

Food Microbiology

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Course syllabus

Fundamental Teaching Unit (FTU)

Credits: 6

Coefficient: 3

Section I: Introduction to Microorganisms in Food

Chapter 1 History and Development of Food Microbiology

Chapter 2 Characteristics of Predominant Microorganisms in Food

Chapter 3 Sources of Microorganisms in Food

Chapter 4 Microbiological Quality of Food and Its Importance

Section II: Response to Microbial Growth in the Food Environment

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Chapter 6 Factors Influencing Microbial Growth in Food

Chapter 7 Microbial Metabolism of Food Components

Chapter 8 Microbial Sporulation and Germination

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Section IV: Microbial Spoilage of Food

Chapter 16 Important Factors in Microbial Spoilage of Food

Chapter 17 Spoilage of Specific Food Groups

Chapter 18 New Spoilage Bacteria in Refrigerated Foods

Chapter 19 Food Spoilage by Microbial Enzymes

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Section V: Microbial Foodborne Diseases

Chapter 23 Highlights on Foodborne Diseases

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Chapter 25 Foodborne Infections

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Chapter 27 Opportunistic Pathogens, Parasites, and Algal Toxins

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Chapter 29 Indicators of Pathogenic Bacteria



Section VI: Control of Microorganisms in Food

Chapter 30 Control of Access (Cleaning and Sanitation)

Chapter 31 Destruction by Physical Removal

Chapter 32 Destruction by Heat

Chapter 33 Destruction by Low and High Temperatures

Chapter 34 Destruction by Reduction of Water Activity A_w

Chapter 35 Destruction by Acidification

Chapter 36 Destruction by Modified Atmospheres

Chapter 37 Destruction by Reduction of Oxidation-Reduction Potential

Chapter 38 Destruction by Antimicrobial Preservatives

Chapter 39 Destruction by Irradiation

Chapter 40 Destruction by New Processing Technologies

Chapter 41 Destruction by Combination of Methods (Hurdle Concept)



Section I: Introduction to Microorganisms in Food

Chapter 1: History and development of food microbiology

1.1 Introduction to Food Microbiology

Food Microbiology is a fundamental discipline within Food Science and Technology that examines the interactions between microorganisms and food systems. It encompasses both the beneficial roles of microbes such as fermentation and enzyme production and their harmful roles in spoilage and foodborne illnesses. Understanding food microbiology is key to producing safe, nutritious, high-quality foods, developing innovative products, improving shelf life, and ensuring compliance with national and international food safety regulations.

1.1.1 Definition, Scope and relevance to food science & technology

A. Definition of Food Microbiology

Food Microbiology is the scientific study of microorganisms such as bacteria, yeasts, molds, viruses, and protozoa that grow, survive, or interact with foods. It deals with understanding microbial behavior, including their beneficial activities in fermentation and enzyme production, as well as harmful effects such as spoilage and contamination. The discipline also covers microbial ecology, detection techniques, foodborne illnesses, spoilage mechanisms, and control strategies used to maintain food safety and quality.

B. Scope of food microbiology

This field covers a broad and interdisciplinary range of topics. It involves **the study of naturally occurring microbial populations in raw agricultural materials**, **the interactions between microorganisms during food storage**, and **the ecological conditions that affect their survival and growth**. Food microbiology also addresses **spoilage caused by various microbes, foodborne pathogens and their toxins, beneficial microorganisms used in fermentation, microbiological testing for quality control**, and **the thermal and non-thermal methods employed to prevent microbial hazards in the food industry**.

i. Microbial ecology of foods

Microbial ecology examines the natural microflora found in raw foods and the ways microorganisms interact with one another. These interactions shape spoilage patterns, fermentation outcomes, and the survival of pathogens during processing and storage.

ii. Food spoilage

Microbial metabolism causes foods to spoil, leading to off-odors, slime, discoloration, texture breakdown, and undesirable flavors. A clear understanding of spoilage is essential for developing effective preservation strategies.

iii. Foodborne pathogens and toxins

Pathogenic microbes and toxin-producing organisms represent significant public health threats. Studying their growth characteristics, survival, toxin formation, and prevention is fundamental to food safety systems.

- ❖ **Food microbiology serves as the scientific backbone for guaranteeing food safety and enhancing food quality. It informs the creation of HACCP plans, GMP (Good Manufacturing Practices), GHP (Good Hygiene Practices), and sanitation procedures. An understanding of microbial spoilage enables better optimization of storage conditions, packaging, and shelf-life extension. Food technologists draw on microbiological principles to design fermentation processes, formulate functional foods, drive technological innovation, and ensure adherence to FSSAI, Codex, ISO, and FDA standards.**

1.1.2 Role of microorganisms in food systems

A. Microorganisms as agents of food fermentation

Microorganisms are essential to fermentation, converting raw ingredients into stable, flavorful, and nutritious foods. Lactic acid bacteria (LAB) are used in dairy, pickles, and fermented meats, lowering pH and adding flavor. Yeasts like *Saccharomyces cerevisiae* are vital for bread and alcoholic beverages. Molds contribute to cheese ripening and soy fermentations, adding distinct aromas and textures.

- **Lactic Acid Bacteria (LAB):** Convert sugars to lactic acid, improving preservation, safety, flavor, and texture; their metabolites (bacteriocins, vitamins) add nutritional and sensory value.
- **Yeasts:** Ferment sugars into carbon dioxide, ethanol, and aroma compounds, central to baking and brewing.
- **Molds:** Used in cheese ripening, enzyme production, and soy fermentation, developing unique flavors and textures.

B. Microorganisms in food spoilage

Spoilage microorganisms cause undesirable changes that make food unacceptable. Bacteria, yeasts, and molds break down food components, producing off-odors, gas, slime, discoloration, and rancidity. Spoilage depends on food composition, storage conditions, and microbial ecology.

- **Bacteria:** Psychrotrophs spoil refrigerated foods; anaerobes degrade canned or vacuum-packed foods through gas and off-flavors.
- **Yeasts and Molds:** Spoil high-sugar, acidic, or low-water-activity foods by fermenting sugars or growing on surfaces, forming visible colonies.
- **Enzymatic and Metabolic Effects:** Spoilage microbes secrete enzymes that degrade proteins, fats, and carbohydrates, accelerating deterioration and shortening shelf life.

► **C. Microorganisms as pathogens**

Certain microorganisms cause infections or intoxications when consumed. Bacterial pathogens such as *Salmonella*, *Listeria*, and *E. coli* are responsible for foodborne diseases, while viruses like Norovirus and Hepatitis A/E spread through contaminated food and water. Parasites can also infect humans via contaminated produce or meat. These organisms represent critical safety hazards and demand strict preventive measures.

► **D. Microorganisms in nutrient cycling and food chemistry**

Microbes shape food chemistry through carbohydrate, protein, and lipid metabolism. These biochemical processes produce acids, gases, volatile compounds, and peptides that influence food flavor, aroma, and stability. While some of these activities are desirable, others promote spoilage.

► **E. Microorganisms in food processing and biotechnology**

Industrially, microbes are used for enzyme production, organic acid synthesis, vitamin formation, and flavor compound generation. They also serve as the foundation of starter cultures, which standardize fermentation and ensure consistent quality in processed foods.

► **F. Microorganisms as indicators of food quality and hygiene**

Indicator organisms such as coliforms and *E. coli* reveal contamination or inadequate sanitation. Total Plate Count (TPC) reflects the overall microbial load, while yeast and mold counts indicate spoilage potential. Monitoring these organisms is essential for maintaining food quality.

► **G. Microorganisms in food safety management**

Understanding microbial behavior is fundamental for risk assessment, predictive modeling, and the design of effective food safety systems. Environmental monitoring of surfaces, equipment, and water helps prevent contamination during food production.

1.1.3 Beneficial, harmful & neutral microorganisms

A. Beneficial microorganisms

Beneficial microbes play a positive role in food production by driving fermentation, enhancing nutritional value, improving flavors, and generating valuable metabolites. Lactic acid bacteria, yeasts, and molds are essential for dairy, bakery, beverage, and traditional fermented foods. Probiotics support gut health and immunity, while microbes used in biotechnology produce enzymes, organic acids, vitamins, amino acids, pigments, and flavor compounds for industrial food applications.

- **Fermentative microorganisms:** LAB, yeasts, and molds that carry out controlled fermentations, yielding stable, nutritious, and flavorful foods.
- **Probiotic microorganisms:** Beneficial microbes that support digestive health, modulate immunity, and contribute to functional food development.
- **Microorganisms used in biotechnology:** Microbes that produce essential industrial metabolites and enzymes for diverse food processes.

B. Harmful microorganisms

Harmful microorganisms cause spoilage, foodborne infections, intoxications, and toxin production. Pathogens include *Salmonella*, *Listeria*, *E. coli*, and viruses such as Norovirus. Mycotoxin-producing molds contaminate grains and nuts, while spoilage microbes degrade sensory quality.

- **Pathogenic microorganisms:** Bacteria, viruses, and parasites that pose significant health risks in food systems.
- **Toxin-producing microorganisms:** Certain molds and bacteria that produce toxins which remain harmful even after cooking.
- **Spoilage microorganisms:** Organisms that degrade food quality through metabolic activities causing undesirable sensory changes.

C. Neutral microorganisms

Neutral or commensal microorganisms neither benefit nor harm foods under normal conditions, but may become opportunistic spoilers when the environment changes. Many raw foods naturally contain environmental yeasts and soil bacteria that form the background microflora. Although usually harmless, they can affect microbial ecology and shelf-life if allowed to proliferate.

1.1.4 Applications of food microbiology in industry

A. Food fermentation and product development

Microorganisms are essential for producing fermented foods such as yogurt, cheese, bread, beer, wine, pickles, and traditional products. Fermentation improves shelf life, enhances flavor, increases digestibility, and adds functional benefits. Controlled starter cultures ensure consistent quality and predictable microbial activity.

B. Food preservation and shelf-life extension

Microbial knowledge guides the design of preservation systems including pasteurization, sterilization, UHT treatment, refrigeration, dehydration, and non-thermal methods such as HPP and cold plasma. Hurdle technology combines multiple preservation factors to inhibit microbial growth without compromising quality.

C. Quality control and microbiological testing

Food industries conduct microbial testing to monitor contamination, detect pathogens, and evaluate product stability. Techniques such as culture methods, rapid tests (PCR, ELISA), and environmental monitoring ensure safe manufacturing conditions and regulatory compliance.

D. Food safety management systems

Microbiology supports HACCP development, sanitation planning, risk assessment, and regulatory compliance. Knowledge of microbial hazards ensures proper preventive controls, hygiene practices, and monitoring during processing.

E. Industrial biotechnology and enzyme production

Microorganisms are employed to produce enzymes, organic acids, vitamins, pigments, and metabolites used in food processing. Starter cultures and microbial enzymes enhance processing efficiency and product quality.

F. Waste management and sustainability

Microbes help treat wastewater, degrade organic waste, and convert by-products into valuable items like biofuels and enzymes. Biopreservation using bacteriocins reduces dependence on chemical preservatives.

G. Innovation in novel and alternative foods

Food microbiology drives innovation in plant-based foods, precision fermentation, cultured meat, and microbiome-enhancing functional foods. Microbial systems help improve texture, flavor, and nutritional profiles of emerging food products.

- ✓ Almost all foods contain microorganisms, except a few sterile foods.
- ✓ Some microbes are desirable (fermentation), while others cause spoilage and disease.
- ✓ Studying microbes requires isolating them in pure culture and examining their morphological, physiological, biochemical, and genetic characteristics.

1.2 History and development of food microbiology

► Discovery of Microorganisms

Year	Scientist	Contribution
1658	Athanasius Kircher	Reported "minute living worms" in putrid meat and milk (microscope too weak to see bacteria)
1664	Robert Hooke	Described the structure of molds
1676–1683	Antony van Leeuwenhoek	First to observe bacteria; described cocci, bacilli, and spirilla; called them "animalcules"; reported to the Royal Society of London
1838	Ehrenberg	Introduced the term "bacteria"; proposed 16 species in 4 genera
1875	Ferdinand Cohn	Developed preliminary classification of bacteria; discovered bacterial spores
1940s	—	Viruses observed after invention of the electron microscope

The history of food microbiology is closely linked to fundamental discoveries in microbiology and humanity's practical need to preserve and consume food safely. It can be divided into four major periods.

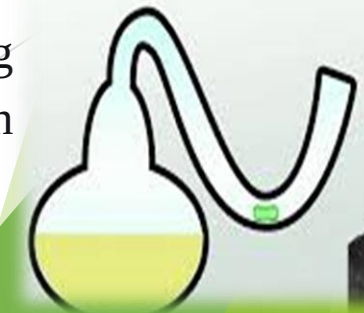
1.2.1. The empirical era: before the discovery of microbes (antiquity - 17th century)

- **Practices without scientific understanding:** People used empirical methods to preserve food and prevent its "rotting" or "spoilage."
- **Common techniques:** Drying, salting, smoking, fermentation (for bread, beer, wine, cheese, yogurt) and preservation in honey or vinegar.
- **Observation:** It was known that certain processes transformed food beneficially (fermentation) while others made it dangerous (rotting, poisoning), but the existence of the responsible microorganisms was entirely unknown.

1.2.2. The era of fundamental discoveries: the invention of the microscope and the "war of the generations" (17th - 19th century)

- **Antoni van Leeuwenhoek (1676):** By perfecting the microscope, he was the first to observe "animalcules" (bacteria and yeasts) in pepper water and later in beer. He opened the door to an invisible world.
- **"Spontaneous generation" vs "Biogenesis":** For centuries, it was believed that life (maggots, molds) could arise spontaneously from non-living matter.
 - **Francesco Redi (1668)** refuted this idea for maggots.
 - **Louis Pasteur (1850s-1860s)** delivered the final blow to this theory with his famous swan-neck flask experiment, proving that microorganisms came from the air and were responsible for fermentation and spoilage.
- **Louis Pasteur (Father of modern microbiology):**
 - **Pasteurization (1864- 1871):** He developed the process of moderate heating (pasteurization) to destroy pathogens and undesirable yeasts in wine and beer, and later in milk. This was a major advance for food safety.

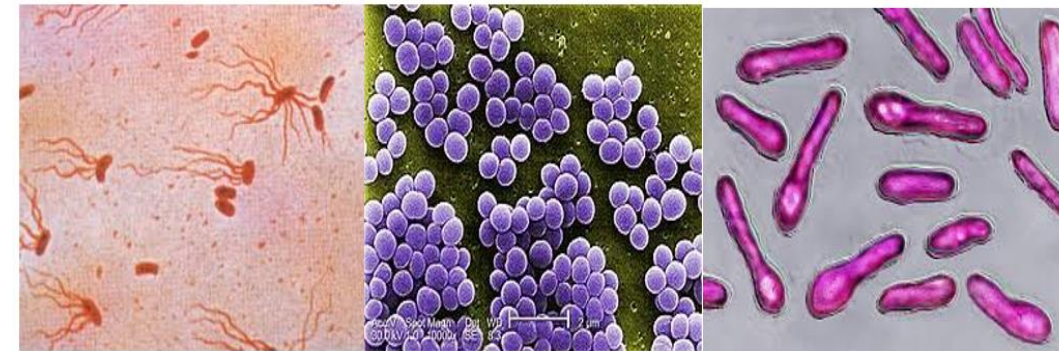
Swan-Necked Flask



1.2.3. The era of pathogens and prevention: the golden age of microbiology (late 19th - early 20th century)

This period saw the identification of specific pathogenic bacteria and the establishment of food safety principles.

- **Robert Koch (1870s-1880s):** He established "Koch's Postulates," a set of criteria to prove that a specific bacterium causes a specific disease.
- **Identification of the first foodborne pathogens:**
 - *Salmonella typhi* (typhoid fever) by Karl Joseph Eberth (1880).
 - *Staphylococcus aureus* by Friedrich Julius Rosenbach (1884).
 - *Clostridium botulinum* (botulism) and its toxin by Emile van Ermengem (1895).
- **Elie Metchnikoff (1908):** He studied lactic acid bacteria and proposed the idea of probiotics, linking the consumption of yogurt (with *Lactobacillus*) to longevity.



Salmonella typhi

Staphylococcus aureus

Clostridium botulinum

1.2.4. The modern era: control, safety, and regulation (20th century - present)

The focus is on prevention, understanding growth mechanisms, and implementing rigorous control systems.

- **Development of preservation systems:** Emergence of freezing, irradiation, and modified atmosphere packaging.
- **Hazard Analysis Critical Control Point (HACCP - 1960s):** Designed by NASA to ensure the safety of astronauts' food, HACCP became the most widespread food safety management system in the world. It is a preventive and systematic approach.
- **Molecular biology and genomics (late 20th - 21st century):**
 - Use of molecular biology techniques (PCR, sequencing) to rapidly detect and identify pathogens.
 - Study of the food microbiome to understand and improve fermentations and prevent spoilage.
 - Traceability and rapid investigation of foodborne disease outbreaks.
- **Focus on viruses and parasites:** Better understanding of the role of viruses (Norovirus, Hepatitis A) and parasites (*Cyclospora*, *Toxoplasma*) in foodborne illnesses.