James F. Price
and
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THE SCIENCE OF MEAT AND MEAT PRODUCTS THIRD EDITION

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PREFACE

Since the publication 25 years ago of the First Edition of The Science of Meat and Meat Products, which was written entirely by members of the research staff of the American Meat Institute Foundation, significant new information developed which warranted a new edition. This was prepared, as the Second Edition which was published in 1971, after consultation with our colleagues in the Department of Food Science at Michigan State University and with other leaders in the field of meat science throughout the country. The same general format used in the First Edition was used. Specifically, the first part emphasized the basic science of meat and the second part, the application of this information in the processing and preservation of meat and meat products. In addition, we maintained our objective of making the material applicable to a wide audience: junior and senior college students, graduate students in food science, meat and animal science, and related fields as a reference source, and scientifically trained personnel in food and allied industries and government agencies. Major additions were made to the book in the areas of the chemistry of proteins, the microscopic structure of meat, water, antemortem and postmortem changes, including muscle contraction and rigor mortis, and the chemistry of meat flavor constituents. The quality control and sanitation aspects were completely reorganized into an additional last chapter.

With the passage of 15 years since the publication of the Second Edition, much new information has developed, warranting the preparation of the Third Edition. In addition to updating and arranging for major revisions of all chapters and sections, entirely new chapters have been added entitled "The Pigments of Meat," "Functional Behavior of Meat Components in Processing." "Sanitation in Meat Plants," and "Quality Control Concepts and Systems" have been written as separate chapters.

It will be noted that a combination of "classical references" and emphasis on recent literature has been used to guide the reader to additional literature.

Again emphasis has been placed on beef, pork and lamb; however, appropriate comparative information was included on other animals used for food throughout the world (poultry, rabbits, horses, game, etc.), as well as other foods of animal and plant origin. The contribution of each author is current through mid-1986 and we believe that the objectives listed

above have again been achieved. We have also made every effort to cross-reference pertinent information in different chapters and sections of the book.

We have been fortunate in having the full cooperation of many leading meat scientists in this country and abroad in the preparation of this edition. Although the inclusion of so many authors has necessarily resulted in more variance in style, continuity, extent of references cited, and scientific level than would be true with fewer authors, the expertise of the authors, the change of pace provided, and the efforts to cross-reference pertinent information should minimize any disadvantages associated with this approach.

We are indebted to many additional meat scientists that served as peer reviewers for individual chapters and sections. Special appreciation is due to colleagues at Michigan State University, the University of California at Davis, and the University of Florida (where we both spent sabbatical leave time in 1983) who by proximity and expertise frequently assisted us in reviewing special topics throughout the book. Particular thanks are expressed to Dr. William Brown and his associates at the ABC Research Corporation, Gainesville, Florida for providing a professional "home" during the sabbatical leave for J. F. Price. The editors are indebted to the secretarial and library staffs of the Department of Food Science and Human Nutrition (principally Bea Eichelberger) at Michigan State University and of the Department of Food Science and Technology (principally Dianne Cave, Carol Cooper, Jull Frommelt and Nicki Martinez) at the University of California at Davis for their assistance with the manuscript and index.

J. F. PRICE
B. S. SCHWEIGERT

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CHAPTER 1

INTRODUCTION

J. F. PRICE and B. S. SCHWEIGERT

The meat industry, in contrast to most large modern industries, has its roots in prehistoric times, and basic procedures for processing meat had been well established by the dawn of recorded history. The early beginnings are mentioned in some of the oldest literature by numerous references that are so completely casual as to indicate that certain meat preservation practices were a matter of common knowledge. Meat was dried by the aborigines; smoking and salting techniques were well established long before Homer's time (about 1000 BC); preparation and spicing of some kinds of sausages were common practices in Europe and in the Mediterranean countries well before the time of the Caesars.

Cattle, hogs, and sheep are not native to the Americas. There is evidence that cattle may have reached the western hemisphere with the Norsemen, landing in "Vinland" in 1007. Certainly, cattle, hogs, and sheep shared Columbus' second voyage in 1493, and all three species reached Mexico within a few years of Cortez' conquest in 1519. Ponce de Leon apparently landed cattle, hogs, and sheep in Florida on his disastrous second visit in 1521. T. Frederick Davis, Florida historian, has expressed the view that, near what is now St. Augustine, animals described by the Indians to the French in 1564, and thought by the French to be unicorns, probably were cattle descended from those brought by Ponce de Leon. It is recorded that DeSoto landed 13 hogs in Florida in 1539 and that this herd had reached some 700 head when he died in Arkansas in 1542. Coronado brought cattle and sheep from Mexico into Arizona in 1540 and presumably into Texas. During the century following, pirates in the West Indies achieved their distinctive name of "buccaneers" from the dried or "boucaned" beef that was used to stock their ships and which they sometimes sold.

The first meat packers in the US, as the term is applied today, actually were New England farmers who began packing in salt not only pork and beef but also venison and even bear meat. William Pynchon, who founded Springfield, Massachusetts, was prominent in the packing and sale of salted meat and sometimes is referred to as the nation's first meat packer. These farmer-packers were able to pre-empt the British trade with the West Indies

in salted meats around 1650. Twenty years before William Penn's famous deal in Pennsylvania, John Pynchon (William Pynchon's son) bought land from the Indians by treaty (1653), paying for it with wampum and store merchandise, and by 1655 he was driving live cattle from Springfield to Boston. He has been termed the nation's first cowboy.

"Uncle Sam," the symbolic characterization of the United States, had its origin in the letters "US," which were stamped on barrels of salted beef sold by New Englander Sam Wilson to the United States Army during the War of 1812. From the letters on the barrels, Sam Wilson's meat soon became known as "Uncle Sam's meat." In due course, the origin of the term became obscure, and "Uncle Sam's" was applied to anything supplied by the army, and finally, it connoted the United States government itself. Salted (or corned) beef seldom is sold by the barrel today, but while the techniques of preservation have been modified and improved, the basic principles of clean barrels and low temperature storage applied by Sam Wilson are accented in today's commercial processes.

Development of an Industry

When the frontiers were pushed beyond the Alleghenies and the prairies of the Midwest were opened to farming before and after the War of 1812, livestock were produced in large numbers, but the meat could be brought to market only by driving cattle and hogs over the mountains to the cities of the East or by shipping animals and cured meats by boat down the Ohio and Mississippi rivers and then up the Atlantic coast.

Cincinnati in this same period became known as "Porkopolis," having perfected a system of feeding 15 bushels of corn to a hog and then packing the pig carcass cuts into a barrel with salt. Relatively large meat packing plants appeared in Buffalo, Milwaukee, and Chicago, but because of the lack of refrigeration this was a winter industry only. Natural ice refrigeration was introduced during the Civil War, and before long ice houses, where blocks of ice cut from rivers and lakes were stored under sawdust for summer use, dwarfed all the other buildings of a packing plant.

Commercial meat packing at this time was still but a magnification of farm procedures. Not until the development of direct-expansion ammonia refrigeration in the late 1800s did the era of natural ice refrigeration end and meat processing become a year-round operation. Also around the turn of the century mechanized "disassembly" procedures in slaughtering livestock and processing meat were pioneered. The development of mechanical techniques as well as plant and railroad car refrigeration, preceded the establishment of chemical laboratories in meat packing plants.

The use of refrigerated railroad cars for transport of beef and hog carcasses was first attempted in the early 1860s. The first practical, though crude, refrigerated car was reputedly designed in 1875 by G. H. Hammond, Chicago packer. Gustavus Swift, founder of Swift & Company, is credited with establishing the first adequate refrigerator car service from Chicago to the East, but P. D. Armour, founder of the company bearing his name, and others were not far behind in moving into this new mode of distribution

Easterners in the meat business and many railroad companies were not happy about the refrigerated railroad car, due to potential for reduced shipments of live animals. Also, beef carcasses in early shipments were loosely hung in the cars and swung violently when the cars were in motion. The cars, responding to this movement, frequently were rocked off the tracks, and wrecks on sharp curves were frequent. The railroads refused to build such rolling stock, and fierce prejudice against Western dressed meats was fostered not only in the East but in England as well. Gustavus Swift and P. D. Armour, never reluctant to accept a challenge, both built their own refrigerated cars and, by using wandering routes over less resistant railway systems, ultimately were able to break the prejudice and establish regular refrigerated shipments to the East.

Icing of refrigerated cars in transit was a special problem, and it was not too long before regular icing stations were built along the railroad routes. Natural ice was used throughout the early years, but as mechanical refrigeration developed, manufactured ice was used. Ice has almost disappeared from use in the distribution of red meats and sausages. Mechanical refrigeration systems are built into rail cars, motor trucks and ships, and in some cases direct circulation of cold gases from solid CO_2 or liquid nitrogen is used inside the bulk shipping containers. The use of cryogenic materials for chilling meats provides a means of achieving a modified atmosphere for microbial inhibition as well as a source of refrigeration. Ice continues in use for ice-pack poultry and fish shipments. However, refrigerated transport, not only for meat but for all perishable products, has become the norm throughout the food processing industry, often in conjunction with vacuum packaging and/or atmosphere control (i.e., CO_2 or nitrogen).

Provision of food for himself and his family has been man's primary concern since the dawn of time, and the production, processing, and distribution of food has had to keep pace with the growth of civilization and increases of population. L. B. Jensen, in his preface to *Man's Foods*, states that "the history of Man perhaps could be written in terms of diet and the fulfilled promises of nutrition."

The magnitude of meat industry operations and its importance to the economy of the United States is illustrated by the figures for 1967 and

1983 given in Table 1.1. The increase in number of federal establishments is due in part to the transfer of inspection from state to federal authority.

TABLE 1.1
IMPORTANCE OF MEAT INDUSTRY OPERATIONS TO U.S. ECONOMY

	1967	1983
Total Production of red meat (carc wt) in US	Mil lb 34,195	Mil lb 39,273
Cash income from Meat Animals	Mil $ 14,705	Mil $ 38,826
Number of establishments slaughtering meat animals under federal inspection	579	1,666
Per Capita Consumption of meat/(carcass wt) in the US		
Beef	106.5	106.5
Pork	64.1	66.2
Lamb & Mutton	3.9	1.7
Veal	3.8	2.0
	178.3	176.4

USDA figures summarizing changes in per capita meat consumption in the United States for the period 1920-1985 are shown in Fig. 1.1 for beef and pork (carcass weight basis) and for poultry (ready-to-cook basis). This graph clearly shows that there has been a marked increase in per capita consumption of beef and poultry but that pork consumption has remained essentially constant. Some reduction in beef consumption has been noted in recent years. Comparisons of annual per capita meat consumption in pounds (carcass weight) for selected countries have been summarized from USDA figures for 1983 in Table 1.2.

Interest and activity in the science of meat and meat products has continued within the meat industry, in land-grant colleges, universities, and federal laboratories in the United States and in research institutes and universities of many countries throughout the world.

In the United States in particular many university programs involving the science of processing all foods, including meat, have been established as departments of food science (and/or technology), frequently merging or cooperating closely with departments of human nutrition, and with close working relationships among faculties in animal science departments. In addition several interdisciplinary programs have developed involving collaboration with schools of engineering (food engineering programs). Undoubtedly these trends will continue.

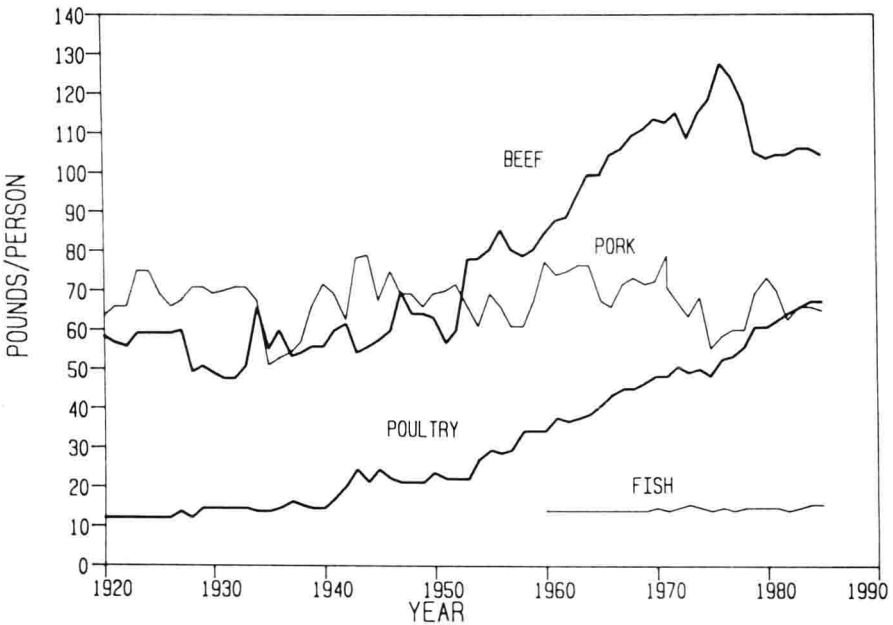

FIG. 1.1. CIVILIAN PER CAPITA CONSUMPTION OF BEEF, PORK AND POULTRY, 1920-1985, AND FISH, 1960-1985.

Contrasting the investigative areas and scope of activities of today's research organizations with those of the earlier meat industry, research institutes, and university laboratories, we find that the research chemists and laboratory "devils" of the pioneer research groups have been joined by scientists highly trained in many scientific disciplines. Research today has passed well beyond the confines of chemical analyses. It utilizes highly complicated scientific procedures and equipment and requires the collaborative efforts of meat and other food scientists and specialists in various branches of chemistry, microbiology, home economics, nutrition, histology, physiology, medicine, and the physical and engineering sciences.

Current Trends

A broadening of the food products processed and marketed by food companies in the United States is continuing. In fact, much of this broadening includes products other than meat, in part due to the merging of meat processing companies with companies engaged in activities other than meat

TABLE 1.2
ANNUAL PER CAPITAL MEAT CONSUMPTION FOR SELECTED COUNTRIES (in lb carcass weight)

Country	Beef and Veal	Pork	Lamb, Mutton and Goat	Poultry
Argentina	151	22	7	16
Canada	93	65	—	50
Japan	12	30	3	25
New Zealand	121	26	100	—
Poland*	41	82	1	—
Rep. of South Africa	44	8	13	28
USSR*	58	43	8	19
United States	108	66	2	66
West Germany	47	111	2	38
United Kingdom	47	60	18	33

*1980 data for these countries.

processing. These rapid changes, plus increased marketing of formulated foods, have resulted in fewer distinctions in the processing of meat than in earlier years.

Although each of the muscle food commodity industries, e.g., meat, poultry, marine and fishery, will continue with distinct backgrounds and traditions, this trend toward less distinction will also continue as further knowledge is gained on the physical and chemical characteristics and functional properties of food constituents (carbohydrates, proteins and fats), with less emphasis on the biological origin (commodity) of foods. While we will have the beef steak and pork chop for a long time to come, more and more formulated meat and other food products will be marketed with controlled composition, sensory quality (flavor, color, appearance, texture), nutritive value, and microbiological and chemical safety, and use characteristics

In view ot the crucial world food problems of providing sufficient food for an expanding world population, we can anticipate even greater attention in the future to maximizing the use of plant and animal food products, minimizing losses from insects, rodents, microbes, etc., and developing additional protein food supplements for use with local foods derived from cereals, legumes, protein from underutilized fish and possibly leaf and single-cell proteins.

These developments present a challenge for the markets for animal food products. In view of the key role of meat and other animal food items in the diets of most cultures, the vital importance of these foods in providing high quality proteins, minerals, and vitamins and a high satiety value to consumers, the demand for these foods will no doubt remain high. It