FOOD QUALITY AND ASSURANCE

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Summary

Food greatly influences the health of populations, therefore food quality control is an important government activity and is legislatively regulated. Food quality is a complex term that includes nutritional, sensory, hygienic-toxicological, and technological points of view. Food has to fulfill all requirements of quality, but above all it has to be safe. High quality products can be produced from high quality raw material. One can say that the raw material influences the quality of the end-products in large degree. The quality of the product is further influenced by the technological procedure used. It depends not only on the technological procedure itself but also above all on the hygienic level of the

machinery used and on the total hygienic manufacturing conditions. During the technological procedure, especially at so-called critical control points, such quality parameters that most influence the total quality of the manufactured product have to be controlled. The quality of the end product has to fulfill the requirements for the given class of food. The labeling, statement concerning weight, and other data, including the date of safe usage, is important to the consumer. The producers are fully responsible for the quality of produced foods. The quality of the end food products is affected above all by the raw materials used. For this reason, close cooperation between agriculture and processing plants is needed. In many cases, farmers make agreements with the food industry not only on the quantity of produced raw materials but also on their quality. The quality of raw material (wheat, milk, eggs, and so on) is evaluated, and farmers are paid accordingly. In all cases the raw material must fulfill all hygienic requirements. Great attention is paid to the presence of different kinds of contamination, such as heavy and toxic metals, toxic metabolites of microorganisms, pesticide residue, and the presence of GMO material, and so on.

In perishable raw materials, microbiological quality plays an important role and has to be controlled. The water content of many raw food materials has the biggest influence on its storability. The water content and weight are measured during acceptance. For quality control of individual raw material, different quality parameters are chosen, according to the quality requirements of the product for which the raw material will be used. Different methods based on different principles may be used. As far as quality determination of raw material is concerned, rapid control methods are preferred. In-process quality control allows the producer to follow all changes that happen during the technological procedures applied. Quality control gives the producer security that the finished product will fulfill all quality requirements. First the product should be safe. To control technological procedures, many systems have been elaborated. The Good Manufacture Practice (GMP) system and quality management praxis were developed and successfully applied in many food-producing plants. These systems were further developed into more effective ones—the Hazard Analysis Critical Control Points (HACCP) system. This system has improved traditional practices by introducing a more systematic rule based on applying knowledge from food microbiology, food chemistry, food analysis, and food technology. It should also be remembered that HACCP is primarily a preventive approach to quality assurance and as such is not just a tool to control quality during processing, but can be used to design quality into new products during their development. The HACCP systems are utilized to prevent disastrous events resulting from microbiological, chemical, and physical hazards.

Specific aspects of in-process control include control systems applied during the production of individual foods. Such systems depend on used raw material and finished food products. The greatest attention is paid to the safety of produced food, from microbiological and chemical points of view. Also, all food components that are important from nutritional and sensory points of view, especially those which are decomposed during food production, are tracked. A great spectrum of methods may be applied for these purposes. The quality of the finished product is basic for consumers. First, food products have to be safe and without danger for consumer health. They must also fulfill consumer requirements from sensory and nutritional points of view. Consumers have to be convinced that the application of the entire control system guarantees the labeling quality of the products. Proper labeling of products is important for the consumer and has to fulfill the requirements given by the state.

The control system of finished food products is regulated by law. The quality of products is followed by at least three types of organizations. The first control step is at the producer level. Every producer controls production in his plant—including regulation of the most important items, such as quantity indices of final food products (weight and volume) and other items important for produced food: content of proteins, sugars, fats, salt, minerals, vitamins, and so on. Plant laboratories do not usually conduct special analyses. Governmental laboratories have the highest responsibility for quality control of finished food products. These laboratories have different structures in different countries (a central laboratory and district laboratories). They are usually well equipped and are able to conduct complicated analyses for determinations of contaminants and so on. Such organizations have great responsibility and authority given by law. They regularly control the production of foods, and special attention is paid to problems that occur in regions with newly developed products and newly imported products with some risk components found in the originating environment, or with new diseases of animals, and so on.

In many countries, consumer protection control institutions and organizations are active. Such organizations are important because they try to find and prove the validity of different, and, in many cases, unofficial information about danger from raw materials, food additives, contaminants, or produced foods. In this way they press the responsible state control organization to improve the control system used. For food quality control, different methods based on different principles may be used. Their selections depend on many factors. In most cases, especially when a product of daily consumption has to be controlled, the time needed for the analysis plays the most important role. The methods used for a contaminant's determination have to be sensitive and specific to be able to detect a low concentration of such compounds. This chapter deals with food quality and assurance that includes quality control of raw materials, in- process foods, and finished products. Basic composition of raw food materials, and methods suitable for control of individual classes of food components, including food additives and contaminants, are summarized.

1. Introduction

Great attention has been paid to food quality for centuries (see *History of Food Quality Standards*). The requirements have been changed according to the development of human knowledge in the field of nutrition, food chemistry, food microbiology, and food analysis. It is necessary first to point out that the term food quality is a complex one that includes many indicators. For food to be classified as good, it has to fulfill the requirements, especially from the nutritional, sensory, hygienic-toxicological, and technological points of view.

Nutritional quality of food. The nutritional quality of food is shown by the composition of nutrients present in it. The consumer should obtain these nutrients in such amounts that are regularly present in the type of product when it is produced from good, raw material, with suitable technology, and stored under suitable conditions.

Sensory quality of food. It is well known that the sensory quality of food plays an important role, because most consumers select food especially from a sensory point of view. Therefore, the sensory quality of food is important not only for the consumer but also for the producer. As will be mentioned later, sensory judgment of food is still essentially part of a quality judgment of food, despite great progress in the instrumental, analytical procedures used for the determination of the individual, sensory, active components of food.

Hygienic-toxicological quality of food. This attribute of food quality is important, because it expresses the safety of a product for the consumer. The food has to fulfill all requirements according to national or international regulation from the microbiological point of view, as well as from other views, of acceptable content of natural toxic compounds and contaminants. Several food safety problems are the subjects of significant public interest, at consumer, public policy, and scientific levels. Among them the safety of genetically modified plants potentially used in food production should be mentioned. The application of recombinant deoxyribonucleic acid (rDNA) technology allows for an effective and efficient transfer of genetic material from one organism to another. Instead of cross-breeding plants for several years to acquire a desired goal, the scientist can identify and insert a single gene responsible for a particular trait into a plant. Genes do not have to come from a related species to be functional; hence, genes can potentially be transferred among all living organisms. The rDNA technology is the most promising, precise, and advanced strategy available for increasing global food production by reducing crop losses and increasing yields while conserving farm lands. Moreover, the use of rDNA technology has already shown that it can reduce the need for chemical pesticides, as well as enhance the nutritive value of crops, in such areas as altered protein or fat content, and increased phytochemical or nutrient content. Malnutrition problems such as deficiencies in vitamin A, iron, iodine, and others may be targeted by using rDNA technology to introduce or to concentrate these nutrients in plants. For example, rice has been genetically modified to contain β-carotene and more iron to help overcome deficiencies of these nutrients in countries where rice is the staple food.

Experts of the American Institute of Food Technologists have reviewed the scientific and policy issues concerning food derived from GMOs and published some conclusions. According to these views, recombinant DNA technology has great promise to increase world food production. The safety of food derived from GMOs is adequately assured by science-based procedures effectively used by the US Food and Drug Administration (FDA) and plant breeders. More than a decade of safety evaluation and experience with genetically modified plants has provided evidence and assurance that risks to the environment posed by these plants are no different from those of plants bred by traditional methods. There is no evidence that genetic transfers between unrelated organisms pose hazards that are new or different from those encountered with any new plant variety. Growing plants rDNA-engineered for pest resistance can reduce the need for chemical pesticides, thereby offering safer environmental strategies for pest and disease control. Genetic modification is compatible with environmental conservation and sustainable agriculture because it takes advantage of biological control mechanisms already adapted to nature. Policy for the assurance of food safety and environmental protection should be based on the characteristics of foods, not on the methods used to develop them.

The regulation of rDNA biotechnologically derived food differs from country to country. Some countries do not allow such foods to be used or imported on the basis that not enough is known about the long-term effects of consuming rDNA biotechnologically derived foods. Other countries permit such foods, with requirements that each food disclose on the label that it was produced using rDNA biotechnology. Still other countries compare the new plant or animal variety to varieties produced using conventional breeding to identify differences for safety evaluation, and to determine whether the differences need to be described on the food label. These countries do not require that food derived using rDNA biotechnology be labeled. The consumer’s right to know is an important factor in the rationale of those supporting mandatory labeling, particularly where consumer confidence in the regulatory system is low. To prove the presence of genetically modified raw material in food production is a complicated analytical task. There are two scientific methods for detecting genetic modification. One method involves testing for specific proteins that have been incorporated into a food through biotechnology, the other is based on the detection of inserted DNA sequences. Each method has two specific techniques: ELISA (Enzyme Linked Immunosorbent Assay) and Lateral Flow Strip (immobilized antibody detection technology) for the detection of specific proteins. Both of these methods detect specific proteins, but only the ELISA, in conjunction with a standard using the protein of interest, can provide quantification. The DNA test method PCR (Polymerase Chain Reaction) relies on complementary specificity of the two standards that form the double helix of double-stranded DNA strands annealed or hybridized in a sequence-specific manner. This specificity is exploited in the detection process. Southern blot analysis consists of using labeled, single-stranded DNA probes to detect fragments of complementary DNA of the protein. Both of these sensitive DNA methods can detect specific sequences within the introduced DNA. While these methods provide a reliable qualitative assessment of introduced DNA sequences, neither method provides an easily performed quantitative determination of the percentage of GM material in a given sample.

Irradiation of food is another procedure that is often discussed. Food irradiation is a physical means of food processing that involves exposing prepackaged or bulk foodstuffs to gamma rays, X rays, or electrons. Irradiation of foods according to various doses can be divided as follows.

Radicidation is the treatment of food with a dose of ionizing radiation sufficient to reduce the number of specific, viable, nonspore-forming pathogenic bacteria to such a population that none is detectable in treated food when examined by recognized bacteriological testing methods. Radicidation may also be applied to deactivate parasites. It is a treatment requiring a relatively low dose (about 0.1 kGY to 8 kGy) to eliminate pathogenic microorganisms other than viruses. Radicidation refers to irradiation pasteurization treatment, with the particular intent of eliminating specific pathogens. Radurization is the treatment of food with a dose of ionizing radiation sufficient to enhance its keeping quality by causing a substantial reduction in the numbers of specific viable spoilage microorganisms. Doses of about 0.4 kGy to 10 kGy improve shelf life of food products. Radicidation also refers to irradiation pasteurization.

Redappertization is the treatment of food with a dose of ionizing radiation sufficient to reduce the number and/or activity of viable mircroorganisms (with the exception of viruses, few of which, if any, are detectable by recognized bacteriological or mycological testing methods applied to the treatment of food). Redappertization treatment must be such that no spoilage or toxicity of microbiological origin is detectable, no matter how long or under what conditions the food is stored after treatment, provided the food is not decontaminated. This irradiation treatment with doses of about 10 kGy to 50 kGy brings about virtually complete sterilization. Redappertization is a term defined thus: irradiation sterilization or commercial sterility, as it is understood in the canning industry, with the resulting product being shelf-stable under normal conditions. Food irradiation is not a miracle food preservation method. Ionizing radiation exhibits advantages (the replacing of chemical treatments; treatments, in many cases, occur after packaging, thus avoiding recontamination; and so on) and limitations (not all foods are suitable for irradiation, treatment creates changes in sensory quality, lack of enzyme inhibition in foods, and so on), like any other method of food preservation.

A reliable procedure for verifying irradiated foods is important. The ability to reliably distinguish between irradiated and nonirradiated foods and ingredients is fundamental to reassure the public that consumer rights are protected. Also, although much progress is being made, it is unlikely that rapid, routine analytical methods suitable for use in the enforcement of food irradiation legislation will be available in the near future for all foods. Detection methods used include electron spin resonance (ESR), viscosity, thermoluminescence, lyoluminescence, conductivity, chemical analysis of volatiles, microflora, and DNA molecular composition. The combined application of selected methods provides a more informative picture of irradiation-induced processes.

To promote the worldwide introduction of food irradiation, it is necessary to develop national and international legislation and regulatory procedures. Variation in the regulations among countries restricts trade of irradiated products. Some countries follow the recommendations of WHO in setting the maximum dosage at 10 kGy, and others restrict irradiation dosage. Labeling is an important issue related to harmonization of irradiated products. Some countries require irradiated foods to be labeled, with the green radura symbol and words such as irradiated, treated with irradiation, radura, protected by ionization, and treated by irradiation; other nations demand just the radura symbol and no descriptive words; and no special label requirements are asked by yet other countries. Food can be processed nonthermally by high hydrostatic pressure (1000 atm to 9000 atm). This technology has been used for a long time to inactivate microorganisms and/or to preserve food. It has gained recognition as a nonthermal method of food preservation. High-pressure technology is a promising nonthermal food preservation method. High pressure can be used not only to preserve foods but also to improve their rheological and functional properties. An important aspect of high-pressure technology is the inactivation of enzymes, while nutrients and flavors are retained in the food. The technical difficulty of fabricating pressure vessels that will tolerate high pressures has limited the commercialization of high-pressure technology. However, efforts are being made to overcome this difficulty.

Other new methods of nonthermal preservation of foods, such as application of high intensity pulsed electric fields, oscillating magnetic fields, and light pulses are studied. When using high-intensity pulsed electric fields, the field is applied to the fluid food as short pulses, with a pulse duration of a few milliseconds. Food may be processed at ambient or refrigerated temperatures. With pulse electric field treatment, the food is processed in a short period of time, and the energy lost due to the heating of foods is minimal. The pulse electric field method can deactivate the microorganisms and enzymes. It is important in pulse electric field processing to avoid the dielectric breakdown of foods. Foods susceptible to dielectric breakdown are not suitable for electric field processing. The risk of dielectric breakdown limits pulse electric field processing to primarily liquid foods. Although liquid foods with small particulates may potentially be processed, the size of the particulates must be much smaller than the gap of the treatment region. Furthermore, solid food containing air bubbles is not suitable for electric field processing because air bubbles are potential sites of dielectric breakdown. The experiments have proved significant shelf-life extensions and minimum changes in the physical and chemical properties of certain foods. The sensory properties of foods are not degraded by a pulsed electric field. It is presumed that electric field treatment of food is accompanied by an increase in the temperature of food, yet the maximum temperature of the foods remains below thermal processing temperatures. Thus, the quality degradation associated with high temperature processing is absent or minimized in electric field treatment. There is little information on the inactivation of microbial spores. Although there are promising results on the inactivation of microorganisms and select enzymes, it is not wise to think of pulse electric field technology as a separate food preservation process. The use of other preservation methods, in combination with pulsed electric field technology, should be explored. Electric treatment is associated with minimum energy utilization and greater energy efficiency than thermal processes. To date, much of the literature discusses the application of pulse electric fields to pumpable foods. Little information is available on liquid foods with particles, or on solid foods. This is undoubtedly because of the difficulty in designing treatment chambers with a uniform electric field distribution.

Processing based on an oscillating magnetic field, where inactivated microorganisms were exposed to a flux of density greater than 2 T (tesla) had the following results. A single pulse with a flux of density between 5 kHz and 50 kHz reduced the number of microorganisms by at least two log cycles. The most important requirement of food successfully preserved with magnetic field technology is high electric resistance: greater than 10 ohm/cm to 25 ohm/cm. Many foods have electrical resistance in this range. Preservation of foods with magnetic fields involves sealing the food in a plastic bag, subjecting it to 1 pulse to 100 pulses in an oscillating magnetic field with a frequency between 5 kHz and 500 kHz at a temperature of 0 ^{o}C to 50 ^{o}C for a total exposure time ranging from 25μs to 10 ms. The exposure time is equal to the number of pulses multiplied by the duration of each pulse. The duration of each pulse includes 10 oscillations. After 10 oscillations, the substantially decayed magnetic field has negligible effect. A metal package cannot be used in the magnetic field process.

No special preparation of food is required before treatment of food by an oscillating magnetic field. Frequencies higher than 500 kHz are less effective for microbial inactivation and tend to heat the food material. Magnetic field treatments are carried out at atmospheric pressure and at a temperature that stabilizes the food material. Food is sterilized without any detectable changes in quality. The temperature of food increases by 2 ^{o}C to 5 ^{o}C, and the organoleptic properties change little after magnetic field treatment. Additional research is necessary to correlate the inactivation of microorganisms in food to the oscillating magnetic field flux density, oscillating magnetic fields to the denaturation of nutritional components of food, and the energy efficiency of magnetic fields to the increased shelf life of food. The effects of magnetic fields on the quality of food and the mechanism of inactivation of microorganisms must be studied in more detail.

One nonthermal method of food preservation involves the use of intense, short-duration pulses of broad-spectrum "white" light. The spectrum of light used for sterilization purposes includes wavelengths in the ultraviolet to the near infrared region. The technology of using light pulses is applicable mainly in sterilizing or reducing the microbial population on the surfaces of packaging materials, on packaging and processing equipment, foods, and medical devices, and on many other surfaces. The material to be sterilized is exposed to at least one pulse of light having an energy density in the range of about 0.01 J/cm^2 to 50 J/cm^2 at the surface, using a wavelength distribution such that at least 70% of the electromagnetic energy is distributed in a wavelength range from 170 nm to 2600 nm. Inactivation of select resistant microorganisms requires treatment with a complete spectrum; other microorganisms are inactivated with the spectrum of a certain wavelength range only. The pulse light process uses short-duration flashes of broad-spectrum white light to inactivate a wide range of microorganisms, including bacterial and fungal spores. The duration of pulses ranges from 1 μs to 0.1 s. The flashes are typically applied at a rate of 1 flash to 20 flashes per second. For most applications, a few flashes applied in a fraction of a second provide a high level of microbial inactivation. The process is rapid and amenable to high throughput. The technology of utilizing short pulses of light is an attractive alternative for disinfecting packaging material and food products packaged in transparent films. Heat generated in the light pulse process is minimal, and microorganisms are inactivated by a combination of photochemical and photothermal mechanisms. Light pulses apparently do not affect nutrient retention in food, although a detailed study is not available. Studies of the effects of light pulses on the properties of food beyond food safety and spoilage are necessary. It has to be clear that before introducing new food processing technologies, adequate and reliable evidence must provide sufficient assurance that the processes not only produce the desired results in food, but also do not have any unacceptable, toxicological, nutritional, or microbiological effects. Therefore several international organizations play an important role in the gathering of evidence at the international level about food irradiation (WHO, FAO, IAEA, and others).

The technological quality of food is important for the producer. It concerns mostly the raw material and its suitability for production of a given food product. As an example, it is possible to mention the quality of wheat (content and quality of gluten), quality of meat (ability to bind water).

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Biographical Sketch

Jiří Davídek, Ph.D., Dr. Sc., is a Professor of Food Science in the Faculty of Food and Biochemical Technology, and is a member of the Department of Food Chemistry and Analysis, Institute of Chemical Technology, Prague, Czech Republic.

Prof. Davídek received his M.Sc. degree from the Institute of Chemical Technology, Faculty of Food and Biochemical Technology, in 1954. He obtained his Ph.D. in 1969 from the same Institute under the direction of Prof. Dr. G. Janíček. After doing postdoctoral work with Dr. J. Fragner at the Research Institute of Food Industry in Prague and with Dr. A. W. Khan at the National Research Council, Division of Biosciences in Ottawa, Canada, he was appointed Associate Professor of Food Chemistry and Analysis at the Faculty of Food and Biochemical Technology, Institute of Chemical Technology, Prague, in 1960, and became a full Professor there in 1970.

Prof. Jiří Davídek is a member of the Czech Chemical Society and the Chairman of the Division of Food and Agricultural Chemistry. He is a national representative in the Food Chemistry Division, Federation of European Chemical Societies (FECS), and is member of the Czech Biochemical Society, the American Institute of Food Technologists, and numerous other scientific societies. He is also a member of the editorial board of the Czech *Journal of Food Sciences*, German *European Research and Technology*, and Chinese *Biomedical and Environmental Sciences*. He has served as the head of the Department of Food Chemistry and Analysis, Dean of Faculty of Food and Biochemical Technology in Prague, and Vice-Chairman of the Czechoslovak Academy of Agriculture. In 1972 he received the State Prize for Research, and in 1982 he was awarded both the Gold Medal from the Czechoslovak Academy of Agriculture and the Silver Medal of Professor Jaroslav Heyrovsky from the Czechoslovak Academy of Science.
Prof. Davídek has published more than 330 papers and is the author of 16 books published variously in Czech, English, German, and Polish. He has also delivered more than 350 lectures at scientific conferences and symposiums. He often works as Chairman at the International meetings organized by the Food Chemistry Division of FECS (Euro Food, Chemical Reactions in Foods). His research interest focuses on food quality, food analysis, Maillard reactions, the formation of sensory active compounds, food additives, and natural toxic compounds.