History, Development and Scope of Food Microbiology

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1. Introduction

Food microbiology encompasses the study of microorganisms, which have both beneficial and deleterious effects on the quality, and safety of raw and processed meat, poultry, and egg products. Food microbiology focuses on the general biology of the microorganisms that are found in foods including: their growth characteristics, identification, and pathogenesis. Specifically, areas of interest which concern food microbiology are food poisoning, food spoilage, food preservation, and food legislation. Pathogens in product, or harmful microorganisms, result in major public health problems are the leading causes of illnesses and death.

Except for a few sterile foods, all foods harbor one or more types of microorganisms. Some of them have desirable roles in food, such as in the production of naturally fermented food, whereas others cause food spoilage and foodborne diseases. To study the role of microorganisms in food and to control them when necessary, it is important to isolate them in pure culture and study their morphological, physiological, biochemical, and genetic characteristics.

2. History of Food Microbiology

Although it is extremely difficult to pinpoint the precise beginning of human awareness of the presence and role of microorganisms in foods, the available evidence indicates that this knowledge preceded the establishment of bacteriology or microbiology as a science. The era prior to the establishment of bacteriology as a science may be designated as the prescientific era. This era may be further divided into what has been called *the food-gathering period* and *the food-producing period*. The former covers the time from human origin over 1 million years ago up to 8,000 years ago. During this period, humans were presumably carnivorous, with plant foods coming into their diet later in this period. It is also during this period that foods were first cooked.

The food-producing period dates from about 8,000 to 10,000 years ago and, of course, includes the present time. It is presumed that the problems of spoilage and food poisoning were encountered early in this period. With the advent of prepared foods, the problems of disease transmission by foods and of faster spoilage caused by improper storage made their appearance. Spoilage of prepared foods apparently dates from around 6000 bc. The practice of making pottery was brought to Western Europe about 5000 bc from the Near East. The first boiler pots are thought to have originated in the Near East about 8,000 years ago. The arts of cereal cookery, brewing, and food storage, were either started at about this time or stimulated by this new development. The first evidence of beer manufacture has been traced

to ancient Babylonia as far back as 7000 bc. The Sumerians of about 3000 bc are believed to have been the first great livestock breeders and dairymen and were among the first to make butter. Salted meats, fish, fat, dried skins, wheat, and barley are also known to have been associated with this culture. Milk, butter, and cheese were used by the Egyptians as early as 3000 bc. Between 3000 bc and 1200 bc, the Jews used salt from the Dead Sea in the preservation of various foods. The Chinese and Greeks used salted fish in their diet, and the Greeks are credited with passing this practice on to the Romans, whose diet included pickled meats. Mummification and preservation of foods were related technologies that seem to have influenced each other's development. Wines are known to have been prepared by the Assyrians by 3500 bc. Fermented sausages were prepared and consumed by the ancient Babylonians and the people of ancient China as far back as 1500 bc.

Another method of food preservation that apparently arose during this time was the use of oils such as olive and sesame. Jensen has pointed out that the use of oils leads to high incidences of staphylococcal food poisoning. The Romans excelled in the preservation of meats other than beef by around 1000 bc and are known to have used snow to pack prawns and other perishables, according to Seneca. The practice of smoking meats as a form of preservation is presumed to have emerged sometime during this period, as did the making of cheese and wines. It is doubtful whether people at this time understood the nature of these newly found preservation techniques. It is also doubtful whether the role of foods in the transmission of disease or the danger of eating meat from infected animals was recognized.

Few advances were apparently made toward understanding the nature of food poisoning and food spoilage between the time of the birth of Christ and ad 1100. Ergot poisoning (caused by *Claviceps purpurea*, a fungus that grows on rye and other grains) caused many deaths during the Middle Ages. Over 40,000 deaths due to ergot poisoning were recorded in France alone in ad 943, but it was not known that the toxin of this disease was produced by a fungus. Meat butchers are mentioned for the first time in 1156, and by 1248 the Swiss were concerned with marketable and nonmarketable meats. In 1276, a compulsory slaughter and inspection order was issued for public use in Augsburg. Although people were aware of quality attributes in meats by the thirteenth century, it is doubtful whether therewas any knowledge of the causal relationship between meat quality and microorganisms.

Perhaps the first person to suggest the role of microorganisms in spoiling foods was A. Kircher, a monk, who as early as 1658 examined decaying bodies, meat, milk, and other substances and saw what he referred to as "worms" invisible to the naked eye. Kircher's descriptions lacked precision, however, and his observations did not receive wide acceptance. In 1765, L. Spallanzani showed that beef broth that had been boiled for an hour and sealed remained sterile and did not spoil. Spallanzani performed this experiment to disprove the doctrine of the spontaneous generation of life. However, he did not convince the proponents of the theory because they believed that his treatment excluded oxygen, which they felt was vital to spontaneous generation. In 1837, Schwann showed that heated infusions remained sterile in the presence of air, which he supplied by passing it through heated coils into the infusion. Although both of these men demonstrated the idea of the heat preservation of foods, neither took advantage of his findings with respect to application. The same may be said of

D. Papin and G. Leibniz, who hinted at the heat preservation of foods at the turn of the eighteenth century.

The history of thermal canning necessitates a brief biography of Nicolas Appert (1749–1841). This Frenchman worked in his father's wine cellar early on, and he and two brothers established a brewery in 1778. In 1784, he opened a confectioner's store in Paris that was later transformed into a wholesale business. His discovery of a food preservation process occurred between 1789 and 1793. He established a cannery in 1802 and exported his products to other countries. The French navy began testing his preservation method in 1802, and in 1809 a French ministry official encouraged him to promote his invention. In 1810, he published his method and was awarded the sum of 12,000 francs.

This, of course, was the beginning of canning as it is known and practiced today. This event occurred some 50 years before Louis Pasteur demonstrated the role of microorganisms in the spoilage of French wines, a development that gave rise to the rediscovery of bacteria. A. Leeuwenhoek in the Netherlands had examined bacteria through a microscope and described them in 1683, but it is unlikely that Appert was aware of this development and Leeuwenhoek's report was not available in French. The first person to appreciate and understand the presence and role of microorganisms in food was Pasteur. In 1837, he showed that the souring of milk was caused by microorganisms, and in about 1860 he used heat for the first time to destroy undesirable organisms in wine and beer. This process is now known as pasteurization.

3. Development of Food Microbiology

The major developments of ideas on the possible roles of microorganisms in foods and their scientific proof were initiated by Pasteur in the 1870s, followed by many other scientists before the end of the 19th century. This paved the way for the establishment of early food microbiology in the 20th century.

Milestones in Food Preservation

1782—Canning of vinegar was introduced by a Swedish chemist.
1843—Sterilization by steam was first attempted by I. Winslow in Maine.
1845—S. Elliott introduced canning to Australia.
1853—R. Chevallier-Appert obtained a patent for sterilization of food by autoclaving.
1854—Pasteur shown heating to remove undesirable organisms was introduced commercially
1855—Grimwade in England was the first to produce powdered milk.
1874—The first extensive use of ice in transporting meat at sea was begun.
1878—The first successful cargo of frozen meat went from Australia to England.
1880—The pasteurization of milk was begun in Germany.
1890—The commercial pasteurization of milk was begun in the United States.
1908—Sodium benzoate was given official sanction by the US as a preservative in certain foods.
1928—The first commercial use of controlled-atmosphere storage of apples was made in Europe

1929—A patent issued in France for the use of high-energy radiation for the processing of foods.
1954—The antibiotic nisin was patented in England for use in certain processed cheeses
1988—Nisin was accorded GRAS (generally regarded as safe) status in the United States.
1990—Irradiation of poultry was approved in the United States.
1997—The irradiation of fresh beef up to a maximum level of 4.5 kGy and frozen beef up to 7.0 kGy was approved in the United States.

Milestones in Food Spoilage

1659—Kircher demonstrated the occurrence of bacteria in milk; Bondeau did the same in 1847.
1780—Scheele identified lactic acid as the principal acid in sour milk.
1857—Pasteur showed that the souring of milk was caused by the growth of organisms in it.
1867—Martin advanced the theory that cheese ripening was similar to alcoholic, lactic, and butyric, fermentations.
1873—The first reported study on the microbial deterioration of eggs was carried out by Gayon.
—Lister was first to isolate *Lactococcus lactis* in pure culture.
1876—Tyndall observed that bacteria in decomposing substances were always traceable to air, substances, or containers.
1887—Forster was the first to demonstrate the ability of pure cultures of bacteria to grow at 0◦C.
1915—*Bacillus coagulans* was first isolated from coagulated milk by B.W. Hammer.

Milestones in Food Poisoning

1820—The German poet Justinus Kerner described “sausage poisoning” (which in all probability was botulism) and its high fatality rate.
1857—Milk was incriminated as a transmitter of typhoid fever by W. Taylor of Penrith, England.
1888—Gaertner first isolated *Salmonella enteritidis* from meat that had caused 57 cases of food
poisoning.
1894—T. Denys was the first to associate staphylococci with food poisoning.
1896—Van Ermengem first discovered *Clostridium botulinum.*
1906—*Bacillus cereus* food poisoning was recognized.
1926—The first report of food poisoning by streptococci was made by Linden, Turner, and Thom.
1938—Outbreaks of *Campylobacter* enteritis were traced to milk in Illinois, USA.
1939—Gastroenteritis caused by *Yersinia enterocolitica* was first recognized
1951—*Vibrio parahaemolyticus* was shown to be an agent of food poisoning by T. Fujino of Japan.
1955—Scombroid (histamine-associated) poisoning was recognized.

1960—The production of aflatoxins by *Aspergillus flavus* was first reported.
1965—Foodborne giardiasis was recognized.
1971—First U.S. foodborne outbreak of *Vibrio parahaemolyticus* gastroenteritis occurred in Maryland.

—First documented outbreak of *E. coli* foodborne gastroenteritis occurred in the United States.
1975—*Salmonella* enterotoxin was demonstrated by L.R. Koupal and R.H. Deibel.
1976—First U.S. foodborne outbreak of *Yersinia enterocolitica* gastroenteritis occurred in New York.

—Infant botulism was first recognized in California.
1978—Documented foodborne outbreak of gastroenteritis caused by the Norwalk virus occurred in Australia.
1979—Foodborne gastroenteritis caused by non-*Vibrio cholerae* occurred in Florida. Earlier outbreaks occurred in Czechoslovakia (1965) and Australia (1973).
1981—Foodborne listeriosis outbreak was recognized in the United States.
1982—The first outbreaks of foodborne hemorrhagic colitis occurred in the United States.
1983—*Campylobacter jejuni* enterotoxin was described by Ruiz-Palacios et al.
1986—Bovine spongiform encephalopathy (BSE)was first diagnosed in cattle in the United Kingdom.

Milestones in Food Legislation

1890—The first national meat inspection law was enacted. It required the inspection of meats for
export only.
1906—The U.S. Federal Food and Drug Act was passed by Congress.
1910—The New York City Board of Health issued an order requiring the pasteurization of milk.
1939—The new Food, Drug, and Cosmetic Act became law.
1957—The U.S. Compulsory Poultry and Poultry Products law was enacted.
1963—The U.S. Food and Drug Administration approved the use of irradiation for the preservation of bacon.
1967—The U.S. Wholesome Meat Act was passed by Congress and enacted into law
1968—The Food and Drug Administration withdrew its 1963 approval of irradiated bacon.
—The Poultry Inspection Bill was signed into law.
1969—The U.S. Food and Drug Administration established an allowable level of 20 ppb of aflatoxin for edible grains and nuts.
1973—The state of Oregon adopted microbial standards for fresh and processed retail meat. They were repealed in 1977.

4. Scope of Food microbiology

Although processes of food spoilage, and methods of food preservation and food fermentation have been recognized since ancient times, it was not until the 1800s that the

relationship between foods and microorganisms was established. In 1837 Schwann proposed that the yeast which appeared during alcoholic fermentation was a miscoscopic plant, and between 1857 and 1876 Pasteur showed that microorganisms were responsible for the chemical changes that take place in foods and beverages. Their observations laid the foundation for the development of food microbiology as we know it today. Soon after these early discoveries were made, knowledge about the role that microorganisms play in food preservation, food spoilage and food poisoning accelerated rapidly until food microbiology gradually emerged as a discipline in its own right. Food microbiology is now a highly developed area of knowledge with the main areas of interest highlighted as follows:

Topics of major interest to the food microbiologist is

- Food-borne disease
- Food spoilage
- Food preservation
- Water quality
- Food hygiene
- Quality control
- Laboratory management

In the early 20th century, studies continued to understand the association and importance of microorganisms, especially pathogenic bacteria in food. Specific methods were developed for their isolation and identification. The importance of sanitation in the handling of food to reduce contamination by microorganisms was recognized. Specific methods were studied to prevent growth as well as to destroy the spoilage and pathogenic bacteria. There was also some interest to isolate beneficial bacteria associated with food fermentation, especially dairy fermentation, and study their characteristics. However, after the 1950s, food microbiology entered a new era. Availability of basic information on the physiological, biochemical, and biological characteristics of diverse types of food, microbial interactions in food environments and microbial physiology, biochemistry, genetics, and immunology has helped open new frontiers in food microbiology. Among these are:

A. Food Fermentation/Probiotics

- Development of strains with desirable metabolic activities by genetic transfer among strains
- Development of bacteriophage-resistant lactic acid bacteria
- Metabolic engineering of strains for overproduction of desirable metabolites
- Development of methods to use lactic acid bacteria to deliver immunity proteins
- Sequencing genomes of important lactic acid bacteria and bacteriophages for better understanding of their characteristics
- Food biopreservation with desirable bacteria and their antimicrobial metabolites
- Understanding of important characteristics of probiotic bacteria and development of desirable strains
- Effective methods to produce starter cultures for direct use in food processing

B. Food Spoilage

- Identification and control of new spoilage bacteria associated with the current changes in food processing and preservation methods
- Spoilage due to bacterial enzymes of frozen and refrigerated foods with extended shelf life
- Development of molecular methods (nanotechnology) to identify metabolites of spoilage bacteria and predict potential shelf life of foods
- Importance of environmental stress on the resistance of spoilage bacteria to antimicrobial preservatives

C. Foodborne Diseases

- Methods to detect emerging foodborne pathogenic bacteria from contaminated foods
- Application of molecular biology techniques (nanotechnology) for rapid detection of pathogenic bacteria in food and environment
- Effective detection and control methods of foodborne pathogenic viruses
- Transmission potentials of prion diseases from food animals to humans
- Importance of environmental stress on the detection and destruction of pathogens
- Factors associated with the increase in antibiotic-resistant pathogens in food
- Adherence of foodborne pathogens on food and equipment surfaces
- Mechanisms of pathogenicity of foodborne pathogens
- Effective methods for epidemiology study of foodborne diseases
- Control of pathogenic parasites in food

D. Miscellaneous

- Application of hazard analysis of critical control points (HACCP) in food production, processing, and preservation
- Novel food-processing technologies
- Microbiology of unprocessed and low-heat-processed ready-to-eat foods
- Microbial control of foods from farm to table (total quality management)
- Food safety legislation

Conclusion: The human civilization began when hunters and gatherers adopted not only production but also preservation of foods. Thus, long before the existence of microorganisms was discovered, their importance on food spoilage and health hazard was conceived by our early ancestors. Once their association and importance in food were proven, efforts were made to understand the basic principles associated with food and microbial interactions. This knowledge was used to control undesirable microbes and effectively use the desirable types. Current investigations are directed toward understanding microbes at the molecular level. A food microbiologist should have a good understanding of the historical and as well as current developments in food microbiology as well as the characteristics of microorganisms important in food.