

The background is a solid blue color. Scattered across the surface are several irregular, torn-edge shapes. Each shape is filled with a fine, horizontal blue and white hatched pattern, giving them a textured, paper-like appearance. These shapes are of various sizes and are positioned around the text, with one notably large shape behind the word 'SCIENCE'.

EXPERIMENTAL FOOD SCIENCE

3RD
EDITION

Marjorie P. Penfield
Ada Marie Campbell

EXPERIMENTAL FOOD SCIENCE

3RD
EDITION

Marjorie P. Penfield
Ada Marie Campbell

The University of Tennessee, Knoxville



Academic Press, Inc.

Harcourt Brace Jovanovich, Publishers

San Diego New York Boston

London Sydney Tokyo Toronto

This book is printed on acid-free paper. ∞

Copyright © 1990, 1979, 1962 by Academic Press, Inc.

All Rights Reserved.

No part of this publication may be reproduced or transmitted in any form or by any means, electronic or mechanical, including photocopy, recording, or any information storage and retrieval system, without permission in writing from the publisher.

Academic Press, Inc.

San Diego, California 92101

United Kingdom Edition published by

Academic Press Limited

24-28 Oval Road, London NW1 7DX

Library of Congress Cataloging-in-Publication Data

Penfield, Marjorie Porter.

Experimental food science / Marjorie P. Penfield, Ada Marie Campbell. -- 3rd ed.

p. cm. -- (Food science and technology)

Includes bibliographical references.

ISBN 0-12-157920-4 (alk. paper)

1. Food. 2. Food--Laboratory manuals. I. Campbell, Ada Marie,

Date. II. Title. III. Series.

TP370.P37 1990

664--dc20

90-294

CIP

Printed in the United States of America

90 91 92 93 9 8 7 6 5 4 3 2 1

FOOD SCIENCE AND TECHNOLOGY

A Series of Monographs

SERIES EDITOR

Steve L. Taylor
Editor
University of Nebraska

ADVISORY BOARD

John E. Kinsella
Cornell University

Douglas Archer
FDA, Washington, D.C.

Jesse F. Gregory, III
University of Florida

Susan K. Harlander
University of Minnesota

Daryl B. Lund
The State University of New Jersey

Barbara O. Schneeman
University of California, Davis

A complete list of the books in this series appears at the end of the volume.

PREFACE

As in the previous editions, this edition of *Experimental Food Science* has two main purposes: to present the scientific basis for understanding the nature of food, and to promote the principles of experimental methodology as applied to food. The book is intended for use in a first course in experimental foods.

The experimental approach will be the emphasis of most courses for which this book will be used. This new edition has been reorganized with an early presentation of basic information on methods, planning, and evaluation for those who will be doing individual work and for those who will only use the methods in class experiments. Although objective measurements should be made on products whenever possible, the lack of all or some of the equipment for making such measurements need not eliminate experiments from the class schedule. Some experiments require only the simplest equipment; improvised tests are described in Appendix D. Sensory evaluation is nearly always feasible. The chapter on sensory methods has been expanded to provide more specific direction for students. Scorecards for several tests as well as statistical charts for analysis of the results are included.

The format is slightly changed. Each chapter begins with an outline to present an overview and facilitate the locating of sections. Cross-references have been increased throughout the book. Celsius temperatures are used throughout, but a temperature conversion table is included in Appendix B. Expanded suggested exercises have replaced detailed experiments at the ends of chapters in order to provide needed experience in planning experiments and to permit the relating of experiments to the interests and resources of specific groups and individuals. Basic formulas and procedures are included in Appendix A.

As with earlier editions, incorporation of recent research findings and recognition of specific technological advances related to food have been major goals of the revision process. Several chapters have been expanded. The meat chapter has been divided into separate chapters on meat, poultry, and fish in recognition of increased interest in poultry and fish. Meat, poultry, and fish cuts now are shown, with scientific names of muscles, to facilitate understanding of the research literature. The chapter on flour includes a much expanded section on nonwheat flours. Technological developments and increased public interest are recognized in sections such as those on surimi, modified starch, alternative sweeteners, synthetic fats, extruded foods, pasta, and flat breads. The subject of microwave heating has been expanded, and some discussion of water activity has

been incorporated. A separate chapter on microbiology expands the treatment of basic principles, with emphasis on foodborne illnesses. Emerging pathogens are covered as their importance continues to be recognized.

Emphasis on relationships between chemical and physical properties is continued. Some background in organic chemistry is assumed, as is some fundamental knowledge about food. The subject matter presentation draws heavily not only on the principles of related sciences, but also on published food research, both early and recent. The reference lists, though far from complete, are meant to be representative. It is hoped that the student will gain an appreciation for the tremendous contribution of early workers in the field, as well as for the advances resulting from more recent work and will recognize the dynamic nature of the field. The perceptive student will observe that new information results in new questions to be answered, and that new approaches to food study become possible as technological advances occur.

The student is encouraged to read both textbook material and research literature critically, to examine evidence presented, and to evaluate statements made and conclusions drawn. In this way the student will realize that reading should be an active, evaluating process, not a passive, accepting one.

Suggestions made by users of the earlier editions have been helpful during the revision process and are gratefully acknowledged. Students in many classes have provided inspiration through their questions, comments, needs, and interests. Their contributions are immeasurable.

CONTENTS

Preface xiii

PART I _____ **FOOD EXPERIMENTATION**

CHAPTER 1 **FOOD EXPERIMENTATION 3**

- I. INTRODUCTION 3
- II. USING AND PRESENTING FORMULAS 5
- III. CONTROLLING EXPERIMENTS 6
- IV. CONTROLLING TECHNIQUES 10
- V. EVALUATING RESULTS OF CLASS EXPERIMENTS 11
- VI. REPORTING THE RESULTS 12
 - Suggested Exercises 13
 - References 15

CHAPTER 2 **PLANNING THE EXPERIMENT 16**

- I. SELECTING AND DEFINING THE PROBLEM 16
- II. REVIEWING THE LITERATURE 17
- III. WRITING THE PLAN 20
 - Suggested Exercises 21
 - References 21

CHAPTER 3 **EVALUATING FOOD BY OBJECTIVE METHODS 23**

- I. CATEGORIES OF OBJECTIVE METHODS 24
- II. APPEARANCE 26

III. COLOR	28
IV. GEOMETRICAL CHARACTERISTICS	29
V. TEXTURE	32
VI. MISCELLANEOUS TESTS	45
References	45

CHAPTER 4

EVALUATING FOOD BY SENSORY METHODS 51

I. SENSORY EVALUATION DEFINED	52
II. PREPARATION AND SAMPLING	53
III. PRESENTATION OF SAMPLES	54
IV. ENVIRONMENT FOR TESTING	57
V. SELECTION AND TRAINING OF PANELISTS	59
VI. TYPES OF TESTS	61
VII. INTERPRETATION OF RESULTS	72
VIII. PRESENTATION OF RESULTS	73
Suggested Exercises	73
References	74

CHAPTER 5

PREPARING THE REPORT 78

I. THE ORGANIZATION OF THE REPORT	79
II. THE LANGUAGE OF THE REPORT	84
III. A SAMPLE REPORT	85
IV. ORAL REPORTS	90
Suggested Exercises	91
References	92

PART II

FOOD SCIENCE TODAY

CHAPTER 6

INTRODUCTION TO FOOD SCIENCE 97

I. WATER	98
II. FOOD DISPERSIONS	102
III. ACIDITY AND HYDROGEN ION CONCENTRATION (pH)	112

IV. ENZYMES	115
V. BROWNING	118
VI. ENERGY TRANSFER AND CONVERSION AND MASS TRANSFER	121
Suggested Exercises	125
References	127

CHAPTER 7

EGGS 130

I. STRUCTURE AND COMPOSITION	130
II. EGG QUALITY	133
III. FUNCTIONALITY OF EGGS AND THEIR ROLES IN PRODUCTS	138
IV. PROCESSED EGGS AND THEIR PERFORMANCE IN FOOD SYSTEMS	151
Suggested Exercises	155
References	157

CHAPTER 8

MILK AND MILK PRODUCTS 162

I. PHYSICAL PROPERTIES	163
II. COMPONENTS OF MILK	165
III. ALTERATION OF MILK AND MILK PRODUCTS BY PROCESSING	169
IV. USE OF MILK AND MILK PRODUCTS IN FOOD PRODUCTION	174
V. USE OF MILK COMPONENTS IN FORMULATED FOODS	176
Suggested Exercises	179
References	180

CHAPTER 9

MEAT 184

I. EATING QUALITY OF MEAT AS DETERMINED BY MUSCLE TISSUE COMPONENTS AND STRUCTURE	185
II. MUSCLES AND MEAT QUALITY	196
III. POST-MORTEM AGING	200
IV. PROCESSED MEATS	202
V. MEAT COOKERY	204

VI. PROCESSES TO TENDERIZE MEAT	213
VII. VEGETABLE PROTEINS AS MEAT EXTENDERS	215
Suggested Exercises	216
References	217

CHAPTER 10

POULTRY 224

I. COMPOSITION AND STRUCTURE	224
II. QUALITY ATTRIBUTES	225
III. PROCESSING AND PRESERVATION	228
IV. INFLUENCE OF COOKING METHODS ON QUALITY	229
Suggested Exercises	238
References	238

CHAPTER 11

FISH 241

I. CLASSIFICATION	242
II. QUALITY ATTRIBUTES	243
III. STRUCTURE AND COMPOSITION	246
IV. PROCESSING	249
V. EFFECTS OF COOKING ON QUALITY	252
Suggested Exercises	254
References	254

CHAPTER 12

FOOD MICROBIOLOGY 257

I. FACTORS AFFECTING SURVIVAL AND GROWTH OF MICROORGANISMS	258
II. MICROORGANISMS AND FOODBORNE ILLNESSES	258
Suggested Exercises	264
References	264

CHAPTER 13

FOOD PRESERVATION 266

I. APPLICATION OF HEAT	267
II. LOW TEMPERATURE	273
III. LOWERING WATER ACTIVITY	280
IV. CHEMICAL PRESERVATIVES AS ANTIMICROBIAL AGENTS	285
V. CONTROLLED OR MODIFIED ATMOSPHERE STORAGE AND PACKAGING	286

VI. IRRADIATION	287
Suggested Exercises	289
References	290

CHAPTER 14

FRUITS AND VEGETABLES 294

I. TEXTURE	295
II. COLOR	301
III. FLAVOR	314
IV. METHODS OF COOKING VEGETABLES	318
V. LEGUMES	320
Suggested Exercises	322
References	325

CHAPTER 15

FATS AND THEIR LIPID CONSTITUENTS 331

I. CHEMICAL STRUCTURE OF LIPIDS	332
II. PHYSICAL STRUCTURE AND PROPERTIES OF FATS	336
III. CHEMICAL REACTIONS OF LIPIDS	340
IV. PROCESSING OF FATS	347
V. FUNCTIONS OF FATS IN FOOD	351
VI. FAT SUBSTITUTES	355
Suggested Exercises	356
References	357

CHAPTER 16

STARCH 358

I. THE CHEMICAL AND PHYSICAL NATURE OF STARCH	359
II. PROCESSES UNDERGONE BY STARCH	368
Suggested Exercises	381
References	381

CHAPTER 17

FLOUR 384

I. WHEAT FLOUR	384
II. NONWHEAT FLOURS	395
Suggested Exercises	402
References	402

CHAPTER 18**LEAVENING AGENTS 406**

- I. LEAVENING GASES 406
- II. CHEMICAL LEAVENING AGENTS 407
- III. BIOLOGICAL LEAVENING SYSTEMS
(YEAST FERMENTATION) 413
 - Suggested Exercises 415
 - References 416

CHAPTER 19**YEAST BREADS 418**

- I. WHITE WHEAT BREAD 418
- II. VARIETY BREADS 434
 - Suggested Exercises 439
 - References 440

CHAPTER 20**QUICK BREADS, EXTRUDED FOODS, AND PASTA 442**

- I. QUICK BREADS 442
- II. EXTRUDED FOODS 447
- III. PASTA 450
 - Suggested Exercises 451
 - References 451

CHAPTER 21**SHORTENED CAKES 452**

- I. INGREDIENTS 452
- II. MIXING 456
- III. BAKING 459
- IV. CAKE QUALITY 459
 - Suggested Exercises 471
 - References 471

CHAPTER 22**PASTRY AND COOKIES 474**

- I. PASTRY 475
- II. COOKIES 477
 - Suggested Exercises 483
 - References 483

CHAPTER 23
SUGARS AND ALTERNATIVE SWEETENERS 485

- I. SUGARS 485
- II. ALTERNATIVE SWEETENERS 490
 - Suggested Exercises 493
 - References 493

CHAPTER 24
CRYSTALLIZATION 494

- I. CRYSTALLINE CANDY 494
- II. FROZEN DESSERTS 498
 - Suggested Exercises 503
 - References 503

- Appendix A. Basic Formulas and Procedures 505
- Appendix B. Conversion Tables for Oven Temperatures 517
- Appendix C. Sources of Equipment 518
- Appendix D. Improvised Tests 519
- Appendix E. Table for Sensory Difference Tests 524

Index 527

PART I

FOOD EXPERIMENTATION

FOOD EXPERIMENTATION

I. INTRODUCTION	3
II. USING AND PRESENTING FORMULAS	5
III. CONTROLLING EXPERIMENTS	6
A. Uniformity of Ingredients	6
B. Temperature Control	7
C. Measurements of Quantity	7
IV. CONTROLLING TECHNIQUES	10
V. EVALUATING RESULTS OF CLASS EXPERIMENTS	11
VI. REPORTING THE RESULTS	12
A. Recording Data	12
B. Analyzing and Interpreting Data	12
C. Drawing Conclusions	13
Suggested Exercises	13
References	15

I. INTRODUCTION

A scientific approach to the experimental study of food is presented in this book. The experimental study of food is concerned with why foods are handled, processed, and prepared as they are, how and why variations in ingredients or treatments influence the quality of food, and how this knowledge can be used to improve the quality of food products. The scientific approach includes three basic steps: defining the problem and arriving at the hypothesis; testing the hypothesis in a carefully designed and controlled experiment; and accepting or rejecting the hypothesis in a report of the results. The scientific study of food is an exciting field of investigation. Adequate answers to some food-related problems have been found, often by applying sciences, such as chemistry, physics, biology, and microbiology, that are basic to the study of foods. Answers to other problems are only partial or not yet known. Incomplete answers and the unknown offer chal-

lenges to the food scientist. Students can find challenging questions to study in an experimental foods class.

This book is divided into two parts. Part I explores methods used in food science and should serve as a reference for laboratory work and for understanding the basic food science principles discussed in Part II. Understanding of the methods described in Chapters 3 and 4 will facilitate an understanding of the literature in food science. Part I can serve as a guide to the student who is starting an independent problem in experimental foods, who wants to expand the suggested exercises outlined at the ends of the chapters, or who wants to develop experiments using the formulas in the Appendix as a guide.

This textbook contributes to several sections of a research report. Part II is essentially a review of literature, both recent and older. The most current literature must always be reviewed, because information in food science changes rapidly; older literature provides the foundation for our understanding of food and its functional properties. Suggestions for reviewing the literature are included in Chapter 2. Appendix A contains experimental formulas. The procedures in Appendix A, although written as instructions, provide information for writing procedures for a report.

The other essential parts of the research report—the data, the discussion of the results, the conclusions, and the reference list—should be incorporated into the student's notebook or laboratory report. The reference list should give credit to the sources of information used in preparation of the report. Those sources should be cited in the text. For reference lists in this text and citations within the text, the Institute of Food Technologists' (IFT) style with some modification has been used. Details of this style are found in the style guide published by the IFT (1988). The style has been modified for this book to provide chapter numbers and inclusive page numbers. This will facilitate the process of obtaining copies of papers via interlibrary loan if not available to the reader. In addition, states are spelled out to facilitate information retrieval by international readers. For class reports, either this style or one of the styles used in other professional journals may be selected. It is important, however, that the same style be used throughout a report.

Suggested exercises at the end of each chapter include suggested experimental variations in treatment or ingredients. Basic formulas and procedures for some basic products are given in the Appendix. For other suggested exercises literature references may be given for formulas and procedure. The product from the basic formula serves as a control, in other words, a basis for comparison of the experimental products. Variations not described in the suggested exercise may better serve the needs and interests of a class. For example, related problems of current concern and interest may serve as a basis for class or individual projects—interesting projects may be suggested by class members. It is assumed that students using this book have some background in food science and thus can be involved in planning the details of experiments based on the suggested exercises.

Carefully controlled experiments with appropriate replication are necessary if the results are to be meaningful and, in the case of more extensive research studies, worthy of publication. Experiments should be controlled experiments. In