foods and inhibited ice crystal growth in frozen foods
- Gene engineered alternative to cocoa butter
- Potato with 30% more solids
- Selective inactivation of toxicity genes

**Irradiation:**

- A process for the future in spite of everything?

**Modified raw material:**

- Surimi technique applied on waste from beef, chicken, sheep and swine

**Fat and sugar substitutes:**

- 31
<table>
<thead>
<tr>
<th>Products, cont.</th>
<th>See page</th>
<th>Reader’s notations</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Additives:</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sterilized spices (by extrusion, microwaves + ultrasound)</td>
<td>31</td>
<td></td>
</tr>
<tr>
<td>Natural preservatives (lysozyme, ovotransferrine, bacteriocins)</td>
<td>31</td>
<td></td>
</tr>
<tr>
<td>Trehalose</td>
<td>31</td>
<td></td>
</tr>
<tr>
<td>INA and AFP</td>
<td>32</td>
<td></td>
</tr>
<tr>
<td>Heme iron</td>
<td>32</td>
<td></td>
</tr>
<tr>
<td><strong>Trend products:</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Fresh – natural:</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>(MA-packed)</td>
<td>33</td>
<td></td>
</tr>
<tr>
<td>Cook-chill and “sous-vide”</td>
<td>33</td>
<td></td>
</tr>
<tr>
<td>Hurdle technology</td>
<td>33</td>
<td></td>
</tr>
<tr>
<td>Superchill</td>
<td>33</td>
<td></td>
</tr>
<tr>
<td>Controlled freezing point</td>
<td>33</td>
<td></td>
</tr>
<tr>
<td><strong>High quality, fresh looking:</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Frozen foods with raised “glass transition” temperature</td>
<td>33</td>
<td></td>
</tr>
<tr>
<td>Osmotic concentration and dehydro-freezing</td>
<td>34</td>
<td></td>
</tr>
<tr>
<td>Application of INA or AFP</td>
<td>34</td>
<td></td>
</tr>
<tr>
<td>Freeze concentration for cold processed jam</td>
<td>34</td>
<td></td>
</tr>
<tr>
<td>Combination freezing, cryogenic – mechanical, for IQF foods</td>
<td>34</td>
<td></td>
</tr>
<tr>
<td>Products, cont.</td>
<td>See page</td>
<td>Reader’s notations</td>
</tr>
<tr>
<td>--------------------------------------------------------------------------------</td>
<td>----------</td>
<td>---------------------</td>
</tr>
<tr>
<td>High quality, fresh looking, cont.:</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Frozen baby foods</td>
<td>34</td>
<td></td>
</tr>
<tr>
<td>Improved aseptic products by Ohmic heating</td>
<td>34</td>
<td></td>
</tr>
<tr>
<td>HTST dried pasta</td>
<td>34</td>
<td></td>
</tr>
<tr>
<td>Super dry technology</td>
<td>34</td>
<td></td>
</tr>
<tr>
<td>High pressure sterilized jam, juices, yoghurt, dressing and gelatinised fish and egg products</td>
<td>35</td>
<td></td>
</tr>
<tr>
<td>Health foods, nutritional foods:</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Functional foods:</td>
<td></td>
<td></td>
</tr>
<tr>
<td>With anticarcinogenic substances</td>
<td>36</td>
<td></td>
</tr>
<tr>
<td>Fermented vegetables and vegetable drinks</td>
<td>37</td>
<td></td>
</tr>
<tr>
<td>Probiotics</td>
<td>37</td>
<td></td>
</tr>
<tr>
<td>Yoghurt based on soy and oatmeal</td>
<td>37</td>
<td></td>
</tr>
<tr>
<td>Isotonic sports drinks</td>
<td>37</td>
<td></td>
</tr>
<tr>
<td>Microencapsulated omega-3-fatty acids in “Omega” bread</td>
<td>37</td>
<td></td>
</tr>
<tr>
<td>Light products:</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Low fat hamburgers</td>
<td>38</td>
<td></td>
</tr>
<tr>
<td>Alcohol free</td>
<td>38</td>
<td></td>
</tr>
<tr>
<td>Convenience foods:</td>
<td></td>
<td></td>
</tr>
<tr>
<td>“Shelf stable” with hurdle technique</td>
<td>38</td>
<td></td>
</tr>
<tr>
<td>High pressure preserved</td>
<td>38</td>
<td></td>
</tr>
<tr>
<td>Products, cont.</td>
<td>See page</td>
<td>Reader's notations</td>
</tr>
<tr>
<td>-----------------------------------------------------</td>
<td>----------</td>
<td>--------------------</td>
</tr>
<tr>
<td>Convenience foods, cont.:</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Extruded products</td>
<td>39</td>
<td></td>
</tr>
<tr>
<td>Microwave snacks</td>
<td>39</td>
<td></td>
</tr>
<tr>
<td>Microwavable products</td>
<td>39</td>
<td></td>
</tr>
<tr>
<td>Soft freezing</td>
<td>39</td>
<td></td>
</tr>
<tr>
<td><strong>Packaging:</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Active packaging:</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Magic bags</td>
<td>40</td>
<td></td>
</tr>
<tr>
<td>Absorbant layers</td>
<td>40</td>
<td></td>
</tr>
<tr>
<td>MAP packs with mechanically made holes</td>
<td>40</td>
<td></td>
</tr>
<tr>
<td>Temperature switching polymers for respiring foods</td>
<td>40</td>
<td></td>
</tr>
<tr>
<td>Antimicrobial packaging</td>
<td>40</td>
<td></td>
</tr>
<tr>
<td><strong>New materials:</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Silicon coated transparent film</td>
<td>40</td>
<td></td>
</tr>
<tr>
<td>Ultrasonically welded multilayer cans</td>
<td>41</td>
<td></td>
</tr>
<tr>
<td><strong>Environment – ecology:</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Edible and biologically degradable films</td>
<td>41</td>
<td></td>
</tr>
<tr>
<td>Natural barrier materials between food components</td>
<td>41</td>
<td></td>
</tr>
<tr>
<td><strong>Encapsulation:</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Microencapsulation with “controlled release” (aroma, functional additives etc.)</td>
<td>42</td>
<td></td>
</tr>
</tbody>
</table>