FOOD SCIENCE

THIRD EDITION

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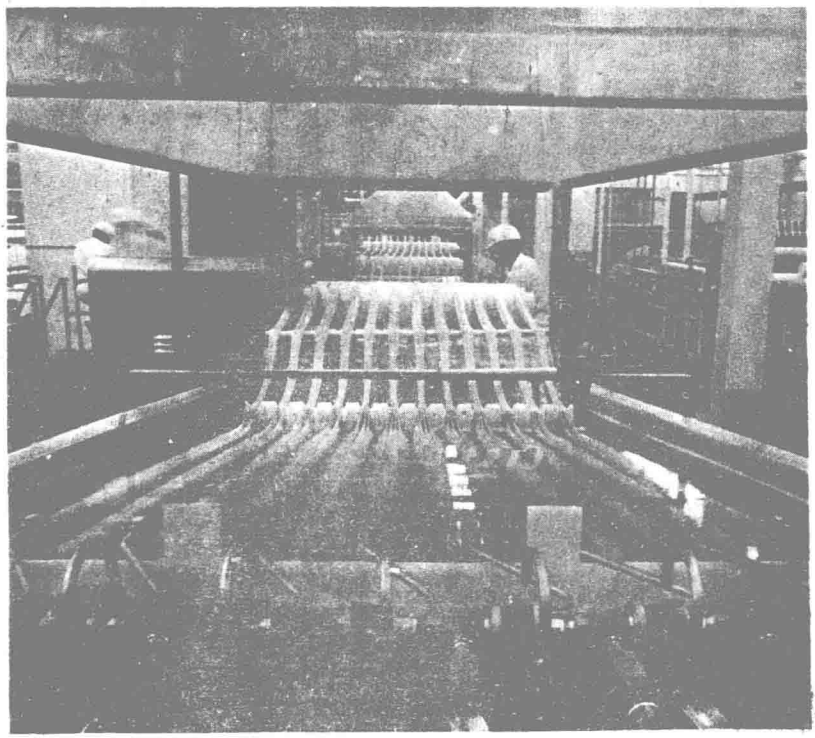

Preface to the Third Edition

Ten years have passed since publication of the First Edition of *Food Science* and five years since the Second Edition. These periods, though chronologically brief, have produced technological advances in all fields and been witness to changing economic, ecological, and social pressures.

Recent and continuing trends that are especially affecting food production practices include heightened concern and accountability for food safety, nutritional quality, and environmental protection. There also is growing need for more efficient use of raw materials and energy to control costs and provide more food for ever expanding populations. These latter demands have intensified interest in the modification of and interrelationships between food ingredients and in the properties of engineered foods. Many of the changes and additions that have been made in this Third Edition of *Food Science* reflect the above developments which are increasingly influencing the activities of all involved in the food production process.

Another change that has been made in this new edition is complete conversion to the International System of Units (SI). To ease in the transition, however, SI metric units have been followed by British or other common units wherever useful. The shift to the SI metric system is now well underway in many countries where previous editions of this book have found favor.

Authoring a book brings one closer to many exceptional people. Sincere appreciation is extended to my colleagues in the Department of Food Science and the Institute of Food Science at Cornell University for their generous and helpful suggestions in the course of preparing this revision. I also gratefully acknowledge the outstanding secretarial help of Mrs. Louise K. Gould and Miss Jacqueline R. Banks in preparing the manuscript and the contributions of the AVI Publishing Company in bringing forth the completed volume.

NORMAN N. POTTER
Ithaca, New York

July 1978

Preface to the Second Edition

Since the First Edition of *Food Science* was published in 1968 it has enjoyed wide circulation in the United States and in several other countries and has been accepted as a textbook in many colleges and universities. It also has been translated into Japanese and Spanish. This response has encouraged me to adhere to the objectives set forth in the preface to the First Edition and to largely retain the original format in revising the volume.

The field of Food Science and Food Technology, like so much else in today's rapidly changing world, has been racing forward at a pace that leaves most of us humbled in the attempt to keep up. In preparing this revision I have endeavored to update, and, where appropriate, expand the original material to keep the book current. Many sections have been added or modified to bring in new subject material broadly ranging from aspects of intermediate moisture food technology and winemaking, to concerns over food waste control, the safety of food additives, and uncertainties of the green revolution. A new chapter on improving nutritional quality and nutrition labeling also has been added. But these additions, in most instances, have purposely been kept short so as not to exceed book length still appropriate to a single volume.

Since the First Edition of this book, many useful suggestions have been received that have helped in preparing the revision and I acknowledge these with sincere appreciation. I further wish to thank Mrs. Barbara I. Lynch for outstanding secretarial help, Dr. Donald K. Tressler and Mr. John J. O'Neil for their assistance with the manuscript, and Cornell University for continuing to provide encouragement for this kind of undertaking.

NORMAN N. POTTER
Ithaca, New York

January 1973

Preface to the First Edition

This book is written primarily for those who have received no previous instruction in the field of Food Science. Its purpose is to introduce and to survey the complex and fascinating interrelationships between properties of food raw materials and their methods of handling and manufacture into an almost unlimited number of useful products.

The literature of Food Science and Food Technology is extensive in its detailed treatment of specific commodities, unit operations, and control methods. This provides the advanced student and seasoned professional with a wealth of excellent reference material generally quite adequate to their particular needs. Much of this literature, however, presupposes a basic training in Food Science or a related discipline. Thus it does not address itself to the needs for insight and appreciation of the broad scope of Food Science by new students considering this field as a career opportunity, or to the needs of professionals in allied fields that today service the food industry in countless capacities.

It would be difficult to select a major field with greater impact upon our everyday lives, upon the economic and political fortunes of nations, and indeed upon the near future of the world itself than the field of Food Science. Yet the terms Food Science and Food Scientist are but vaguely understood by the majority of people who could fairly well describe the realm and activities of chemists, physicists, electronic engineers, and molecular biologists.

The field of Food Science employs professionals from each of the above disciplines, and from at least a score more of the time-honored sciences and technologies. Food Science today teams together such specialists as the physicist, mathemetician, and rheologist to study the extensibility and extrusion properties of bread dough; the microbiologist, nutritionist, and toxicologist to investigate the safety of a processed spread; the microwave engineer, packaging engineer, and statistician to define a quality controlled high speed unit process; and the oceanographer, demographer, and political

scientist to determine the feasibility of a new source of food for narrowing the widening gap between world food production and an exploding population. Today this gap is wider than ever before in history and contributes to such current statistics as a projected mortality rate in India alone of some 50 million children from malnutrition or starvation over the next ten years. The world food shortage has been termed the greatest challenge that mankind ever has been called upon to face. The incorrect image of a Food Scientist dressed in white standing over a large kettle armed with a stirring paddle cannot be expected to attract students of the caliber that is essential to cope with such sober problems now and in the immediate years ahead.

But Food Science is also a study in contrasts. While more than half the world's people go hungry, in the United States there are to be found some 8000 food items on supermarket shelves. The degree of sophistication built into many of them by Food Scientists may be criticized in some instances on the grounds that such effort may better be put into studies on nutrition, preservation, and production of foodstuffs essential to life in less fortunate regions of the world. However, it is evident that the luxury of this new product proliferation could only follow upon the fulfillment of more basic food needs through mastery of the fundamental principles underlying Food Science and the application of Food Technology.

The food industry in the United States and in other highly developed countries is in a dynamic state of change, with many of the traditional methods of production, processing, and control giving way to more efficient and less costly techniques. In less developed areas of the world, food industries are evolving which will first utilize to a great extent the basic technology from which further innovations can stem, but the process is slow and one can only grossly estimate the countless millions that are expected to starve in the course of this evolution.

An introductory text on Food Science should recognize these contrasts and the rapid rate of change that is taking place in Food Science and applied technology, and at the same time not overlook the common fundamental principles upon which all are based. This is attempted in the current book.

In preparing the text the author was fully aware of the futility of any attempt to cover thoroughly in a single volume a body of knowledge so broad as is encompassed by the term Food Science, even in an introductory fashion. The masterful work prepared by a group of specialists and edited by Professor Morris B. Jacobs, entitled *The Chemistry and Technology of Food and Food Products* required three volumes. But unfortunately good technical books unlike good wines do not improve with age, and the last printing of this authoritative work was made in 1951. More recently the series of texts of the AVI Publishing Company have done much to gather and update the knowledge of various segments of Food Science and food industry practice. These works, and others too numerous to cite here, have been drawn upon

heavily in the gathering of representative material for this book. The many publications of the U.S. Department of Agriculture and the Quartermaster Food and Container Institute for the Armed Forces, now incorporated into the U.S. Army Natick Laboratories, Army Material Command, also have been found invaluable, as have the journals of the Institute of Food Technologists, and such publications as *Food Engineering* and *Food Processing-Marketing,* to name but a few.

The author further wishes to acknowledge with gratitude the many industrial companies and other sources that have permitted reproduction of photographs and illustrative material used throughout this book.

Special appreciation is here expressed to the many reviewers who have examined and commented on the various chapters, and particularly to Dr. Donald K. Tressler and Mr. John J. O'Neil for their many helpful suggestions during the preparation of the manuscript.

Finally I am indebted to Mrs. Mary Kuss for typing and outstanding secretarial help, to Cornell University for allowing the time for this undertaking, and to Professor Robert F. Holland, Head of the Food Science Department at Cornell, for his continued encouragement.

NORMAN N. POTTER
Ithaca, New York

June 1968

Dedication

To my parents, sons, and dear wife, Adele

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Introduction: Defining Food Science

It is appropriate for the introduction to a beginning book on Food Science to attempt to define the meaning of the term Food Science. This is not easy to do in a fashion that would satisfy a majority of professionals in the field.

Up to about 20 years ago the vast majority of scientists, technologists, and production personnel in the food field did not receive formal training in Food Science as it has come to be recognized today. This was because very few colleges and universities offered a total curriculum leading to a degree in Food Science. Rather, many of these institutions, including the U.S. Land Grant Colleges, were organized according to specialty along commodity lines. Thus the food industry today, as well as governmental and academic institutions, is made up largely of persons who received their original technical training in Dairy Science, Meat Science, Cereal Chemistry, Pomology, Vegetable Crops, Horticulture, etc. Many others were trained as specialists in the basic sciences and applied fields of Chemistry, Physics, Microbiology, Statistics, and Engineering. This has had many 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.

PREPARATION FOR FOOD SCIENCE

Past views of industry and the academic community have often differed with respect to a definition of the term Food Scientist, and what should constitute appropriate formal training. Similarly, the major schools offering a

Food Science degree have not always agreed in this regard. In 1966, the Council Committee on Education of the Institute of Food Technologists adopted a set of minimum standards for an undergraduate curriculum in Food Science. These standards, offered as a guide to curricula development, provide an insight to what Food Science is coming to mean.

Course work to have been completed at the high school level should be such as to prepare the student for a rigorous science-oriented college program and would generally have included appropriate courses in mathematics, chemistry, physics, biology, a foreign language, English, and social sciences, in accordance with the more precise admission requirements of appropriate colleges and universities.

At the college level, recommended minimum standards (updated in 1977) include a solid core of food science and technology courses plus additional required courses to serve as the basis for the B.S. degree. The standards are based on a 120-semester-hour or 180-quarter-hour requirement for graduation in four years, and specified courses should carry at least 3-5 semester hours or 4-8 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:

(1) FOOD CHEMISTRY. A course with lecture and laboratory covering the basic composition, structure, and properties of foods and the chemistry of changes occurring during processing and utilization. Prerequisites should be four courses in chemistry including organic chemistry and biochemistry.

(2) FOOD ANALYSIS. A course with lecture and laboratory designed to study the principles, methods, and techniques necessary for quantitative physical and chemical analyses of food and food products. The analyses will be related to the standards and regulations for food processing. Prerequisites should be 4 courses in chemistry and one course in food chemistry.

(3) FOOD MICROBIOLOGY. A course with lecture and laboratory to study the relationship of habitat to occurrence of microorganisms of foods, the effect of environment on growth of various microorganisms in food, the microbiology of food spoilage and food manufacture, the physical, chemical, and biological destruction of microorganisms in foods, the microbiological examination of foodstuffs, and public health and sanitation bacteriology. One course in general microbiology should be a prerequisite.

(4) FOOD ENGINEERING. A course with lecture and laboratory to study engineering concepts and unit operations used in food processing. Engineering principles should include mechanics, fluid mechanics, transfer and rate processes, and process control instrumentation. Prerequisites should be one course in physics and mathematics, competency in algebra, trigonometry, and calculus.

(5) FOOD PROCESSING. Two courses with lecture and laboratory to cover general characteristics of raw food material, harvesting, assembling and receiving raw materials, methods of food preservation, processing objectives including factors influencing food acceptability and preferences, packaging, and water,

waste disposal, and sanitation.

(6) OTHER COURSES IN FOOD SCIENCE AND TECHNOLOGY. The courses listed above are considered minimal. Generally it is expected that other courses will be available in the department that will appeal to special interests of students and facilitate the development of options. Such courses may deal with food laws and regulations, sensory analysis, toxicology, quality assurance, etc.

In addition to the core courses other required courses include:

Chemistry. Two courses in general chemistry followed by two courses in organic chemistry-biochemistry.

Biological Sciences. One course in general biology and one course in general microbiology.

Nutrition. One course dealing with the elements of nutrition.

Mathematics. Competency in college algebra and trigonometry and an understanding of the concepts of calculus is necessary. Ordinarily, two courses in college mathematics should be adequate.

Statistics. Competency in elementary statistics is essential and at least one course is needed.

Physics. One course in general physics.

Communications. Competence in both the written and spoken word is essential. Ordinarily, a minimum of two courses beyond high school English would be necessary to ensure competence.

Humanities and Social Sciences. This requirement is usually determined by policies of the college or university. In the absence of such requirements, about four courses may be selected from such fields as history, economics, government, literature, sociology, philosophy, psychology, or fine arts.

The above minimum requirements would provide a sound undergraduate training for 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 who acquire 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 preparation requirements for Food Science still fall short of an adequate definition of Food Science. Some would say that Food Science covers all aspects of food raw material production, handling, processing, distribution, marketing, and final consumption. Others would choose to limit Food

Science to the properties of food materials and their relation to processing and wholesomeness. The latter 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, plant and animal genetic characteristics, methods of harvest and slaughter, and so on. At the other end, not to encompass such determinants of consumption as cultural and religious dictates and psychological acceptance factors, would be to ignore the end use for which a product is produced. Unfortunately, this has been all too common in the past. Psychology and sociology prove important in an affluent society where there is much to choose between in the selection of purchased foods, as well as in the less fortunate areas of the world where customs and taboos often are

FAO Photo Courtesy of C. Bavagnoli

FIG. 1.1. WORLD FOOD NEEDS REMAIN ONE OF MAN'S GREATEST CHALLENGES

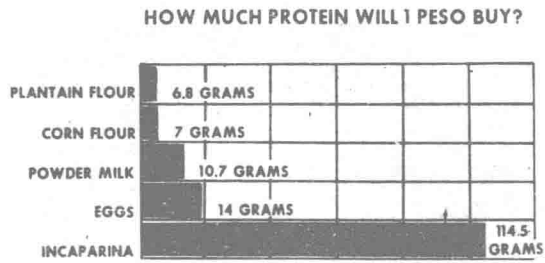

FIG. 1.2. RELATIVE COST OF PROTEIN FROM INCAPARINA AND OTHER FOODS

responsible for malnutrition although there may be no shortage of essential nutrients.

Where definitions can be restrictive, more on the scope of current Food Science can be illustrated by way of examples.

It has been estimated that nearly two billion people do not have enough to eat and that perhaps as many as 10,000 die every day for either the lack of enough food or enough protein and vitamins to prevent malnutrition (Fig. 1.1). Many Food Scientists are engaged in developing cheap sources of protein sufficiently palatable to be used to supplement the diets of the poor, which 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 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. So also is Incaparina, a cereal formulation containing about 28% protein and prepared from a mixture of maize, sorghum, and cottonseed flour. Incaparina and similar type products, originally developed to utilize highly nutritious low cost crops grown in Central and South America, can be made largely from ingredients available in many countries where the diet is deficient in protein (Fig. 1.2). A protein rich dairy product has been developed from ingredients readily available in India. Called Miltone, it contains peanut protein, hydrolyzed starch syrup, and cow or buffalo milk. Food Scientists of some petroleum companies also have produced protein-rich food by growing microorganisms on petroleum wastes, but this development has been slowed by various problems. Among them is the cost and uncertainty of refining petroleum wastes to remove the potentially carcinogenic compound benzpyrene. Other growth media, including alcohol that may be produced from petroleum, avoid this problem.