Microbiology *of* Thermally Preserved Foods

Canning and Novel Physical Methods

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Foreword

THERMAL processing of foods is among the most basic of technologies used for their preservation. Different degrees of heat treatments can be applied to foods largely depending on the preferred level of preservation and desired quality characteristics of the treated product. Such heating processes have varying influences on the surviving microflora originally present.

This book provides a comprehensive presentation of the wide array of influences affecting the microbiological types of microbes of concern from both public health and also spoilage perspectives in thermally-treated foods. It describes the composition of heat-treated foods; overviews the various kinds of equipment that can be used in thermal food processing from the farm through the final product; discusses the microbial content of food products receiving thermal treatments; and concludes with the principles used to monitor and verify the safety of thermally-processed foods during processing and in their final container. Not only does this volume contain up-to-date information regarding the types of microbes of interest in heat-treated foods, but it also provides, as a complete resource, details of the many aspects of the food chain and processing environment that influence the microflora of thermally-processed foods. This is what I find separates this book from the many other published treatises on heat-processed foods.

I commend the book's authors for their efforts in developing this reference for those of us interested in the microbiological safety and quality of our foods. It will be a useful resource for educators, students, and food processors and regulators.

MICHAEL DOYLE
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Preface

DURING the past decades, there have been major advances in understanding the basic role of microorganisms in food production, product safety improvement and shelf-life extension. Simultaneously, superior processing technologies have led to broadening the assortment of products and offering more nutritious and natural properties. Even traditional canned foods preserved by high temperatures have been reinvigorated through novel formulations and packaging. Such advances provide one rationale for the present book, which integrates microbiology, thermal processing and canning technology. In this context, however, microbiological aspects are given the highest priority, as a variety of microrganisms are related to the thermal processing of foods, i.e., "canning," which is understood in a broad sense.

The subject of this book is divided into eight chapters. The first three chapters are a general presentation about fundamental knowledge on microorganisms related to the safety and quality of foods. The remaining chapters describe the applied aspects of thermal food processing—mainly canning—starting with raw materials, heat treatment, and the quality, stability and spoilage of products. The final section covers the control and monitoring of microbiological safety, including a brief treatment of methods of inspection and investigation.

Chapter 1 introduces the central theme of food production: the pathogenic and spoilage microorganisms and their prevention in food. Most foods are perishable, and in order to prevent foodborne illness and food spoilage, various ways of preservation are applied. The historical development of preservation techniques is outlined (Section 1.2). Of the common and traditional methods of preservation, including salting, sugaring, cooling, freezing, drying, adding preservatives and (more recently) irradiation, heating is by far the most commonly used method for inactivation of microorganisms. Various degrees of heating (e.g. boiling, frying, baking) are frequently used during food processing, and the final heat treatment is made by pasteurization or sterilization. Using heat preservation, a special and independent branch of the food industry, namely canning, has evolved through the years. Originally, canning referred to heat processing of products in hermetically sealed containers (mostly in metal canisters), and also in glass jars and bottles. In the meantime, many other packaging methods and materials have come into use, including post-production heating of pre-sterilized products under aseptic conditions. Heat preservation is applied beyond traditional canning for dairy and meat products, beverages and other food products. Today, the range of heat-preserved, thermally-processed foods has widened considerably, to a point where the concept of canning covers a wide range of processes and products.

In Section 1.3, the various factors determining the life and fate of microorganisms are summarized in the concept of microbial ecology. Exploitation of ecological factors provides the fundamentals for all food processing operations used in food manufacturing, revealing the sources and vectors of microbial contaminants as well as the extrinsic, intrinsic and implicit ecological factors controlling the growth and death of microorganisms.

Chapter 2 reviews the range of groups, species and types of microorganisms important in foods. Food technologists, food engineers, quality managers and inspectors should be acquainted with the types of foodborne microorganisms, at least to the degree that will enable them to know their properties and activities—beneficial or harmful. Beyond this, food microbiologists should be able to recognize (identify) those microorganisms commonly encountered in foods in order to evaluate the results of microbiological investigation from a technological point of view, particularly for their relevance to quality and safety. Sections 2.1 and 2.2 will give a taxonomic outline of the main groups of bacteria and fungi, respectively. The classification of relevant microorganisms will be discussed for those not directly involved (or interested) in taxonomy. Taxonomy and classification of microorganisms develop rapidly, with the consequence of numerous nomenclatural changes. Knowledge and usage of the current and proper names can help in the reliable determination of the role of individual species in food manufacturing, spoilage or foodborne disease. This kind of knowledge will have significance in understanding the microbial ecology of food systems and will promote improvement of preservation methods, as well as increasing the quality and safety of products. Otherwise, inadequate taxonomies and false nomenclature can lead to tremendous confusion and serious consequences. In the treatment of microbial taxons, the up-to-date molecular classification will be followed.

Two main groups of foodborne microorganisms will be considered with particular attention. These are the common contaminants and spoilage organisms (2.3) and the foodborne pathogens of primary importance for the safety of products (2.4).

In Chapter 3, the fundamentals of heat destruction of microorganisms will be addressed, in which the processes of thermal treatment are based. Heat treatment at high temperatures is the most important method of preservation in the canning industry and beyond. The practice of heat preservation predates a scientific understanding of microbial lethality. Today, the sterilization process rests upon solid theoretical fundamentals, on which the determination of heat process requirements can be based. This chapter will explain the rules of thermal inactivation of microorganisms and show how they can be extended and applied to novel modes of heat treatment, as well as to non-thermal preservation technologies (3.4).

The practice of heat preservation requires the use of dedicated equipment, and Chapter 4 provides a brief overview of the equipment and machinery used for in-container and aseptic processing and packaging, including a wide variety of container types. Specialized autoclaves (retorts) for heat treatment under pressure, heat exhangers used mainly for pasteurization, and seaming machines for hermetic closing of containers will be described from a microbiological point of view, without entering into details of engineering and mechanics.

Food manufacturing begins with the processing of raw materials. The canning industry and other branches of the food industry make use of a diversity of raw materials, mostly of plant and animal origin, that are able to support microbial populations. Chapter 5 deals with the microbiology of raw materials derived from livestock, poultry, fish, and fruit and vegetable produce that are the main components of processed products. Also, a great variety of other materials, called auxiliary materials and additives, are used for adjusting the physical and chemical characteristics and sensory properties of food, increasing their nutritive values and often contributing to food preservation, as well. This chapter will also discuss the loading of potentially contaminating microorganisms in raw food materials, which are loaded by different degrees of contaminating microorganisms.

Chapter 6 is a central part of the book, describing the unit operations of food processing, starting with harvesting of fruits and vegetables and slaughtering of meat animals. Depending on the type of product, various pre-treatment operations lead to the final step of heat preservation, which may be followed by post-process operations. The chapter shows how each of the individual unit operations impacts the microbiological state of the product, how the totality of unit operations forms a processing chain, and how both can increase or decrease the microbiological load on the product to be preserved. Chapter 6 includes a Section (6.8) on cleaning and sanitary operations, which gives many examples of operational practices for creating a clean and hygienic manufacturing environment.

The second main part of the book, Chapter 7, will discuss the microbiology of canned products and other kinds of thermally processed foods. In recent decades, food technology has undergone a dynamic evolution. In responding to market needs, environmental constraints and changing consumer demands for more natural, nutritious and convenient products, the industry has developed new and more effective processing technologies, while continuously giving first priority to the safety and quality of products. As a consequence, the variety of food products and their manufacturing technologies has broadened and diversified. Canning has remained a reliable, well-proven technology; however, besides the traditional established forms of heat-processed food in containers, new ones are emerging. This chapter will discuss all products which receive any form of heat preservation being processed in every branch of the food industry.

Chapter 8, the final part, is devoted to regulatory issues and control management of the safety and quality of preserved foods. In the past several decades, substantial improvements have been made in quality management systems. International agencies and national governments have prepared and implemented principles of Good Manufacturing Practices for design of food production plants, processing and equipments, as well as the Hazard Analysis and Crirical Control Point system for process control and monitoring. These topics will be discussed in the first sections of this chapter.

Routine testing and continuous monitoring of the entire food processing chain are essential parts of an effective quality assurance plan. Tracking sources of microbial contamination and routes of post-process spoilage have been a concern for assuring the safety and shelf life of food preserved through commercial processing. Isolation and identification of the causative agent of spoilage is an integral part of the investigation process. The traditional cultivation methods for the testing of microorganisms in foods are well established; however, they are time-consuming, and provide results that are both late and post-problem. Recent advances in the development of molecular identification and typing methods provide tools that allow more reliable, accurate and more rapid determination of causes of failures in manufacturing processes. The closing section of this chapter provides an overview of the novel instrumental, automatized and molecular methods relevant to the food preservation industry.

Our endeavor through these eight chapters has been to provide comprehensive information and explanations for the success of processing in producing high quality and safe food products preserved for long periods of time without spoilage. It is our sincere hope that the final result will benefit both food technologists and food microbiologists alike.

CHAPTER 1

Introduction

CHAPTER 1 introduces the general theme of food production, as well as pathogenic and spoilage microorganisms and their prevention in food. Most foods are perishable, and in order to prevent foodborne illness and food spoilage, various modes of preservation are applied. Heating is by far the most commonly used method for inactivation of microorganisms. The historical development of preservation techniques is outlined in Section 1.2. Various factors determining the life and fate of microorganisms are summarized in the concept of microbial ecology, which is detailed in Section 1.3. The presentation of microbial ecologies reveals the sources and vectors of microbial contaminants, and the extrinsic, intrinsic and implicit ecological factors controlling the growth and death of multiple pathogens.

1.1 PATHOGENIC AND SPOILAGE MICROORGANISMS AND THEIR PREVENTION IN FOOD

Nutrition is needed to maintain life—not only for human beings, but for microorganisms alike. It is an unfortunate coincidence that certain microorganisms, while feeding on human food, may cause diseases when co-ingested with what we eat. These microorganisms threaten human health and induce food spoilage. Globally, 15–25% of food produced is lost, mainly due to microbial spoilage. Also, each year 1.5–2.0 million people die from diarrheal disease; a great proportion of these cases can be attributed to contamination of food and drinking water by microorganisms (including viruses and parasites).

Compared to the importance of—and interest in—food safety, related problems of food spoilage have faded into the background. This happened despite the considerable technical advances made in the processing, formulation, and packaging of food and in the development of new techniques of food preservation. Although it is generally known that a substantial ratio of food loss is due to microbiological spoilage, exact figures on its effects either nationwide or globally are missing. The WHO estimates that in developing countries, more than 10% of cereals and legumes, and as much as 50% of vegetables and fruits, are lost to microbiological spoilage, in which fungi play the most important role. It is also known that substantial postharvest losses occur worldwide; however, they are attributed more to insects and rodents than microorganisms. The Economic Research Service of the United States Department of Agriculture (USDA) has presented some estimates in percentages about losses in the United States' food supply from production to consumption (ERS/USDA 2005). Losses may be due to damage by insects and rodents, microbiological spoilage, chemical and physical spoilage during transportation, substandard storage, poor home preparation and waste (Table 1.1). The produced weight (pounds/capita/year) refers to the amount of processed food; the consumed weight is the amount actually eaten; the difference is expressed in percent as loss.

TABLE 1.1. Percent Loss of the United States' Food Supply from Production to Consumption.

	Data (pounds/capita/year 2003)		
Food	Produced	Consumed	Percent Loss
Meat products			
Red meat	161	68	58
Poultry	113	41	64
Fish	16	11	31
Grains and cereal	194	136	30
Dairy products	194	137	30
Fruits			
Fresh	127	53	58
Canned	17	11	33
Vegetables			
Fresh	196	86	56
Canned	101	40	60

Data from Economic Research Service/USDA 2005 (1 Feb.).

The average loss for all foods is about 40%, which may be an underestimate of the actual figure. On the other hand, the amount not consumed does not necessarily refer to spoilage loss. For example, although only 40 pounds/capita/year was consumed from the 101 pounds of canned vegetables that were produced, the roughly 60 lbs. difference is counted as a loss. However, it can be surmised that part of the 60 unconsumed pounds is still available for consumption in subsequent years and is not spoiled, since canned products have a long shelf-life. From these data, it is not possible to estimate which proportion of the food losses has actually been caused by microbiological spoilage.

A recent book compiled by Sperber and Doyle (2009) gives an excellent overview of the wide possibilities of microbiological spoilage of both perishable and preserved foods, leaving no doubt that foods are spoiled mostly through the action of microorganisms. In order to prevent foodborne illness and spoilage, food preservation is applied worldwide. The major objective of food processing, storage and preservation is to provide a continuous supply of food products year-round, independently of agricultural growing seasons. In addition, food processing aims to maintain an acceptable quality of food and to provide nutritional variety and value-added products. Beyond all these, however, the main goal of food technology remains to make food as safe as possible, whether fresh or processed. Most foods are perishable, and deterioration is caused by inanimate physical and chemical factors as well as living organisms, of which microbiological effects are the leading cause (Desai, 2000; Hui, 2006). Hence, food preservation can be achieved by methods for the inhibition and inactivation of microbes, or preventing recontamination after processing and during storage (Figure 1.1). In addition to slowing down the growth of microorganisms and/or killing pathogenic and spoilage organisms, preservation methods inactivate enzymes and retard deterioration of food constituents.

Traditionally, food preservation is accomplished by well-proven technologies, such as heating, drying, salting, cooling and even fermentation by microorganisms. New technologies are being added, including irradiation, high pressure, microwave and others.

In order to fulfill consumer demands, new products are being developed that are less processed, fresher, and more nutritious. Production of these emerging food items requires more effective control procedures and regulations for food safety. These measures also help to protect product quality, extend shelf-life and reduce spoilage. In the 1970s, the implementation of Good Manufacturing and Hygienic Practices (GMP,

Food preservation
by physical, chemical, microbiological techniques

Inhibition	**Inactivation**	**Avoiding recontamination**
Low temperature	Pasteurization	Packaging
Freezing	Sterilization	Surface coating
Reducing a_w	Radiation	Aseptic filling
Decreasing O_2	High pressure	Cleaning, sanitation
Increasing CO_2	Electrical	
Acidification	Chemical	
Fermentation		
Preservatives		

FIGURE 1.1. *Methods of food preservation.*

GHP) resulted in substantial improvements in food production and preservation technologies, and the development and wide acceptance of the Hazard Analysis Critical Control Points (HACCP) system of food safety management was also a significant step forward in assuring food quality and in reducing food spoilage (Doyle *et al.*, 1997).

Preservation usually involves preventing the growth of bacteria, fungi, and other microorganisms. Common methods of applying these processes include drying, freezing, vacuum-packing, canning, adding preservatives and more recently, irradiation. Other methods that not only help to preserve food, but also add flavor, include pickling, salting, smoking, and curing. Some preservation methods, such as canning, require the food to be sealed after treatment to prevent recontamination with microbes, such as filling and sealing into metal containers before heat treatments. As mentioned above, heating is by far the most commonly used method for preservation. Various levels of, and strategies for, heating are used during processing, and the final heat treatment is often pasteurization or sterilization. The canning industry has an outstanding record of success in preservation, considering the billions of cans, jars, packets, and pouches produced annually. It is the safest process of food preservation, assuring a very long shelf life—up to two years or longer. Heat processing will destroy most microorganisms, although some spore-forming bacteria are resistant to heat and may survive heating. The history of canning gives evidence of the often-fatal cases caused by the toxins produced by the spore-forming bacillus, *Clostridium botulinum.* In the 1920s, canning procedures were improved to kill the vast majority of *C. botulinum* spores that might occur (one survivor in 10^{12} spores), and the incidence of foodborne botulism decreased drastically. Still, in the U.S., about 10 to 30 cases of foodborne botulism are reported every year (CDC 1996), although of these only 4% can be attributed to commercially-canned products, with the majority of cases involving home-canned food and restaurant-associated outbreaks (Shapiro *et al.*, 1998).

The nutritional and other quality attributes, like the microbiological and sensory properties of the product, are essential factors in the canning industry, and therefore improving conventional heating processes and sterilizing methods are of great interest to the canning sector. A main reason for this is to minimize the destructive influence of heat on valuable food components (Durance, 1997). The need for enhancing microbial safety and quality via heating without compromising the nutritional, functional and sensory characteristics of food has created an interest in low-temperature, innovative processes for food preservation. In contrast to the traditional thermal methods, emerging low-temperature technologies are predominantly reliant on physical processes, including high-pressure processing, electro-heating (radio frequency, microwave and ohmic heating), pulsed electric fields, ultrasound, microfiltration and low-temperature plasmas that inactivate microorganisms at ambient or moderately elevated temperatures and short treatment times (Fellows, 2000). Despite promising lab-scale results, however, each process must be capable of operating in a factory environment, a limiting factor for the general use of many of these alternative sterilizing processes (see Sections 3.3 and 3.4).

Traditional canning denotes the heat processing of products in hermetically sealed containers. In the strict sense, "can" (short for ''canister") refers to a metal container, but since the beginning, canned products were packaged in glass jars and bottles, and later also in plastic pouches, laminated boxes and various other heat-resistant materials. Moreover, since the development of aseptic technology—filling the pre-sterilized product into containers sterilized by radiation and/or chemicals—methods of preservation for canned foods have become considerably different from those in conventional canning. In addition to traditional canned products, several branches of the food industry apply heating (sterilization or pasteurization) and other means of preservation to dairy products, beverages, and beer and wine—foods which are not normally considered canned products. If we add the recently-developed treatments of non-thermal preservation, the range of canned products becomes extremely wide, and the notion of canning begins to become ill-defined. In this book, canned food will be defined in the traditional sense as thermally processed, shelf-stable products in sealed containers, regardless of the mode of heating and packaging. Brief consideration will also be given to non-thermal preservation methods and products processed by heating and manufactured beyond the traditional boundaries of the canning industry.

1.2 HISTORY OF FOOD MICROBIOLOGY AND CANNING

The history and development of microbiology can be followed along four paths. Food production and preservation is one of these, connected partly to the other areas. A second path is the recognition of diseases and their treatment. Agricultural and industrial relations constitute the third line of knowledge, and the fourth (and most recent) is the exploration of the molecular-genetic constituents of microbes.

Historical evidence shows that humans have practiced certain methods of food preparations for thousands of years, such as drying, salting, smoking, and pickling, which also served for preservation and storing of foods. Babylonians, Egyptians and other early civilizations fermented beer, wine, cheese and leavened bread. Although these were practiced effectively, they had no rationale other than the prevention of food spoilage, whose exact causes were not understood. Centuries later, still before the discovery of microorganisms, the Italian Lazzaro Spallanzani demonstrated that beef broth that was boiled and then sealed remained unspoiled. Soon after, in 1795, motivated by a tender of Napoleon Bonaparte offering 12,000 francs for developing a practical way to preserve food, a confectioner named Nicholas Appert successfully preserved meat placed and boiled in glass bottles (Figure 1.2). He pat-

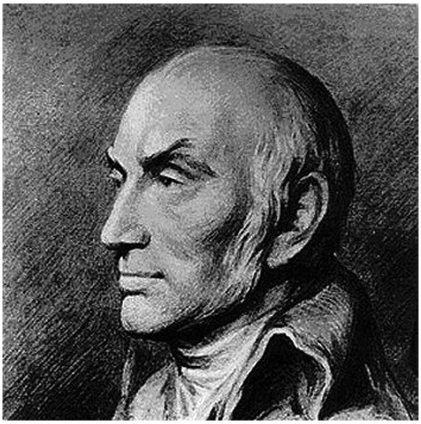

FIGURE 1.2. *Nicolaus Appert (from wikipedia/commons).*

FIGURE 1.3. *Louis Pasteur (from wikimedia.org).*

ented the process and this was the beginning of food preservation by canning. Fifty years later, Louis Pasteur demonstrated the role of microbes in food spoilage (Figure 1.3). Among other foundational work in microbiology, Pasteur made notable discoveries in food microbiology. He demonstrated that different types of fermentation (i.e., lactic, butyric, etc.) were caused by specific types of microorganisms. He also found that microbes were responsible for the putrefaction of meat and milk, as well as for "diseases" of wine, and developed a heat process (pasteurization) to preserve wine.

From the late 19th century on, discoveries of microbes implicated in food poisoning and food infection proceeded rapidly. In 1885, a veterinarian, Daniel Salmon, described a microorganism that caused gastroenteritis with fever when ingested in contaminated food. The bacterium was eventually named *Salmonella.* In 1896, Émile Pierre-Marie van Ermengem isolated the agent of sausage poisoning, and named it *Clostridium botulinum.* It was not until 1914 when Mary Barber demonstrated that the already-known pus bacterium, *Staphylococcus aureus,* produces a heat-resistant enterotoxin that causes food poisoning. Since that time, many other foodborne pathogens have been described, and emerging new ones are being catalogued almost constantly (see 2.4).

Meanwhile, discoveries have been made about disease-producing microorganisms. Although humans learned very early that spoiled food can be poisonous and cause disease, they were ignorant of any microbial cause and prevention of it. Ancient Chinese documents warned against consuming sour rice and uncooked food. References about the causes of diseases were made in the 17th century by the Italians Francisco Redi and Lazzaro Spallanzani, who raised doubts about spontaneous generation. Antonie van Leeuwenhoek, the Dutch microscopist, had the first glimpse of tiny organisms in 1673. The discovery of bacteria in the late nineteenth century led to the idea that unsanitary conditions can contribute to disease. One pioneer who realized this was the Hungarian physician, Ignaz Semmelweiss, who in 1847 required hospital doctors to wash their hands before delivering babies. Louis Pasteur elucidated the link between microorganisms, spoilage and disease with his work on fermentation and pasteurization in the mid-1800s. In the 1880s, the German Robert Koch provided incontestable evidence for microbes causing disease. In the following years, the Golden Age of microbiology, numerous pathogenic bacteria, as well as viruses and parasites, were discovered, among them agents of foodborne illness, and methods for prevention and treatment were also found.

Even before scientists uncovered the microbial causes of foodborne diseases, the canning industry was introducing techniques that could forestall the growth of pathogens in food. The 19th century was marked by progress in food canning. Appert's methods, the foundation of commercial canning, spread from France to England, where, in 1810, Peter Durand had obtained a patent covering the use of iron and tin to make canisters for preserving foods. John Hall and Bryan Donkin started preserving foods in iron canisters. Appert's bottles were replaced with Mason's jars, sealed by a tight cover. The most significant inventions were the Mason Jar in 1858 (named for its inventor, John Landis Mason), a glass jar with a thread at the neck that could be closed by screwing on a metal cap, and the Crown Cap for bottles, invented by William Painter in 1898. Later, instead of glass bottles, cylindrical tin canisters (i.e., "cans") became widely used, having been patented by P. Durand in 1810. The new food preservation method reached the United States about 1820, and there began to grow into the most important industry in the world economy. In 1821, the William Underwood Company in Boston introduced commercial canning in the United States. (Other sources claim that Robert Ayars established the first cannery in 1812 in New York City.) The extensive growth of commercial food production was greater in the United States than anywhere else. Important factors in the industry's growth were the continual changes and adaptations made to containers, and the machinery and the equipment used to fill them. Canned foods were used in famous Arctic expeditions (Parry[J1] in 1824, Ross in 1829, and Franklin in 1845), and commercial canneries were established for supplying armies. Canning of food spread in Europe, too; among others, the "First Hungarian Conserving Factory" was founded in Csepel, Budapest in 1880 by Manfred and Berthold Weiss (Figure 1.4).

Canning of foods, however, did not eliminate food poisoning, and in some cases contributed to it. Underprocessing and poor hygiene in manufacturing allowed contamination of canned foods by *Clostridium botulinum,* leading to severe illness and death. In poorly handled and cooked mushrooms, *Staphylococcus aureus* also developed, which has a thermotolerant enterotoxin that is not always destroyed by subsequent canning. These and other incidents called for a more thoroughly-performed heat treatment, and the microbiological backgrounds were developed by the American scientists Ball, Esty, Meyer and Bigelow in the 1920s (see 3.1). Since heat treatment was based on the major destruction of *C. botulinum,* the safety of canning was ensured (Ball and Olson, 1957).

Nowadays, the canning industry is a strong branch of food production. During its recent history, some products have become convenient

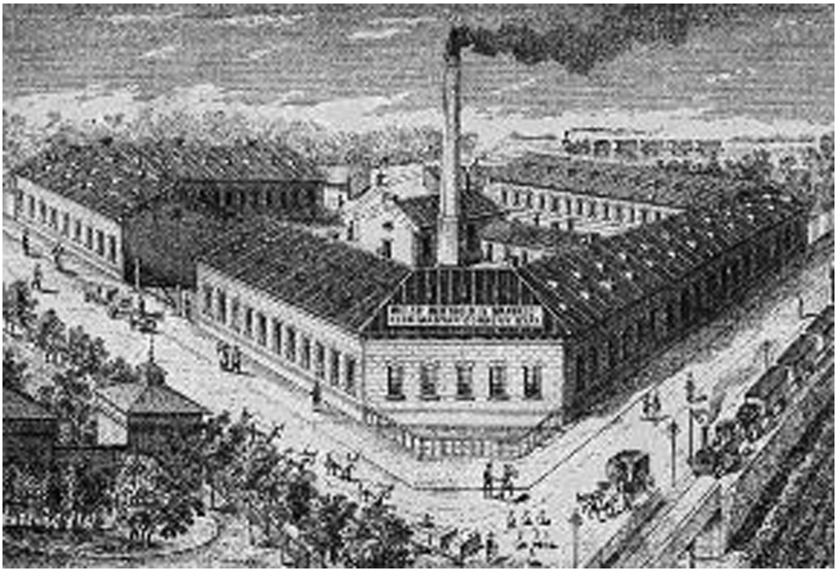

FIGURE 1.4. *The first Hungarian canning factory, 1880 (file from wikimedia commons).*

staple foods known worldwide. Examples are Hormel Food's "SPAM" since 1937, Heinz catsup and Campbell's tomato soup, baked beans, corned beef, Vienna sausage (frankfurter) and others, to name a few.

Simultaneously with the development of medical microbiology, important discoveries were made about the role of microorganisms in agriculture and industrial fermentation. Research done by the Russian Sergei Winogradsky and the Dutchman Martinus Beijerinck established the primary role of bacteria in the recycling of elements in soil. In 1837, three scientists, Charles Cagniard-Latour, Theodore Schwann, and Friedrich Kützing, independently proposed that yeasts bring about alcoholic fermentation. Eduard Buchner discovered the role of enzymes in fermentation, and this started the development of biochemistry. From the beginning of the 20th century, large-scale industrial fermentation has produced several microbial metabolites, among them active ingredients for pharmaceuticals. This reached its peak with the discovery of penicillin by Alexander Fleming in 1927, which helped establish the antibiotic industry.

Genetics and molecular biology can be considered the most recent disciplines of microbiology. In 1947, Joshua Lederberg and Edward L. Tatum discovered that bacteria reproduce sexually, opening up the new field of bacterial genetics. Oswald Avery, Colin McLeod and Macklin McCarty proved in 1944 that DNA is the genetic material, the structure of which was revealed in 1953 by James Watson, Francis Crick and Rosalind Franklin. In the following decades, numerous breakthrough discoveries were made, leading to the recombinant DNA technology that pervades all basic and applied fields of today's microbiology and biotechnology. More thorough historical surveys can be found in several sources, including Brock (1999), Beck (2000), Hartman (2001) and Thorne (1986).

1.3 MICROBIAL ECOLOGY OF FOODS

The metabolism, growth, activity and survival of microorganisms are determined by the conditions prevailing in their natural and artificial habitats, which includes raw and processed foods. A variety of abiotic and biotic factors exert their effects (Table 1.2). For the microbial cells, these factors act as stress conditions to which they must adapt, withstand, or die. In food microbiology, knowledge of these ecological factors is important in order to control (moderate and inhibit or facilitate and utilize) the activity of microorganisms. In particular, prevent-

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About the Authors

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Dr. Deák received his B.Sc. degree in biology and chemistry from the University of Szeged in 1957, and his M.Sc. degree in microbiology from the Eotvos University of Budapest in 1963. He received his Ph.D. and D.Sc. degrees in biological sciences in 1970 and 1989, respectively, from the Biology Section, Hungarian Academy of Sciences, Budapest. After gaining experiences at the Budapest Canning Co. and the Research Institute for the Canning Industry, he was appointed an Assistant Professor in Microbiology at the University of Horticulture and Food Science in 1967. He became an Associate Professor in 1970 and full Professor in 1980. Dr. Deak was appointed the Head of the Department from 1970 to 1996, and served two terms as Dean of the Faculty of Food Science and Technology (1986–1991) and one term as the Rector of the University (1993–1996).

Dr. Deak has been the President of the Hungarian Scientific Society for Food Industry, and currently is Vice-President of the International Committee for Food Microbiology and Hygiene, a board member of the International Committee for Yeast, International Committee for Food Mycology, Hungarian Society of Microbiology, and a member of the World Federation of Culture Collection, the European Culture Collection Organization, and the American Society of Microbiology. He is a

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Dr. Deak is author or co-author of more than 230 research papers and eleven books, as well as 15 textbooks and manuals. His current research interests include the microbial ecology of foods, biodiversity of yeasts in agro-ecosystems, yeasts as spoilage agents in foods and the detection and identification of yeasts.

JÓZSEF FARKAS, D.Sc., is emeritus professor of food science at the Corvinus University, Budapest, Hungary, and Member of the Hungarian Academy of Sciences (HAS). He received his Ph.D. and D.Sc. in radiation microbiology in 1968 and 1979, respectively. In 1957, he joined the Central Food Research Institute, Budapest and served there in various research positions until 1986, when he was appointed to the Faculty of Food at Corvinus University of Budapest, where he was professor and department head until his retirement in 2003. Dr. Farkas's research activities have covered a broad areas of food microbiology and chemistry, and have included multiple aspects of non-thermal food preservation methods. From 1980 till 1985, he was Director of the International Facility for Food Irradiation Technology, Wageningen, The Netherlands. He was elected member of the International Commission on Microbiological Specifications for Foods (ICMSF) for eight years. Presently, he is chairman of the Sub-Committee on Food Safety of the HAS, and the Scientific Advisory Board of the Hungarian Food Safety Office.