PRACTICAL FOOD MICROBIOLOGY & TECHNOLOGY

THIRD EDITION

Practical Food Microbiology and Technology

Third Edition

George J. Mountney
Wilbur A. Gould

An avi Book
Published by Van Nostrand Reinhold Company
New York

An AVI Book
(AVI is an imprint of Van Nostrand Reinhold Company Inc.)

Library of Congress Catalog Card Number 87-18887

ISBN 0-442-22688-8

Printed in the United States of America

Van Nostrand Reinhold Company Inc.
115 Fifth Avenue
New York, New York 10003

Van Nostrand Reinhold Company Limited
Molly Millars Lane
Wokingham, Berkshire, RG11 2PY, England

Van Nostrand Reinhold
480 La Trobe Street
Melbourne, Victoria 3000, Australia

Macmillan of Canada
Division of Canada Publishing Corporation
164 Commander Boulevard
Agincourt, Ontario MIS 3C7, Canada

16 15 14 13 12 11 10 9 8 7 6 5 4 3 2 1

Library of Congress Cataloging-in-Publication Data

Mountney, George J.
Practical food microbiology and technology.

Rev. ed. of: Practical food microbiology and technology / Harry H. Weiser. 2nd ed. 1971.
"An AVI book."
Bibliography: p.
Includes index.
1. Food—Microbiology. 2. Food—Preservation.
I. Gould, Wilber A., 1920– II. Weiser, Harry H. (Harry Howard). Practical food microbiology and technology. III. Title.
QR115.M68 1987 664'.001576 87-18887
ISBN 0-442-22688-8

Practical Food Microbiology and Technology

Preface to Third Edition

The original objective of writing a book for food technologists, restaurant and foodservice students, sanitarians, and for those in industry who need a general description of the microflora and their effects on specific foodstuffs rather than for microbiologists interested in basic metabolic reactions has been continued in the third edition.

A major rearrangement of chapters into more closely related subject areas and into a more logical development of chapters has been attempted. Several old chapters have been omitted and several new ones added. The subject matter areas have been regrouped into six general sections: characteristics of microorganisms and food; factors influencing microbiological activity; food preservation methods; the microbiology of specific foodgroups; food spoilage characteristics; and finally, the public health implications of food pathogens.

As in the first and second editions, which emphasized the practical aspects of food microbiology and technology, we continue to emphasize the fermentative, spoilage, and pathogenic microorganisms found on specific food types; the role of food processing on food contamination and control; the effects of different microorganisms on the several foods; the characteristics of the different types of food spoilage; and finally, the efficacy of different types of preservation treatments on different groups of foods.

The authors are particularly indebted to Dr. Mason E. Miller, former communications scientist, Cooperative State Research Service, United States Department of Agriculture, for his assistance in editing the revised manuscript.

Contents

1 Introduction

SCOPE OF FOOD MICROBIOLOGY

The science of microbiology deals with organisms that are invisible or barely visible to the unaided eye. These microorganisms include viruses, bacteria, protozoa, algae, fungi, and certain small worms. Food microbiology deals with such organisms in and on food. Food microbiologists are concerned with the practical implications of the microflora of the food. Can the organism cause a disease in humans? Does the organism cause food spoilage? Is the presence of the organism aesthetically acceptable in human food? Does the organism change the functional properties of a foodstuff resulting in new tastes, odors, or textures?

Understanding the relationships among the various organisms making up the microflora of a food is important for food microbiologists. Relationships may be symbiotic, antagonistic, or commensurate. The implications of these relationships for safety, spoilage, or new product development are important.

Food microbiologists are primarily concerned with what microorganisms do to a particular human food or to consumers under a given set of conditions. They may also be concerned with the presence in foods of extraneous materials that may be toxic or displeasing for aesthetic reasons.

Both food microbiology and food technology deal with the handling, processing, preserving, storing, preparation, nutritional content, and safety of food. These disciplines are closely related. The roles that a microbiologist may fill in a food company include training production personnel, quality control of incoming and outgoing material, drafting and implementing new standards, sanitation, process development, trouble shooting, and dealing with regulatory agencies.

In the area of food safety it is essential for the food microbiologist to know the "critical hazard points" in a food processing operation. Since these are the points where contamination can take place, the food microbiologist needs to sample at these operational points as part of an overall quality assurance program. In the manufacture of cheese or fermented milk, the microbiologist must be aware of the possible presence in the milk supply of antibiotics that are illegal and interfere with the growth of the starter cultures.

CLASSIFICATION OF MICROORGANISMS

Microorganisms can be classified according to various criteria, such as optimal temperature for growth, peculiar growth requirements, and major nutrient source. The classification and terminology adopted by the American Public Health Association are described briefly here (Speck 1984).

Microorganisms are commonly classified based on their optimum growth temperature ranges. *Psychrotropic* microorganisms grow relatively rapidly at commercial refrigeration temperatures. Included in this group are the bacterial genera *Pseudomonas, Achromobacter, Flavobacterium,* and *Alcaligenes* and the mold genera *Geotrichum* and *Botrytis. Thermophilic* microorganisms survive and grow well at elevated temperatures. Species able to survive some significant level of heat treatment (e.g., pasteurization) for a short time are termed *thermoduric.* Included in this group are some species in the bacterial genera *Micrococcus, Streptococcus* (primarily enterococci), *Microbacterium, Arthrobacter, Lactobacillus, Bacillus,* and *Clostridium.* Molds in this group include *Byssochlamys fulva* and some species of *Aspergillus* and *Penicillium* under certain conditions. *Mesophilic* microorganisms are aerobic and anaerobic sporeforming bacteria that grow at 35 °C but not at 55 °C. All species of the genus *Bacillus* are aerobic sporeformers. Anaerobic sporeforming mesophiles that cause food spoilage by putrifaction include *Clostridium sporogenes, C. botulinum, C. putrefaciens,* and *C. perfringens.* Most mesophiles are heat resistant.

Another classification is based on peculiar growth requirements. *Osmophilic* microorganisms, which cause spoilage in honey, soft-centered chocolate candies, jams, molasses, concentrated fruit juices, and other highly concentrated sugar solutions, are adapted to growth in substrates of high osmotic pressure. Yeasts such as *Saccharomyces rouxii* and *S. mellis* are examples of osmophiles. *Halophilic* microorganisms require a minimum concentration of salt for active growth. Species in the genera *Halobacterium* and *Halococcus* and other bacterial species found principally in marine environments are examples. These microorganisms cause spoilage of fish, bacon, and hides preserved in sea salts. *Staphylococcus aureus* and *Clostridium perfringens* can also multiply in moderately salted foods.

A third way to classify microorganisms is based on the type of nutrients they metabolize. *Proteolytic* microorganisms break down proteins, accompanied by formation of undesirable flavors and odors. Genera that include proteolytic organisms are *Bacillus, Clostridium, Pseudomonas,* and *Proteus. Lipolytic* microorganisms cause spoilage of lipid-containing foods by hydrolysis and oxidation. These microorganisms are responsible for the formation of desirable flavors in cheese and fermented foods. *Saccharolytic,* or acid-forming, microorganisms break down sugars to form acids. The lactic acid bacteria, which are important members of this group, cause milk souring and are used under controlled conditions to produce cheese and fermented milk drinks. Various species in the genera *Streptococcus, Leuconostoc,* and *Pediococcus* are also saccharolytic microorganisms.

Pectinolytic microorganisms, which break down pectin, are responsible for some kinds of spoilage of fruits and vegetables. *Achromobacter, Aeromonas, Arthrobacter, Agrobacterium, Enterobacter, Bacillus, Clostridium, Erwinia, Flavobacterium, Pseudomonas,* and *Xanthomonas* are examples of genera containing species of this type. *Amylytic* microorganisms break down starch to sugars. *Cellulytic* microorganisms break cellulose into simpler compounds.

PATHOGENIC ORGANISMS

Food microbiologists must always be on the watch for the possible presence of human pathogenic organisms in foods. To help determine whether a food is free from human pathogens, microbiologists use *indicator* organisms. These can be the pathogen itself or another organism, such as *Escherichia coli,* that grows under the same conditions as the pathogen. The presence or absence of bacterial toxins is also used as an indicator for pathogens and as a means to help insure that a food is safe. Examples of pathogenic microorganisms of concern to food microbiologists are coliforms of the genera *Salmonella, Streptococcus, Staphylococcus, Shigella, Yersinia, Vibrio, Enterococcus, Bacillus,* and *Clostridium.*

SELECTED REFERENCES

Anon. 1963. "Microbiological Quality of Foods." Proc. Conf. Franconia, New Hampshire. Academic Press, New York.

Anon. 1964. An Evaluation of Public Health Hazards from Microbiological Contamination of Foods. Subcommittee on Food Protection, Food and Nutrition Board. National Academy of Sciences, Washington, DC.

Anon. 1975. Prevention of Microbial and Parasitic Hazards Associated with Processed Foods: A Guide for the Food Processor. National Academy of Sciences, Washington, DC.

Anon. 1985. An Evaluation of the Role of Microbiological Criteria for Foods and Food Ingredients. National Academy of Sciences, Washington, DC.

Frazier, W. C., and Westhoff, D. C. 1978. "Food Microbiology," 3rd ed. McGraw-Hill, New York.

Speck, M. L. 1984. Compendium of Methods for the Microbiological Examination of Foods. Am. Public Health Assoc., Washington, DC.

2
Composition of Foods

Foods are composed of carbohydrates, proteins, fats, fatty acids, nucleic acids, minerals, vitamins, hormones, water, nucleotides, and other minor constituents. The composition and nutritive value of food are affected by the fertility of the soil, growth conditions, plant cultivar, animal breed, environment, and feed in the case of animals. The stage of maturity and other factors such as pH also can cause considerable variations.

The principal nutrients present in foodstuffs also differ among various types of foods. For example, butter is mainly fat, meat has a high protein content, and fruits have varying amounts of carbohydrates. The biochemical changes that foods can undergo during processing and storage depend on their composition. Fat products are susceptible to oxidative rancidity, while protein products are susceptible to proteolytic degradation. Some foods are protected by a tough hard shell or outer coating, which helps retard biochemical reactions. Nuts in the shell keep for a long time, but if the shell is removed, chemical and other changes occur in a short time unless some other provision is made for protection.

Adequate preservation of foods requires a knowledge of food technology and of the many biochemical and microbiological changes that usually take place in various foods during processing and storage. Many foods are produced over a wide range of geographical and climatic conditions. Often large volumes of fresh foods are produced within a relatively short time and cannot be consumed as they become available. Such foods must be preserved. The microflora and nutrients are altered by this processing and handling.

Another variation among groups of foods is their pH. Many fruits are high in acid; while vegetables, as a rule, are low. The acid content of a food helps determine the flavor and the microflora of the product. Because molds and yeast can tolerate fairly high acidity, they are most likely to be found on fruits. Molds not only tolerate severe acid conditions but can actually use the acid as a source of energy. Most bacteria, however, cannot survive in a highly acid environment, even though they produce many organic acids. There are some exceptions in the case of food fermentations where acid-tolerant bacteria can survive for a long time. The effect of food composition and other factors on microbial growth is discussed in detail in Chapter 5.

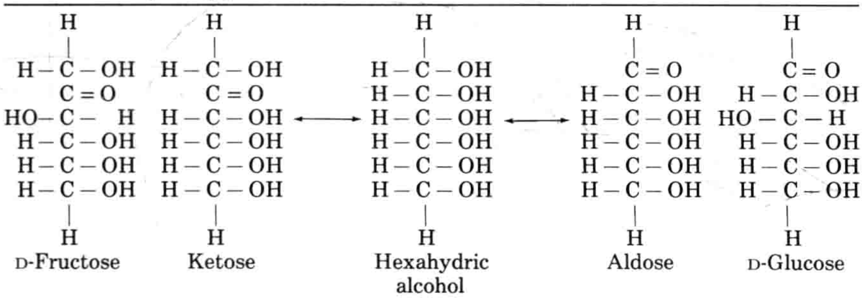
CARBOHYDRATES

By definition carbohydrates contain carbon, hydrogen, and oxygen. The name *carbohydrate* implies that hydrogen and oxygen are present in the same ratio as they are in water, that is, 2:1. Chemically, simple carbohydrates are aldehyde or ketone derivatives of polyhydric alcohols. The structural formulas shown in Table 2.1 illustrate this relationship. The common sugar D-glucose is an aldose, and D-fructose is a ketose.

Classification of Carbohydrates

Carbohydrates are generally classified into two major groups: simple sugars and compound sugars. Simple sugars are called monosaccharides and are classified according to the number of carbon (C) atoms they contain and whether an aldehyde (aldose) or ketone (ketose) group is present. Compound sugars are made up of two or more monosaccharide units and are further classified as oligosaccharides (two to nine monosaccharides) and polysaccharides (ten or more monosaccharides). A

Table 2.1. Simple Sugars



general classification scheme with examples of specific carbohydrates (in italics) is as follows:

- I. Monosaccharides
  - A. Dioses
    - 1. Aldoses: *Glycolaldehyde*
  - B. Trioses
    - 1. Aldoses: *Glyceric aldehyde*
    - 2. Ketoses: *Dihydroxy acetone*
  - C. Tetroses
    - 1. Aldoses: *D- and L-Erythrose*
    - 2. Ketoses: *Erythrudose*
  - D. Pentoses
    - 1. Aldoses: *Xylose*, *Arabinose*
    - 2. Ketoses: *Ribulose*, *Xylulose*
  - E. Hexoses
    - 1. Aldoses: *Glucose*, *Mannose*, *Galactose*
    - 2. Ketoses: *Fructose*, *Sorbose*
- II. Oligosaccharides
  - A. Disaccharides
    - 1. Reducing: *Maltose* (glucose + glucose), *Lactose* (glucose + galactose)
    - 2. Nonreducing: *Sucrose* (glucose + fructose)
  - B. Trisaccharides: *Raffinose* (glucose + fructose + galactose)