New Technologies

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Relationships between humans and their food are evolving rapidly. From prehistoric times until now this evolution has developed through long stages but these have been becoming much shorter. Since the end of the 18th century, the process has accelerated along with the development of the basic sciences, industrialization, and changes in the socioeconomic environment (see chapters by Blaxter and Horman in this volume). The evolution is such that consumers expect more as far as their food is concerned, i.e., more variety, better quality, more convenience, better nutritive value, more safety, and more choice. Industry is obliged to innovate to meet consumer expectations and to survive.

To innovate in a field that has always concerned mankind and his survival is not an easy task as it requires a change in behaviors established over a long period, and in the traditional means of providing raw materials and preparing foods. The consumer’s attitude toward industrially prepared foods and those issuing from new technologies is ambiguous and somewhat contradictory. On the one hand, consumers believe that the food industry creates new needs that are not essential, though they do not take into consideration the fact that if the need is nonexistent, the new products will not be purchased. On the other hand, consumers who expect more from industrial products remain suspicious because they are produced by machines and not by hand, anonymously and not at home, using technology and not traditional methods.

The new technologies develop along three main lines:

(a) the adaptation of old processes to new applications, e.g., fermentation;
(b) the optimization of existing concepts in utilizing new techniques, e.g., sterilization; and
(c) the application of new concepts needing new tools or new machines, e.g., gamma irradiation, microwaves, molecular biology.

Lines (a) and (b) are traditional; the innovation is aimed at optimizing existing technologies, so consumers are less apprehensive about them. Line (c), based on new concepts, needs a more serious evaluation before being used. In each case, introduction of an innovation requires detailed studies by the initiators to establish va-
lidity, feasibility, advantages over existing technologies, and evaluation of nutritional and safety aspects. It frequently happens that specific regulations are established on request of the health authorities as is the case with the "novel foods" (see Chapter by Walker in this volume).

The results of some new technologies are apparent and their level of innovation can easily be assessed by consumers, e.g., freeze-dried instant coffee extracts and microwave ovens. Many of the new technologies are less evident to the consumer because they involve process improvement. They constitute the day-to-day responsibility of the manufacturer. An example is the huge amount of innovation in the fields of safety and nutritional control of which the consumer is unaware.

The new technologies can be conveniently treated under the following headings:

Production of raw materials and food ingredients;
Preservation of foodstuffs;
Organoleptic properties and convenience;
Nutritional value and safety.

PRODUCTION OF RAW MATERIALS AND FOOD INGREDIENTS

Until recently, man found his food in the animal and vegetable kingdom, mainly from limited local production and for immediate or short-term consumption. Nowadays, although the resources remain the same, the food technologist has a large variety of raw materials at hand, and has a large choice of food ingredients that can be used for their functional or nutritional properties.

Agriculture, Farming, and Aquaculture

These activities, which remain the basis of our nourishment, are improved by a better control of growing conditions: fertilizers, specific herbicides, pesticides (plants), nutritional requirements (animals, fish farming), and hormone treatments (animals) (1). A typical example is the production of lean animals by using strain selection, nutritional manipulation (less starch), somatotropin or β-antagonist treatments, immunological suppression of adipocytes, strain selection, noncastration, or transgenic species (2).

New varieties of plants are developed by traditional genetic selection (low erucic acid rapeseed, high lysine corn) and by modern genetic manipulations: tissue culture (potato, tomato), gametoclonal variation (cereals), protoplast fusion (hybrid plants), and recombinant DNA technology (herbicide and insect resistance) (3–6). In some cases, productivity in agriculture is practiced at the expense of environmental quality, for example pollution of water with fertilizers and pesticide residues in foods. Moreover, the maintenance of the rustic varieties has to be seriously considered as they are the unique genetic patrimony of the planet (see Chapter by Hulíc in this volume).
Production by Physical Processes

Simple physical processes traditionally have been used in a wide range of technologies: pressing to extract oils and fruit juices, grinding and sieving to extract bran from cereals. Physical processes are used today in food technology to extract desirable ingredients from cheaper raw materials. These include precipitation at the isoelectric point to produce protein isolates, ultrafiltration and microfiltration to concentrate high molecular weight fractions, reverse osmosis, electrodialysis or ion exchangers to deionize water solutions, and solvent extraction to remove lipids, caffeine, and flavors (7).

Fermentation, Microbial Production

Traditional fermentations were empirically developed to preserve unstable foods or to provide a good taste (wine, beer, yogurt, cheese, salami, and many soy-based products such as miso, tempeh, natto, and soy sauce). They have become increasingly professional through better control of the fermentation conditions, providing highly standardized and safe products at the expense of traditionality. New strains are also introduced for their putative beneficial properties, for example lactobacillus bifidus.

The possibility of large-scale cultivation of microorganisms selected for their ability to synthesize specific molecules provided a means for food scientists to produce single nutrients, e.g., vitamins, amino acids, and even edible proteins (yeast, bacteria, filamentous fungi) (8) for the fortification of feeds and foods. Food ingredients are increasingly produced by fermentation, for example seasonings (monosodium glutamate, soy sauce), gums (microbial polysaccharides), acidulants (gluconic, lactic, and citric acids), and flavor compounds (yeast extracts, nucleotides). Current research is directed to the production of colors, flavors, antioxidants, and polyunsaturated fatty acids (2).

Microorganisms are also utilized as sources of enzymes for their application in food science to improve functional or organoleptic properties, and in nutrition (see the following chapter by Walker). Recent developments in molecular biology offers a new means of producing these enzymes and other active proteins. Growth hormones are already being prepared this way and many other enzymes are on the way to being developed, for example, rennet for cheese-making, amylase, glucose isomerase, alkaline proteases, and glucoamylase (9,10). For application to foods, the strains have to be of food grade and appropriate food safety regulations need to be established.

Production of Ingredients by Enzymes

Purified enzymes are used to modify foods or ingredients for changing their functional properties or for improving their nutritional value. Two types of enzymic activity are utilized:
(a) Hydrolyzing activity: proteases, amylases, and lipases are used to improve functional properties, e.g., solubility, gelification, water retention, emulsifying capacity of proteins and starches by proteases or amylases; organoleptic properties, e.g., browning inhibition (proteases) (11), juice clarification (pectinase), sugar taste (invertase), cheese ripening (lipase); and nutritive qualities, e.g., better digestibility of proteins in producing peptides and of starch in producing malto-dextrins, decrease in allergenic properties of dietary proteins by proteases (12), treatment of lactose intolerance by lactase (13).

(b) Synthesizing activity: lipases are being developed to produce structured triglycerides, and proteases to modify functional and nutritive qualities by the plastein reaction (14); glucono-lactone oxidase is utilized for the synthesis of ascorbic acid.

Chemical Synthesis or Modifications

Many micronutrients are chemically synthesized: vitamins, amino acids, and mineral salts. In addition, many food ingredients are also produced either by complete synthesis, e.g., additives (aromas, dyes, antioxidants), sweeteners (aspartame, cyclamate, and saccharine), or by chemical modification of existing ingredients, e.g., hydrolyzed plant proteins (seasonings), hydrolyzed starch (sweeteners), hydrogenated reducing sugars (sorbitol, xylitol, etc.), hydrogenated polyunsaturated fatty acids (margarines), and transesterified triglycerides.

Conclusion

The current technological revolution has completely changed older notions of raw material production and of food preparation. This advance has opened the way to the production of tailor-made new foods to meet very specific nutritional needs and organoleptic properties. Most of the new raw materials and ingredients are considered as food additives or as “novel foods” that necessitate new regulations (see Chapter by Walker in this volume).

PRESERVATION OF FOODS

In the past, men used empirically developed methods of food preservation: air drying (fish and meat), cooking, fermentation (wine, cheese), acidification (vinegar), smoking, salting, spices, etc. The recent advances in knowledge in microbiology, biochemistry, and food science have established the theoretical bases that enable one to understand the reasons why these empirical means work and how to improve them. It is well established that the deterioration of foods has the three following causes:

(1) contamination by microorganisms: molds, yeasts, and bacteria that spoil the foods and develop mycotoxins;
NEW TECHNOLOGIES

(2) action of endogenous enzymes present in fresh foods: hydrolases, lipases, oxidases responsible for the changes in texture and the development of off-flavors and colors (enzymic browning); and

(3) chemical reactions resulting from the effect of oxygen on lipids that develop rancidity, or from reactions between proteins and sugar (Maillard reaction) responsible for nonenzymic browning.

Food technologists can attack these causes of degradation by careful manipulation of water activity, temperature, pH (fermentation or additives), and chemical reactions (oxidation, Maillard reaction) in foods.

Influence of Water Activity

The water content, or more precisely the water activity, influences the microbial, enzymatic, and chemical modification of foods (15). At low water activity (0–0.2), lipid oxidation is at a maximum, leading to rancidity. As the water activity increases, this oxidative reaction decreases while the Maillard reaction increases, reaching a maximum at water activity in the range of 0.5–0.7 and producing off-flavors and browning, e.g., dried vegetables and dried milk.

At higher water activity, the activity of enzymes such as the oxygenase enzymes (lipooxygenases and phenoxidas), proteases, and lipases increases, generating off-flavors, browning, and texture modification. Finally, the microorganisms—molds, yeasts, and bacteria—develop progressively with increasing water activity. While having maximum activity at low moisture content, the Maillard reaction still develops in liquid products because of the heat treatments needed for sterilization. Based on this knowledge, specific technologies can be applied in dry products, intermediate moisture foods (IMF), and liquid products.

Influence of Temperature

Microbial Contamination

Microbial contamination, which remains the most serious and dangerous source of spoilage, is mainly controlled by temperature.

(1) Low-temperature storage—such as freezing and refrigeration—prevents or retards the development of microorganisms. The access to refrigerators and to freezers in every family in developed countries has totally changed the storage conditions of the homemade and industrially prepared foods. The industrial technique of deep-freezing and the achievement of a cold chain from the food producer to the consumer has stimulated the development of many types of frozen foods, e.g., fresh meat, fish, and vegetables; frozen dishes; and refrigerated foods such as yogurt.

(2) Heat treatments such as pasteurization and sterilization—kill pathogens and
spores. There is very good documentation of the time necessary to kill any particular microorganism at a given temperature (16,17).

**Enzymes**

Enzymes are inhibited at very low temperature (freezing) and inactivated at temperatures higher than 50°C, depending on the type of enzyme. Very often a food can be stabilized by inhibiting its endogenous enzymes. This can be achieved by mild heat treatments such as blanching, which is now being replaced to some extent by gamma irradiation or microwave treatment.

**Chemical Reactions**

Chemical reactions develop very slowly at room temperature but more rapidly at high temperatures. Because the temperature effect is more pronounced on the viability of microorganisms than on the rate of the chemical reactions (18), heat treatment combining a very high temperature for a very short period of time (HTST, UHT) is recommended over the heat treatments that combine low temperature and long time period (in-can sterilization) (19). The steam injection process associated with aseptic filling is now the preferred technology for products sensitive to heat damage, such as milk (20). For those types of products for which heat treatment has to be reduced, the addition of gamma irradiation is envisaged but, for technical and emotional reasons, this new process is taking a long time to be adopted (21–23).

Microwaves have now been introduced into the food industry as a new technique which has the property of rapidly energizing foods (24,25). They are also utilized by consumers as a convenient system to rapidly thaw, reheat, and cook foods. Due to its advantages over other heating processes, microwave technology will certainly have many interesting applications in food science (drying, rapid sterilization).

High-pressure technology is a new process that could be applied in food science. The effect of high hydrostatic pressure on the viability of microorganisms has been known for over 90 years. The recent development of high hydrostatic pressure machines has renewed interest in this technique. Very high pressures have a similar effect to heat treatment on the denaturation of proteins. High-pressure technology (4,000–5,000 kg/cm²) is now being studies in Japan as a means of killing vegetative microorganisms at room temperature. A combination of high-pressure and hyperpression high-temperature treatments is the most efficient method of inactivating microorganisms (26).

**Fermentation**

Fermentation is a classic method for stabilizing foods. It reduces substrates, e.g., glucose and fructose in fruit juices, lowers pH, and produces antibacterial factors
such as alcohol, lactic acid, or antibiotics. Traditional methods of preparing wine, beer, cheese, salami, yogurt, soy sauce, etc. have been transformed into industrial production of very high quality products using starter strains selected for their yield, organoleptic quality, or resistance to phages, and with a better control of all the steps of the process. As an example, enology is no longer an art but a science which benefits from the improvements in microbiological and biochemical know-how. The same is true for all fermented products.

Fermentation can improve nutritional properties. Examples include the oxidation of cholesterol and the production of essential nutrients. In addition, the direct effect of viable microorganisms on health is also of interest: some intestinal microorganisms produce β-glucuronidase and nitroreductase, which are known to convert procarcinogens into carcinogens in the large intestine (27). Modification of the intestinal microflora could therefore be beneficial.

Food Additives

Preservation of foods can also be achieved by adding chemicals that reduce or stop microbial development (NaCl, nitrate, benzoic acid, Ca propionate, SO₂) and chemical reactions such as oxidation (antioxidants) and browning (SO₂). The list of these additives is strictly limited and their levels well regulated (see Chapter by Walker in this volume). Because consumers are suspicious about food additives, the current trend is to replace them with natural products that have the same properties as acidifiers or antioxidants (vitamin E, vitamin C, plant extracts) or by technologies derived from food science (fermentation, control of pH and water activity, adapted packaging).

Packaging

Packaging is an important aspect for the keeping quality of industrially prepared foods and often plays a role complementary to the process used. Plastic and aluminum-coated plastic films have been developed to be waterproof, oxygen proof, and opaque to ultraviolet light. In some cases, they can maintain an inert atmosphere (N₂, CO₂, vacuum). Plastic barrier films controlling the atmosphere of vegetables and fruits are being used increasingly to improve storage (28). However, packaging materials are not inert and can interfere and contaminate food.

New developments are now being studied to develop active packaging to regulate water, CO₂, or oxygen levels with specific scavengers (lime, reduced Fe), to develop time-temperature indicators (for frozen foods), and to inhibit the microbial growth (29) by incorporation of antibacterial agents.

Most packaging materials (plastics, aluminum-coated plastics) are not biodegradable. New materials based on natural products (e.g., modified starch and other edible polymers) are being studied to resolve this environmental problem.
Conclusion

The technologies of food preservation are being developed for better microbiological safety in preserving as far as possible the organoleptic qualities and the nutritional properties, and for longer shelf life. Heat treatments are less severe and additives are reduced as much as possible. Every modification needs strict control for safety and sometimes requires specific regulation.

ORGANOLEPTIC PROPERTIES—CONVENIENCE

Eating is a physiological activity that has to be a pleasure. To be purchased, a food has to have the appearance, color, texture, taste, and aroma that consumers expect.

Flavors, Taste, Color

Keeping the optimal organoleptic properties until consumption is a challenging problem for many foods, e.g., fresh fruits which have to be ripe when the consumer eats them, and precooked and baked products that loose their aroma in the factory. In some cases, aromas can be recovered and reintroduced into the final product, but very often they are lost; this is the case when precooked products are reheated by microwaves, in which case artificial flavors or susceptors* can partially resolve the problem. Artificial flavors can palliate a defective process or a tasteless product. Flavor binding and release, as well as their perception, are the key elements of a superior product. The in situ generation of flavors by enzymes and the modification of receptor physiology are new approaches that are being investigated. In parallel there is a need to describe and quantify better the sensory quality of foods.

Texture

In every culture, people are accustomed to the texture and the “mouth feel” of their traditional foods. These specific organoleptic properties can be reproduced either from food ingredients especially prepared for their mouth feel properties—such as modified starches, protein fractions, etc.—or through physical treatments—such as extrusion cooking, spinning, or roller-drying. Methods are being developed to correlate texture measurements (via instrumentation) with mouth feel ratings.

* Susceptors: metal-coated packaging material which absorbs microwave energy. The high temperatures which result heat the surface of the foods.
Convenience

The number and diversity of products prepared by the food industry is such that it is possible to go without cooking any food at home for a long period of time. Many families are able to live by buying their food only once a week. This very important change in providing food is partly responsible for the dramatic change in eating habits.

Conclusion

Recent technological advances in preserving the natural organoleptic properties of traditional foods and improving the quality of industrially prepared foods have opened the way to the manufacture of high quality products with specific gastronomic characteristics.

NUTRITIVE VALUE AND SAFETY

As well as tasting good, successfully processed foods have to be nutritious and safe. They must provide the nutrients that are expected to be present, and manufacturers must as far as possible take into account dietary guidelines and recommendations given by expert committees aimed at preventing nutrition-related health problems such as obesity, hypertension, coronary heart disease, diabetes, cancer, etc.

Food Formulation

Food composition tables contain a large amount of information on the formulation of balanced or tailor-made diets. The recent accessibility of these tables in computerized programs has provided a much appreciated tool for food technologists, dieticians, or physicians to adjust the nutrient composition of foods or dishes.

Nutrient Bioavailability

Industrially processed foods are sometimes submitted to conditions that can destroy nutrients sensitive to heat, acid, or alkaline treatments, to oxidation, and to reactions with other food components, such as reducing sugars and polyphenols. This mainly affects vitamins (B-1, B-6, C, folic acid) and some amino acids (lysine, methionine, cystine, and tryptophan) (30). Chemical and biological tests are being developed to control the bioavailability of these nutrients in complete foods and to guide process modification to reduce nutrient loss.
Fortification

Nutrient fortification is often the most efficient way to balance a complete diet both for large populations deficient in minor nutrients—e.g., iodine, vitamin A—and for special groups—e.g., iron fortification of baby foods. The choice of technology depends on the situation. These used include microencapsulation, incorporation into salt or seasoning, or even incorporation into fertilizers—e.g., selenium in Finland. For mineral salts such as selenium, calcium, or iron, the choice of the most appropriate molecule often involves considerable research. For example, the iron salt to be used has to possess all of the following properties: good absorption, no color, no taste, and no tendency to catalyze lipid oxidation.

Antinutritional Factors

Many foods contain antinutritional factors that can decrease bioavailability of essential nutrients (phytic acid, tannins) or have adverse physiological effects (goitrogens, saponins, polyphenols, flatulent sugars, trypsin inhibitors). Technological solutions exist to extract and to inactivate these or to compensate for their effects. These include genetic manipulations of plants.

Functional Foods: Tailor-made Formulations

More and more foods are being designed to prevent or to treat specific disorders. This involves careful choice of raw materials, ingredients, techniques, and preparations. Thus malabsorption syndrome and chronic diarrhea in babies can be treated by a product containing a protein hydrolysate to reduce the antigenic sites and to improve the nitrogen digestibility, maltodextrins, and medium chain triglycerides to improve digestibility of carbohydrates and lipids, no lactose to avoid intestinal fermentation, and a low osmolarity to reduce diarrhea. Many other examples can be given in the field of the metabolic disorders, clinical nutrition, and organ failure.

Safety

Processed foods can become contaminated by several routes. The most common are microbial, accidental, and environmental. Contamination can also result from processing, (e.g., mutagens produced by pyrolysis). Advances in the analytical tools available to quantify contamination and assess toxicologic risk are an important aspect of nonapparent technologies. In parallel, regulations are being established to protect consumers from known risks. In spite of the conscientiousness of responsible people and authorities, unexpected problems often emerge. A good example is the increase in microbial infections among people consuming microwave-treated foods.
The development of new technologies necessitates rigorous controls and a great deal of modesty from the scientists.

CONCLUSION

Recent technological developments in food science and nutrition are globally beneficial for the consumer. Processed foods are safer, have better organoleptic properties, are more convenient, nutritive, diverse, and are available in adequate amounts. Not all new technologies succeed: single-cell proteins based on yeasts and bacteria, the spinning of protein isolates to produce meat analogs, and gamma irradiation to sterilize foods have all experienced setbacks. Technical factors are not the only reason for failure. The cost of the processes may be too high or full safety evaluation of the new products may be too expensive. Emotional factors are also important for the consumer who is not ready to eat everything that issues from technologies that he or she cannot understand.

In the future, an important domain of development will be in biotechnology to produce the most suitable varieties and the more adapted ingredients for high quality products, in quality control and safety, in packaging to improve shelf life and food quality, and in the protection of the environment. In parallel, laws will continue to be developed to protect the consumer and to regulate the application of these new technologies.

REFERENCES


**DISCUSSION**

**Dr. Hulse:** Could you comment on the European attitudes toward food irradiation?

**Dr. Finot:** The process is utilized in Canada for different purposes than have been promoted in Europe. For example, we use it to treat potatoes to reduce germination, and to treat fruits such as strawberries. In Europe the technology is not being readily accepted at present because radiation has a bad public image. In addition there are experts in Europe who feel we do not have enough evidence that the process is safe. Free radicals are produced during irradiation, which can give rise to new components. Many chemical reactions occur that we are not able to quantify.

**Dr. Müller:** You mentioned high-pressure treatment for sterilization. If you kill bacteria in food by this means won’t you also denature proteins?

**Dr. Finot:** The intensity of the pressure can of course be varied. Studies on this are under way, mainly in Japan. It seems that it may be possible to select a pressure range in which bacteria are killed but protein denaturation is reversible.

**Dr. Grütte:** You spoke about new technologies and new procedures in food manufacture. Will there be new developments in margarine manufacture, or artificial sweeteners?
Dr. Finot: Improvements in margarine can certainly be made. For example, better control of the hydrogenation process can reduce the amounts of trans fatty acids. Concerning sweeteners I think we have at our disposal a large variety of sweeteners made from carbohydrates by specific hydrolysis—enzymatic or acid hydrolysis—and the synthetic sweeteners, polyols and so on. One of the problems that has not been solved is how to mimic the salty taste.

Dr. Georgala: I should like to comment on fermentation processes as a possible way of dealing with food shortages. I don't think it is likely that technological fermentation will be able to play a general role in the supply of bulk foods on the basis of present knowledge. The cost is too great. There is plenty of evidence, however, that fermentation processes can be used for many food ingredients and there are commercial processes in operation, usually for higher priced special ingredients. An interesting example is a product which is now on sale in the United Kingdom. It is a fungus-based fermentation material with meatlike characteristics. It has taken 20 years to develop and government clearance also took a number of years to achieve.

Dr. Vis: What is the importance of lysine blockage in human milk substitutes made from animal milks?

Dr. Finot: This depends on the product. The more manipulation occurs the greater the lysine blockage. If you take cow's milk and dry it you will only block 1% to 2% of the lysine, but if you produce an adapted milk made from whey protein, the whey has to be treated first, then dried, both steps causing lysine blockage. By optimizing the technology for producing adapted milk our company now keeps lysine blockage below 10%, which is the limit we have set. The problem is more difficult to control when hypoallergenic milks are produced, but all products are tested for nutritional value by animal tests of digestibility and nitrogen balance. The final product should have a quality and protein value no less than casein.