Chapter 01

The Economic Importance of Microorganisms

1.1. Overview of Microorganisms

The term "microorganism" comes from the Greek words for "small organism." Indeed, microorganisms are tiny living organisms that are invisible to the naked eye and are found almost everywhere on Earth. They play a crucial role in nature but also cause many problems in the food industry. Their metabolic activity changes the composition of the food they infect. The term "microorganism" refers to bacteria, some fungi (molds, yeasts), and sometimes viruses (according to certain biologists). These organisms form a very diverse group (including both prokaryotes and eukaryotes), with the only common characteristics being their size and shape.

1.2. Different Types of Microorganisms

A) Bacteria

Bacteria are single-celled prokaryotic microorganisms (without a nucleus). Their genome consists of circular DNA (one chromosome and possibly plasmids). Bacteria can synthesize their own macromolecules and cell components from nutrients. They range in size from 0.1 to 10 micrometers and have a variety of shapes. For example, their cells can be round (cocci), elongated (bacilli), intermediate (coccobacilli), or spiral. Bacteria are found in most environments on Earth and reproduce through binary fission, where the parent cell divides into two identical daughter cells.

B) Fungi

Like bacteria, fungi are found in soil, water, and air. The term "fungi" includes edible and non-edible species such as mushrooms, morels, and others, which have a cap and a stem. However, we will focus on microscopic fungi, which are divided into yeasts and molds.

B.1. Yeasts

Yeasts are microscopic (6 to 10 microns), unicellular, eukaryotic fungi involved in the fermentation of animal or plant materials by converting sugars into alcohol and carbon dioxide. They mainly reproduce asexually (through budding or fission) and some can reproduce sexually. Yeasts can live in both aerobic (respiration) and anaerobic (fermentation) conditions. Yeast fermentation can cause swelling in some food products and result in an alcoholic fermentation taste.

B.2. Molds

Molds are microscopic (1 to 60 micrometers), filamentous, unicellular or multicellular, eukaryotic heterotrophic fungi (which obtain nutrients by breaking down organic matter or parasitizing a host). Molds reproduce asexually by releasing spores or sexually (in some species). A mold consists of a vegetative part that absorbs nutrients from the environment and reproductive structures used for multiplication. When food is stored improperly, molds can contaminate and degrade the food. Some molds can even release mycotoxins into the food, which can have serious health effects.

C) Viruses

A virus is a microscopic infectious biological entity that contains only one type of nucleic acid (DNA or RNA). It can only multiply by entering a cell. The size of viruses ranges from 20 to 300 nm.

1.3. Factors Influencing the Growth of Microorganisms

Several factors can influence the development and growth rate of bacteria.

A) Nutritional Requirements

For microorganisms to grow, the environment must contain all the necessary elements for their development. Bacteria need water, a carbon source, oxygen, hydrogen, nitrogen, sulfur, and phosphorus, which are mainly provided by sugars like glucose and mineral salts. Molds also require water but are less demanding. In fact, when the ambient humidity is high, some molds can attack dry foods like powdered milk or cereals.

B) Temperature Influence

Temperature has a significant impact on microorganism growth because cold can slow down microbial metabolism and even cause high mortality during freezing. Most bacteria grow rapidly between 20 and 45°C, but three types of bacteria are classified based on their optimal temperature:

- Psychrophiles: Their optimal growth temperature is below 20°C (they are involved in the degradation of dairy products and foods stored in cold conditions).
- Mesophiles: Their optimal growth temperature is between 20 and 45°C (these are the bacteria that can be harmful to humans).
- Thermophiles: Their optimal growth temperature is above 60°C. Refrigeration of food is effective in preventing foodborne illnesses because human body bacteria (mesophiles)

grow slowly at temperatures below 15°C. Likewise, most molds grow well between 15 and 25°C and stop growing under refrigeration, except for some species.

C) pH Influence

Microorganisms react differently to pH. Yeasts and molds can tolerate a wide pH range for growth (from 2 to 8.5), with an optimal pH between 4 and 6. Most bacteria multiply in neutral environments. When the pH is lower than 4.5, bacterial growth is inhibited. This is why acidic foods (such as lemons, vinegar, tomatoes, and oranges) preserve better, and vinegar is used for preserving some foods. Molds and yeasts grow on the surface of acidic fruits, while bacteria colonize meats and fish, which have a neutral pH.

D) Oxygen Influenc

Some bacteria only grow in the presence of oxygen (aerobes), while others only grow in the absence of oxygen (strict anaerobes). Others can grow in both oxygen-rich and oxygen-free environments (facultative anaerobes). Fungi are aerobic organisms, but some can grow anaerobically and thus deeper within foods.

E) Salt Influence

Since prehistoric times, salt has been used to preserve meat and fish because it reduces the multiplication of microorganisms. Salt draws in water and retains it. As a result, microorganisms are deprived of water and cannot grow. Salt thus has a bacteriostatic effect on most bacteria. However, some bacteria, known as halophiles, require high concentrations of salt to survive. Most molds can tolerate high levels of salt and sugar, meaning that very salty cured meats, jams, and candies can be infected.

F) Nutrient Influence

The composition of food favors the growth of different types of bacteria. For example, an opened fruit juice left at room temperature promotes yeast growth and causes alcoholic fermentation. In contrast, fresh milk will undergo lactic fermentation by bacteria.

1.4 The Economic Importance of Microorganisms

Microorganisms have been used for thousands of years in food processing (e.g., alcoholic beverages, bread, cheese). More recently, with the development of biotechnology, new processes have been created to use microorganisms for breaking down organic and mineral compounds to clean soil, water, and air. They are also used to produce valuable primary and secondary metabolites with important biological activities.

In the energy sector, where there is a need for renewable energy, microalgae are being explored as a promising source for biofuel production.

To make biofuels economically and environmentally viable, several challenges must be addressed:

- Reducing production costs.
- Optimizing yield through genetically modified microorganisms.
- Implementing safety measures to control the spread of microalgae in large-scale cultivation.
- Studying the impact of microalgae farming on greenhouse gas emissions.
- Identifying suitable locations for large-scale microalgae cultivation.

For profitable biomass production, microalgae are grown using different types of photobioreactors. To make biofuels commercially viable, the production cost should ideally be around €1 per kg of biomass.

1.5. Industrial Biotechnology

Industrial biotechnology mainly relies on fermentation and biocatalysis. Microorganisms (yeasts, algae, bacteria) or their components (mainly enzymes) act as small factories for production processes.

1.5.1. Biocatalysis

To speed up biochemical reactions, enzymes are used. They work quickly and precisely while being environmentally friendly, unlike chemical catalysts that require harsh conditions to function.

Enzymes act like tiny machines that bring molecules together to react. Similar to a key fitting into a lock, each enzyme works only on specific substances. Large-scale biocatalysis is replacing many polluting processes in industries such as paper, leather, textiles, and detergents.

1.5.2. Fermentation

In a controlled, oxygen-free environment, microorganisms (such as molds, yeasts, and bacteria) – whether genetically modified or not – transform organic substances like sugars and oils into a wide range of products. Choosing the right microorganism, monitoring its metabolism and growth, and scaling up production are key factors in fermentation.

Some well-known types of fermentation include:

- Alcoholic fermentation (conversion of sugars into alcohol).

- Acetic fermentation (conversion of alcohol into vinegar).
- Lactic fermentation (conversion of milk into cheese).

Fermentation has many industrial applications, including food production, chemistry, pharmaceuticals, agriculture, and environmental management.