THE SANITARY DESIGN AND CONSTRUCTION OF FOOD PRODUCTION FACILITIES

Troller, John A.
John A. Troller Consulting Inc., Cincinnati, Ohio, USA

Keywords: Thermal processing, microorganisms, ISO 9000, HACCP, GMP, sanitation, clean design, bio-films, sanitation programs, food-borne diseases

Contents

Summary

The application of engineering concepts to the protection of the worlds food supply has long been a goal of the food industry. Basic sciences, such as chemistry, physics, microbiology, and molecular biology have provided the necessary underpinnings for

food safety and nutrition programs throughout much of the world. Once haphazardly applied and ineffectively organized and utilized, many of the factors that reduce risks in processed food have now been identified and enhanced. This development has been accomplished to the point that contemporary commercial food processes are some of the most effective and efficient in the industry. This is reflected in epidemiological data showing significant improvements in the incidence of many food-borne diseases afflicting consumers of commercially processed food products. Important improvements in attitudes and management of food protection, as well as quality programs such as HACCP and ISO, have similarly augmented and improved strategies for controlling risks. Pre-emptive approaches, based on the identification of critical process control points and their integration into overall hazard control schemes, have been particularly well-received and effective. While food-borne disease will probably continue to occur in the future, albeit less frequently, modern scientific and engineering approaches assure that severity and frequency will be significantly reduced.

1. Introduction

In the dim, distant past of human history, early humans were essentially nomadic, largely carnivorous creatures forced to live in close proximity to large concentrations of animals from which they obtained much of their sustenance, clothing, tools and even shelter. Most of these animals conveniently existed in large concentrations: herds of animals, large flocks of birds and huge schools of fish and crustaceans. Naturally, this concentration of prey required that contact be maintained between the hunted and the hunter; hence, it was necessary to continuously follow migrating animal food sources. Harvesting such food also probably involved significant danger to the hunter/gatherer both from the intended "victim" and from other predators with which these early bipeds competed for food. Other sources of danger included climatic disturbances, which made food gathering a difficult and often dangerous task.

Perhaps the greatest source of risk, however, was the almost continuous preoccupation with the vital, but energy inefficient, function of food gathering. The task of manufacturing and equipping easily transportable homes, designed to facilitate following the seasonal migration of prey, for example, must have been enormous. Portable dwellings were required, which poorly protected their inhabitants, with the result that diseases and other contingencies of living in inadequate surroundings had to be contended with. The need to maintain fresh supplies of energy-yielding fresh meat must have been all-encompassing and exhausting, especially during periods of movement which might have lasted for months. Unlike their competitors, these early humans gradually began to improve upon their existence, and one of the earliest advances consisted of the preservation and storage of food to provide sustenance during times of food scarcity. Certainly, the examples of food storage by animals, such as squirrels, bees and even some quadruped carnivores, must have been observed and emulated. Modern anthropologists are aware that honey and tree nuts were consumed regularly, and one is led to the conclusion that the preservation of meat by drying and/or smoking was also practiced. Someone must have noticed that certain plants and their extracts made food taste good and, more importantly, masked the flavor of spoiled meats. Eventually, foods to which these materials were added did not deteriorate as rapidly, thus expanding the ways that food could be prepared and preserved. Heating foods was also found to produce a product that was less subject to spoilage and, like the preceding techniques, gave its practitioners a competitive survival advantage.

Once preservation techniques were developed and adopted, the need to follow migrating food sources was, to an extent, obviated. Eventually, a mode of existence that once demanded almost constant and exhausting movement was supplanted by a more permanent way of life. The development of an agrarian culture followed the discovery that food could be created by growing specific plants, which frequently could be preserved by the same techniques that were used so successfully to preserve animal flesh. It was also learned that animals that were formerly hunted could now be "cultivated."

This empowerment was not without risks, however. Those who attempted to preserve foods eventually became aware of the fact that for some foods, consumption resulted in illness, sometimes with fatal consequences. Ancient Egyptian and Coptic cultures were aware of these problems and even studied the "forces" that controlled them. The walls of ancient granaries throughout Egypt were often embellished with gods of humidity and temperature, who received such recognition in the fervent hope that the food the granaries contained be maintained in an edible and safe condition.

The first inkling that foods could cause illness when consumed may be seen in some of the early proscriptions, usually religious in nature, concerning the consumption of specific foods at certain times of the year. Many of these have been retained in modern times, even though the reasons for their existence have long been obviated by improvements in harvesting, processing and storage.

Relatively more recently, the processing of foods has moved from individual homes where the homemaker was responsible for food processing and preservation as well as its safety. Where foods were implicated in disease, the number of persons affected was often limited to immediate family members. Occasionally, however, outbreaks occurred in large gatherings (for example church picnics) where local health authorities became aware of a problem when overworked hospital staffs complained of sudden onslaughts of patients possessing similar symptoms. These often resulted in local and state proscriptions of their own, along with advice on safe food processing to the people responsible for preparing the food for the family.

At this time (the early 20th century) the first fledgling governmental agencies dedicated to the production of safe foods began to be formed. Concurrently, the site of food preparation and processing began to shift dramatically to large-scale production in huge "factories" owned by enormous companies. It soon became apparent that the mass production of food, by its very nature, put huge numbers of consumers at risk when something went wrong. Laws and regulations relating to the production of safe food were eventually promulgated throughout much of the world, and the agencies created became responsible for safeguarding our food supplies. The system is not perfect, as witnessed by the continuing reporting nearly every year of outbreaks involving thousands of consumers. With this comes the realization that each new technology relating to the mass production of a food seems to bring with it a new set of problems relating to its safety. The concept of "emerging pathogens" is now widely accepted and carries with it the implication that specific pathogenic bacteria have existed all along. The food preparation (not the offending organism) has changed to the extent that an opportunity for contamination and growth, which allows the pathogen to "emerge," may have been created. While advances in food technology that create more nutritious, more convenient foods are welcomed, it is seldom that a revolutionary food or process is designed with consideration of food safety issues in mind. In fact, the creation and control of food processes to produce safe and wholesome food, of course, is the goal of modern food sanitation, and must be preemptively built into the product and be a part of every aspect of the process from its inception, rather than an afterthought.

The major thrust of this article is to briefly describe strategies, schemes, engineering designs, and procedures that can recognize and prevent conditions and situations that contribute to health risk in food production situations. It should also be stated that in addition to commercially produced food products, other sources of prepared food could produce foods that cause significant illness. In fact, outbreaks from the consumption of home-prepared food and food prepared by food service organizations far outnumber those occurring from the consumption of commercially-prepared food products. Such statistics are subject to significant differences depending on a number of factors, such as the country involved, cultural and sociological differences and, quite simply, reporting reliability. For example, a homemaker who inadequately bakes a meat pie and fails to refrigerate the product may promptly produce a very small, family-sized outbreak. Those made ill may have severe and memorable symptoms, but medical help is seldom sought and, in any event, the outbreak may not be considered of epidemiological significance. Thus, it is unreported. On the other hand, illness caused by commercially-prepared foods potentially affects many people, and often attracts a great deal of public attention. A list of some factors that complicate the surveillance of food-borne illness is shown in Table 1.

1. Under-reporting
2. Difficulty in determining role of causative organism in disease process
3. Inability to determine etiological agent
4. Failure or inability to relate illness to a specific place, event, or food consumed

Table 1: Factors influencing the surveillance of food-borne disease in the U.S.

2. Programs

2.1 ISO 9000

The various sanitation programs available to food sanitarians are generally not exclusive, and effectively interrelate within the overall sanitation program. ISO 9000 is a series of standards (Table 2) established by the International Organization for Standardization, a worldwide federation of national standards bodies that operate through a series of technical committees. Their activities consist primarily of a very broad program designed to establish the existence of a quality control plan. The ISO 9002 standard is generally established in conjunction with, and can be applied to, a wide variety of materials, including processed materials such as food.

ISO 9000 Quality management and quality assurance standards. Guidelines for selection and use. **ISO 9001** Quality systems. Model for quality assurance in design/development, production, installation, and servicing. **ISO 9002** Quality systems. Model for quality assurance in production and installation. **ISO 9003** Quality systems. Model for quality assurance in final inspection and test. **ISO 9004** Quality management and quality system elements- guidelines.

Table 2: The ISO 9000 series of quality standards

2.2 HACCP

Another type of quality system, the Hazard Analysis Critical Control Point (HACCP) program, is now widely accepted throughout the world. In fact, some countries require its application by law to certain types of processes, for example processors of meat. The basis of HACCP lies in a mode of failure system originally developed by the U.S. Army's Natick Laboratories. In this type of scheme, a food process is treated as an interlocking total system. Each part is then broken down and analyzed for its contribution to the overall level of risk associated with consumption of the product. Implicit in this type of approach is the recognition that "produce and analyze" programs traditionally used in the food industry are unreliable. These programs depend on methods that poorly predict (sometimes days after actual production) the microbiological risk inherent in the product and/or process. In HACCP programs, each portion of the production sequence, from raw materials production to consumption, is analyzed for its influence on the product's safety. In this way, each production step is isolated and evaluated for its ability to achieve control within the overall process. Such microbial control factors as temperature, pH, water activity (see *Colligative Properties*) and oxidation-reduction potential can easily be measured and applied to existing knowledge about their effect on microorganisms. Thus, physical and chemical limits (as opposed to biological limits, i.e., microbiological count levels), that can be continuously and accurately monitored, are relied upon to ensure the process is under microbiological control.

2.2.1 Establishment and Facilitation of HACCP Programs

The first step in the establishment of an HACCP program is to obtain complete management commitment to this endeavor. This usually ensures that financial resources will be available, and that there is a commitment to the implementation of the program. Additional steps are listed in Table 3, which among other things emphasizes the importance of detailed flow diagrams. Also important are the operational principles (Table 4) that govern the actual implementation of the program on a day-to-day basis.

1. Identify members of the HACCP team.
2. Consider the nature of the food to be processed.
3. Determine the intended use of the food and who will consume it.
4. Develop the flow diagram.
5. Verify the flow diagram.

6. Analyze hazards and list preventive measures.
7. Establish a "paper trail" of actions and verifications of actions

Table 3: Steps in the development of HACCP programs

1. Conduct a hazard analysis of the entire process.
2. Identify critical control points.
3. Establish critical control points.
4. Establish monitoring requirements.
5. Establish corrective actions.
6. Document the HACCP system.
7. Establish procedures for verification.

Table 4: HACCP Principles

The existence of a well-conceived HACCP program is, without a doubt, a rational approach to superior process control systems. Whether adoption of these programs has achieved a significant (or even detectable) diminution in the incidence of food-borne disease is debatable, and probably will never be known with certainty. Nevertheless, the increasing endorsement of, and requirement for, such programs by regulatory agencies throughout the world has now become a fact of life. Like all strategic plans of this type, intelligent implementation of the plan on a day-to-day basis is necessary for optimum effectiveness. The scope of this subject is extensive and well beyond the limitations of this article; however, excellent resources exist in the literature that provide practical and informative details. Several of these are noted in the Bibliography at the end of this article.

2.3 Good Manufacturing Practices (GMPs)

A third sanitation-related program that is widely employed throughout the U.S. food industry is published in the U.S. Code of Federal Regulations and is generally known as Good Manufacturing Practices. These regulations are somewhat more detailed and specific than either the more general ISO or HACCP programs. In fact, GMPs are not programs at all, but represent minimal sanitary requirements that must be met by a food plant operating in the U.S. Enforcement is the responsibility of the various FDA districts, which have the prerogative of removing non-complying products from interstate (U.S.) commerce.

3. The Product

Specific products may involve specific hazards depending on their nature and type. For example, a plant and/or process for the production of yogurt will be much different from one producing a dry breakfast cereal. For this reason, it is mandatory that those involved in process and plant design have a thorough understanding of the product's chemical and physical properties. A useful arrangement may be the inclusion of food engineers, development personnel and food sanitarians on the committee that oversees the design of such production facilities. In this way, alterations can be made during the design phase rather than attempting to make costly and difficult changes after the plant is constructed and the process equipment installed.

4. Site Selection and Plant Design

Many of the site requirements for a food plant are similar to those for any manufacturing facility. For example, good drainage is important to prevent periods of flooding that lead to contamination. Locations near wildlife refuges, waste disposal sites, and bodies of water, or on flood plains, should be avoided. Sites with sufficient area to accommodate future plant expansion should be chosen. Overcrowding of processing facilities greatly increases risk, primarily because processing equipment requires regular maintenance and cleaning, neither of which can be accomplished efficiently in a crowded interior area. Another important requirement is that sites near outdoor equipment storage areas, waste dumps, and other undesirable locations be avoided because they often harbor pests. Landscaping in the vicinity of the building should be minimal because, like storage areas mentioned above, plant materials, earth berms, decorative ponds, and other landscaping features attract pests. Most food sanitarians recommend that a grass-free strip be provided, 30 to 36 inches wide, immediately adjacent to the exterior walls. This strip is covered with gravel and provides a barrier to rodents and convenient access for inspection of traps and bait stations placed against the exterior wall. A perimeter fence, usually a chain-link fence, should be provided to prevent the incursion of children, pets and incidental waste such as windblown paper and plastic wrappers. Fences should be regularly cleaned and maintained.

5. Plant Layouts

There are two primary factors to be aware of in designing the layout of food plants. The first is to ensure that adequate space is enclosed to accommodate the process itself, allowing generous access to process areas to accommodate cleaning, as well as space for future expansion. A “clear” zone of a minimum of 36 inches surrounding each piece of process machinery should be achieved. The second factor is to establish a product flow through the process area that is virtually linear and does not permit contamination by entering raw materials or cross-over of the product stream.

A useful approach is to reserve manufacturing areas for that purpose only. Analytical tasks (including flavoring test product) should be performed only in laboratories separated from process areas. Similarly, heating and air conditioning, administrative areas, meeting rooms, and offices should not be open to the processing area. Interior spaces within food plants should be categorized as either food production areas, or as areas devoted to support functions. This distinction dictates that areas devoted to production activities should be under stricter control with regard to sanitation. Non-production areas, while required to be clean and orderly, are not ordinarily subject to the same stringent standards for construction, inspection, and maintenance as production areas.

Most modern food plants are single-floor structures. Where gravity-feed systems are required, these can usually be installed on mezzanines. The disadvantage of single-floor installations is that utilities such as wiring conduits, exhaust ducts, and in-place cleaning systems must be placed in the floor, suspended from the ceiling, placed in an overhead “crawl space,” or installed in a utility corridor adjacent to the process area. The last, from the sanitation point of view, is much preferred, providing that the corridor does not have direct access for personnel into the process area, and is kept pest-free and clean. Generally, the goal should be to reduce overhead utilities of all types to a minimum, and either to seal (dustproof) them in conduits or chases, or provide access for frequent inspections and cleaning.

-
-
-

Bibliography

Christian J.H.B. (1994). Problems with HACCP. *Food Australia*. 46, 650-655. [A rational approach to what HACCP may or may not be expected to accomplish].

Frank J.F. and Koffi R.A. (1990). Surface-adherent growth of *Listeria monocytogenes* in association with increased resistance to surfactant sanitizers. *J. Food Prot*. 58, 550-554 [Discusses the difficulty inherent in preventing growth of a food-borne pathogen in adherent films].

ICMSF (1988). Application of the hazard analysis critical control point (HACCP) system to ensure microbiological safety and quality. *Microorganisms in Foods* Vol. 4. Oxford, UK: Blackwell Scientific Publications. [Comprehensively discusses the principles and applications of HACCP].

Imholte T.R. (1984). *Engineering for Food Safety and Sanitation*. 283 pp. Crystal, MN, USA: Technical Institute of Food Safety Publishers. [Presents a thorough discussion of the sanitation-related design requirements for food plants].

Jowitt R., ed. (1980). *Hygienic Design and Operation of Food Plants*. 292 pp. Westport, CN, USA: AVI Publishers. [This edited book primarily discusses the sanitary design of food processing equipment].

Lindsay D., Geornaras I., and von Holy A. (1996). Bio-films associated with poultry processing equipment. *Microbios* 86, 105-116. [A research article that discusses the importance of adherent populations in food plants].

von Schothorst M. and Baird-Parker A.C., eds. (1994). Special issue on HACCP: Basic principles, applications and training. *Food Control* 5(3). [Presents many aspects of HACCP implementation].

Shapton D.F. and Shapton N.F. (1991). *Principles and Practices for the Safe Processing of Food*. Oxford, UK: Butterworth-Heinemann Publishers. [A practical and detailed discussion of sanitation as it relates to operations in food plants].

Troller J.A. (1993). *Sanitation in Food Processing*. 2nd Ed. New York, USA: Academic Press. [Written by the author of this article; a comprehensive discussion of food sanitation and its implications].

U.S. Department of Agriculture (1995). U. S. *Inspected Meat and Poultry Plants. A Guide to Construction and Layout. Handbook* 570. Washington, DC, USA: U.S. Govt. Printing Office. [Presents detailed specifications for the construction of meat and poultry plants].

Vail R. (1994). Fundamentals of HACCP. *Cereal Foods World* 39, 393-395. [A discussion of HACCP applications].

Biographical Sketch

John Troller Following his retirement from Procter & Gamble Company in 1992, John Troller formed his own consulting firm, JTI Inc, which specializes in food processing and regulatory issues. Prior to this time, his professional career was spent in Research and Development and Professional and Regulatory Relations sectors at Procter & Gamble. He has authored a volume on *Food Sanitation* (Academic Press), followed by a second edition in 1993. His research interests have centered on moisture as related to growth and virulence of food borne disease organisms. He co-authored a book, *Water Activity and Food* (Academic Press), with J.H.B. Christian (CSIRO-Australia) in 1978 on this subject. He has published nearly 100 peer-reviewed research articles and has lectured at universities and institutions throughout the world during his professional career, which spans more than 40 years.