FOOD SCIENCE

FIFTH EDITION

NORMAN N. POTTER
JOSEPH H. HOTCHKISS

SCIENCE FST FOOD TEXTS

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JOSEPH H. HOTCHKISS

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To our dear families whose support and encouragement make all things seem possible

Preface

It has been nearly 30 years since the first edition of *Food Science* was published. It and the subsequent three editions have enjoyed worldwide use as introductory texts for curriculums in food science and technology. This favorable response has encouraged us to adhere to the same basic format and objectives of the previous editions. Our goal is to provide readers with an introductory foundation in food science and technology upon which more advanced and specialized knowledge can be built. We are also aware that the book is widely used as a basic reference outside the academic environment. The fifth edition has been substantially updated and expanded where new information exists or was needed. The fifth edition continues to be aimed primarily at those with little or no previous instruction in food science and technology. The text introduces and surveys the broad and complex interrelationships among food ingredients, processing, packaging, distribution, and storage and explores how these factors influence food quality and safety. Foods are complex mixtures of mostly biochemicals and the number of methods available to convert raw agricultural commodities into edible foods is almost endless. It was not our intent to be comprehensive but rather to address the need for insight and appreciation of the basic components of foods and the processes most commonly used in food technology. We also hope to provide insight into the scope of food science for people considering food science as a career. As with previous editions, this one should continue to serve as a reference for professionals in food-related fields that service, regulate, or otherwise interface with food science and technology.

Food science and technology, like many other science-based disciplines, has advanced rapidly since the fourth edition was published in 1986. Although many of the basic unit operations have changed little, new knowledge and concerns about biotechnology and foods, food safety, environmental issues, packaging technologies, government regulation, globalization of foods, nutrition, and others, as well as new processing technologies such as ohmic heating and supercritical fluid extraction, have emerged. Many of the changes and additions to the fifth edition of *Food Science* reflect these and other developments which increasingly influence all involved in food processing as well as government agencies around the world. However, true change can only be measured against the broad principles and conventional food production practices of proven value. Therefore, most basic principles and practices continue to be described at an appropriate introductory level in the fifth edition.

We would like to acknowledge our colleagues at Cornell University and elsewhere who provided much of the insights and materials for this edition. We are indebted to Mrs. Terry Fowler for her technical assistance with the production of this text.

Joseph H. Hotchkiss
Norman N. Potter
Ithaca, New York

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Introduction: Food Science as a Discipline

Food Science can be defined as the application of the basic sciences and engineering to study the fundamental physical, chemical, and biochemical nature of foods and the principles of food processing. Food technology is the use of the information generated by food science in the selection, preservation, processing, packaging, and distribution, as it affects the consumption of safe, nutritious and wholesome food. As such, food science is a broad discipline which contains within it many specializations such as in food microbiology, food engineering, and food chemistry. Because food interacts directly with people, some food scientists are also interested in the psychology of food choice. These individuals work with the sensory properties of foods. Food engineers deal with the conversion of raw agricultural products such as wheat into more finished food products such as flour or baked goods. Food processing contains many of the same elements as chemical and mechanical engineering. Virtually all foods are derived from living cells. Thus, foods are for the most part composed of "edible biochemicals," and so biochemists often work with foods to understand how processing or storage might chemically affect foods and their biochemistry. Likewise, nutritionists are involved in food manufacture to ensure that foods maintain their expected nutritional content. Other food scientists work for the government in order to ensure that the foods we buy are safe, wholesome, and honestly represented.

At one time, the majority of scientists, technologists, and production personnel in the food field did not receive formal training in food science as it is recognized today. This was because very few universities offered a curriculum leading to a degree in food science. Many of these institutions had departments that were organized along commodity lines such as meats or dairy products. The food industry, government, and academic institutions continue to employ many persons who received their original technical training in dairy science, meat science, cereal chemistry, pomology, vegetable crops, and horticulture. Many others were trained as specialists in the basic sciences and applied fields of chemistry, physics, microbiology, statistics, and engineering. Such training has had the advantages generally associated with specialization. It also has resulted in certain limitations, especially for commodity-oriented individuals in segments of the food industry undergoing rapid technological change. Hence, the more general discipline of food science was established. Now, more than 40 universities in the United States and many more around the world offer degrees in food science.

PREPARATION FOR A CAREER IN FOOD SCIENCE

Industry and academic specialists have often differed about the definition of the term *food scientist,* and what should constitute appropriate formal training. Similarly, the major schools offering a degree in food science have not always agreed on the requirements for such a degree. The Education Committee of the Institute of Food Technologists (IFT) adopted a set of minimum standards for a university undergraduate curriculum in food science. These standards are followed by most universities which offer degrees in food science and reflect the scientific nature of food science. The most recent (1992) recommended minimum standards include both basic science courses and core food science and technology courses for the B.S. degree. The standards are based on a 120-semester-hour or 180-quarter-hour requirement for graduation. Courses should carry three to five semester hours or four to eight quarter hours of credit.

The core of food science and technology courses, representing a minimum of 24 semester hours or 36 quarter hours, includes the following, most of which include both lecture and laboratory components:

- *Food Chemistry* covers the basic composition, structure, and properties of foods and the chemistry of changes occurring during processing and utilization. Prerequisites should be courses in general chemistry, organic chemistry, and biochemistry.
- *Food Analysis* deals with the principles, methods, and techniques necessary for quantitative physical and chemical analyses of food products and ingredients. The analyses should be related to the standards and regulations for food processing. Prerequisites include courses in chemistry and one course in food chemistry.
- *Food Microbiology* is the study of the microbial ecology related to foods, the effect of environment on food spoilage and food manufacture, the physical, chemical, and biological destruction of microorganisms in foods, the microbiological examination of food stuffs, and public health and sanitation microbiology. One course in general microbiology is the prerequisite.
- *Food Processing* covers general characteristics of raw food materials; principles of food preservation, processing factors which influence quality, packaging, water and waste management, and good manufacturing practices and sanitation procedures.
- *Food Engineering* involves study of engineering concepts and unit operations used in food processing. Engineering principles should include material and energy balances, thermodynamics, fluid flow, and heat and mass transfer. Prerequisites should be one course in physics and two in calculus.

A senior-level "capstone" course that incorporates and unifies the principles of food chemistry, food microbiology, food engineering, food processing, nutrition, sensory analysis, and statistics should be taught after the other food science courses. The specific orientation of this course, that is, whether it's product development or product processing is left to the discretion of the university.

These courses are considered minimal. Additional required and optional courses should be integrated into the curriculum. Courses in computer science, food law and regulation, sensory analysis, toxicology, biotechnology, food physical chemistry, advanced food engineering, quality management, waste management, advanced food processing, and so on are important components of a food science program.

In addition to the core courses in food science and technology, other typical requirements for a food science degree include the following:

- Two courses in general chemistry followed by one each in organic chemistry and biochemistry.
- One course in general biology and one course in general microbiology which has both lecture and laboratory.
- One course dealing with the elements of nutrition.
- Two courses in calculus.
- One course in statistics.
- One course in general physics.
- A minimum of two courses which emphasize speaking and writing skills.
- Courses in the humanities and social sciences. This requirement is usually established by the college or university. In the absence of such requirements, about four courses may be selected from history, economics, government, literature, sociology, philosophy, psychology, or fine arts.

The above minimum requirements provide sound undergraduate training in the field of food science. The terms food scientist and food technologist are both commonly used and have caused some confusion. It has been suggested in the past that the term *food technologist* be used to describe those with a B.S. degree and the term *food scientist* be reserved primarily for those with an M.S. or Ph.D. degree as well as research competence. This distinction, however, is not definitive and both terms continue to be used widely and interchangeably.

ACTIVITIES OF FOOD SCIENTISTS

The educational requirements for a food science degree still fall short of an adequate description of food science. Some suggest that food science covers all aspects of food material production, handling, processing, distribution, marketing, and final consumption. Others would limit food science to the properties of food materials and their relation to processing and wholesomeness. The later view imposes serious limitations if it fails to recognize that the properties of food materials can be greatly influenced by such factors of raw material production as amount of rainfall, type of soil, degree of soil fertilization, genetic characteristics, methods of harvest or slaughter, and so on. At the other end, cultural and religious dictates and psychological acceptance factors determine the end use of a product.

Psychology and sociology prove important in an affluent society where there is choice, as well as in other areas where customs and taboos sometimes are responsible for malnutrition although there may be no shortage of essential nutrients. Since definitions can be misleading, the activities of today's food scientists can be illustrated by way of examples.

It has been estimated that as many as 2 billion people do not have enough to eat and that perhaps as many as 40,000 die every day from diseases related to inadequate diets, including the lack of sufficient food, protein, and/or specific nutrients. Many food scientists are engaged in developing palatable, nutritious, low-cost foods. Inadequate nutrition in extreme cases can produce in children an advanced state of protein deficiency known as kwashiorkor, or the more widespread protein–calorie malnutrition leading to marasmus. Dried milk can supply the needed calories and protein but is relatively expensive and is not readily digested by all. Fish "flour" prepared from fish of species not commonly eaten can be a cheaper source of protein. Incaparina, a cereal formulation containing about 28% protein, is prepared from a mixture of maize, sorghum, and cottonseed flour. Incaparina and similar products were developed to utilize low-cost crops grown in Central and South America. Miltone was developed from ingredients—peanut protein, hydrolyzed starch syrup, and cow or buffalo milk—that are readily available in India. As food losses during storage and processing can be enormous, food scientists are involved in adapting and developing preservation methods appropriate and affordable to various regions of the world.

Food scientists have developed thousands of food products including those used in the space shuttle program (Fig. 1.1). The first astronauts added a small quantity of water to dehydrated foods in a special pouch, kneaded the container, and consumed the food through a tube. They had to deal with space and weight limitations, little refrigeration and cooking equipment, special dietary requirements dictated by stress and physical inactivity, and weightlessness. There was concern that crumbs or liquid might get loose in the spacecraft and become a hazard. Currently, food scientists are developing systems which "recycle" foods for space voyages into deeper space. If astronauts are to be in space for extended periods without resupply, foods will have to be grown and processed in space. The problems inherent in such systems present unique challenges to the food scientist.

Perhaps the largest single activity of food scientists working in industrial organizations is the improvement of existing and development of new food products (Fig. 1.2). In the United States in 1993, there were over 12,000 new products introduced if one considers all products "new" even if they are simply a standard product with only a slight change. Consumers like to have new products available. Industrial food scientists

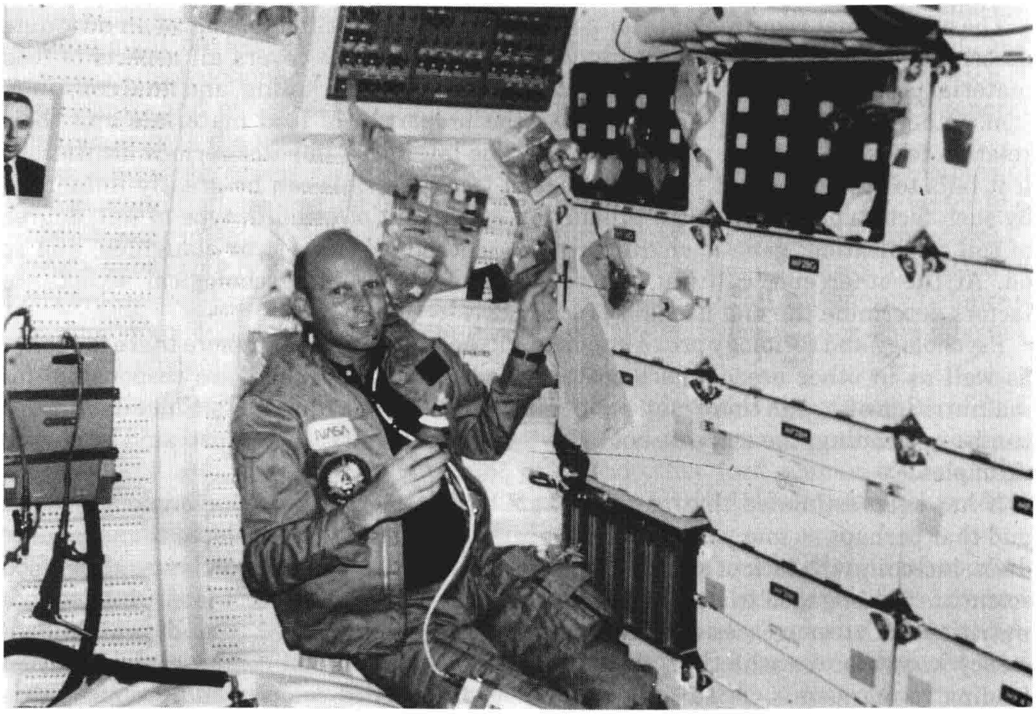

Figure 1.1. An astronaut consuming food aboard the space shuttle. *Courtesy of the Institute of Food Technologists.*

Figure 1.2. A food scientist works "at the bench" to optimize the formulation of a cookie product. *Courtesy of the Institute of Food Technologists.*

must find creative ways to meet this consumer demand for new and different products. Successful product development requires a blend of science and creativity.

Food scientists today are often involved in altering the nutrient content of foods, particularly reducing the caloric content or adding vitamins or minerals. Reducing the caloric content is accomplished in several ways, such as replacing caloric food components with low or non-nutritive components. The caloric content of soft drinks is reduced by replacing the nutritive sugar sweeteners (e.g., sucrose) with aspartame or saccharin. Aspartame goes by the trade name Nutrasweet. Aspartame contains the same number of calories as sugar but is 200 times sweeter, so much less is used for the same degree of sweetening, thus reducing the caloric content. In other cases, food scientists reduce the caloric content of fat containing foods by replacing the fat with substances which have similar properties but are not metabolized in the same way as fat. For example, low-fat ice cream can be made by removing the normal milk fat and adding specially treated proteins. These proteins are made into very small particles which give ice cream the smooth texture associated with the fat. Protein has four calories per gram, whereas fat has nine. Thus, the net effect is a decrease in the caloric content of the ice cream.