Microbiology in Food Sanitation

The food-industry sanitarian is concerned with aseptic practices in the preparation, processing, and packaging of the food products of a plant (or plants), the general cleanliness and sanitation of plant and premises, and the health of employees. Specific duties in connection with the food products may involve quality control and storage of raw products; the provision of a good water supply; prevention of the contamination of the foods at all stages during processing from equipment, personnel, and vermin; and supervision of packaging and warehousing of finished products. The supervision of cleanliness and sanitation of plant and premises includes not only the maintenance of clean and well-sanitized surfaces of all equipment touching the foods but also generally good housekeeping in and about the plant and adequate treatment and disposal of wastes. Duties affecting the health of the employees include provision of a potable water supply, supervision of matters of personal hygiene, regulation of sanitary facilities in the plant and in plant-operated housing units, and contact with sanitary aspects of plant lighting, heating, and ventilation. The sanitarian may also participate in training employees in sanitary practices. Only bacteriological aspects of plant sanitation will be discussed here. For other facets of the problem the reader is referred to the references at the end of this chapter.

For the most part, sanitarians concern themselves chiefly with general aspects of sanitation, making inspections, consulting with personnel responsible for details of sanitation and executives directing such work, and training personnel in sanitation. They may or may not be connected with a plant laboratory.

BACTERIOLOGY OF WATER SUPPLIES

The water for drinking purposes and for plant use may be from the same source or from different sources.

❑ Drinking Water

The water that the employees drink must meet public health standards when tested by methods recommended in the latest edition of Standard Methods for the Examination of Water and Wastewater (American Public Health Association, 1985). Coliform bacteria must not be present at levels indicating contamination of the water by sewage. Total plate counts of the water sometimes are made to indicate when trouble may be incipient so that such trouble can be forestalled.

❑ Plant Water

All water that comes into contact with foods should meet the bacteriological standards for drinking water, and preferably all fresh water at the plant should be that good. But this water also should be satisfactory from a bacteriological standpoint for use with the particular food being processed. A water supply may be adjudged potable yet be unsatisfactory for use with a food. Thus, for example, water containing appreciable numbers of psychrotrophs of the genera *Pseudomonas* or *Alcaligenes* might be unsatisfactory without treatment in a dairy plant making butter or cottage cheese. The slimy growth of iron bacteria in water supplies often leads to trouble in the food plant.

More likely to be important is the chemical composition of the water, which must be suited to the use to be made of it. Thus hard water is undesirable in pea canning and in brewing; iron and manganese are bad in beet canning and in brewing; excessive organic matter may lead to off-flavors, etc.

Of special interest in canning factories is the bacteriology of the water in which the cans of processed foods are cooled after their heat treatment. If this water contains microorganisms able to spoil the food, it can enter defective cans through minute leaks and increase the percentage of cans of food spoiling during storage. Many canneries routinely chlorinate the cooling water to reduce or eliminate this problem.

The shortage of water in many food plants has necessitated reuse of part of the water, and microorganisms may build up in such reused water. Water employed for the final rinse of a food must be fresh and potable, but after use it may be returned for soaking, first wash, or fluming, preferably after treatment with chlorine, chlorine dioxide, or a similar germicide.

In-plant or continuous chlorination beyond the break point (the point where the chlorine demand has been satisfied) to a residual of 5 to 7 ppm of chlorine is employed for continuous application to areas and equipment where slime bacteria may be a problem, e.g., conveyors or belts, can coolers, product washers, and flumes. The chlorinated water may be applied as a spray, or parts of equipment may be immersed. When operations cease, chlorinated water may be applied to fillers, peelers, dicers, and similar equipment. Contaminated or polluted water lines are held filled with chlorinated water containing 50 to 100 ppm of chlorine for 12 to 48 hr, the strength of chlorine and length of time depending on the extent of pollution (Table 27.1).

Ice used in contact with foods should meet the bacteriological requirements for potable water. Much work has been done on the incorporation of bacteriostatic or bactericidal chemicals in water and in ice to aid in food preservation. It has been noted previously that a chlortetracycline or oxytetracycline dip for dressed poultry had been approved, but approval was later revoked; however, these antibiotics may be incorporated in ice to be applied to fish and other seafood.

SEWAGE, AND WASTE TREATMENT AND DISPOSAL

The food sanitarian is concerned directly or indirectly with the adequate treatment and disposal of wastes from the industry. Solid and concentrated wastes ordinarily are kept separate from the watery wastes and may be used directly for food, feed,

Table 27.1 *Suggested Concentrations of Chlorine for Various Purposes in Food Processing Plants*

	*ppm**
Drinking water	0.2
Process water	0–0.5
Cleaning	10–20
Sanitizing	100–250
Rinse water	1.0–5.0
Cooling (can)	0.5–10.0
Conveying water	0.5–5.0
Belt sprays	1.5–3.0
Hydrocooling meat	5.0–200
Fish thawing	5.0–10.0

*As total residual chlorine.
Source: Troller (1983).

fertilizer, or other purpose; may first be concentrated, dried, or fermented (e.g., pea-vine silage); or may be carted away to available land as unusable waste. Care is taken to keep out of the waste waters as much wasted liquid or solid food material as possible by taking precautions to avoid introduction into the watery wastes of drip, leakage, overflow, spillage, large residues in containers, foam, frozen-on food, and food dust during the handling and processing of the food. It is recommended that sewage of human origin be kept separate from other plant waters because of the possible presence of human intestinal pathogens and the necessity for a guarantee of their removal or destruction. Such sewage may be turned into a municipal system, if one is available, for adequate treatment and disposal or may be treated separately at the food plant. Other food-plant wastes should not contain human pathogens.

Wastes from food plants ordinarily contain a variety of organic compounds, which range from simple and readily oxidizable kinds to those which are complex and difficult to decompose. The strength of the sewage or food waste containing organic matter is expressed in terms of **biochemical oxygen demand** (BOD), which is the quantity of oxygen used by aerobic microorganisms and reducing compounds in the stabilization of decomposable matter during a selected time at a certain temperature. A period of 5 days at 20 C is generally used, and results are expressed as 5-day BOD. The BOD is determined by dilution of a measured quantity of waste with water that has been saturated with oxygen and incubation of the mixture at 20 C, along with a control of dilution water alone. After 5 days, the residual oxygen in both control and test sample is measured by titration. The difference represents the oxygen-consuming capacity of the waste and is calculated to be expressed as parts per million of oxygen taken up by the waste. The strength of the waste in terms of pounds of BOD is calculated as follows:

$$\frac{\text{ppm 5-day BOD} \times \text{gallons of waste} \times 8.34}{1{,}000{,}000} = \text{pounds BOD}$$

This value can be converted to population equivalent (PE) by assuming that the domestic sewage of one person is equivalent to one-sixth of a pound of BOD per day.

Whenever appreciable amounts of wastes high in oxidizable organic matter (high BOD) are emptied into natural waters, such as streams, ponds, or lakes, the 7 to 8 ppm of free oxygen normally present in the waters is used up soon by oxidation processes carried out by aerobic or facultative microorganisms. When the oxygen drops below 3 ppm, the fish either leave or die, and when anaerobic conditions have been attained, hydrolysis, putrefaction, and fermentation by microorganisms will follow, with the result that the body of water will become malodorous and cloudy and hence unsuited for recreational use and unfit for drinking and for use in the food plant. Wastes from a food plant to be emptied into a body of water must either be so greatly diluted by that water as to be innocuous or must be treated first to reduce the oxidizable compounds to a harmless level. Even the effluent from an efficiently operated sewage treatment system will encourage the growth of algae and higher aquatic plants in the water and make it less attractive for recreational purposes.

Preliminary treatments of food-plant wastes by chemical means may be employed, but most systems of treatment and disposal depend on (1) screening out of large particles, (2) floating off of fatty and other floating materials, (3) sedimentation of as much of the remaining solids as practicable, (4) hydrolysis, fermentation, and putrefaction of complex organic compounds, and finally (5) oxidation of the remaining solids in the water to a point where they can enter a municipal sewage treatment and disposal system, a plant disposal system, a lake or stream, or soil. The completeness of oxidation required will depend on the disposal to be made. Thus less oxidation might be required for feeding to a municipal system or for irrigating soil than for entering a stream or lake.

❑ Chemical Treatment

In chemical pretreatments, a chemical or mixture of chemicals is added to the sewage or waste so as to cause formation of a flocculent precipitate, which, in settling, carries with it much of the suspended and colloidal material, including bacteria. The effluent then is run into a body of water, onto soil, or into a biological treatment system. The chemicals commonly used are soluble aluminum or iron salts, such as alum or ferrous sulfate, plus lime, giving a flocculent precipitate of aluminum or ferric hydroxide. Disposal of the sludge (settlings) so obtained may be difficult.

❑ Biological Treatment and Disposal

The general biological methods for waste disposal and/or treatment include (1) **dilution**, by running waste waters into a large body of water, (2) **irrigation**, in which waste waters are sprayed onto fields of open-textured soil, (3) **lagooning**, by running the waste waters into shallow artificial ponds (with or without other treatments), (4) use of **trickling filters**, made of crushed rock, coke, filter tile, etc., (5) use of the **activated-sludge** method, in which waste water is inoculated heavily with sludge from a previous run and is actively aerated in tanks, and (6) use of **anaerobic tanks** of various kinds, where settling, hydrolysis, putrefaction, and fermentation take place, usually to be followed by some aerobic treatment.

The dilution method seldom is practicable because a sufficiently large or rapidly moving volume of water rarely is available or because the location is such that sewage decomposition cannot proceed without objections from nearby populations. Irrigation is increasing in popularity and is especially adaptable to use by plants located in rural areas and near open-textured soil. Lagooning has been used especially for seasonal wastes, as from canning factories. The wastes are decomposed slowly in these shallow ponds or lagoons until the liquid part can be run into a stream or other body of water during the rainy season or time of melting snow, when there is a good volume of water. Usually, sodium nitrate is added to reduce obnoxious odors. Sometimes the liquid is pumped from and returned to a lagoon, or it may be pumped from one lagoon to another in a series of lagoons. Trickling filters and activated sludge systems are probably the most effective of the systems listed, but they are expensive to run and require supervision by an expert. Anaerobic tanks yield an effluent that needs further treatment and should be either turned into a municipal system or given an aerobic treatment.

❑ Types of Food Wastes

An extended discussion of the nature and composition of wastes from the different food industries cannot be given here. It should be noted, however, that each type of waste has a characteristic BOD that may be high, low, or intermediate and that each presents its own problems of treatment and disposal. Dairy wastes, for example, are usually high in protein and lactose and contain many microorganisms. Such wastes, if not already acid, will turn acid if kept under anaerobic conditions and then will be more difficult to treat. Some wastes may be acid originally, e.g., wastes from fruit canneries. Malthouse, brewery, distillery, sweet-corn cannery, and corn-products plant wastes are high in carbohydrates and likely to become acid under anaerobic conditions. Wastes high in proteins, e.g., pea- or fish-cannery and packing-plant wastes, are likely to putrefy under anaerobic conditions. Other wastes may contain antiseptic chemicals, such as the sulfite in waste sulfite liquors from paper mills, and therefore may be difficult to decompose by means of microorganisms. Ranges of 5-day BOD values reported for wastes from various types of food-processing plants are shown in Table 27.2. Most industry-related wastes have been the subject of extensive research on waste utilization.

MICROBIOLOGY OF THE FOOD PRODUCT

To reduce contamination with microorganisms to a minimum and obtain good keeping quality of the product, the raw materials are examined; the equipment contacting the food is adequately cleaned, sanitized, and tested; the preserving process is checked; and packaging and storage are supervised.

❑ The Ingredients

The raw product is inspected and tested for quality, but this does not necessarily involve bacteriological laboratory testing in all instances. Some of the ingredients of some products may contain numbers and kinds of microorganisms that can affect

Table 27.2 *Range of 5-day BOD Values for Wastes from Various Food Processing Plants*

Source of waste	*5-day BOD, ppm*	*Source of waste*	*5-day BOD, ppm*
Dairy plants	500–2,000	String bean cannery	160–600
Meat-packing plants	Up to 2,500	Lima bean cannery	190–450
Poultry plants	300–7,500	Sweet-corn cannery	625–6,000
Sugar processing	500–1,500	Pea cannery	380–4,700
Fruit cannery	200–2,100	Pumpkin cannery	2,800–6,900
Tomato cannery	180–4,000	Spinach cannery	280–730
Brewery	420–1,200	Sauerkraut cannery	Up to 6,300

the keeping quality of the product or even its acceptability. Some ingredients, such as sweetening agents, starch, and spices, can be purchased on specification as to maximal allowable content of microorganisms or of numbers of certain kinds. The numbers of bacteria in ingredients are important in foods for which there are bacterial standards. Large numbers of spores of aerobes are undesirable in dry milk to be used in breadmaking because of the increased risk of ropiness developing; heat-resistant spores in sugar and starch may add to the difficulty in adequately heat-processing canned vegetables to which sugar or starch is added; and large numbers of bacteria in spices may favor the spoilage of summer sausage.

The microbiology of the main raw product often is important. Excessive mold mycelium in the raw fruit, which is indicative of the presence of rotten parts, may lead to condemnation of the canned or frozen product. Large numbers of thermoduric bacteria in raw milk may yield a pasteurized milk that will not meet the bacterial standards for numbers as estimated by the standard platecount method. Large numbers of bacteria on vegetables or in fruits may indicate inferiority that will carry over into the frozen product. Laboratory examination may be employed to detect these undesirable organisms and estimate their numbers.

Often there is opportunity for microorganisms to grow in a food product during handling and processing in the plant. Examples are the buildup of thermophiles where foods are kept hot, as in forewarmers and blanchers, and increases in total numbers of bacteria in vegetables between blanching and freezing. Line samples may be tested in the laboratory to ascertain where appreciable growth of microorganisms is taking place.

❑ Packaging Materials

Packaging materials are a possible source of contamination of foods with microorganisms, but ordinarily the penetrability of nonmetallic materials to moisture and to gases is of more significance in the preservation of foods than the microbiology of these materials, for they harbor mostly low numbers of innocuous microorganisms or no organisms. Also, as indicated previously, wrappers may be treated or impregnated with bacteriostatic or fungistatic compounds, e.g., cheese wraps with sorbic or caprylic acid.

Paper and paperboard used for milk cartons contain mostly bacilli and micrococci, and occasionally other rods, actinomycetes, and mold spores, but no organisms of public health significance. Wax paper is practically sterile as produced, as are most plastic packaging materials. All packaging materials should be protected from contamination with dust or other sources of microorganisms in handling.

According to federal regulations a food is deemed to be adulterated "if its container is composed, in whole or in part, of any poisonous or deleterious substance which render its contents injurious to health."

❑ The Equipment

Unless the equipment that comes in contact with foods is adequately cleaned and sanitized, it may be an important source of contamination of foods with microorganisms. Not only may organisms persist on equipment, they may increase in numbers when treatment has been inadequate.

Cleaning From a bacteriological viewpoint, cleaning equipment is primarily to remove as much food for microorganisms as is practicable. Equipment may be disassembled for cleaning and sanitizing, although this is difficult with some pieces. To aid in the cleaning action of water, cleaning agents called **detergents** are employed. These agents may serve to soften or condition the water, improve the wetting ability of the cleaning solution, emulsify or saponify fats, solubilize minerals, deflocculate or disperse suspended materials, and dissolve as much soluble material as possible. At the same time the detergents should be noncorrosive and readily rinsed from the surfaces. Among the detergents used alone or in mixtures are the **alkaline** varieties, such as lye, soda ash, sodium metasilicate, trisodium phosphate, and the polyphosphates; **acid** detergents, usually organic acids, such as hydroxyacetic, gluconic, citric, tartaric, and levulinic acids; and **wetting agents**. These wetting agents may be anionic (NaR), such as the hydrocarbon sulfonates; nonionic, e.g., polyether alcohol; or cationic (RC1), for example, the quaternary ammonium compounds. Cleaning is often made easier by using brushes (Figure 27.1) and water under pressure. High-pressure cleaning eliminates many problems associated with hand scrubbing. Commercially available systems for cleaning or sanitizing generate water sprays at 300 to 1,000 psi.

Sanitizing The sanitizing process is an attempt to reduce the number of microorganisms on equipment surfaces. The kind of sanitizer, the concentration employed, the temperature of the sanitizer, and the method of application vary with the kind of sanitizing agent, the conditions during use, the type of equipment to be treated, and the microorganisms to be destroyed. Among the sanitizing agents in common use are hot water, flowing steam or steam under pressure, halogens (chlorine or iodine) and halogen derivatives, and the quaternary ammonium compounds.

Steam under pressure is the most effective way of applying heat as a sanitizing agent, but its use is limited to closed systems that can withstand pressure. Steam jets, flowing steam, or hot water may be used, but jets are ineffective except at very short distances, flowing steam may condense and drop in temperature as it passes through equipment, and hot water may undergo a similar drop in temperature. All

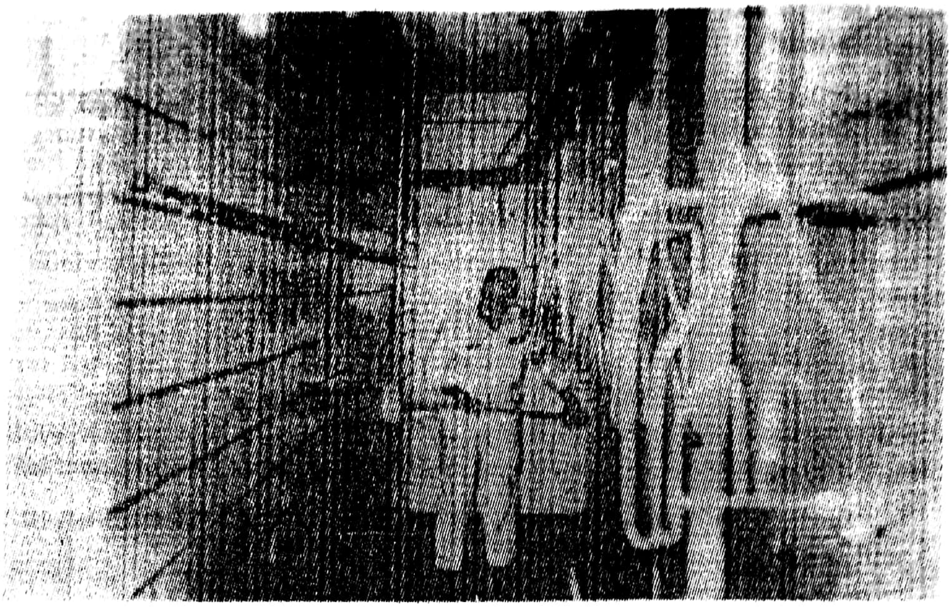

Fig. 27.1 *General cleanup in a food processing plant. (Klenzade Products. Beloit, Wisc.)*

microorganisms and their spores can be killed by adequate treatment with high-pressure steam. Effectively applied flowing steam and boiling water will kill all but some of the more resistant bacterial spores. The lower the temperature of hot water, the less effective it will be in killing organisms.

Chlorine, iodine, and their compounds (hypochlorites, chloramines, iodophors, etc.) are effective germicides if in proper concentrations and if given enough time to act. Usually, more sanitizer is necessary in the presence of organic matter. Bacterial spores are especially resistant to these sanitizers. Chlorine is used to destroy undesirable bacteria in water for drinking, for use in foods, for washing foods or equipment, and for cooling. Hypochlorites are more labile but more effective at acid pH values than at alkaline ones. As stated earlier, in-plant or continuous chlorination beyond the break point (where chlorine demand has been satisfied) to a residual of 5 to 7 ppm is employed for continuous application to areas where slime bacteria may be a problem, e.g., on conveyors, belts, or product washers. Chlorine (50 to 100 ppm) also is used to treat contaminated or polluted water lines.

Quaternary ammonium compounds are in general more effective against gram-positive than gram-negative bacteria. These compounds have a residual effect— i.e., they adhere to equipment surfaces and deter bacterial growth—but they rinse off onto foods coming into contact with these surfaces and, if they are present in detectable concentrations, might be considered undesirable. Many of these compounds are active under alkaline conditions. Most are affected by hardness of water.

Detergent sanitizers, which usually are a combination of an alkaline detergent and a quaternary ammonium compound, sometimes are used to clean and sanitize utensils or equipment in one operation.

Cleaned-in-Place Systems Some industries, especially the dairy industry, leave pipelines permanently connected and clean and sanitize them in place. Apparatus is available for accomplishing this automatically. Different sequences of treatments are recommended for different cleaned-in-place (CIP) systems. Milk pipelines, for example, are rinsed first with tepid water, which is pushed or pulled through the system. Then hot (71 C) detergent solution may be passed through, followed by rinsing water and finally a sanitizing agent, such as hot water (77 C or over), chlorine solution (200 ppm), or a quaternary ammonium compound (200 ppm). Often a sanitizing treatment is given immediately before use.

References listed at the end of this chapter should be consulted for more detail on detergents and sanitizers and their selection and use.

❑ The Preservation Process

The sanitarian usually has little to do with the processing of the foods except to check through the laboratory, if one is available, for the effectiveness of the processing. The laboratory, for example, might run keeping-quality tests on canned foods and bacterial counts on frozen foods, pasteurized milk, dry milks, etc.

❑ Vending Machines for Foods and Beverages

With the rapid expansion of the use of vending machines to dispense perishable foods has come increased interest in the sanitation of these machines and dispensed foods. The United States Public Health Service Ordinance and Code (The Vending of Foods and Beverages) covers sanitation of foods and machines, operation of machines, and inspection. "Readily perishable foods" are defined as those consisting in whole or in part of milk, milk products, eggs, meat, fish, poultry, etc. These are foods which can support rapid growth of microorganisms and can cause food infections or intoxications. Adequately dried or canned foods are excepted. Perishable foods include sandwiches, pastries, hot coffee, tea or chocolate, malted milk, fluid milk, ice cream, frozen desserts, and hot-food plates (meat, stews, soup, baked beans, poultry, fish, etc.).

During transportation from the commissaries and in the machine, perishable foods should be kept either cold (3.3 to 4.4 C) or hot (66 C or above). Slow growth of psychrotrophs can take place at the lower temperatures and of thermophiles in the hot foods if these recommendations are barely met, and excessive heat will deteriorate many foods. All parts of vending machines in contact with readily perishable foods should be cleaned and sanitized periodically, daily if the above temperature limitations are not met. Water used in connection with the foods should be potable, and waste disposal should be adequate. Most machines dispensing perishable foods are equipped with safety devices to stop dispensing food when refrigeration or heating fails.

❑ Food Handling on a Large Scale

Food handling on a large scale by caterers, commissaries, restaurants, institutions, airlines, camps, etc., are subject to similar considerations. General recommendations and a Food Service Sanitation Ordinance and Code are included in the Food Service Sanitation Manual published in 1962 by the Public Health Service of the U.S. Department of Health, Education, and Welfare. The ordinance defines "safe" temperatures for storage of foods as 7.2 C or below, or 60 C or above, except during necessary periods of preparation and service. It requires the washing of raw fruits and vegetables and the thorough cooking of stuffing, poultry, stuffed meats and poultry (heating to at least 74 C), and pork and pork products (all parts heated to at least 66 C) before being served. The ordinance has regulations concerning the health and cleanliness of personnel; the cleanliness, sanitization, and protection of food utensils; and the potability of water. It specifies foods that are clean, wholesome, unspoiled, free from adulteration and misbranding, safe for consumption, and capable of meeting any standards of quality or inspection. Also described is the handling of pastry fillings and of puddings.

❑ Sandwiches

Sandwiches and other foods may be retailed without vending machines. Such foods may be a potential food-poisoning hazard, for they often are held at ambient temperatures for 18 to 24 hr before being sold. One survey (Adame et al., 1960) indicated that the wrapped sandwiches examined showed signs of contamination during preparation and of growth of bacteria before vending. All sandwiches showed high total numbers of bacteria per gram, no salmonellae or *Clostridium perfringens*, and considerable numbers of staphylococci (most of which, however, were coagulase-negative), with higher numbers in the moist sandwiches than in the dry, and appreciable numbers in those heated to 55.5 C and served hot. Similar results were obtained by McCroan et al. (1964), who concluded that spiced-ham sandwiches and cheese sandwiches were more hazardous than sandwiches containing mayonnaise, e.g., egg-salad and chicken-salad sandwiches, for contact with the acid dressing helped repress the staphylococci. A more recent survey by Christiansen and King (1971) stated that 60 percent of the sandwiches examined contained coagulase-positive staphylococci.

GOOD MANUFACTURING PRACTICES

make widely known

Several recent regulations promulgated by the Department of Health, Education, and Welfare, Public Health Service, Food and Drug Administration (FDA), specify current good manufacturing practices (GMPs) in the manufacturing, processing, packing, or holding of human foods. These can be found in the Code of Federal Regulations, Title 21. Of particular interest are the "umbrella GMPs" since they cover many aspects of the food industry in a general way. The code does cover regulations that would be of interest to the food sanitarian including plant and grounds, equipment and utensils, sanitary facilities and control, sanitary operations, processes and controls, and personnel. In addition, there are specific GMPs written for fish and seafood products; cacao products and confectionery; bottled water; bakery foods; tree nuts and peanuts; pickled, fermented, acidified, and low-acid foods (proposed); and thermally processed low-acid foods packaged in hermetically sealed containers.

HAZARD ANALYSIS AND CRITICAL CONTROL POINTS (HACCP)

Product processing lines in industry usually are distinct entities producing one item under constant control. In this type of operation, a careful analysis of microbiological hazards can be made and an in-house, effective monitoring system for quality assurance applied. HACCP is basically a statement of a preventive system of controls based on the hazard analysis and critical control points. **Hazard analysis** involves the identification of ingredients and products which might have a pronounced effect on food safety: might be consumed by special populations such as infants or the elderly; or might have no history of implication as the source of pathogens. Once the sensitivity of the ingredients is known, various **critical control points** can be identified. This involves the identification and control over those processing parameters whose loss of control would result in an unacceptable risk to consumers. Microbiological critical control points have been summarized for frozen foods and canned foods. Ito (1974), Peterson and Gunnerson (1974), and Bauman (1974) should be consulted for more detail.

The HACCP concept is really a sophisticated food-control option that incorporates many of the traditional approaches that have been attempted over the years. As outlined in Table 27.3, many government agencies and other organizations have relied on various food control measures, including (1) education and training, (2) inspection of processing facilities or food handling operations, and (3) microbiological surveys and testing. The HACCP concept is a new approach, but it also utilizes some of the above principles.

How is a hazard analysis done? Knowledge that a food represent a hazard suggests that adequate epidemiological information is available (indicating that the food is potentially a health hazard) or that there is sufficient technical information on hand to indicate that the product poses a health hazard. If neither the epidemiological

Table 27.3 *Principal Food Control Options Available*

Approach	*Components*
Education and training	Develop an understanding of food hazards Develop an appreciation of personal hygiene, sanitation, and food hygiene Develop an understanding of microbial contaminants and control measures Introduce factors affecting microbial growth and survival
Inspection of processing facilities, food handling operations, warehouse etc.	Monitor adherence to a recommended or required food handling practice Follow a recommended or required guideline such as a good manufacturing practice (GMP) Cite violations or make recommendations for improving performance
Microbiological surveys and testing of product	Sample and analyze ingredients, components, and finished product Monitor for pathogens, indicators, total numbers, etc. Compare to a standard, a guideline, a defect action level, etc., and advise or regulate accordingly
"New approaches"	Combinations of the above to improve upon the prevention of food-borne diseases HACCP concept

information nor the technical information is available or if one is concerned about a new product, information and knowledge about that product must be obtained. The report of the World Health Organization/International Commission on Microbiological Specification of Foods (Subcommittee on Microbiological Criteria, Committee on Food Protection, Food and Nutrition Board, National Council, 1985) suggests that the following questions be asked in an attempt to gather the necessary information.

Hazard Analysis and Critical Control Points (HACCP) is a process-control system designed to identify and prevent microbial and other hazards in food production. It includes steps designed to prevent problems before they occur and to correct deviations as soon as they are detected. Such preventive control systems with documentation and verification are widely recognized by scientific authorities and international organizations as the most effective approach available for producing safe food.

HACCP is endorsed by the scientific and food-safety authorities such as the National Academy of Sciences and the National Advisory Committee on Microbiological Criteria for Foods (NACMCF), and by international organizations like the Codex Alimentarius Commission and the International Commission on Microbiological Specifications for Foods.

Hazard Analysis Critical Control Points (HACCP) is a tool that can be useful in the prevention of food-safety hazards. While extremely important, HACCP is only one part of a multi-component food-safety system. Implementation of HACCP along with other practices such as good manufacturing practices, sanitation standard operating procedures, and a personal hygiene program are required to ensure the success of the program.

HACCP was introduced as a system to control safety as the product is manufactured, rather than trying to detect problems by testing the finished product. This new system is based on assessing the inherent hazards or risks in a particular product or process and designing a system to control them. Specific points where the hazards can be controlled in the process are identified.

The HACCP system has been successfully applied in the food industry. The system fits in well with modern quality and management techniques. It is especially compatible with the ISO 9000 quality assurance system and just in time delivery of ingredients. In this environment, manufacturers are assured of receiving quality products matching their specifications. There is little need for special receiving tests and usually time does not allow for extensive quality tests.

There are seven discrete activities that are necessary to establish, implement, and maintain a HACCP plan, and these are referred to as the 'seven principles' in the Codex Guideline (1997).

The seven principles are the following:

Principle 1: Conduct a Hazard Analysis

Identify hazards and assess the risks associated with them at each step in the commodity system. Describe possible control measures. Hazards (biological, chemical, and physical) are conditions which may pose an unacceptable health risk to the consumer. A flow diagram of the complete process is important in conducting the hazard analysis. The significant hazards associated with each specific step of the manufacturing process must be listed. Preventive measures (temperature, pH, moisture level, etc.) to control the hazards are also listed.

Principle 2: Determine the Critical Control Points (CCPs)

A critical control point is a step at which control can be applied and is essential to prevent or eliminate a food-safety hazard, or reduce it to an acceptable level. A Critical Control Point (CCP) is a point, step, or procedure in a food process at which control can be applied and, as a result, a food-safety hazard can be prevented, eliminated, or reduced to an acceptable level. A food-safety hazard is any *biological, chemical,* or *physical* property that may cause a food to be unsafe for human consumption.

Principle 3: Establish Critical Limits

Each control measure associated with a CCP must have an associated critical limit which separates the acceptable from the unacceptable control parameter. A *critical limit* is the maximum or minimum value to which a physical, biological, or chemical hazard must be controlled at a critical control point to prevent, eliminate, or reduce the hazard to an acceptable level.

Principle 4: Establish a Monitoring System

Monitoring is the scheduled measurement or observation at a CCP to assess whether the step is under control, i.e. within the critical limit(s) specified in Principle 3. Monitoring is a planned sequence of measurements or observations to ensure the product or process is in control. It allows processors to assess trends before a loss of control occurs. Adjustments can be made while continuing the process. The monitoring interval must be adequate to ensure reliable control of the process.

Principle 5: Establish a Procedure for Corrective Action, when Monitoring at a CCP indicates a Deviation from an Established Critical Limit

These are actions to be taken when monitoring indicates a deviation from an established critical limit. The final rule requires a plant's HACCP plan to identify the corrective actions to be taken if a critical limit is not met. Corrective actions are intended to ensure that no product injurious to health or otherwise adulterated as a result of the deviation enters commerce. HACCP is intended to prevent product or process deviations. However, should loss of control occur, there must be definite steps in place for disposition of the product and for correction of the process. These must be pre-planned and written. If, for instance, a cooking step must result in a product center temperature between 165°F and 175°F, and the temperature is 163°F, the corrective action could require a second pass through the cooking step with an increase in the temperature of the cooker.

Principle 6: Establish Procedures for Verification to Confirm the Effectiveness of the HACCP Plan

Such procedures include auditing of the HACCP plan to review deviations and product dispositions, and random sampling and checking to validate the whole plan. The HACCP regulation requires that all plants maintain certain documents, including its hazard analysis and written HACCP plan, and records documenting the monitoring of critical control points, critical limits, verification activities, and the handling of processing deviations. The HACCP system requires the preparation and maintenance of a written HACCP plan together with other documentation. This must include all records generated during the monitoring of each CCP and notations of corrective actions taken. Usually, the simplest record keeping system possible to ensure effectiveness is the most desirable.

Principle 7: Establish Documentation Concerning all Procedures and Records Appropriate to these Principles and their Application

Validation ensures that the industry or the plant complies with the required design or plan; that is, they are successful in ensuring the production of safe products. Plants will be required to validate their own HACCP plans. FSIS (Food Safety and Inspection Service) will not approve HACCP plans in advance, but will review them for conformance with the final rule.

Verification ensures the HACCP plan is adequate, that is, working as intended. Verification procedures may include such activities as review of HACCP plans, CCP records, critical limits, and microbial sampling and analysis. Requirement of FSIS is that the HACCP plan includes verification tasks to be performed by plant personnel. Further, verification tasks would also be performed by FSIS inspectors. Both FSIS and industry will undertake microbial testing as one of several verification activities.

Verification has several steps. The scientific or technical validity of the hazard analysis and the adequacy of the CCPs should be documented. Verification of the effectiveness of the HACCP plan is also necessary. The system should be subject to periodic revalidation using independent audits or other verification procedures.

HACCP offers continuous and systematic approaches to assure food safety. In light of recent food-safety-related incidents, there is a renewed interest in HACCP from a regulatory point of view. Both FDA and USDA are proposing umbrella regulations, which will require HACCP plans of industry. The industry will do well to adopt HACCP approaches to food safety whether or not it is required.

HACCP system verification activities include the following:

- Review of the HACCP system and its records
- Observation of operations at CCPs
- Asking employees questions, especially those that monitor CCPs
- Routine checks of monitoring procedures and equipment
- Review of critical limit deviations and non-conforming product handling and dispositions
- Internal auditing of the HACCP system
- External third-party auditing of the HACCP system
- Microbiological sampling of product contact surfaces
- Microbiological sampling of the product
- Official evaluation of the product