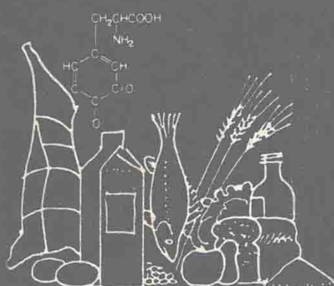

ELEMENTARY FOOD SCIENCE

SECOND EDITION

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Preface to the Second Edition

We are pleased with the reception this book has received in many colleges and universities, not only in the United States, but in other countries as well.

In the Second Edition of *Elementary Food Science*, the following changes have been made: All measurements which were formerly listed as units only of the English system, have been herein recorded in both the English and the metric systems. The chapter on dairy products has been rewritten and brought up to date, especially from the standpoint of processing as applied to the various items included in this group of foods. A new section on whey has also been added. The chapter on fish and shellfish has been rewritten in such a manner as to exclude some of the data and detail concerning the biology of various marine species listed in the First Edition. In its place, a more detailed and up-to-date description of the processing of the different edible marine fish and shellfish has been included. In the chapter on food processing methods, a new section on glass containers has been added. In the chapter on food additives, the section on nonnutritive sweeteners has been expanded to include nutritive sweeteners. Minor changes have been made in all chapters in an attempt to make the general text easier to understand, and the index has been made more comprehensive than that of the First Edition.

JOHN T.R. NICKERSON
LOUIS J. RONSIVALLI

April 1980

Preface to the First Edition

This book was written with the hope that it will help to fill several needs. Food science, while taught in as many as 40 universities throughout the United States, is not widely recognized as a profession. Yet the subject is among the most relevant and important of endeavors. Food science is in a somewhat awkward classification, for it is not a discipline in the same sense that is either chemistry or mathematics. It is more nearly related to the class of professions that require a wide scientific background before an exacting study of the particular subject can begin, for instance, medicine.

Food science can be practiced at various levels of sophistication. As an illustration, the work of the analysts who try to interpret protein denaturation systems or to determine the effect of high energy such as radiation on the chemistry of foods is complex, while that of the individual in charge of quality control in a small food processing plant may, though not necessarily, be relatively simple. Medicine is practiced only at high levels of sophistication. Nurses, paramedics and hospital aides are those who deal with less exacting needs of the medical profession. The parallel between food science and medicine is only a convenient one, but it is interesting to note that these professions are much more related than is generally recognized.

Many food scientists categorize those concerned with the less difficult food applications as food technologists, perhaps for good reasons. This distinction has been avoided in this book.

It is the opinion of the authors that the handling of foods should be permitted only by knowledgeable people. Recently a newspaper reported that 200 people were victimized by food poisoning in an airliner. There is need for all people to have some understanding of the proper handling of foods. Yet it is probable that over 95% of all of those who work in this field have little knowledge of the subject. It is the opinion of the authors that the kind of information contained in Sections 1 and 2 of this text should be a required part of the curriculum of the last year of high school. It would prepare the student for two year courses in food science (Associate Degree) or even for further education in the regular four year food science college programs.

While this book is directed at those students in the last year of high school and students aspiring to obtain the two year Associate Degree, it should be definitely helpful to freshmen at the university level. Sections 1 and 2 would also prepare adults who never go to college and who are eventually employed in food handling establishments, restaurants, hotels, airlines, food processing plants, etc., to better qualify them for their work.

As with any introductory text, it was not possible to cover subjects thoroughly. For example, the chapter on fish and shellfish, while relatively long, is problably the least adequate considering the vast information which has been omitted. It is recognized that separate and complete texts could be written, and in some cases have been written, on a number of the subjects covered in this book, and appropriate references have been made. Also, some topics such as water, nuts and soft drinks have been omitted. This was not done because these subjects are not important, but because they could best be dealt with in separate texts.

JOHN T.R. NICKERSON
LOUIS J. RONSIVALLI

November 1975

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Section I

Interrelated Food Science Topics

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Why Food Science?

The scientific study of food is one of man's most important endeavors, mainly because food is his most important need. It is necessary for his survival, his growth, his physical ability and his good health. Food processing and handling is the largest of all of man's industries. Many factors require that those scientists who choose to study foods be prepared to absorb as many of the physical and life sciences and as much engineering as possible. Among these are the chemical complexity of foods, their vulnerability to spoilage, their role as a disease vector, and the varied sources of foods. The availability, nutritional adequacy and the wholesomeness of foods are also quite varied.

Whether we know enough of the facts to trace the development of food science from the beginning is questionable. History reports that the Romans realized, more than the Greeks, Egyptians, or any of the prior civilizations, that agriculture was a prime concern of the government. The Romans, as the Egyptians and the Greeks before them, were able to preserve a variety of foods by holding them in vinegar (with or without brine), in honey or in pitch. Some foods were dried, either by the sun or over a fire. These civilizations also produced cheeses and wines. Yet it is generally believed that until the latter part of the 18th century, the preservation of foods had evolved as an art handed down from generation to generation. Its development was slow, depending on accidental discovery, observation, trial and error, and attempts to reproduce and put into practice the newly found techniques. Drying, freezing, smoking, fermenting, cooking and baking had been practiced for centuries—even by illiterates. Foods frozen accidentally in cold climates and foods dried accidentally in dry climates were observed to have a longer "shelf-life" than foods which were neither frozen nor dried. Foods that might have been put over a fire to hasten drying could easily have led to the smoking process. Thus, chance occurrences led to preservation methods that permitted man to conserve foods during times of glut so that he might survive the leaner spells. It can be said that those who made the observations and realized their impact, then put their interpretations to the test until the new practice was proven, were the first food scientists. Spallanzani (1765) and Appert (1795) were among the first to apply the quasi-scientific methods for preserving foods, and in 1809, Appert won a prize from the French government for developing a thermal processing technique for foods to be used by the military. Appert is credited with developing the canning process. Because of the scarcity of scientific information, Appert had to employ trial and error tactics, but his records attest to the accuracy of his observations and conclusions and show that he applied the scientific approach to gain his outstanding achievement, even though he did not know why his method worked.

It was not until the discoveries of Pasteur in 1850 and the work of other microbiologists, such as Prescott and Underwood in 1895, that man learned that bacteria spoiled food and why thermal processing prevented food spoilage.

By 1875, man had learned to preserve foods by artificial refrigeration using first, natural ice, and later, manufactured ice, to preserve fish and meats. He also learned that brine could be made colder than 32°F (0°C), and this enabled him to freeze foods. By 1890, mechanical refrigeration had come into wide use, opening the way to the frozen storage of foods. Quick freezing was first used in 1924 to preserve fish. During the period 1932–1934, Clarence Birdseye, with laboratories in Gloucester, Mass., developed over 100 different frozen food items, and this achievement won for him the reputation and the credit for the beginning of the quick-frozen food industry. One of the most important ensuing technological developments was the invention of the fish blocks by Birdseye technologists. This is considered by many to have revolutionized the fish processing industry.

In 1898, it was noted that bacteria were destroyed by exposure to radioactive salts of radium and uranium. By 1930, the use of ionizing radiations to preserve food was patented by O. Wust. However, the irradiation preservation of foods was not actively investigated until the team of Proctor, Van de Graaf and Fram from the Massachusetts Institute of Technology undertook the project in 1943.

Modern technology has made possible such controlled, automated drying processes and sophisticated modifications as freeze-drying, drum drying, spray drying, and fluidized-bed drying. Controlled, automated versions of thermal and refrigeration processes have also been developed.

Radiation processing (by electron-, X-, and gamma-rays), microwave processing and aseptic canning have also been introduced.

Though many food processes alter foods so that the finished product is more palatable or otherwise more acceptable (to some at least) than the original raw material (sauerkraut, tuna, wine, roquefort cheese, etc.), in many cases it is desirable that preservation processes do not alter the food (fish fillets, beef steak, pork chops, etc.). Only refrigeration can preserve most foods without altering them substantially.

FOOD—MAN'S MOST IMPORTANT NEED

It is universally accepted that man's basic needs are food, clothing and shelter. Of course, such a list ignores man's need for oxygen and water, two critical requirements, but this is understandable since we take for granted the presence of adequate amounts of oxygen in the air we breathe, and we are ever aware of the copious supplies of water in the many rivers, lakes and wells in most parts of the world. It is only lately that a concern for water supplies is evident. It should be quite clear that food is listed before clothing and shelter because it is the most important of the three. In fact, like oxygen and water, food is a critical need without which man cannot survive. Clothing and shelter, on the other hand, are not critical to his survival, although their availability makes life more convenient for man and permits him to live in areas where the climate would be intolerable without them. Clothing may last for relatively long periods (months or years) and shelters may last for decades or even a lifetime; therefore, man has had to spend relatively little of his time in the procurement of these needs. His need for food, however, is relentless, and he is reminded to eat by the hunger sensations he feels at least three times each and every day of his life. Little wonder that primitive man, the hunter, spent a large part of his time foraging for food! Technological advances have made it possible for inhabitants of developed countries to spend considerably less time than ever before to earn enough to buy the food they need.

The availability of an abundant supply of food does not necessarily guarantee survival unless the food is nutritionally complete and contains no deleterious substances. Unfortunately, serious and sometimes fatal illnesses result from diets that lack sufficient proteins, vitamins or other nutritional components. Serious adverse consequences may also result from the consumption of foods containing such harmful substances as infectious microbes, microbial toxins, viable parasites, allergenic agents and a large number of chemical toxins. Thus, throughout his evolution man has had to concentrate on many factors affecting foods. He has had to increase the efficiency of food procurement to ensure a sufficient availability; to learn ways to preserve foods to carry him through times of scarcity or crop failures; and to learn specific processing methods, such as baking, pickling and fermenting to increase the variety and desirability of his food. Also, he has had to learn the rudiments of the nutritional and medical aspects of food diets to maintain his health, and to learn how to minimize food-borne illnesses. However, he has a long way to go, and the little that he already knows about foods only serves to make him aware of their complexity and of the ponderous work that needs to be done in food science.

Military leaders, throughout history, have been cognizant of the role of food in a military operation. An abundance of food has always been and will always be necessary to maintain the morale of the soldiers and to sustain invasion tactics; but the nature of the foods is also important, since the mobility of an army is affected by the mass of material it must carry. Thus, dried, compact foods enhance mobility. One of the outstanding facets of the military successes of Genghis Khan was the mobility of his army of mounted soldiers. With only a very scant food supply he was able to engage in swift cavalry attacks over long periods, which often caught his enemies off guard, too bewildered to rally an effective defense. Marco Polo is credited with reporting the Khan's solution to his food supply problem. Apparently, each of the Khan's horsemen carried two leather bags—one larger than the other. In the large one, he carried dried milk—produced by drying fluid milk in the sun during periods of rest. When sufficient dried milk was produced, the horsemen were prepared to start an offensive. During each morning of the offensive, some dried milk and water were put into the small bag wherein the dried milk was rehydrated, helped, in some measure, by the agitation resulting from the motion of the horse. The rehydrated milk was consumed at some time during the day. With a supply of dried milk, the lightly equipped army of the Khan could cover long distances in weeks, and when the supply of milk was exhausted, the men were able to continue, when necessary, by employing one more innovative technological tactic. They bled their horses once each day, taking about one pint of the animal's blood which they drank for nourishment. It is reported that the army was able to continue for at least one additional week by this scheme.

The full impact of a concerted technological effort in the food logistics for the military was first evident during World War II, when American troops were equipped with light, compact, nutritionally balanced food packets that could sustain them during a military action. The proven value of the application of food science for military purposes has resulted in a continuing effort by food scientists at the U.S. Army Natick Development Center, Natick, Mass., whose efforts are augmented by those of industrial and academic scientists.

FOOD SCIENCE AND HEALTH

The optimum physical and mental functioning of the body is dependent on the nutritional quality of the foods it receives. Man has observed this from the beginning of time, and certain diets have evolved as a result of these observations. The analysis and planning of diets were not possible until food science became established to a degree and produced the basic information that made these activities possible. From the knowledge acquired through the development of food science emerged conclusions that resulted in the classification of foods into nutritional groups, representatives of which are considered to be necessary in all diets to ensure the intake of a recommended minimum of protein, carbohydrates, vitamins, minerals, etc. Evidence of the links between diets and certain symptoms of ill health became easier to obtain as food science developed, and the potential of specific diets in corrective and preventive medicine has been gradually recognized and is now effectively practiced.

FOOD—THE LARGEST OF ALL INDUSTRIES

The food industry is the largest of all industries in the United States. It employs about 14,000,000 people. Its activities include farming, fishing, processing, transportation, wholesaling, retailing, warehousing and containerizing. These activities require many others. Included among them are those that supply work clothes, farm equipment, processing equipment, trucks, railroads, air transports, ships, and communication facilities. Also involved are industries that supply forklifts and other plant equipment; public utilities; recreation facilities; building materials and tradesmen to build the plants and install water, heat, refrigeration, computers, fishing gear, electrical and detection equipment, and other materials. It does not take much imagination to realize that the ramifications of the food industry reach into nearly all other industries. Although one might question which industry is ancillary to which, resolution of the question depends on which industry is most important to man. Obviously, it is the food industry.

The amount spent for food in the United States is about $100 billion annually, about 1/5 of all spending. The largest of the many conglomerates that produce food products have annual sales in the hundreds of millions to billions of dollars and annual earnings in the tens to hundreds of millions of dollars. For example, the 25 largest food companies have annual sales totaling nearly $34 billion and annual earnings totaling over $1.2 billion.

Because the food industry is so large and involves such vast amounts of money, it has attracted large investments by giant diversified international corporations. The competition among these business giants has resulted in greater varieties of products and product forms, and intensified growth in prepared foods development, automatic vending, fast-order franchises, and other innovative strategies aimed at that $100 billion spent by American consumers for their food. Expansion of the food industry has accelerated under the impetus of growth by the new conglomerates, and considerable expansion has spread into other countries.

The advent of the large food store or supermarket, together with the growth of the automotive industry, has led to the large shopping centers —a concept that fosters the growth of the supermarket and the supermarket chains and the discontinuance of the small food stores. Supermarkets offer many attractions to the food shopper. Three major factors concerned with the success of supermarkets are: (1) large variety of foods, (2) large variety of brands, and most important, (3) lower prices due to buying in large quantities.

FOOD SCIENCE FOR SOCIETY'S SAKE

We are in an era where food and what is done to it are oftentimes topics for newspapers and other public communication media. Some of the publicity is authoritative and authentic, but some of it is less than authentic, even misleading and deceptive. In addition, the public is confused by the vacillation of authorities concerning the potential hazard of cyclamates, DDT and other compounds that are intentionally or unintentionally added to foods. The public is alarmed by the incessant warnings by authorities and pseudo-authorities against a variety of food additives, and it is bilked mercilessly by misleading assertions on the purity of organically grown foods and on the properties of certain foods that cause a decrease in obesity. Even in well-meaning drives to substitute oleomargarine for butter to lower the risk of heart disease, the public is misled to a degree. There is an awareness that public education on food science is sorely lacking, and the Institute of Food Technologists (the national society for food scientists) is intensifying a program initiated to remedy this. Professors of food science at a number of universities and scientists in private industry have also set up public education programs. As a result of the efforts of these dedicated people, a number of informative publications have been issued and are available at no cost to the general public. The Institute of Food Technologists has published short articles on the following subjects:

- Botulism
- Nitrites, Nitrates, and Nitrosamines
- Carrageenin
- Mercury in Food
- Organic Foods
- Phthalates in Foods
- Nutrition Labeling
- Shelf-life of Foods
- The Effects of Food Processing on Nutritional Values

Other relevant articles are scheduled for publication in the future. For those interested in food additives, an informative publication of about 64 pages was published by the Manufacturing Chemists Association, and it is reportedly available to the general public from that organization at no cost.

There is another basic reason to encourage the spread of knowledge of food science in society. Although we have an excellent network of regulatory agencies in municipal, state, and federal governments, we are still faced with a considerable incidence of food-borne illness. Botulism has been caused by mushrooms packed in a plant which did not have a food scientist on its staff. Countless cases of perfringens poisoning, salmonellosis, and staphylococcal poisoning due to foods eaten in restaurants, institutions, and even on airliners could be avoided were suitable expertise in food science exercised in the handling of the foods involved. It is recognized that small food businesses and small restaurants might not be financially capable of employing a food scientist. However, it would make a significant difference in the operations of these facilities if they obtained the services of a food consultant from time to time (e.g., to set up a process, to make periodic evaluations of time operations, etc.). It would also be helpful to subscribe to a food trade journal.

While it is not new to state that the increase of the world's population is more rapid than the increase in food supplies required to feed that population, it is only because of food science that the situation is not far more serious. Basic information on the growing of crops and on genetics has permitted significant increases in agricultural productivity. However, the widening discrepancy between supply and demand will ultimately be resolved by political or social action, and food science will serve only to delay or to cushion the effects of the inevitable if effective measures are not taken. In the United States, population growth is under