

Food Microbiology

Third Edition

Food Microbiology

Third Edition

W. C. Frazier

*Professor Emeritus of Bacteriology
University of Wisconsin*

D. C. Westhoff

*Associate Professor of Food Microbiology
University of Maryland*

McGraw-Hill Book Company

New York St. Louis San Francisco Auckland Bogotá Düsseldorf
Johannesburg London Madrid Mexico Montreal New Delhi Panama
Paris São Paulo Singapore Sydney Tokyo Toronto

FOOD MICROBIOLOGY

Copyright © 1978, 1967, 1958 by McGraw-Hill, Inc. All rights reserved. Printed in the United States of America. No part of this publication may be reproduced, stored in a retrieval system, or transmitted, in any form or by any means, electronic, mechanical, photocopying, recording, or otherwise, without the prior written permission of the publisher.

1234567890 DODO 78321098

This book was set in Times Roman.

The editors were James E. Vastyan and James W. Bradley;

the cover was designed by Anne Canevari Green;

the production supervisor was Dennis J. Conroy.

R. R. Donnelley & Sons Company was printer and binder.

Library of Congress Cataloging in Publication Data

Frazier, William Carroll.

Food microbiology.

Includes index.

1. Food—Microbiology. 2. Food—Preservation.

I. Westhoff, Dennis C., joint author. II. Title.

QR115.F7 1977 576'.163 77-12599

ISBN 0-07-021917-6

Preface to the Third Edition

Since publication of the second edition much new information on the microbiology of foods has become available. New techniques in food processing eliminate some microbiological problems and create new ones. Methods once thought promising have been abandoned, e.g., the irradiation of foods with gamma rays, no longer permitted in the United States.

In response to suggestions, changes have been made in the arrangement of some of the information presented. For example, the characteristics of foods which affect their microbiology have been moved to the first chapter. In the light of information available since the previous edition, the chapters on food-borne diseases have been expanded.

Because the latest edition of Bergey's Manual of Determinative Bacteriology has made changes in the nomenclature of many of the bacteria familiar to food microbiologists and invalidated the names of others, an appendix has been included which briefly describes the current status of the names of these organisms. Names that are no longer accepted are marked with an asterisk in the text and are discussed in the appendix.

We regret that we are unable to give acknowledgment and thanks to all the people whose reports have been the basis for many of the facts presented. We have attempted to use and refer to major papers or review articles, which can be a source of additional references.

We wish to express our thanks for criticism and advice from those who have made suggestions for revision of the second edition: Dr. E. H. Marth of the University of Wisconsin, Dr. H. W. Walker of Iowa State University, Dr. D. Y. C. Fung of Pennsylvania State University, and Dr. R. H. Vaughn of the University of California. We also are grateful for suggestions and materials from Dr. F. L. Bryan of the Center for Disease Control, Dr. D. E. Bigbee of the University of Maryland, Dr. D. A. Kautter of the Food and Drug Administration, Dr. R. W. Johnston of the United States Department of Agriculture, Dr. V. W. Christiansen of Miles Laboratories, Dr. H. P. Fleming of North Carolina State University, and S. Doores and F. Feldstein of the University of Maryland.

W. C. Frazier

D. C. Westhoff

Preface to the Second Edition

Since the writing of the first edition of this textbook considerably more information has become available on the microbial content of foods and on their preservation and spoilage. New methods of handling and processing foods have created new microbiological problems. Catering and mechanical vending of foods are on the increase, as are the uses of partially or completely precooked foods and of freeze-dried foods. Irradiation of potatoes and bacon with gamma rays is now permitted, and it probably will be allowed soon for more foods. Definite rules have been formulated concerning chemical preservatives permitted in foods. Biological hazards in food are receiving an increased amount of attention, as are suggested microbiological standards for foods.

All this new information demands the expansion of the size of this volume. However, in the interest of keeping the new edition down to textbook size, most additions have been made as brief as practicable, and some sections of the first edition have been shrunk or even eliminated.

In response to suggestions, a few changes have been made in the arrangement of material. Individual chapters deal with the contamina-

tion, preservation, and spoilage of each important class of food, and a chapter has been added on chemical changes produced by micro-organisms in constituents of foods.

The author regrets that he has been unable to give acknowledgment and thanks to all the numerous authors whose reports have been the bases for the facts presented in this textbook. He is especially grateful to the many authors from whose publication the data in Tables 10-1, 16-3, 16-4, and 26-2 were gathered.

The author wishes to express his thanks for criticism and advice from those who read parts of the manuscript: Dr. E. M. Foster, Dr. K. B. Raper, and Dr. Elizabeth McCoy of the Department of Bacteriology of the University of Wisconsin. Also, thanks for suggestions regarding the revisions are due Dr. Carl S. Pederson of Cornell University and Dr. John C. Ayres of Iowa State University.

W. C. Frazier

Preface to the First Edition

The purpose of *Food Microbiology* is to condense into a volume of modest size the basic principles of food microbiology, together with illustrations of these principles, in such a form that the book can serve as a college textbook or as an aid to workers in the fields related to the food industries. An attempt has been made to summarize and digest material for the reader and to avoid referring to and quoting long lists of reports from various workers. Although hundreds of scientific papers on food microbiology have been consulted during the preparation of the manuscript, reference has been made, whenever possible, to adequate books and review articles, each of which gives an extensive bibliography, and to individual articles only when books and reviews are not available. The summarizing references should be especially useful to the student, who can and will consult only a limited number of sources.

Each of the main subjects treated in this book is worthy of a separate volume, but limitations of space have not permitted the inclusion of all of the material that each specialist, in his enthusiasm for his field, might wish to see. The author has tried to avoid giving undue attention to any single phase of food microbiology. It has been found

necessary, of course, to include a limited amount of food technology, enough for an understanding of the microbiology of some foods.

The subject matter in *Food Microbiology* has been divided into six main parts: Part One on the microorganisms important in food microbiology, their characteristics and their entrance into foods; Part Two on the preservation of foods, including basic methods and their application to specific foods; Part Three on the general principles concerned in the spoilage of foods and the spoilage of specific foods; Part Four on foods and enzymes produced by microorganisms; Part Five on foods in relation to disease, with emphasis on food poisonings and infections; and Part Six on food sanitation; control, and inspection.

By the time this volume is published new methods and discoveries will have been reported. Nevertheless, the basic principles of food microbiology as presented here should still apply.

The author wishes to express his thanks for criticism and advice from those who read parts of the manuscript: Dr. E. M. Foster, Dr. K. B. Raper, Dr. J. B. Wilson, and Dr. Elizabeth McCoy of the Department of Bacteriology of the University of Wisconsin, and Dr. H. J. Peppler of the Red Star Yeast and Products Company.

W. C. Frazier

Food Microbiology

Contents

Preface to the Third Edition	x1
Preface to the Second Edition	xiii
Preface to the First Edition	xv

1

FOOD AND MICROORGANISMS

1 Food as a Substrate for Microorganisms	3
Hydrogen-Ion Concentration (pH). Moisture Requirement: The Concept of Water Activity. Oxidation-Reduction Potential. Nutrient Content. Inhibitory Substances and Biological Structure.	
2 Microorganisms Important in Food Microbiology	17
Molds. General Characteristics of Molds. Classification and	

Identification of Molds. , Molds of Industrial Importance.
Yeasts and Yeastlike Fungi. General Characteristics of Yeasts.
 Classification and Identification of Yeasts. Yeasts of Industrial
 Importance. **Bacteria.** Morphological Characteristics Important
 in Food Bacteriology. Cultural Characteristics Important in
 Food Bacteriology. Physiological Characteristics Important in
 Food Bacteriology. Genera of Bacteria Important in Food
 Bacteriology. Groups of Bacteria Important in Food
 Bacteriology.

- | | | |
|----|--|----|
| 3. | Contamination of Foods | 65 |
| | From Green Plants and Fruits. From Animals. From
Sewage. From Soil. From Water. From Air. During
Handling and Processing. | |
| 4 | General Principles Underlying Spoilage: Chemical Changes
Caused by Microorganisms | 77 |
| | Fitness or Unfitness of Food for Consumption. Causes of
Spoilage. Classification of Foods by Ease of Spoilage. Factors
Affecting Kinds and Numbers of Microorganisms in Food.
Factors Affecting the Growth of Microorganisms in Food.
Chemical Changes Caused by Microorganisms. | |

2

PRINCIPLES OF FOOD PRESERVATION

- | | | |
|---|--|-----|
| 5 | General Principles of Food Preservation: Asepsis,
Removal, Anaerobic Conditions | 93 |
| | Methods of Food Preservation. Principles of Food
Preservation. Asepsis. Removal of Microorganisms.
Maintenance of Anaerobic Conditions. | |
| 6 | Preservation by Use of High Temperatures | 101 |
| | Factors Affecting Heat Resistance (Thermal Death Time). Heat
Resistance of Microorganisms and Their Spores. Determination
of Heat Resistance (Thermal Death Time). Thermal-Death-Time
(TDT) Curves. 12D Concept. Heat Penetration.
Determination of Thermal Processes. Heat Treatments
Employed in Processing Foods. Canning. | |

7	Preservation by Use of Low Temperatures	130
	Growth of Microorganisms at Low Temperatures. Temperatures Employed in Low-Temperature Storage. Effect of Subfreezing and Freezing Temperatures on Microorganisms.	
8	Preservation by Drying	143
	Methods of Drying. Factors in the Control of Drying. Treatments of Foods before Drying. Procedures after Drying. Microbiology of Dried Foods. Intermediate-Moisture Foods.	
9	Preservation by Food Additives	154
	The Ideal Antimicrobial Preservative. Added Preservatives. Developed Preservatives.	

3

CONTAMINATION, PRESERVATION, AND SPOILAGE OF DIFFERENT KINDS OF FOODS

10	Contamination, Preservation, and Spoilage of Cereals and Cereal Products	173
	Contamination. Preservation. Asepsis. Use of Heat. Use of Low Temperatures. Use of Chemical Preservatives. Use of Irradiation. Spoilage. Cereal Grains and Meals. Flours. Bread. Cakes and Other Bakery Products. Macaroni and Tapioca.	
11	Contamination, Preservation, and Spoilage of Sugars and Sugar Products	185
	Contamination. Sucrose. Maple Sirup. Honey. Candy. Preservation. Spoilage. Sucrose. Maple Sap and Sirup. Honey. Candy.	
12	Contamination, Preservation, and Spoilage of Vegetables and Fruits	194
	Contamination. Preservation. Asepsis. Removal of Microorganisms. Use of Heat. Use of Low Temperatures. Drying. Use of Preservatives. Preservation by Irradiation. Preservation of Fruits and Fruit Products. Asepsis. Removal of Microorganisms. Use of Heat. Use of Low Temperatures. Drying. Use of Preservatives. Spoilage. General Types of Microbial Spoilage. Spoilage of Fruit and Vegetable Juices.	

13	Contamination, Preservation, and Spoilage of Meats and Meat Products	218
	Contamination. Preservation. Asepsis. Use of Heat. Use of Low Temperatures. Use of Irradiation. Preservation by Drying. Use of Preservatives. Spoilage. General Principles Underlying Meat Spoilage. Spoilage of Different Kinds of Meats.	
14	Contamination, Preservation, and Spoilage of Fish and Other Seafoods	243
	Contamination. Preservation. Use of Heat. Use of Low Temperatures. Use of Irradiation. Preservation by Drying. Use of Preservatives. Spoilage. Factors Influencing Kind and Rate of Spoilage. Evidences of Spoilage. Bacteria Causing Spoilage. Spoilage of Special Kinds of Fish and Seafoods.	
15	Contamination, Preservation, and Spoilage of Eggs	256
	Contamination. Preservation. Asepsis. Removal of Microorganisms. Use of Heat. Use of Low Temperatures. Preservation by Drying. Use of Preservatives. Use of Irradiation. Spoilage. Defects in the Fresh Egg. Changes during Storage.	
16	Contamination, Preservation, and Spoilage of Poultry	270
	Contamination. Preservation. Asepsis. Use of Heat. Use of Low Temperatures. Use of Preservatives. Carbon Dioxide Atmosphere. Use of Irradiation. Spoilage.	
17	Contamination, Preservation, and Spoilage of Milk and Milk Products	278
	Contamination. On the Farm. In Transit and at the Manufacturing Level. Preservation. Asepsis. Removal of Microorganisms. Use of Heat. Use of Low Temperatures. Drying. Use of Preservatives. Use of Irradiation, Sound Waves, and Electric Currents. Spoilage. Milk and Cream. Condensed and Dry Milk Products. Frozen Desserts. Butter.	
18	Spoilage of Heated Canned Foods	306
	Causes of Spoilage. Appearance of the Unopened Container. Grouping of Canned Foods on the Basis of Acidity. Types of Biological Spoilage of Canned Foods.	
19	Miscellaneous Foods	319
	Fatty Foods. Essential Oils. Bottled Beverages. Spices and Other Condiments. Salt. Nutmeats. Other Foods.	

4

FOODS AND ENZYMES PRODUCED BY MICROORGANISMS

- 20 Production of Cultures for Food Fermentations 331
General Principles of Culture Maintenance and Preparation.
Bacterial Cultures. Yeast Cultures. Mold Cultures.
- 21 Food Fermentations 341
Bread. Malt Beverages. Wines. Distilled Liquors. Vinegar.
Fermented Vegetables. Fermented Dairy Products. Spoilage
and Defects of Fermented Dairy Products. Tea, Coffee, Cacao,
Vanilla, Citron. Oriental Fermented Foods.
- 22 Foods and Enzymes from Microorganisms 398
Microorganisms as Food: Single-Cell Protein. Fats from
Microorganisms. Production of Amino Acids. Production of
Other Substances Added to Foods. Production of Enzymes.

5

FOODS IN RELATION TO DISEASE

- 23 Food-borne Infections and Intoxications: Bacterial 419
"Poisoning" by Microorganisms and Their Products. Food
Intoxications. Food Infections.
- 24 Food-borne Poisonings, Infections, and Intoxications: 454
Nonbacterial
Mycotoxins. Viruses. Rickettsia. Various Parasites.
Seafood Toxicants. Poisoning by Chemicals.
- 25 Investigation of Food-borne Disease Outbreaks 473
Food-borne Diseases. Objectives of Investigation. Personnel
Involved in Investigation. Materials and Equipment Required.
The Field Investigation. Laboratory Testing. Interpretation
and Application of Results. Preventive Measures.

6

FOOD SANITATION, CONTROL, AND INSPECTION

26	Microbiology in Food Plant Sanitation	487
	Bacteriology of Water. Sewage and Waste Treatment and Disposal. Microbiology of the Food Product. Good Manufacturing Practices. Hazard Analysis: Critical Control Points (HACCP). Health of Employees.	
27	Food Control	502
	Enforcement and Control Agencies. The Federal Food, Drug, and Cosmetic Act. Title 21 of the Code of Federal Regulations. Food Additives Amendment of 1958. The Meat Inspection Act of 1906. The Poultry Products Inspection Act of 1957. Inspection and Grading by Agricultural Marketing Service. State and Municipal Food Laws. Control by Food Plants. Microbiological Criteria for Foods.	
	Appendix	513
	Index	517

Part One

Food and Microorganisms

An understanding of the interactions between microorganisms and foods can be appreciated only if we realize that the food, by its composition, dictates the resulting flora. Understanding a food's chemistry is a necessary prerequisite to understanding its microbiology. Chapter 1 outlines those important parameters of foods that affect their microbiology. Chapter 2 discusses the major groupings of food-borne microorganisms. The contamination of foods with microorganisms (Chapter 3) is discussed only briefly in this first section because this subject will be considered repeatedly in following sections of the text. Similarly, Chapter 4 outlines general principles of spoilage with additional discussions on specific commodities to follow in later sections.