FOOD SCIENCE

SECOND EDITION

by NORMAN N. POTTER, Ph.D.

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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 nutritional 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.

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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 8,000 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.

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June 1968

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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 yr 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 Land Grant Colleges, were organized according to specialty along commodity lines. Thus the food industry today, as well as governmental and academic institutions, are 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

Often the views of industry and the academic community differ 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 yet reached full agreement 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.

Recommended course work to have been completed at the high school level includes 4 yr of college-preparatory Mathematics permitting the student to enter a college-level course in Analytical Geometry and Calculus, 1 yr each of Biology and Chemistry with an additional year of Physics desirable, at least 2 yr of a foreign language, 4 yr of English, and at least 2 yr of Social Sciences.

At the college level proposed standards include a solid core of required lecture and laboratory courses equivalent to the following:

(1) Food Chemistry (1 semester or 4 credits) covering the basic composition, structure, and properties of food and the chemistry of changes occurring during processing and utilization.
(2) Food Analysis (1 semester or 4 credits) covering the principles, methods, and techniques of quantitative physical and chemical analyses of foods and food products, the analyses to be related to the standards and regulations pertaining to food processing.
(3) Food Microbiology (1 semester or 4 credits) including the relationship of habitat to the occurrence of microorganisms on foods; microbiological action in relation to food spoilage and food manufacture; physical, chemical, and biological destruction of microorganisms in foods; methods for microbiological examination of foodstuffs; and public health and sanitation bacteriology.
(4) Food Engineering (2 or 3 semesters equal to 8 or 9 credits) covering engineering concepts and unit operations applicable to food processing. Principles would include mechanics, fluid mechanics, transfer and rate processes, and process control instrumentation. Unit operations would include fluid flow, heat transfer, evaporation, drying, extraction, distillation, filtration, mixing, and material handling.
(5) Food Processing (2 semesters or 8 credits) dealing with the general characteristics of food raw materials; harvesting, assembling, and receiving of 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 related to Food Science and Technology to strengthen knowledge in areas of interest for either professional or graduate work.

To the above has since been added appropriate course work to give the student a good understanding of human nutrition.

Required courses in fields other than Food Science, many of which are necessary as prerequisites to the above material, include English, Mathematics, Statistics, Physics, Biology, Microbiology, Humanities, and Chemistry including General Chemistry, Quantitative Analysis, and Organic Chemistry.

To complete the usual 120-semester hour requirement for the undergraduate degree, the Institute of Food Technologists advises that the student further elect courses from a complementary discipline and develop a sequence that will lead to greater competence in an area of special interest. This can serve as a base for a subsequent graduate program. Such areas could be Chemistry, Engineering, Microbiology, Nutrition, Economics or Business. Courses in Physical Chemistry, Biochemistry, Genetics, world feeding problems, and computer science also are recommended where they can be fitted in.

The above minimum requirements would provide a sound undergraduate training for the field of Food Science. But the student completing such a curriculum could not yet rightly be called a Food Scientist. The terms Food Scientist and Food Technologist are often used interchangeably and confuse some. The same Council Committee suggests 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. In the words of the Committee, "The primary difference in these types of preparation is that the food technologist is concerned with the acquistion of knowledge and its professional application. The food scientist has much of the same preparation but he acquires additional knowledge and skills that will enable him to develop new knowledge of a more basic nature. The additional preparation of the food scientist is concerned with developing research competence." It can be added that the graduate curriculum through additional courses also generally provides the Food Scientist with a second area of specialization and competence which may be commodity oriented or represent enlargement of any of the above or related subject areas.

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 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). Many Food Scientists are attempting to develop 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. Dried milk in sufficient quantities will supply the needed protein but is relatively expensive, especially when

FAO Photo by C. Bavagnoli

FIG. 1. WORLD FOOD SHORTAGES ARE THE GREATEST CHALLENGE OF THIS CENTURY

it must be exported to needy regions of consumption. Fish "flour" prepared from whole fish of species not commonly eaten, is 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 cottenseed 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. 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 are trying to produce cheap food by growing microorganisms on petroleum wastes, but this work is still in the experimental stage. Among problems to overcome is cost of

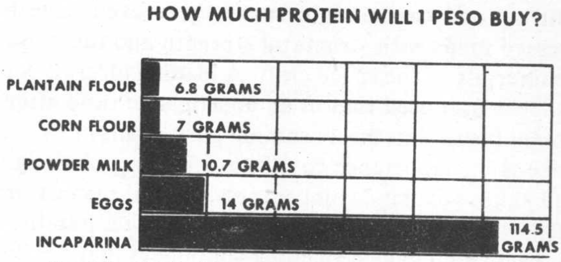

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FIG. 2. RELATIVE COST OF PROTEIN FROM INCAPARINA AND OTHER FOODS

refining petroleum to remove the potentially carcinogenic compound benz-pyrene.

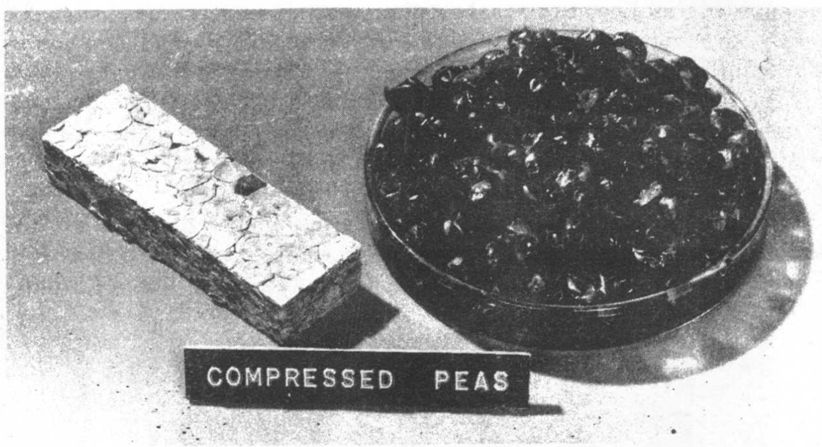
A knowledge of Food Science is required for the feeding of men under extremely adverse conditions (Fig. 3). The astronaut adds a small quantity of room temperature water from a water gun to dehydrated meat and gravy in a special pouch, then kneads the container and consumes the food through a tube. The special problems he faces are limited space, limited weight of refrigeration and cooking equipment permitted, special dietary requirements dictated by the stress and physical inactivity of his mission, and weightlessness. Weightlessness is the reason for the feeding tube. Any crumbs or liquid that might get loose in the space craft would float and become a hazardous nuisance. If one wishes to note the still more exotic,

Courtesy of Food Engineering

FIG. 3. MEAL OF POT ROAST AND GRAVY BEING RECONSTITUTED BY ASTRONAUT

to save weight of food carried into space there even have been devised highly compressed foods with structural strength and these may be used as construction materials of the space craft. A leading aircraft company holds such a patent. It is proposed that at an appropriate time after landing the pilot can augment his rations by consuming parts of his craft.

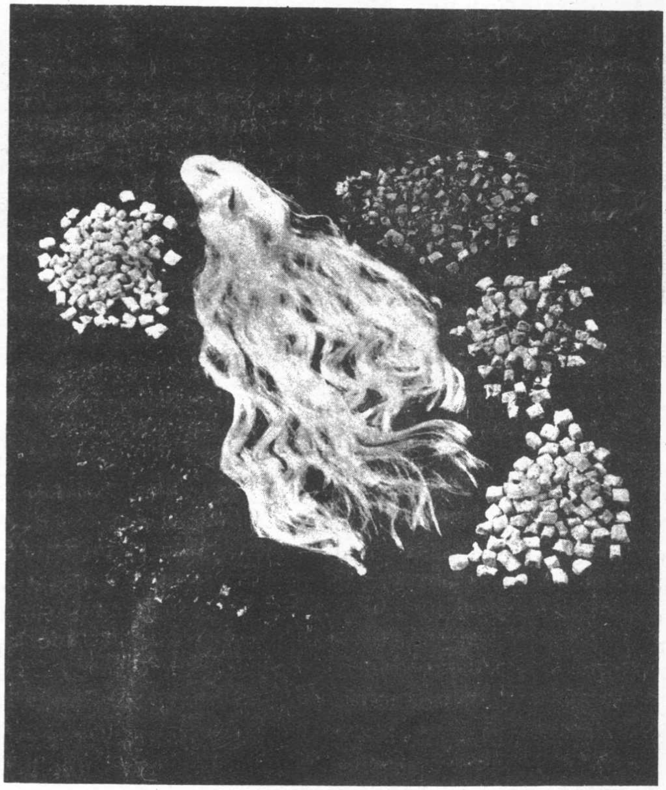
Food Science is of importance to military feeding. Among the requirements are high caloric density, compactness, ease of reconstitution (that is, solubility when water is added), long term storage stability at elevated temperatures, packaging in easy opening containers that are light in weight and do not have hard sharp edges that can bruise a soldier in action (this usually means flexible foil and plastic), and above all nutrition combined with palatability. To develop foods with these properties requires the greatest skills of the Food Scientist. One such food is the compressed bar of freeze-dried peas (Fig. 4).



Courtesy of U.S. Army Natick Laboratories

FIG. 4. COMPRESSED FREEZE-DRIED PEAS AND THEIR REHYDRATED COUNTERPART

Food Science is involved in the making of foods that look and taste like meat but are made from soybean proteins. If soybean proteins are dissolved in alkali they form a sticky liquid. This liquid may be extruded through tiny holes and then recoagulated in an acid bath in the form of fibers. The fibers then can be spun into ropes with texture approaching the fibrous texture of chicken or beef muscle tissue. The fabricated tissue then can be interlaced with fats, food flavorings, and food colors. Products are almost indistinguishable from chicken meat, fish, ham, or beef. The products also may be dehydrated, compressed, or otherwise processed (Fig. 5). Meat-like products for vegetarians, for patients with special dietary restrictions such



Courtesy of Food Engineering

FIG. 5. SOY PROTEIN FIBERS AND SIMULATED MEAT PRODUCTS MADE FROM THEM

as controlled levels of fat, and for numerous other food uses are now available commercially from several manufacturers. The "bacon" chips to be found in some brands of peanut butter are thus fabricated from soybean proteins. A meat-like texture, with blandness that permits flavoring for individual tastes, also has been produced from skim milk. By adding calcium chloride to the milk a curd is formed, which after cutting into appropriate pieces may be fried in hot oil to yield meat-like snacks high in milk protein.

Food scientists today are involved in the development of the widest range of fabricated foods and food analogs that challenge conventional natural products. Besides simulated meat and milk products, a novel method for preparing synthetic caviar has recently been disclosed by Russian scientists. It involves mixing a suspension of protein with gelatin, dispersing the suspension into a water immiscible liquid to form jellylike beadlets, and

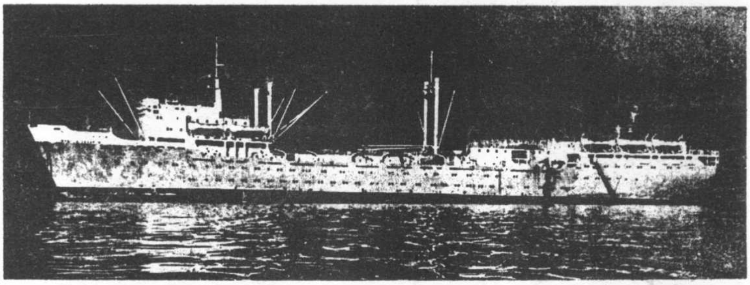


FIG. 6. THE ANDREI ZAKHAROV, FLAGSHIP OF THE SOVIET CRAB-FISHING FLOTILLA

firming the beadlets with a tanning agent. The protein-gelatin suspension may be colored and flavored to produce beadlets closely resembling the natural eggs of sturgeon, salmon, and other fish.

Food Science is involved in the operation of fishing vessels that are floating factories (Fig. 6). Facilities include automatic separators for small and large fish, mechanized fish cooling tanks, automatic oil extractors, ice making equipment, complete canning factories, equipment for preparing fish fillets and cakes, and equipment for dehydrating fish and preparing dried fish meal. The reason for this factory approach is to prevent bacterial spoilage and to minimize protein and fat losses that otherwise would limit how long a fishing vessel could remain at sea. These factories can remain at sea for two months or more and range as much as 4000 miles from their home base. The Japanese and Russians have been most active in this kind of development.

Food Science is required to perfect controlled atmosphere storage of fruits and vegetables. Fruits such as apples, after they are harvested, still have living respiring systems. They continue to mature and ripen. They require oxygen from the air for this continued respiration which ultimately results in softening and breakdown of the apple tissue. It has long been known that if the air is depleted of much of its oxygen and is enriched in carbon dioxide then respiration is markedly slowed down. For some fruits the best atmosphere is one that contains about 3% of oxygen and about 2 to 5% of carbon dioxide, the rest being nitrogen. Such atmospheres are produced commercially by automatic generators which sample the atmosphere continuously and readjust it as needed. Refrigerated warehouses using controlled atmosphere storage now permit year round sale of apples (Fig. 7) which was not possible due to storage deterioration before this innovation. Controlled atmospheres low in oxygen also are currently being used to preserve lettuce quality during refrigerated truck transport and to reduce