DOI: 10.7251/QOL1001041G UDC: 613.2:664
Original scientific paper

Science for Food Safety, Security and Quality: a Review - Part 2

Enne Giuseppe[1]
Serrantoni Monica
Istituto Sperimentale Italiano "Lazzaro Spallanzani", Milan- Italy
Greppi GianFranco
Dip. Scienze Zootecniche- Laboratorio di Bionanotecnologie –Università degli Studi di Sassari, Sassari- Italy

Abstract: Authors are continuing to analyze factors which influence on three food essential elements: food safety, food security and food quality. There are discus about innovation in food technology, nanotechnologies, and food packaging. Novel sensing technologies using bio or nano materials can be used to detect quality and safety attributes in packaged foods. These sensing technologies range from rapid non-destructive and non-contact to highly specialized micro and nano-biosensing structures. In addition, the authors analyze the latest research on the application of biosensors to measure parameters that affect the safety and quality of products.

Future priorities for research in food science should build on the existing knowledge base and extend the impact of basic and strategic research in delivering high quality foods and food products and improving human health.

Key words: Food safety, Food security, Nanotechnologies, Biosensors, Food research priorities

Innovation In Food Technology

Various traditional food technologies have been advanced and new technologies developed in order to efficiently produce nutritious food and food ingredients for health food formulations. Today, innovation in food technology plays a crucial role in translating nutrition information into consumer products (National Science Technology Council, 2005). Food must both taste good and look appealing to be acceptable. Unfortunately, many of the so-called "nutraceutical" ingredients have a bitter taste or unpleasant flavour when incorporated into prepared foods. It is thus difficult for consumers to make them part of their regular diet regardless of their health appeal. In order to develop foods with added health value without compromising their flavour, texture, appearance, and functional efficacies, a wide array of food technologies must be employed (Thompson, 2003; Xu et al., 2001; Yun-Hwa, 2007).

One example is the use of encapsulation technology for delivering active ingredients. Encapsulation can maintain the stability and viability of these ingredients under harsh processing conditions, reduce nutrient interactions, mask the off-flavours inherent in many of these nutraceutical ingredients, and even control the release time, rate and target location of the encapsulated material.

On the other hand, certain natural food components that are deemed undesirable or perceived as deleterious to health can be removed or reduced to achieve healthier end products. For example, various processing procedures have been developed to remove caffeine from caffeine containing beverages or reduce anti-nutritive compounds from the natural food matrix. Artificial fats have been created to replace natural fats and oils for caloric reduction while still maintaining all the functional properties of natural lipids. Fermentation and enzymes can be used not only to break down toxic, allergenic, or anti-nutritive compounds in natural food materials, but also to enhance flavour and increase the bioavailability of essential nutrients.

The challenge of flavour is a major driving force for innovations in food technology for health food development.

[1] Correspoding author: E-mail: giuseppe.enne@istitutospallanzani.it

Modern biotechnology offers powerful new approaches to achieve these goals. Recent advances in gene science allow the accurate identification of the precise genes that produce an individual nutrient, flavour, or toxic compound found in natural plants, making possible the manipulation of specific components in a natural food material of plant or animal origin. Some examples of genetically modified foods for enhanced health value include higher oleic acid soybeans that offer better frying stability and taste, peanuts with an improved protein balance, tomatoes with a higher antioxidant (lycopene) content, potatoes with an improved amino acid content, garlic cloves that produce more alicin to lower cholesterol, oils such as canola oils that contain more stearate, making them more healthful, and strawberries that contain increased levels of cancer-fighting eliagic acid. Recently, nanotechnology has also begun to find potential applications in the area of functional food by engineering biological molecules toward functions very different from those they have in nature, opening up a whole new area of research and development.

Nowadays many successful projects have been performed within the food industry focusing on cost minimization and product development (WTO, 1998). In order to optimize food process and products there are software environments with predictive process and product models covering practically all processes and products. These process and product models have proven that they can greatly improve the efficiency and product quality in food processing (at the same time).

The research in quantitative protein and micro-organism fouling in heaters and evaporators has lead to the development of a module used to calculate and predict the impact on protein fouling and bio-fouling including the effects on product properties, resulting in longer running times, decrease of energy consumption, cleaning frequency, etc.

About food microstructures there is a a powerful technology Confocal Scanning Laser Microscopy that makes possible to visualize the microstructures of food matrices through a fairly straightforward sample preparation. CLSM allows to observe the behaviour of a given ingredient responsible for the formation of specific microstructures (foam, gel, emulsion,…). Another advantages of the CLSM is that ingredients are observed at microscopic scale in the real environment (sauce, meat batter, dessert, bread...) that can be dry, semi-solid or fluid.

As far as the future of food processes is concerned, CLSM analysis is one of the tools used to assess and understand: the influence of a process on a texture, the interactions between different ingredients, the texture stability, the changes of microstructures during cooking or under shear, the variation of ingredient functionality from one batch to another.

There are process control systems that controls product properties such as texture, taste and shelf life rather than process conditions such as temperature or flow (Togrul, Arslan, 2004). Such an approach is significant in the food industry. Based on a predefined list of product specifications, the systems calculate the optimal set-point values of the process parameters. Production costs related to energy consumption and fouling are taken into account. The systems allow continuous optimisation of production and more flexibility with regard to composition and quality of raw material, and so enabling new client requirements to be met. In this way it is a concrete answer to what food industrials expect. Pilot studies have shown that reductions of operational costs of more than 10% can be achieved.

To produce fresh foods with extended shelf-life new technologies have been developed to guarantee the safety and an extended shelf-life while preserving the freshness attributes of liquid food products (beverages, sauces,…). Based on existing UHT treatments, the technologies have a higher process temperature during a shorter time : 150°C to 200° during less than 0.1s ! This allows a better inactivation of thermo-resistant spores, a major problem for liquid food with extended shelf-life, than current UHT treatments. Besides, the systems have a lower processing cost than alternative technologies such as micro-filtration. Furthermore a better knowledge of chemistry will help researchers optimize solid foods and beverages; better analyze and develop methods of cooking, canning, freezing and packaging; and study the effect of processing on the appearance, taste, aroma, freshness and nutritional content of food.

The advances have been achieved in 4 important areas of food chemistry: protein, lipid, emulsifier and antioxidant research. For the most part, these innovations are still under development, but they have commercial potential in the near term. Or development has been completed, and researchers are looking to license the technology or collaborate in other ways with industry to commercialize the technologies.

Nanotechnologies

It has been recognized that in a few decades healthcare will become a large financial burden to industrialized societies. A solutions to this problem is to shift from curative healthcare (solve health problems) to preventive healthcare (prevent health problems from occurring or postpone them to a later age). Food is an important component of preventive healthcare and micro- and nanotechnology can contribute to that concept (Baeumner, 2004; Chen et al., 2006; Clark, 2006). Foods are generally complex, heterogeneous systems, often containing high concentrations of naturally occurring nano-particles (proteins!). Production and characterisation of nano-particles in foods has hitherto been called 'food colloid science', so there is a wealth of experience in this area upon which nano-technology may draw upon. Ultrasound spectroscopy offers the best prospect for the characterisation of concentrated systems of nano-particles.

Nanotechnologies involve the study and use of materials (nanomaterials) at nanoscale (sizes of 100nm or less) dimensions, exploiting the fact that some materials at these ultra small scales have different physiochemical properties from the same materials at a larger scale. Nanomaterial are produced using two building strategies, either a "top down" or a "bottom up" approach. With the innovations in food technology former approach, nanomaterials are created by breaking up bulk materials using such means as milling, whereas with the latter approach the nanomaterials are built from individual atoms or molecules that have the capacity to self-assemble (Marlowe, 2005; Morrissey, 2006). Currently federally-funded nanotechnology research in food and agriculture is devoted primarily to the areas of food packaging and pathogen detection and various innovative nano-sensors for the detection of pathogenic bacteria have been developed.

Recent research, however, has begun to address the potential applications of nanotechnology for functional foods and nutraceuticals by applying the new concepts and engineering approaches involved in nano-materials to target the delivery of bioactive compounds and micronutrients. Nano-materials allow better encapsulation and release efficiency of the active food ingredients compared to traditional encapsulating agents, and the development of nano-emulsions, liposomes, micelles, biopolymer complexes and cubosomes have led to improved properties for bioactive compounds protection, controlled delivery systems, food matrix integration, and masking undesired flavours.

Nanotechnology also has the potential to improve food processes that use enzymes to confer nutrition and health benefits. For example, enzymes are often added to food to hydrolyze anti-nutritive components and hence increase the bio-availability of essential nutrients such as minerals and vitamins. To make these enzymes highly active, long-lived and cost-effective, nano-materials can be used to provide superior enzyme-support systems due to their large surface-to-volume ratios compared to traditional macroscale support materials.

As with any innovative technology, it is difficult to predict the long-term effects of nanotechnology. Some concerns have therefore been expressed concerning the use of nanotechnology in food processing. Because of the small size of these nano-materials, the concern is that they may enter the food chain undetected, accumulate within tissues and organs, and can be taken up by individual cells. Researchers are also concerned that nanotechnology would give people too much control. Though these concerns are genuine, the huge benefits that nanotechnology promises to the food industry cannot be brushed aside. There is thus an urgent need for nanotechnology to be further studied and applied wisely for the benefit of humankind.

Food Packaging

Food is a complex biomaterial that is subject to many biological, chemical, and physical changes that affect its quality and shelf life. Biological changes are caused by micro-organisms (spoilage and pathogenic), insects and rodents (Sharma and Singh, 2000). Chemical changes result from environmental influences and include oxidation, flavour deterioration, and colour loss among others. Physical changes include moisture gain or loss, breakage, textural changes and contamination by foreign materials. Food quality refers to the degree to which a food meets expectations including sensory characteristics (taste, odour, texture, and appearance), nutritional profile, convenience, storage shelf life, safety, and other attributes related to product acceptance. Food quality is measured by several factors including microbial counts and types, nutrient content, colour, appearance, and moisture content. Minimum acceptable quality can be set based on regulatory limits, noticeable differences, or customer complaints among others. Shelf life is the time it takes for a food product to deteriorate to an unacceptable degree and is dependent on processing method, storage conditions and form of packaging. The major goals of food packaging are to reduce the rate of quality loss and to increase product shelf life to the extent required by the distribution system (Han, 2003). Packaging technologies have been developed to meet these goals such as high barrier packaging and modified atmosphere packaging.

Due to the fact that packaging is an essential part of preservation and quality assurance of foods, its basic functions are to protect against contaminants and environmental influences such as gases, light and moisture; to cushion against shock during transportation; and to serve as tamper-evidence devices (Park, 2005; Rooney, 2005). More importantly, packaging has the ability to hinder or minimize the growth of unwanted microbes in the food. New trends and demands in the global food supply chain present new challenges, which create an increasing demand for safer foods (Trezza, 2002). For example, global s bipolarization, while companies are merging and centralizing production and processing sites resulting in increased distribution of both raw materials and finished products. As a consequence, longer shelf life is demanded. At the same time numerous small niche production sites are appearing with a very different set of food safety challenges. This calls for new research in food packaging as an instrument to ensure a safer global food supply. Other trends and demands that significantly influence food safety are documentation and traceability, legislation, and consumer demand for safer, healthier, more convenient, better tasting, lower cost and environmentally friendly products. Packaging technologies such as modified atmosphere packaging and antimicrobial active packaging based on volatile (essential oils and alcohols) or non-volatile components (chitosan and nisin) have been developed as a result of these demands. The increase in crude oil prices and the growing environmental concerns have led to increased research on alternative packaging materials from renewable or bio-derived resources. Food products have specific micro-organisms associated with them. However, changes in environmental condition in the package can leave products vulnerable to other micro-organisms. Therefore there is need for detailed studies on the interplay among products, related micro-organisms and packaging materials. Such knowledge will form the foundation for the development of better preservation methods for new and existing products.

Novel and advanced polymeric materials are being developed for enhanced food packaging. The development of these materials is based on conventional polymer science methods, as well as newer technologies including biopolymers, nanotechnology and nano-composites, active and intelligent packaging.

Nanotechnology has great potential application in food packaging to improve properties of existing materials (for example increasing barrier properties for plastics) or develop new materials with unique properties. Polymer/inorganic nano-composites utilize ultra-small inorganic particles to achieve non-trivial changes in the nature of a polymeric material, and when properly designed and formulated can concurrently improve mechanical, barrier, thermal, and flammability properties. Nano-fillers are used in much smaller amounts (1-5 weight %) compared to traditional fillers such as silica (50%) to achieve similar performance.

The main advantage of these systems is the opportunities that they afford to uncouple and independently improve material properties. Polymer/inorganic nano-composites are thus a viable technology for “new” materials with various functionalities for food packaging applications.

Bio-based materials in conjunction with nanotechnology are expected to create a major breakthrough in the plastic packaging industries. The bio-based materials (polymeric blends/composites/nano-composites) can find niche applications in both the flexible and rigid packaging sectors. The future of packaging will be sustainable if it is designed through innovative and synergistic research approaches. New material development is now transitioning from hydrocarbon chemistry (petroleum-based) to carbohydrate chemistry (biomass derived).

Active packaging senses change in the internal or external environment of a food package and responds by altering its properties to help better deliver the food product. Intelligent packaging senses changes and signals them. It is expected that intelligent packaging signals may be upgraded to active ones to help control the environment and thus enhance the safety or quality retention of the contained product.

Biosensors For Food Quality and Safety

The latest research developments for food quality and safety are based on biosensors and other sensing technologies, with specific attention to rapid detection of microbial activity, biochemical activity and other reactions that cause food deterioration.

Novel sensing technologies using bio or nano materials can be used to detect quality and safety attributes in packaged foods. These sensing technologies range from rapid non-destructive and non-contact to highly specialized micro and nano-biosensing structures. Micro- and nano-based sensors that utilize a variety of transduction mechanisms to sense microbial and biochemical changes in food products are being explored. The following are examples of technologies with potential application in food quality and safety detection. Non-contact ultrasound imaging technique can be used to detect foreign objects such as glass or bone fragments in boneless chicken or cheese. Spectroscopy methods, such as the Midinfrared Photoacoustic, Fourier Transform Raman and possibly Near Infrared can be used for rapid assessment of microbial contamination of food surfaces or packaging films. Biosensor technologies that are based on coupling of a ligand-receptor interaction to a transducer have more specific detection capabilities.

Optical biosensors such as SPR (surface plasmon resonance) based pathogen detection systems provide for selective detection of microbial species. Mid-infrared biosensors, which combine bio-sensing and spectroscopy capabilities, may provide improved pathogen detection specificity.

Nano-bio sensors and integrated micro systems could play a significant role of detecting deteriorative changes in food packaging. In intelligent food packaging appropriate sensing technologies are required to detect substances in parts per trillion for food safety, quality and process control. Development of new sensing devices may be achieved by taking advantage of miniaturization of electronics and nano-bio materials. These novel sensing systems can be used to facilitate on-line analysis of food stuffs. The devices can also be used to determine specific components in food and drinks such as sugars, proteins, vitamins and fats and to detect and quantify chemical contaminants such as pesticides, heavy metals, and antibiotics. They can also be used to detect pathogenic bacteria (E coli, Listeria, Salmonella, Campylobacter, Vibrio), viruses, toxins (Staphylococcus enterotoxins, Botulinum neurotoxins, Mycotoxins and Paralytic/Diarrhetic shellfish toxins), and to monitor the freshness of aquatic foods including fish, and fermentation processes. The integration of biosensor with micro systems further revolutionizes the performance of these biosensors with respect to sensitivity and resolution, accuracy, repeatability, dynamic range, speed of response and cost.

Role of the International Scientific Community On Food Safety

The vision for future food production was summarised as 'Safe, sustainable and ethical'.

Although much progress has been made in recent decades and some claim that 'our food has never been safer', those involved in trying to ensure the safety of the food supply should recognise that there is still a long way to go before that goal is reached (FAO, 2000; FAO 2003; FAO 2007; USDA, 2002).

Previously, food control often concentrated on the examination of end products and inspection of food processing and catering establishments. However, in recent decades there has been a growing awareness of the importance of an integrated, multidisciplinary approach, considering the whole of the food chain (and in some cases beyond what is conventionally regarded as the food chain). Many food safety problems have their origins in primary production and one result of the change in approach is a much greater awareness of the need for better control on the safety of animal feed, an area which until fairly recently had received scant attention from those responsible for food safety. In recent years, much stricter control on animal feed has been introduced in the EU and the Codex Alimentarius Commission (CAC) has established an ad hoc Task Force on Animal Feeding (FAO, 1999).

Towards the end of the last century, there was a paradigm shift in the food safety area with the introduction of a risk-based approach. One reason for this was the advent of the World Trade Organisation Agreement on the Application of Sanitary and Phytosanitary Measures (the SPS Agreement). This Agreement requires Member States (MS) to base their food safety measures on risk assessments, taking into account risk assessment techniques developed by the relevant international organisations – the CAC in the case of food safety. However, Article 5.7 of the SPS Agreement allows MS to take provisional measures, where relevant scientific evidence is insufficient.In order to stimulate the application of risk analysis principles in food safety work, FAO and WHO jointly organised a series of expert consultations on the different components of risk analysis – risk assessment, risk management and risk communication (FAO-WHO, 2007). The recommendations from those Consultations have been used as the starting point for the introduction of risk analysis principles into the Codex system. They have also been used by many government agencies in developing food safety risk management. There should be a functional separation of risk assessment and risk management in order to ensure the scientific integrity of the risk assessment. However, risk analysis is an iterative process and interaction between risk managers and risk assessors is essential for the practical application of risk analysis. This has been recognised in the proposal for the new European Food Safety Authority (EFSA), which will have responsibility for risk assessment in all matters having a direct or indirect impact on food safety. The Authority will work closely with the European Community bodies that have responsibility for risk management (the Commission, the Council and the Parliament). In line with the holistic approach to food safety, the mandate of the Authority will cover the whole 'farm-to-fork' continuum.

A risk-based approach to food safety risk management implies that food control resources should be directed towards problems that pose the largest threats to health and where the potential risk reduction is large - in relation to the resources used. In order to make priorities more risk-based, much better systems for follow up and reporting on food-related diseases are needed and better international co-operation in this area. WHO is making a major effort to improve the current situation, but is, of course, dependent on the active co-operation of national agencies.

Therefore WHO is developing policies that will further promote the safety of food and cover the entire food chain from production to consumption.

The Work of the WHO includes strengthening food safety systems, promoting good manufacturing practices and educating retailers and consumers about appropriate food handling. Education of consumers and training of food handlers in safe food handling is one of the most critical interventions in the prevention of foodborne illnesses.

WHO is promoting in-country laboratory-based surveillance of priority foodborne diseases in humans and animals, as well as the monitoring of pathogens in food. In co-operation with its Member States, WHO is working to support the development of internationally agreed-upon guidelines for data collection in countries. WHO is also compiling outbreak and surveillance databases, and is broadening its epidemic surveillance capacity to include foodborne disease outbreaks.

WHO is expanding its global network of participating institutions to monitor chemical contamination of the food supply, particularly in developing countries.

WHO is promoting the use of all food technologies which may contribute to public health, such as pasteurization, food irradiation and fermentation.

WHO has undertaken an important new initiative to strengthen the scientific basis of food safety activities through the establishment of a WHO/FAO (Food and Agriculture Organization of the United Nations) expert advisory body to assess microbiological risks in food.

WHO is increasing its involvement in the work of the FAO/WHO Codex Alimentarius Commission, whose standards, guidelines and recommendations are regarded as the international reference for food safety requirements by the World Trade Organization. WHO and FAO is initiating a thorough review of Codex primo 2002 (FAO-WHO, 2002).

Biotechnology has become a major public issue in developed as well as developing countries. WHO, jointly with FAO, will convene a series of expert consultations to assess the safety and nutritional aspects of foods derived from genetically modified plants, microorganisms, and animals. WHO has initiated work to establish a knowledge base focusing on a broader evaluation of risks, benefits and other considerations related to the production and consumption of foods derived from biotechnology.

In Developing Countries

Weak food safety systems can lead to a higher incidence of food safety problems and diseases caused by micro-organisms such as Salmonella, E. coli, Campylobacter, and Listeria, by residues of agricultural chemicals (pesticides, veterinary drugs, etc) and by the use of unauthorized food additives. Food production systems in developing countries are facing a series of challenges: population growth and urbanization, changing dietary patterns, intensification and industrialization of food and agricultural production. Climate conditions, poor sanitation and weak public infrastructure compound these difficulties. Food safety legislation in many developing countries is often incomplete or obsolete or not in line with international requirements. Responsibility for food safety and control tends to be dispersed across many institutions. Laboratories lack essential equipment and supplies.

In order to ensure safe food production for their own consumers and to meet international sanitary and phytosanitary requirements for food exports, national food safety authorities should be more vigilant.

Producers and traders should be held accountable for safe food production throughout the food chain.

The rules of the World Trade Organization stipulate that developed countries help exporting developing countries to achieve the necessary high level of food safety for international trade. This assistance should contribute to building or strengthening integrated national food safety systems covering the entire food chain. This often requires long-term multi-billion dollar investments and technical advice.

FAO and WHO are supporting national governments to improve the institutional set-up and the performance of food inspection, enforcement, laboratory analysis and diagnosis, certification, food-borne disease surveillance, emergency preparedness and response. They also provide scientific advice on many food safety issues such as food additives, chemical and microbiological contaminants, and agro-chemical residues.

The Codex Alimentarius Commission established by FAO and WHO develops science- and risk-based food safety standards that are a reference in international trade and a model for countries to use in their legislation. The application of these standards and guidelines would ensure food safety and consumer protection.

Food Security Control System

To enable the traceability of animals across borders, in April 2004, the EU introduced the TRAde Control and Expert System (TRACES), a community system to manage animal movements and prevent the spread of animal diseases. This provides a central database for tracking the movement of animals both within the EU and from third countries. In the event of a disease outbreak, TRACES ensures that all potentially affected animals can be quickly identified and that authorities can take appropriate measures.

The Rapid Alert System for Food and Feed (RASFF) is a tool to enable the quick and effective exchange of information between Member States and the Commission when risks to human health are detected in the food and feed chain. All Members of the RASFF (EU-27, Commission, EFSA and Norway, Liechtenstein and Iceland) have a round-the-clock service to ensure that urgent notifications are sent, received and responded to in the shortest time possible. Thanks to RASFF, many food safety risks have been averted before they could do any harm to consumers. The RASFF report breaks down the overall number of notifications in 2006 into alert (934) and information (1989) notifications. Alert notifications are sent when the food or feed presenting the risk is already on the market and immediate action is required. The majority (62%) of alert notifications in 2006 related to products originating in the EU, and most of these problems were detected by controls carried out on the market. Among the risks most reported through these alerts were the presence of potentially pathogenic micro-organisms, heavy metals (such as mercury in fish) and mycotoxins. Information notifications are sent when a risk has been identified but immediate action by other Member States is not necessary as the product has not reached their market e.g. consignments stopped at the borders. Most information notifications (75%) were on products originating in third countries, and 40% of these related to mycotoxins (e.g. aflatoxins in nuts). Almost half of all notifications through the RASFF in 2006 were about products rejected at the EU border due to a risk they were found to pose to food safety. When such a product is identified, the RASFF informs the third country in question, in order to prevent a recurrence of the problem. In 2006, 1959 information notes were transmitted to third countries about risky products originating in their country. When a serious and persistent problem is detected, the Commission sends a letter to the national authorities of the third country concerned, so that they implement corrective measures such as delisting establishments, blocking exports or intensifying controls. The RASFF report also outlines future activities which are planned in this area. One example is a project to promote the idea of a worldwide rapid alert system for food safety. Initially, the Commission will help interested third countries to develop a national system to improve consumer protection, and 3 training seminars are organised to this end in 2007 under the Better Training for Safer Food initiative. The ultimate goal will be to join all of these national systems in a global network of food safety alert systems.

The Need For Future Research

In light of the expected doubling of food demand by 2050, the world's shrinking supply of arable land and water, and the growing use of agricultural feed stocks for industrial purposes, technological advancements will continue to play a vital role in the ability of agricultural and food production to meet the world's growing food needs. Innovation in food and agricultural production is necessary but often also invites controversy (International Process Alimentaire, 2006; Beier, Pillai, 2007).

The innovation process can work in either of two ways: from research to practice or from practice to research. Nutrition information is being translated into consumer products at an accelerated pace with the aid of food technology. Scientific evidence has prompted consumers to increasingly opt for low calorie and low fat foods, as well as other foods that hold out the promise of health benefits.

Food processors are eagerly adding value to their products based on nutritional information to meet the current consumer demand for healthier food products. These added values include removing or reducing anti-nutritive components that are present naturally in the food matrix; reducing food components such as fat, caffeine or calories; adding bioactive ingredients that offer health benefits; and increasing the amount of essential nutrients present in food. Various food technologies must work together to achieve the goal of manufacturing healthy foods while at the same time maintaining their sensory qualities. With continuing advances in food technology, coupled with the seemingly unending stream of newly discovered functional ingredients, the sky is the limit for the development of novel food products for health benefits. Research in several key areas, including ingredient synergy, biological efficacy, and the safety aspects of the long-term consumption of value-added food produced using novel food technologies, will thus be needed as a consequence. Research into the creation of new health foods promises to continue to be an exciting endeavour that is likely to exceed our wildest imaginings. Research should cover a range from supply of raw materials, through processing and manufacture, through consumer behaviour, to physiological impacts on health.

Food contains bioactive components, which include nutrients (proteins, carbohydrates, lipids, vitamins, minerals), flavours and many other non-nutrients which act as physiological modifiers (these affect a wide range of cellular processes and some may act as stimulants or appetite suppressants). The objective of food production is to deliver these in an appropriate manner to benefit health. Once food has been ingested its interaction with the GI (gastrointestinal) tract affects the supply of nutrients and bio-active non nutrients to the body. The quality, form and kinetics of metabolites that enter the systemic circulation and their impacts on physiological functions at the cellular and molecular level will have a major impact on health. Genotypic differences and epigenetic changes can influence responsiveness to diet and understanding individual variation in dietary requirements and risk will be a major challenge. Some of the future research areas necessary for the improvement of food quality, safety and for the application in the food industries, from primary manufacture to retail, can be broken down as follows:

Research relating to the delivery of bioactive components in food that benefit health

This area includes research to maximise the production, yield and delivery of nutrients and physiological modifiers that benefit health.

Research to improve:

- *understanding of metabolism in crop plants and farm animals,*
- *separation methods for bioactive components,*

- *analytical methods to measure beneficial components,*
- *efficient bio-processing in food fermentation,*
- *understanding of the reaction chemistries in food processing,*
- *understanding of microbial physiology in processing environments,*
- *technologies to protect and deliver beneficial components,*
- *composition of foods to meet the low energy-high nutrient modern dietary requirements.*

Research leading to an improved understanding of what constitutes healthy food

This area includes research to improve the health benefits of foods and maintaining consumer satisfaction.

Research:

- *to understand the influence of food structure and composition on human nutrition and physiology to enable foods to be designed with precise nutritional and physiological properties;*
- *to ensure that beneficial bioactive food components are delivered to the point where they can be used. This includes, for example, active delivery of nutritional benefit to the gastrointestinal tract and post-absorptive tissues, or of flavour to the nose and mouth;*
- *to understand the basis of taste, texture and flavour at a fundamental level to enable reductions in salt, sugar and fat content without adversely affecting consumer response;*
- *to investigate the role of food constituents, particularly minor food components, on regulating energy intake through signalling satiety;*
- *to study the GI tract in order to characterise the biology underlying the interactions between nutrients, bioactive non-nutrients, the intestinal microflora and the gut.*

Understanding the effects of food and food components on human physiology, metabolism, health and behaviour

This area includes research to improve our understanding of the effects of food and food components on human health:

- the effect of the physical properties of food on the physiology of the gut;
- nutrient and bioactive non-nutrient uptake and assimilation, and systemic distribution of food metabolites;
- the immunology of the gut in relation to food allergens and other dietary components;
- the microbial ecology of the gut in health and disease;
- satiety signalling and the role of food components;
- individual genetic variation and personalised nutritional requirements.

Tools and technologies for food research

This area is generic and is required to underpin a number of aspects of food research and would include:

imaging technologies at cellular and organismal level;

- *high throughput methods for metabolomic studies of food plants and animals;*
- *high throughput methods for genomics and metabolomics in understanding the cellular*

responses to nutrients and other food bioactives;

- *application of new methods in the analysis of food composition;*
- *development of novel technologies for assessing exposures to foods and food components;*
- *materials technology for delivery of bioactive components.*

Food Research Priorities

Future priorities for research in food research should build on the existing knowledge base and extend the impact of basic and strategic research in delivering high quality foods and food products and improving human health.

Innovative areas of research that should contribute significantly to the objectives of the food quality improvement, to the development of policy and to the nation's health are proposed below.

Genomics and metabolomics of food-producing organisms

This priority will address the intrinsic properties of crops, food animals and food-processing micro-organisms to provide the evidence base for breeding crops and animals with improved properties for delivering bioactive components and for specific processing objectives. At present this would be by natural genetic processes, but the possibility of using genetically-modified crops and animals must be considered.

The properties of micro-organisms used for dairy and fermentation bioprocesses influence the final product. The application of metabolomics to understanding the complex process of fermentation, particularly in optimising food structure and/or flavour and reducing undesirable by-products, is an important new technique to understand and manipulate microbial physiology for food processing. With the increasing understanding of such micro-organisms and the availability of genome sequences, there are significant opportunities to study and improve fermentation micro-organisms.

Physico-chemical structures of foods

The physical nature of foodstuffs is important in the technologies that need to be applied in processing the raw materials and the delivery of nutrients and bioactive non-nutrient components of food to the human body. It has become increasingly apparent that the fine structure of food at the nano- and micrometre scale is important in defining its physical, chemical and biological properties. This affects food processing, has a major impact on delivery of bioactives and is likely to regulate nutrient release in the gut, yet is relatively poorly understood.

An understanding of the physics and chemistry of foods requires collaboration between biologists, physical scientists, and engineers, with input from mathematicians and modellers. There is a specific requirement for materials scientists. New analytical methods for analysing desirable and undesirable constituents of foods will be important. Having suitable physico-chemical models for foods will better enable the modification of foods to have desirable properties conferring health benefits with optimal processing conditions and costs.

This will include the active modification of foods to ensure better delivery of flavour, nutrients and physiological modifiers at the appropriate sites of action. A better knowledge of food structure should help develop processing protocols to reduce salt, fat or sugar contents of some foods.

The human GI tract as a biological system

The primary site of action of food is on the human GI tract. Via its role in taste and satiety and regulation of rates of absorption and metabolism of nutrients and fluids, the gut acts as the gate keeper in whole body homeostasis. The health of the large gut is related to its microbial ecology (commensal and pathogenic micro-organisms), and to complex interactions between these microorganisms, the epithelial lining and mucosal immune defences, and to the chemical and physical properties of the gut contents (pH and ionic balance, food residues, allergens, toxins). Metagenomic techniques may be used in the analysis of the gut microbial flora, and new analytical and imaging techniques may give better information on the chemical and physical properties of the gut contents in vivo.

A full understanding of the physiology, immunology and biochemistry of the gut, including nutrient sensing, transporter regulation, musculature and endocrine and neural feedback systems, is required in order to be better able to address issues of diet and health. It is important to study gut function across the lifecourse, from infancy to old age. There are some generic properties that need to be better understood (e.g. the rate and efficiency of macronutrient and micronutrient absorption by the enterocytes, and transport into the systemic circulation, interactions of commensal and pathogenic bacteria, effect of allergens and toxins), in order that the functional components of the alimentary tract can be modeled using systems approaches. This will require the collaboration of biologists, mathematicians, engineers and physical scientists to develop theoretical models of the functions of specific sub-components of the whole system, and to test the predictions through cell, animal and human volunteer studies. This is a significant challenge and may require new methods, including imaging techniques, in order to determine the data required to populate and test the models proposed.

Diet as a modifier of development and health

Although there is considerable evidence and public acceptance that diet affects health and the risk of chronic disease in adults, as illustrated by public health campaigns to reduce salt intake and increase fruit and vegetable consumption, the role of diet in affecting development at critical life stages, beyond minimal nutritional requirements, seems less well understood. In particular, little is known about the detailed mechanisms whereby nutrition early in life e.g. during fetal development or infancy, can affect health and cognitive functioning decades later.

Evidence from animal studies suggests that epigenetic modifications introduced by dietary insults and constraints are “remembered” throughout the life-course with consequences for gene expression and cell function. Recent advances in characterization of the epigenome provide a unique opportunity to understand the molecular basis of early life programming on later health. It is also possible that early-life nutritional experience leaves an imprint through stochastic damage and/or the long-term consequences of altered organ growth, which can affect later health and cognitive functioning.

Nutrition, metabolic regulation, ageing and health – a life course approach

An individual’s body weight results from the sum of metabolic activities functioning under differing circumstances, and reflects complex interactions among genotype, gender, metabolic phenotype and the environment. A better understanding of these interactions and markers of dysfunction over the life-course are needed. There is particular need to understand the effects of childhood obesity, patterns of weight gain and differences in body fat distribution on long term health outcomes. A consensus is emerging that sleep restriction has an impact on appetite regulation and metabolic function and chronically may contribute to failing homeostasis. Maintaining metabolic homeostasis throughout the life course is likely to be key to healthy ageing.

Individuals in an ageing population now risk spending more of their later years in ill-health, and hence placing higher demands on healthcare provision. It is now recognized that diet can moderate the rate of ageing directly through an ability to retard the loss of homeostatic decline, but our understanding of the underlying mechanisms of ageing and how diet can ameliorate the physiological and cognitive decline into ill-health is very incomplete. Many aspects of nutrition and metabolic regulation undergo alterations with age that result from an accumulation of cellular and molecular damage. For example, age-related changes to the gut epithelium, neurons, muscle, endocrine signaling pathways and mucus secretion have important effects on many aspects of health, yet are little understood. There is significant interest in the differences between individuals and the potential role of personalized nutrition in achieving and maintaining optimal health. There is considerable opportunity to determine the effects of individual genetic (and physiological) variation in response to nutrients, allergens and microorganisms. Knowledge of the extent of individual variation in response to diet (nutrigenetics) and capacity for manipulation of phenotype according to genotype, is of importance in optimizing individual health.

In view of the intrinsic complexity of the relationship between the gut, diet and health, there is an urgent need for systems approaches to studying nutrition, endocrinology and metabolism, including linking diet to physiological programming. It is unclear how far into the life course such programming can occur to affect the subsequent health trajectory and if such physiological programming is reversible. This will require high throughput data collection including exploitation of emerging knowledge of the epigenome and modelling of dietary effects on metabolism and development, including the biology of the GI tract, to develop predictive dietary approaches to minimize dysfunction and to optimize health.

Food microbiology and food safety

Microorganisms are crucially important in the harvesting, production and safety of foodstuffs. Microorganisms responsible for food production have long attracted research interests, particularly to develop more stable and more efficient strains for the dairy industry. With increasing emphasis on the reduction of preservatives in food and the environmental cost of large-scale refrigeration, spoilage of raw and processed foods may increasingly be an issue. There has been relatively little recent work on spoilage microorganisms other than those that cause problems in human health (e.g. toxin-producing or pathogenic microorganisms). Although there has been a significant amount of research on the mechanisms of pathogenesis of food-borne pathogens, there has been less work on their detection and removal from the food chain. The role of probiotics in altering the gut flora is a topic of increasing commercial and scientific interest.

Tools and technologies for food research

The EU experts identified the engagement of individuals from the high technology disciplines and cutting edge life sciences as being important to the future of nutrition research. Such engagement would include simulation of human metabolism and the prediction of individual nutritional need, technologies (including nanotechnologies) for targeted delivery of bioactive components, new methods for chemical sensing of metabolites, and non-invasive imaging for visualisation of nutritional status and of cellular and tissue responses to particular foods or food components. There is significant opportunity for new methods from other disciplines to contribute to food research.

REFERENCES

Baeumner A. (2004). Nanosensors identify pathogens in food. Food Technol., 58, 51-55.

Beier, R.C., Pillai, S.D. (2007). Future directions in food safety. In: Shabbir, S., editor. Foodborne Diseases. Totowa, NJ: Humana Press. p. 511-530.

Chen HD, Weiss JC, Shahidi F. (2006). Nanotechnology in nutraceuticals and functional foods. Food Technol., 60, 30-36.

Clark JP. (2006). Nanotechnology: a processing topic this year. Food Technol., 60, 135-140.

FAO. (1999). Understanding the Codex Alimentarius. ISBN 92-5-104248-9.

FAO. (2000). Twenty Second Regional Conference for Europe. Food Safety and Quality as affected by organic farming. Porto, Portugal,

FAO/WHO. (2002). PAN-European Conference on Food Safety and Quality. Budapest.

FAO/WHO. (2007). Countries urged to be more vigilant about food safety. ROME/GENEVA.

FAO. (2003-2004). Agricultural Biotechnology Meeting the Needs of the Poor?

Han JH. (2003). Antimicrobial food packaging. In: Ahvenainen R, editor. Novel food packaging techniques. Cambridge, U.K.: Woodhead Publishing Ltd. p 50–70.

http://www.fao.org/documents/show_cdr.asp?url_file=/docrep/006/Y5160E/Y5160E00.htm

International Process Alimentaire (IPA) - (2006).- World Food Process Exibition "Driving continuous innovations"

Marlowe DE. (2005). Nanotechnology and the U.S. Food and Drug Administration. ASTM Stand News; 33, 29-31.

Morrissey S.(2006). Nanotechnology in food and agriculture. Chem Eng News, 84, 31-31.

National Science and Technology Council. (2005). The National Nanotechnology Initiative: Research and development leading to a revolution in technology and industry – Supplement to the President's 2006 budget. Nanoscale Science, Engineering, and Techology (NSET) Subcommittee, National Science and Technology Council, U.S. Govt; www.nano.gov/html/about/home_ about. html.

Park HJ. (2005). Edible coatings for fruit. In: Jongen W, editor. Fruit and vegetable processing. Boca Raton, Fla.: CRC Press LLC.

Rooney ML. (2005). Introduction to active food packaging technologies. In: Han JH, editor. Innovations in food packaging. San Diego, Calif.: Elsevier Academic Press. p 63–79.

Sharma RM, Singh RR. (2000). Harvesting, postharvest handling and physiology of fruits and vegetables. In: Verma LR, Joshi VK, editors. Postharvest technology of fruits and vegetables Vol. 1. Handling, processing, fermentation and waste management. Tagore Garden, New Delhi: Indus Publishing Co. p 94–147.

Thompson AK. (2003 a). Preharvest factors on postharvest life. In: Fruit and vegetables. Ames, Iowa: Blackwell Publishing Ltd. p 1–8.

Thompson AK. (2003 b). Postharvest treatments. In: Fruit and vegetables. Ames, Iowa: Blackwell Publishing Ltd. p 47–52.

Togrul H, Arslan N. (2004). Extending shelf-life of peach and pear by using CMC from sugar beet pulp cellulose as a hydrophilic polymer in emulsions. Food Hydrocolloids, 18, 215–26.

Trezza TA, Krochta JM. (2002). Application of edible protein coatings to nut and nut-containing food products. In: Gennadios A, editor. Protein-based films and coatings. Boca Raton, Fla.: CRC Press.

USDA (United States Department of Agriculture). (2002). Traceability for Food Marketing & Food Safety: What's the Next Step? Agricultural Outlook/January–February 2002. 21–25.

WTO (1998). WTO Annual Report 1998.

Xu S, Chen X, Sun DW. (2001). Preservation of kiwifruit coated with an edible film at ambient temperature. J Food Eng., 50,211–6.

Yun-Hwa Peggy Hsieh, Jack Appiah Ofori. (2007). - Innovations in food technology for health. Asia Pac J Clin Nutr., 16 (Suppl 1) 65-73.

Recived: 10.04.2010.
Accepted: 17.07.2010.