

Introduction

Food products, whether of **animal or plant origin**, naturally undergo **microbiological and enzymatic deterioration** during storage. These alterations cause changes in **texture, color, and taste**, quickly rendering foods **unfit for consumption** by reducing their **nutritional and organoleptic quality**. In some cases, these alterations may even lead to **serious health problems**.

The characteristics of a food product influence its **keeping quality**. These characteristics may be **intrinsic** (inherent to the food itself) or **extrinsic** (related to environmental conditions). Therefore, in order to preserve food quality and extend shelf life, it is essential to **stabilize food products**. This process requires the application of **preservation treatments based on chemical or physical processes**.

Food preservation is a **very ancient practice** aimed at maintaining food quality for as long as possible. Preservation techniques range from the **classic methods** (sun drying, smoking, salting) to more recent ones developed through **technological advances**. The principle behind these methods is the same: to **modify one or more intrinsic or extrinsic factors** that determine **microbial growth or non-microbial spoilage mechanisms**. Over time, preservation techniques have become increasingly **sophisticated** as scientific progress has advanced.

Today, effective food preservation results from a successful **optimization of several requirements**: shelf life (marketing and distribution), scientific and technological factors (research and development constraints), cost (economic and commercial constraints), and food quality (regulatory requirements and consumer expectations)

What is Food Preservation?

Food preservation refers to the process of handling and preserving food using certain techniques that stop or slow down spoilage. Food preservation techniques help prevent loss of quality, nutritional value and edibility. These practices have been essential for centuries as they allow people to store food for future consumption. Methods of food preservation are followed by all companies in the food industry to extend the shelf life of their products. However, these techniques are not only required for increasing the shelf life. They are also crucial to reduce food waste. There are various types of food preservation methods. However, all these methods aim to preserve food.

Objectives of Food Preservation

Below are the major objectives of the 5 methods of food preservation.

- The primary objective of food preservation is to inhibit the growth of microorganisms in food using methods like drying, freezing, canning and refrigeration.
- Food preservation techniques help retain the nutritional value of food items for longer.

- Proper preservation of food allows to reduce the risk of foodborne diseases caused by pathogens.
- These techniques help extend the usability of food. They also minimise food wastage, which is essential for food sustainability and security.
- Methods of food preservation increase convenience as they allow to easily have prepared food without needing to cook it.

2/ Factors affecting the quality deterioration of foods

Food deterioration refers to any sudden change in the specific composition of a food, which **reduces its nutritional value** and makes it **unfit for consumption**. Several factors can promote food deterioration:

2.1/ Intrinsic factors

a) Water activity (A_w)

Water in foods can exist in **two forms: bound water (H_2O bound)** and **free water (H_2O free)**.

- **Bound water (H_2O bound):**
This water is an integral part of living cells, like proteins and carbohydrates (i.e., it is part of the food matrix). **Bacteria cannot use bound water**. Certain methods can reduce its level, such as the addition of solutes, ions, and hydrophilic colloids (gels), or by freezing, which crystallizes water.
- **Free water (H_2O free):**
This water is **necessary for bacterial growth** and is found both inside and mainly **outside the cells**. Free water participates in various reactions and supports the growth of microorganisms. The amount of available water in food, **quantified by water activity (A_w)**, can be used to **predict which types of microorganisms may develop**.

Bacteria require **more free water** than yeasts and molds to grow. The table below provides the **minimum water activity and water requirements of certain microorganisms at their optimal temperatures** (Table 1 shows the A_w values favorable to microbial activity in foods).

Water activity (A_w) enables a **food protection strategy** by controlling **physicochemical, enzymatic, and microbial deterioration**:

- $0 < A_w < 1$; A_w depends mainly on the **presence of dissolved substances** (sugars, salts) and **temperature** — it is **not the same as water content**.
- When **$A_w < 0.62$** , no microorganism can multiply (though survival is possible).

It should be noted that preservation techniques such as **dehydration, salting, sugar addition (jams), and freezing** largely rely on **reducing Aw**.

The concept of **water availability (free water)** in food can also be defined by:

- **Equilibrium Relative Humidity (ERH)**

$$\text{HRE} = \frac{\text{Pression partielle de la vapeur d'eau de l'aliment à la température } \theta}{\text{Pression partielle de la vapeur d'eau saturante à la température } \theta} \times 100$$

$$\text{HRE} = \frac{P_w}{P_{w0}} \times 100 \quad (1) \quad \text{or}$$

$$A_w = \frac{P_w}{P_{w0}} = \frac{\text{HRE}}{100} \quad (2)$$

Water activity (Aw) and **equilibrium relative humidity (ERH)** at the same temperature **T** are therefore **closely related**. For example, a relative humidity of **80% corresponds to a water activity of 0.8**.

Aw decreases as **binding forces become stronger**, and conversely tends toward **unity** when water approaches the **free state**. Water activity also allows for the **prediction and prevention of physicochemical deterioration, enzymatic activity, and microbial growth**.

Regarding microorganisms, **bacteria, yeasts, and molds** can only grow at Aw values higher than **0.91, 0.88, and 0.80**, respectively (see Table 1 above).

Water content and **Aw** are related parameters—the **higher the water content of a food, the higher its Aw**—but they are **not necessarily linearly correlated**. Foods with the same water content can have **different Aw values** (see below for some numerical examples of Aw).

Table 1: Water content and water activity of some foods

<i>food</i>	<i>Water content</i>	<i>Aw</i>
Fresh vegetables	95%	0,99
Frozen vegetables	94 %	0,81
jam	44 %	0,86
sweetened condensed milk	26 %	0,83

b) pH

Microorganisms are generally classified based on whether they can grow **below or above a pH of 4.5**. This value allows foods to be divided into two groups according to their ability to support the growth of major pathogenic bacteria. **Below pH 4.5, health risks are minimal**. Each microorganism has a **pH threshold** below which it cannot grow.

- **If 6 < pH < 7.5:** All microorganisms can survive (this is the pH of most foods).

- If $4.5 < \text{pH} < 6$: Only **acid-tolerant microorganisms** survive (this is the pH of many fruits).
- If $2.2 < \text{pH} < 4.5$: Microbial activity and survival are very limited (e.g., fruit concentrates like lemon).

Special types of microorganisms based on osmotic resistance:

- **Osmophilic species:** Can resist **high sugar concentrations**.
- **Halophilic species:** Can resist **high salt concentrations**.

c) Temperature

Microorganisms are classified according to their **optimal growth temperature** into different categories:

- **Psychrophiles:** $-5\text{ }^{\circ}\text{C}$ to $+15\text{ }^{\circ}\text{C}$
- **Mesophiles:** $+15\text{ }^{\circ}\text{C}$ to $+40\text{ }^{\circ}\text{C}$
- **Thermophiles:** $+40\text{ }^{\circ}\text{C}$ to $+55\text{ }^{\circ}\text{C}$

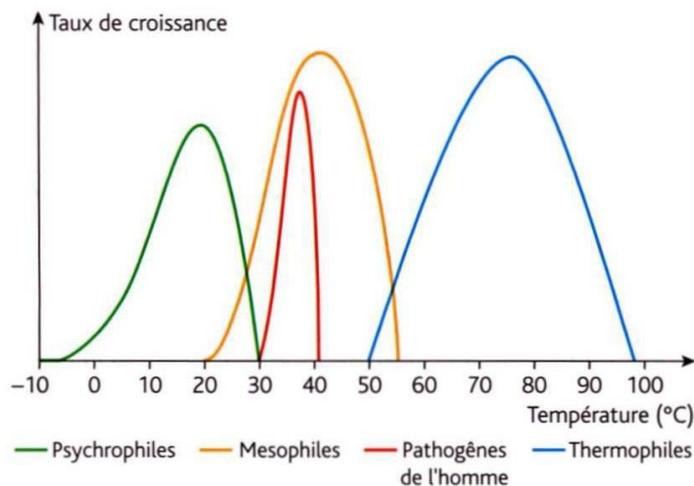


Figure 1: Temperature ranges of different microorganisms

The **doubling time** of microorganisms (the time it takes for their population to double) depends on temperature. For example, in **raw milk**, the doubling time varies with temperature as shown in the table below:

Examples:

- **Doubling time (tg) depending on temperature:**
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Temperature	7°C	20°C
Streptococcus	≥ 12h	1,3 h
Pseudomonas	4h	1,3 h

Escherichia	≥ 6	1,1 h
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The following table also shows **bacterial growth in raw milk after 24 hours**, depending on temperature:

- **Bacterial growth in 24 hours as a function of temperature ($N_0 = 2000$):**

<i>Temperature (°C)</i>	<i>N_{24h}</i>
4	2500
10	12000
20	500 000
35	2 500 000

d) Food composition

- Foods rich in **carbohydrates** (bread, jam, fruits...) are **favorable to fungi** (they generally produce little odor).
- Foods rich in **proteins and/or fats** (meat, butter...) are **favorable to bacteria**.

The main **food spoilage processes** are summarized in the table below:

Table 2: Food spoilage processes

Substrat	Aliment	Processus	Produits et effets
Pectine (polyoside)	Fruits/légumes	Pectinolyse	Méthanol, acides uroniques <i>Perte de structure, pourriture molle</i>
Protéines	Viande	Protéolyse, désamination	Amines biogènes (histamine, putrescine, cadaverine), H ₂ S, ammoniac, indole <i>Amertume, aigrissement, odeur nauséabonde, viscosité</i>
Lipides	Beurre	Hydrolyse des acides gras	Glycerol, acides gras mixtes <i>Rancissement, amertume</i>
Sucres	Féculeux	Hydrolyse	Acides organiques, alcools <i>Aigrissement, acidification</i>

c) **Redox potential (E):**

This parameter indicates the **availability of oxygen** in the food. Generally, **aerobic microorganisms** tolerate $E > 200$ mV, while **anaerobic microorganisms** tolerate $E < -200$ mV.

d) **Natural antimicrobial agents:**

Some foods contain natural **germ-inhibiting substances**, such as **lysozyme in milk**.

2.2 Extrinsic factors

a) Temperature and relative humidity:

An **optimal temperature** (depending on the type of microorganism) and **high relative humidity** favor microbial growth.

b) Presence of gases:

The presence of **oxygen** promotes the growth of surface-contaminating microorganisms. An **excess of CO₂** lowers pH and limits the growth of certain microbial agents.

3/ Types of food deterioration

a) Physical deterioration:

Caused by **shocks, injuries, changes in state, or variations in water content**, etc.

b) Biological deterioration:

Due to the **proliferation of microorganisms**, such as **bacteria** (pathogenic, e.g., *Salmonella*, or saprophytic, e.g., *E. coli*) or **fungi**, especially molds (*Penicillium*, *Aspergillus*). These microorganisms are responsible for **fermentations that alter food quality**, the production of **toxins** (e.g., **botulinum or staphylococcal toxins**), and **enzymes** such as **peroxidase**.

c) Biochemical deterioration:

Caused by **enzymes naturally present in foods**, responsible for **enzymatic browning, vitamin degradation** (e.g., vitamin C), **oxidation of lipids** (via lipoxygenase), and **lipolysis or hydrolysis of lipids** (via lipases).

d) Chemical deterioration:

Mainly represented by the **Maillard reaction**, which deteriorates the **nutritional and organoleptic quality** of foods. **Oxidation of unsaturated lipids** (in the presence of oxygen and metal ions) leads to the **degradation of biochemical, organoleptic, and nutritional properties** of the food