MODERN FOOD MICRO-BIOLOGY

Third Edition

JAMES M. JAY
Wayne State University

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PREFACE

This third edition of *Modern Food Microbiology* is designed primarily for a second or subsequent course in microbiology in liberal arts, food science, nutrition, or related course programs. Organic chemistry and biochemistry are desirable prerequisites, but students with a good grasp of general biology and chemistry should be able to handle most of the material.

The twenty-five chapters are organized in seven sections. Section I (Chapter 1) consists of an outline of the history of food microbiology. In section II (Chapters 2, 3, and 4), the sources and types of microorganisms in foods are presented along with discussions of the parameters that affect the growth and activity of the food flora. Three new chapters (5, 6, and 7) form section III, and these chapters are devoted to methods of determining microorganisms and/or their products in foods. Essentially all information in the text on methodology has been placed in these three chapters. Section IV consists of three chapters (8, 9, and 10) devoted to microbial food spoilage, with emphasis on mechanisms to the extent known. Methods of preserving foods are presented in the six chapters (11 through 16) that constitute section V, and section VI comprises six chapters (17 through 22) devoted to indicator and food-borne pathogens. The final section, VII, consists of three chapters (23, 24, and 25) that deal with psychrotrophs, thermophiles, and radiation-resistant microorganisms. Some of the material in these three chapters may be combined with Chapters 12, 13, and 14 for textbook use or may be used in an advanced food microbiology course. The relationship between the common genera of food-borne bacteria is depicted schematically in the appendix section.

Numerous references have been consulted in the preparation of this

edition, and I thank the many investigators whose findings I have drawn upon so heavily. I have been assisted in this revision by a number of individuals who critiqued various sections of the draft, and they are listed below in alphabetical order.

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I

HISTORICAL BACKGROUND

1.

HISTORY OF MICROORGANISMS IN FOOD

Although it is extremely difficult to pinpoint the precise beginnings 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 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 one million years ago up to eight thousand 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 eight thousand to ten thousand 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 B.C. The practice of making pottery was brought to Western Europe about 5000 B.C. from the Near East. The first boiler pots are thought to have originated in the Near East about eight thousand 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 B.C. (7). The Sumerians of about 3000 B.C. 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 B.C. Between 3000 B.C. and 1200 B.C., 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 B.C. Fermented sausages were prepared and consumed by the ancient Babylonians and the people of ancient China as far back as 1500 B.C. (7).

Another method of food preservation that apparently arose during this time was the use of oils such as olive and sesame. Jensen (6) 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 B.C. 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 man 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 A.D. 1100 Ergot poisoning (caused by *Claviceps purpurea*, a fungus that grows on rye and other grains) caused many deaths during the Middle Ages. Over forty thousand deaths due to ergot poisoning were recorded in France alone in A.D. 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 abattoirs in Augsburg. Although people were aware of quality attributes in meats by the thirteenth century, it is doubtful that there was any knowledge of the causal relationship between meat quality and microorganisms.

Perhaps the first man 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 since 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. While 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 event that led to the discovery of canning had its beginnings in 1795, when the French government offered a prize of 12,000 francs for the discovery of a practical method of food preservation. In 1809, a Parisian confectioner, François (Nicholas) Appert, succeeded in preserving meats in glass bottles that had been kept in boiling water for varying periods of time. This discovery was made public in 1810, when Appert was issued a patent for his process. Not being a scientist, Appert was probably unaware of the long-range significance of his discovery or why it worked. This, of course, was the beginning of canning as it is known and practiced today. This event occurred some fifty years before L. 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 since he was not a scientist, and Leeuwenhoek's report was not available in French.

The first man 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, of course, now known as pasteurization.

HISTORICAL DEVELOPMENTS

Some of the more significant dates and events in the history of food preservation, food spoilage, food poisoning, and food legislation are listed below.

Food preservation

1782—Canning of vinegar was introduced by a Swedish chemist.
1810—Preservation of food by canning was patented by Appert in France.
1810—Peter Durand was issued a British patent to preserve food in "glass, pottery, tin or other metals or fit materials." Patent was later acquired by Hall, Gamble, and Donkin, possibly from Appert.
1813—Donkin, Hall, and Gamble introduced the practice of post-processing incubation of canned foods.
1813—Use of SO_2 as a meat preservative is thought to have originated around this time.
1825—T. Kensett and E. Daggett were granted U.S. patent for preserving food in tin cans.

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