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Faculty of Natural Sciences and of Life and Earth Sciences

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# Course handout:

# AGRI-FOOD TECHNOLOGY

**Department:** Agronomic Sciences

**Option:** Animal Production

**Cycle:** Master 2

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# SUBJECT DATA SHEET

**Faculty:** Natural and Life Sciences and Earth Sciences

**Department:** Agricultural Sciences

**Specialization:** Animal Production

**Level:** Master

**Semester:** 3

**Methodology Unit 2**

**Subject:** Agri-food technology

**Credits: 4**

**Coefficient: 2**

**Course objectives:**

To teach students the processes used in the preservation and processing of animal products.

**Recommended prior knowledge:**

Biochemistry, microbiology, and nutritional qualities of animal products.

**Course content:**

Students will learn about the functioning of agri-food businesses and the manufacturing or processing of animal products.

# INTRODUCTION

Food products of animal origin occupy a central place in human nutrition, providing essential proteins, lipids, vitamins, and minerals that are fundamental to health and development. However, due to their complex biochemical composition and high water activity, these products are among the most perishable foodstuffs, making them particularly vulnerable to microbial, enzymatic, chemical, and physical alterations. Their preservation and processing have therefore always represented a major challenge for societies, not only from the perspective of public health and consumer safety but also regarding economic efficiency and year-round food availability.

Historically, humans developed empirical methods—such as salting, drying, smoking, and fermentation—to extend the shelf life of perishable foods. Over time, these practices have been refined and complemented by modern technologies, including pasteurization, sterilization, refrigeration, freezing, and, more recently, non-thermal techniques such as high hydrostatic pressure, irradiation, and pulsed electric fields. Today, food preservation extends beyond ensuring microbiological safety to encompass the preservation of nutritional value, sensory qualities, and technological functionality of raw materials.

This manual is designed to provide Master's students in Animal Production with a comprehensive overview of the principles and techniques used in the preservation and processing of animal-derived products. It explores the specific characteristics of major commodities—milk, meat, eggs, fish, and honey—while analyzing both traditional and innovative approaches. Particular emphasis is placed on the scientific foundations of these processes, their industrial applications, and their implications for food safety, quality control, and consumer health. The objective is to equip students with solid theoretical and practical knowledge, enabling them to critically evaluate preservation strategies, adopt appropriate technologies, and contribute to the sustainable development of the agri-food sector.

# CHAPTER I: PRESERVATION OF FOODSTUFFS OF ANIMAL ORIGIN

The preservation of foodstuffs of animal origin is a major challenge for both food safety and the economic development of the agri-food industry. Foods of animal origin, including meat, dairy products, eggs and fish products, are particularly perishable due to their nutrient-rich composition and high water content, which make them particularly favorable environments for microbial development.

Since prehistoric times, human beings have developed various techniques for prolonging the shelf life of foodstuffs. These methods have developed considerably and become more sophisticated over the centuries, evolving from traditional empirical techniques to modern technologies based on precise scientific knowledge.

## 1. Basic principles of food preservation

### 1.1. Definition and objectives

Food preservation encompasses all processes aimed at slowing down or preventing the deterioration of foodstuffs while maintaining their nutritional and organoleptic qualities. The main objectives are :

- Inhibit the growth of pathogenic and spoilage microorganisms
- Slowing down enzymatic and chemical weathering reactions
- Prevent unwanted physical changes
- Extending product lifespan
- Maintain sensory and nutritional characteristics

Preservation also responds to economic and logistical challenges, enabling food to be transported, stored and made available regardless of the season or geographical area of production.

## 1.2 Spoilage factors for foods of animal origin

Foods of animal origin are particularly sensitive to various types of spoilage:

- **Microbiological spoilage:** Caused by bacteria (*Salmonella, Listeria, Clostridium*, etc.), yeasts and molds. It is favored by the high nutrient content and water activity of these products. Microorganisms can lead to changes in appearance, odour, texture and taste, and in the case of pathogens, to food poisoning.
- **Enzyme alteration:** Endogenous enzymes naturally present in animal tissues (proteases, lipases) continue their activity after slaughter or fishing, causing changes in texture and taste, sometimes desirable (meat maturation) but often undesirable beyond a certain threshold.
- **Chemical alteration:** Mainly lipid oxidation, particularly problematic for fatty meats and fish, leading to rancidity and the formation of potentially toxic compounds.
- **Physical alteration:** Dehydration, migration of constituents, textural changes due to phase transitions (crystallization during freezing, for example).

## 1.3. Parameters influencing conservation

The stability of foods of animal origin depends on several intrinsic and extrinsic factors:

### a. Intrinsic factors

- pH: Most microorganisms thrive at a neutral pH. Acidification is therefore an effective barrier.
- Water activity (aw): Its reduction considerably limits microbial growth.
- Oxidation-reduction potential (Eh): Influences the nature of microorganisms capable of growth (aerobic vs. anaerobic).
- Nutritional composition: Protein, lipid content, etc.
- Presence of natural protective structures (shells, skins).
- Natural antimicrobial factors (lysozyme, lactoferrin in milk).

### b. Extrinsic factors

- Storage temperature
- Relative humidity

- Gas composition of the surrounding atmosphere
- Light exposure
- Potential cross-contamination

Conservation techniques aim to modify one or more of these parameters to create conditions unfavorable to deterioration.

## 2. Traditional preservation techniques

### 2.1 Salting and brining

Salting is one of the oldest methods of preservation, particularly suitable for meat and fish. Its principle is based on reducing water activity (aw) by adding salt (NaCl), creating an osmotic environment unfavorable to microorganisms. A distinction is made between :

- **Dry salting:** Direct application of salt to the surface of the product, with gradual penetration by diffusion. This technique is used for dried meat and dried-salted fish such as cod.
- **Brining:** Immersion of the product in a salt solution, sometimes enriched with spices, aromatics, sugars or nitrites/nitrates. This process is used for certain meat, bacon and cooked cured meats.
- **Brine injection:** direct introduction of the saline solution into the muscle mass using multi-needle injectors, enabling salt to be distributed more evenly and rapidly in large parts.

**Figure 1:** Cheese brining

**Figure 2:** Meat brine injection

At concentrations of 10-15%, salt effectively inhibits most pathogenic bacteria, although some halotolerant microorganisms may still develop. Nitrites and nitrates, often associated with the salting of meats, contribute to preservation by specifically inhibiting *Clostridium botulinum*, and are involved in the formation of the characteristic red color of cured products.

Salting considerably alters the organoleptic properties of products (flavor, texture) and can lead to a reduction in water-soluble vitamin content through leaching.

### 2.2. Drying and dehydration

Drying reduces the product's water content, lowering water activity to levels that inhibit microbial growth (generally <0.7). Several methods are used for animal products:

- **Natural drying:** Exposure to air, sun or wind, as in the production of traditional dried meats or certain dried fish.
- **Artificial drying:** Use of enclosures with controlled parameters (temperature, humidity, air speed):

- Hot-air drying (tunnels, ovens)
- Lyophilization (sublimation of water after freezing)
- Atomization (for liquid products such as certain dairy-based preparations)

**Figure 3:** Dehydrated meat

Drying affects the sensory and nutritional characteristics of products. It generally concentrates nutrients, but can lead to losses of oxidation-sensitive vitamins. Rehydration of dried products can be problematic, particularly for protein products such as meat.

### 2.3 Smoking

Smoking is a traditional process applied mainly to meat and fish, combining a drying effect with the deposition of compounds resulting from the incomplete combustion of wood. A distinction is made between :

- Cold smoking (temperature <30°C): Preferred for products eaten raw or lightly cooked (smoked salmon, smoked meat).
- Hot smoking (50-85°C): combines a partial cooking effect with the action of smoke (hot-smoked fish, certain sausages).

The conservative effects of smoking are manifold:

- Surface dehydration
- Antimicrobial action of phenolic compounds in smoke
- Antioxidant action of certain compounds
- Formation of a protective film on the surface

**Figure 4:** Smoking fish

The type of wood used (beech, oak, etc.) has a considerable influence on the organoleptic characteristics of the final product. Smoking also contributes to the characteristic golden color through Maillard reactions between carbonyl compounds in the smoke and surface proteins.

Health concerns about potentially carcinogenic polycyclic aromatic hydrocarbons formed during smoking have led to the development of purified smoke and liquid smoke substitutes.

### 2.4. Fermentation

Fermentation represents a special case where microbial alteration is directed and controlled to produce stable products with specific organoleptic characteristics. For products of animal origin, a distinction is made between :

- Lactic fermentation: Development of lactic bacteria that acidify the environment by producing lactic acid. This acidification inhibits pathogenic and spoilage germs. This process is used for :

- Fermented meat products (dry sausages, salami)
- Fermented dairy products (yoghurts, cheeses)

- Alcoholic and acetic fermentation: More rare for animal products, but present in certain traditional Asian preparations.

Fermentation offers several advantages:

- Preservation by acidification and/or dehydration
- Development of characteristic flavors
- Potential improvement in the digestibility and bioavailability of certain nutrients
- Production of antimicrobial substances (bacteriocins)

Traditional empirical fermentations have progressively evolved towards the use of selected ferments (starter cultures), enabling better control and standardization of the process.

## 3. Thermal techniques

### 3.1 Refrigeration and freezing

Cold treatments slow down or inhibit the enzymatic, chemical and microbiological reactions responsible for food spoilage.

❖ **Refrigeration (0 to +4°C**): Significantly slows down microbial growth without stopping it completely. It is suitable for short and medium-term storage (a few days to a few weeks depending on the product). Refrigeration:

- Generally preserves organoleptic and nutritional qualities
- Requires rapid processing after slaughtering/fishing (cold chain)

- May favour certain psychrotrophic microorganisms such as *Listeria monocytogenes*

❖ **Freezing and deep-freezing (-18°C and below):** Causes crystallization of available water, which :

- Stops virtually all microbial growth (bacteriostatic effect)
- Significantly slows down enzymatic and chemical reactions
- For long-term storage (several months)

The quality of frozen products strongly depends on the freezing speed:

- Slow freezing forms large ice crystals that damage cell structures
- Rapid freezing forms small, less damaging crystals

The main alterations during frozen storage are lipid oxidation and ice sublimation "freezer burn".

**3.2. Pasteurization**

Pasteurization is a moderate heat treatment designed to destroy non-spore-forming pathogenic microorganisms and significantly reduce spoilage flora. It extends shelf life while preserving the organoleptic and nutritional qualities of the products relatively well.

For products of animal origin, a distinction is made between :

❖ **Pasteurization of milk**

- Low pasteurization: 63-65°C for 30 minutes
- High pasteurization: 72-75°C for 15-20 seconds
- Micro-filtration + heat treatment: Combined technique for reducing the intensity of heat treatment

❖ **Pasteurization of egg products:** Typically 64-65°C for 2.5 minutes, with adjustments according to product pH.

❖ **Pasteurization of processed meat and fish products:** Application of variable scales depending on the product, generally with core temperatures of 65-70°C.

Pasteurization does not ensure product sterility, and must generally be combined with refrigerated storage to effectively extend shelf life. Its impact on nutritional qualities is limited, with a moderate loss of heat-sensitive vitamins (B1, C).

### 3.3. Sterilization and appertization

**Sterilization** aims to destroy all microorganisms, including bacterial spores, to achieve microbiological stability at room temperature over a long period. **Appertization** (canning) combines sterilization with hermetic packaging.

- **Conventional sterilization:** Treatment at temperatures above 100°C (generally 115-121°C) for varying lengths of time, depending on the product, its acidity and format. Sterilizing values (F0) are calculated to guarantee the destruction of the spores *of Clostridium botulinum*, considered the reference organism.
- **UHT (Ultra High Temperature) sterilization**: 135-150°C for a few seconds, followed by aseptic packaging. This technique, mainly used for milk and certain liquid products, reduces thermal impact while ensuring sterility.

The impact of sterilization on organoleptic and nutritional qualities is significant:

- Modification of aromas and colors (Maillard reactions)
- Texture modification (protein coagulation)
- Loss of heat-sensitive vitamins (30-80% depending on the vitamin)
- Possible formation of neoformed compounds

### 3.4. Vacuum cooking

Vacuum cooking is a technique combining vacuum packaging and moderate heat treatment. It involves :

1. Packaging the raw product in an airtight, heat-resistant container
2. Air extraction (vacuum)
3. Controlled, relatively low-temperature cooking (generally 65-90°C)

This technique offers several advantages for animal products:

- Preservation of organoleptic qualities (aromas, tenderness)

- Reduced weight loss during cooking
- Reduced lipid oxidation
- Prolonged refrigerated storage (generally 3-4 weeks)

From a microbiological point of view, the absence of oxygen limits the development of aerobic microorganisms, but can favor certain anaerobes. Precise control of time-temperature couples is therefore essential to guarantee food safety, particularly with regard to *Clostridium botulinum* and *Listeria monocytogenes*.

**4. Modern and emerging techniques**

**4.1 Irradiation**

Irradiation involves exposing food to ionizing radiation (gamma rays, X-rays or accelerated electrons) to destroy microorganisms and inhibit biological processes such as germination. Its effectiveness depends on the dose applied:

- Radurization (low dose, <1 kGy): Inhibits germination, delays ripening
- Radicidation (medium dose, 1-10 kGy): Eliminates non-spore-forming bacteria, including pathogens
- Radiation treatment (high dose, >10 kGy): Eliminates all microorganisms, including spores

For animal products, irradiation is mainly used for :

- Eliminate pathogens from fresh meat and poultry
- Extending the shelf life of seafood products
- Decontaminating dehydrated egg products

The advantages of this technology include :

- Cold treatment, without significant temperature rise
- Possibility of processing pre-packaged products
- Efficient product penetration

Despite these advantages, irradiation remains controversial due to negative consumer perceptions, and requires specific labeling in many countries. It can also induce certain organoleptic changes, notably characteristic aromas due to lipid radiolysis.

### 4.2 High hydrostatic pressures

High-pressure processing (HPH) involves subjecting pre-packaged foods to pressures of 100 to 1000 MPa, generally between 400 and 600 MPa, for a few minutes. This non-thermal technology :

- Inactivates pathogenic and spoilage microorganisms through protein denaturation, cell membrane modification and enzymatic inactivation
- Preserves heat-sensitive compounds (vitamins, flavors)
- Maintains product freshness and organoleptic quality

Applications for foods of animal origin include :

- Decontamination of sliced meats and delicatessen products
- Extending the shelf life of fresh and processed seafood products
- Dairy product treatment to inactivate pathogens while preserving sensory qualities

High pressures mainly affect the non-covalent bonds of macromolecules, which explains their limited effect on small molecules such as vitamins and aromatic compounds. However, they can modify the structure of proteins and thus the texture of certain products (Campus, 2010).

### 4.3. Pulsed electric fields

Pulsed electric field (PEF) technology involves applying brief, high-intensity electrical pulses (10-50 kV/cm) to a product placed between two electrodes. These pulses cause electroporation of the microorganisms' cell membranes, leading to their inactivation.

This technology is particularly well suited to liquid and semi-liquid products of animal origin:

- Milk and liquid dairy products
- Liquid egg products
- Emulsions based on animal products

CEP benefits include :

- Non-thermal or moderate-temperature treatment
- Preserving nutritional and sensory qualities
- Lower energy consumption than heat treatments

However, the effectiveness of CEP is limited against bacterial spores and in products with a high fat content or low electrical conductivity. This technology is often used in combination with other preservation techniques.

**4.4 Active and intelligent packaging**

Active and intelligent packaging represents an innovative approach to the preservation of foodstuffs of animal origin:

❖ **Active packaging:** Intentionally interacts with the product or its environment to improve shelf life:

- Oxygen absorbers: Reduce lipid oxidation and inhibit aerobic microorganisms
- $CO_2$) emitters/absorbers: $CO_2$ has antimicrobial properties
- Antimicrobial films: Incorporating substances such as lysozyme, nisin or essential oils
- Moisture regulators: particularly useful for meats and cheeses

❖ **Intelligent packaging:** Monitor food condition and provide information on quality and safety:

- Time-temperature indicators (TTI): Signal breaks in the cold chain
- Freshness indicators: Detect weathering metabolites (amines, $CO_2$)
- Biosensors: specifically detect certain pathogens

These technologies enable more targeted and adaptive preservation, responding to the specific requirements of each product. They can also help to reduce food waste by providing more accurate information on the actual state of the product than simply the use-by date.

## 5. Preservation by additives and preservatives

### 5.1. Chemical preservatives

Chemical preservatives are substances intentionally added to food to inhibit the development of microorganisms and extend shelf life. For products of animal origin, the main authorized preservatives include :

❖ **Organic acids and their salts :**

- Lactic acid (E270) and lactates (E325-327): Used in meat products, act by acidification
- Acetic acid (E260) and acetates (E261-263): For marinades and certain preparations
- Sorbic acid (E200) and sorbates (E201-203): Effective against yeasts and moulds, used on the surface of cheeses and cured meats.

❖ **Nitrites and nitrates (E249-252):** Essential in cured meats for :

- Inhibit *Clostridium botulinum*
- Stabilize the red color of meats (formation of nitrosomyoglobin)
- Contribute to the development of the characteristic aroma

Their use is strictly regulated due to the risk of formation of potentially carcinogenic nitrosamines.

❖ **Sulfites (E220-228):** Mainly used for crustaceans, inhibit enzymatic browning and have antimicrobial action.

The choice of preservatives depends on many factors: product pH, organoleptic compatibility, regulations, microbiological target. Changing consumer expectations towards "clean label" products are driving the industry to seek alternatives to conventional chemical preservatives.

### 5.2. Bioconservation

Biopreservation uses naturally occurring or intentionally added microorganisms and/or their metabolites to inhibit undesirable flora and extend shelf life. For products of animal origin, it is mainly based on :

Lactic acid bacteria: Produce organic acids, hydrogen peroxide and bacteriocins. Used in :

- Fermented products (yogurts, cheeses, sausages)
- Certain fresh meat preparations as natural preservatives

Bacteriocins: Antimicrobial peptides produced by certain bacteria:

- Nisin (E234): Effective against Gram-positive bacteria, used in processed cheeses and certain meat products.
- Pediocins: Active against *Listeria monocytogenes*
- Sakacins, lacticins, etc.

Protective cultures: strains selected for their antimicrobial activity but which, unlike ferments, do not significantly alter the organoleptic properties of the product.

Bio-conservation offers several advantages:

- A "natural" image that meets consumer expectations
- Often targeted action spectrum, preserving useful technological flora
- Possible synergistic effects with other preservation techniques

Its limitations include a generally lower efficacy than chemical preservatives and a possible influence on organoleptic qualities.

### 5.3. Antioxidants

Antioxidants are substances that delay or prevent lipid oxidation, thus protecting animal products against rancidity and deterioration of sensory qualities. They fall into two categories:

❖ **Synthetic antioxidants :**

- BHA (E320, butylated hydroxyanisole)
- BHT (E321, butylated hydroxytoluene)
- Gallates (E310-312)
- TBHQ (E319, tert-butylhydroquinone)

Effective and stable, they are nevertheless used less and less due to consumer concerns about chemical additives.

❖ **Natural antioxidants**

- Tocopherols (vitamin E, E306-309): Extracts from plant sources
- Ascorbic acid (vitamin C, E300) and ascorbates (E301-302)
- Plant extracts rich in polyphenols: rosemary (E392), tea, grapes, etc.
- Proteins and peptides with antioxidant activity

Antioxidants are particularly important for products rich in polyunsaturated fatty acids, such as certain fish, and for products with a long shelf life. Their effectiveness depends on many factors: concentration, time of application, interaction with other ingredients, processing conditions and storage.

## 6. Impact of preservation methods on quality

### 6.1. Nutritional qualities

Preservation techniques can significantly affect the nutritional value of foods of animal origin:

❖ **Protein**

- Heat treatment: Denaturation modifies digestibility (improvement at moderate temperature, decrease at high temperature).
- Maillard reactions: formation of compounds between amino acids and reducing sugars, reducing the bioavailability of certain amino acids, particularly lysine.
- High pressures: Generally limited structural changes

❖ **Lipids**

- Oxidation: Degradation of polyunsaturated fatty acids during heat treatment or prolonged storage.
- Hydrolysis: release of free fatty acids modifying the organoleptic profile

❖ **Vitamins**

- Water-soluble vitamins (B, C) : Sensitive to heat treatment and leaching
- Fat-soluble vitamins (A, D, E, K): More heat-stable but sensitive to oxidation

- ❖ **Minerals:** Generally stable, but their bioavailability may be altered by interactions with other food components formed during storage.

The nutritional impact varies considerably from one technology to another:

- Non-thermal technologies (HPP, CEP) generally preserve nutrients better
- Fermentation can improve the bioavailability of certain nutrients
- Freezing preserves most nutrients if storage conditions are optimal.

**6.2. Organoleptic qualities**

Preservation methods have a considerable influence on the sensory properties of foods of animal origin:

- ❖ **Color**

- Heat treatments: browning (Maillard reactions), pigment denaturation (myoglobin in meats)
- Salting with nitrites: Stabilizing the red color of meats
- Smoking: Formation of coloured compounds on the surface
- Irradiation: Possible discoloration of red meats

- ❖ **Texture**

- Heat treatments: Coagulation of proteins, loss of water (hardening or tenderization depending on intensity)
- Freezing: formation of ice crystals that can damage cell structures
- Drying: Concentration of constituents and modification of rheological properties
- HPP: Modification of protein structures that can affect tenderness

- ❖ **Aroma and flavour**

- Development of cooking aromas during heat treatment
- Formation of specific aromatic compounds during smoking and fermentation
- Possible appearance of oxidative flavors during storage
- Altered perception of saltiness, acidity, etc., depending on the preservatives used

Traditional methods such as fermentation, salting or smoking are often used deliberately for their organoleptic effects as much as for their preservative properties. Modern technologies generally aim to minimize organoleptic changes, except in cases where such changes are desired.

### 6.3. Service life

The shelf life of a food product is the period during which it remains safe from a health point of view and retains acceptable organoleptic qualities under defined storage conditions.

For foods of animal origin, shelf life depends on a number of factors:

❖ **Intrinsic factors**

- Initial product composition (water content, pH, etc.)
- Initial microbial load
- Presence of endogenous enzymes

❖ **Factors related to preservation treatments**

- Nature and intensity of treatment
- Combining several techniques ("barrier" concept)
- Homogeneity of treatment in the product

❖ **Conditioning factors**

- Type of packaging (gas permeability, water vapor permeability, etc.)
- Modified/controlled atmosphere
- Active or intelligent packaging

❖ **Factors related to storage conditions**

- Temperature and fluctuations
- Relative humidity
- Light exposure

Lifetime estimation methods include :

- Accelerated ageing tests

- Microbial challenge tests
- Predictive modeling
- Monitoring chemical or physical weathering markers

Optimizing shelf life requires an integrated approach, often combining several preservation technologies adapted to the specific characteristics of the product.

# CHAPTER II: MILK PRESERVATION AND PROCESSING

Milk has been a mainstay of the human diet for thousands of years. A complete food produced by mammals, it is a precious source of essential nutrients such as proteins, lipids, carbohydrates, minerals and vitamins. Milk processing and preservation represent an area of constant technological innovation, with major challenges in terms of nutrition, taste, economics and the environment.

## 1. Milk definition

Milk is a white, opaque liquid with a slightly sweet taste, making it a complete and balanced food. It is secreted by the mammary glands of female mammals. The most commonly used type of milk is cow's milk, but humans also consume goat's, sheep's, buffalo and camel's milk, depending on the country.

The designation "milk", without indication of the animal species from which it comes, is reserved for cow's milk. Any milk from a dairy female other than a cow must be designated by the name "milk" followed by an indication of the animal species from which it comes: "goat's milk", "sheep's milk", etc.

- **Legal definition of milk**: Milk was defined at the first International Congress for the Repression of Fraud in Geneva, in 1908, as the entire product of the total and uninterrupted milking of a healthy, well-nourished and not overworked dairy cow. It must be collected cleanly and be free of colostrum.

## 2. Composition and physico-chemical properties of milk

### 2.1 Chemical composition

Milk is a complex emulsion made up of water (87%), fat (3.5-4%), protein (3.3-3.5%), lactose (4.8-5%), minerals (0.7%) and vitamins. Composition varies according to species, breed, feed, stage of lactation and health status.

- **Dairy proteins:** These are mainly divided into two groups: caseins (80%) and serum or whey proteins (20%). Caseins are organized in micelles, spherical structures stabilized by colloidal calcium phosphate. Serum proteins, mainly β-lactoglobulin, α-lactalbumin, serum albumin and immunoglobulins, remain soluble in serum.

- **Fat:** It takes the form of globules (2-5 µm) enveloped by a phospholipid membrane. It is 98% triglyceride, with over 400 different fatty acids identified, including a significant proportion of saturated fatty acids (70%) and a minor but nutritionally important fraction of unsaturated fatty acids (30%).
- **Carbohydrates:** Lactose, a disaccharide composed of glucose and galactose, is the main carbohydrate in milk (4.8%). Its concentration remains relatively stable between species. Its sensitivity to heat treatment has a considerable influence on the properties of processed products.
- **Minerals and vitamins:** Milk contains macronutrients (Ca, P, K, Na, Mg) and trace elements (Zn, Fe, Cu, Se), as well as fat-soluble vitamins (A, D, E, K) and water-soluble vitamins (B1, B2, B6, B12, C).

### 2.2 Physical structure

Milk is a complex colloidal system that simultaneously presents :

- A fat-in-water emulsion
- A colloidal suspension of casein micelles
- A true solution of lactose, serum proteins, soluble minerals and minor compounds

This three-dimensional structure has a direct influence on the behavior of milk during processing.

### 2.3 Sensory properties

The organoleptic characteristics of milk are :

- **Color:** dull white to slightly yellowish.
- **Taste**: slightly sweet with a hint of fat.
- **Odor**: characteristic, not very pronounced.
- **Texture:** fluid with a slight viscosity.

These sensory properties are influenced by composition, in particular fat content, and can be significantly modified by heat treatment or fermentation.

### 2.4 Microbiological characteristics

Raw milk is an excellent culture medium for many microorganisms. These include :

- **Spoilage flora:** psychrotrophs (*Pseudomonas* spp.), responsible for spoilage of chilled milk
- **Technological flora**: lactic acid bacteria (*Lactococcus, Lactobacillus, Streptococcus*), essential for the manufacture of fermented products.
- **Pathogenic flora:** potentially present in raw milk (*Listeria monocytogenes*, *Salmonella* spp., *Escherichia coli* O157:H7, *Staphylococcus aureus*)

Controlling this flora is a major challenge for preservation and processing.

In Algeria, official microbiological standards for raw milk have been established by governmental authorities, setting threshold limits for potentially hazardous microorganisms, with specific parameters published in the Algerian Official Journal (Table 1).

**Table 1:** Microbiological criteria for raw milk (J.O.R.A. 2017).

| **Microorganisms** | **Microbiological limits (CFU(1)/g or CFU/ml)** |
|---|---|
| Aerobic bacteria at 30 °C | $3.10^6$ |
| Coagulase-positive staphylococci | $10^3$ |
| Thermotolerant coliforms | $5.10^3$ |
| *Salmonella* | Absent in 25 ml |
| *Listeria monocytogenes* | 100 |

## 3. Conventional milk preservation methods

### 3.1 Refrigeration

Refrigeration is the first barrier to microbial multiplication. Keeping milk at temperatures between 0 and 4°C considerably slows the growth of most mesophilic bacteria, but does not completely halt the development of psychrotrophs. This method extends the shelf-life of raw milk from 24-48 hours to 5-7 days.

The cold chain, from producer to consumer, is a major challenge. Modern refrigeration systems can cool milk from 35°C to 4°C in less than 30 minutes after milking, significantly limiting initial bacterial multiplication. However, this method has its limitations:

- Selection of psychrotrophic flora producing heat-resistant enzymes (lipases, proteases)
- Significant energy costs

- The need for appropriate infrastructures

### 3.2 Pasteurization

Pasteurization is a moderate heat treatment designed to destroy non-spore-forming pathogenic microorganisms and significantly reduce spoilage flora. Several time-temperature combinations are used:

- Low-level pasteurization: 63-65°C for 30 minutes (rarely used industrially)
- High pasteurization: 72-75°C for 15-20 seconds
- Ultra pasteurization: 85-90°C for 1-2 seconds

HTST treatment, carried out continuously in plate heat exchangers, is now the industry standard. This process enables milk to be kept for 5 to 15 days under refrigeration, with only a moderate impact on its nutritional and organoleptic properties.

### 3.3 Sterilization and UHT

The aim of these treatments is to completely destroy the vegetative and spore-forming forms of microorganisms, enabling them to be stored for long periods at room temperature.

❖ **Sterilization in containers:** Packaged milk undergoes treatment at 110-120°C for 10-20 minutes, generally in a rotary autoclave. This treatment causes significant changes:

- Browning (Maillard reaction)
- Strong cooked taste
- Near-total denaturation of serum proteins
- Significant vitamin loss (30-80% of vitamins B1, B6, B12, C)

❖ **UHT (Ultra High Temperature) treatment:** The milk is heated to 135-150°C for 2-8 seconds in a continuous flow, then aseptically packaged. Two methods are used:

- Direct UHT: steam injection followed by vacuum cooling
- Indirect UHT: heat exchangers without direct contact

UHT treatment causes fewer alterations than conventional sterilization, with 70-80% denaturation of serum proteins and moderate vitamin losses. Shelf-life reaches 3-6 months at room temperature.

### 3.4 Evaporation and concentration

The aim of these processes is to reduce the water content of milk, thus enabling :

- Better preservation.
- Reduced storage and transport volumes.
- Standardization of certain cheese production processes.

❖ **Vacuum evaporation:** Milk is heated under reduced pressure (50-70°C), allowing water to evaporate at low temperature. This process produces concentrated milks (containing 30-35% dry matter) or sweetened concentrated milks (with the addition of 40-45% sucrose), which can be stored for several months.

❖ **Membrane concentration:** Ultrafiltration (UF) and reverse osmosis (RO) enable selective concentration of milk components without intense heat treatment. UF concentrates proteins and fats while allowing lactose and minerals to pass through, while RO retains all components except water.

### 3.5 Dehydration

Dehydration consists in removing almost all the water from the milk (up to 96-98%), producing a powder that is stable at room temperature for several months.

❖ **Spray drying:** Pre-concentrated milk is sprayed into a drying tower through which a stream of hot air (160-200°C) flows. The droplets dehydrate instantly, forming powder particles. This technique is particularly suited to large-scale industrial production.

❖ **Roller drying:** Concentrated milk is applied to rotating heated rollers, forming a film that rapidly dehydrates. The dried product is then broken down into flakes or powder.

❖ **Lyophilization**: Drying technique involving the sublimation of previously frozen water, for maximum preservation of organoleptic and nutritional qualities. Its high cost limits its industrial use to high value-added products.

Milk powders can be whole (26% fat), partially skimmed or skimmed (<1.5% fat), instant (agglomerated), or enriched with specific components.

## 4. Modern preservation technologies

### 4.1 Microfiltration

Microfiltration (MF) is a membrane technology using membranes with pores of 0.1 to 10 µm. In the dairy industry, MF with 1.4 µm membranes eliminates over 99.5% of bacteria from milk without significantly altering its composition or organoleptic properties.

### 4.2 High hydrostatic pressures

High hydrostatic pressure (HPH) treatment is a non-thermal technology that subjects milk to pressures of 300-800 MPa for a few minutes. This treatment inactivates pathogenic and spoilage microorganisms, while preserving the product's nutritional qualities:

- Destruction of microorganisms by membrane rupture and protein denaturation
- Preservation of vitamins and heat-sensitive aromatic compounds
- Limited change in organoleptic properties
- Variable enzyme inactivation (depending on the pressure applied)

This process is mainly used for high value-added products, due to its high investment cost.

### 4.3 Pulsed electric fields

Pulsed electric field (PEF) technology involves applying high-intensity electrical pulses (15-40 kV/cm) to milk for very short periods (microseconds). This treatment causes electroporation of the microorganisms' cell membranes, resulting in their destruction without any significant rise in temperature.

Key benefits include:

- Minimal impact on heat-sensitive components
- Low energy consumption
- Optimum preservation of sensory properties

A 3 to 5 log10 reduction in total microbial flora can be achieved, with particular efficacy against Gram-negative bacteria. However, the technology shows limitations against spores and certain resistant microorganisms, often requiring a combination with other preservation processes (barrier technology).

### 4.4 Pulsed light and UV

- **Pulsed light:** This technology uses intense flashes of light (200-1100 nm spectrum) of very short duration (μs) and high intensity. The antimicrobial effect is attributed mainly to the UV fraction of the spectrum, which causes lesions in microbial DNA.
- **UV treatment:** UV-C irradiation (wavelength 254 nm) is particularly effective against microorganisms. This technology is mainly used as a complement to other treatments.

These technologies are particularly well suited to the surface treatment of packaging and the disinfection of water used in the dairy industry, with emerging applications for the direct treatment of milk.

### 4.5 Active and intelligent packaging systems

- **Active packaging:** These systems deliberately interact with the product or its environment to extend shelf life:
  - Oxygen absorbers
  - CO emitters/absorbers$_2$
  - Humidity controllers
  - Antimicrobial systems (incorporation of agents such as nisin, essential oils)
- **Intelligent packaging:** monitors product condition and provides information on quality:
  - Time-temperature indicators (TTI)
  - Freshness indicators based on the detection of microbial metabolites
  - Leak detectors
  - RFID systems with integrated sensors

Recent innovations include active biodegradable materials and nanocomposites enabling controlled release of antimicrobial agents, significantly extending the shelf life of dairy products.

## 5. Milk processing: fermented dairy products

### 5.1 Yogurts and fermented milks

Fermented milks result from the action of specific microorganisms on milk, causing acidification by fermentation of lactose and conferring particular organoleptic characteristics.

❖ **Yogurt:** Produced by the fermentation of milk by *Streptococcus thermophilus* and *Lactobacillus bulgaricus*. The process includes:

1. Milk standardization (dry matter, fat content)
2. Homogenization
3. Heat treatment (90-95°C, 3-5 min) promotes texture by denaturing serum proteins
4. Inoculation and fermentation (42-45°C, 3-4h) to pH 4.5-4.6
5. Rapid cooling and conditioning

A distinction is made between:

- Firm yogurt: pot fermentation
- Brewed yogurt: fermented in vats, then stirred
- Drinkable yogurt: diluted stirred yogurt

❖ **Other fermented milks:**

- Kefir: alcoholic and lactic fermentation by a complex microbial consortium
- Koumis: fermented mare's milk
- Skyr: Icelandic fermented condensed milk
- Lben: traditional Maghreb fermented milk

Fermented milks offer a number of nutritional advantages, including improved digestibility, greater calcium bioavailability and probiotic content.

### 5.2 Cheese

Cheeses are made by coagulating milk, draining it and then maturing it. There are over 1,000 varieties worldwide, classified according to:

❖ **Coagulation mechanism :**

- Cheeses with enzymatic coagulation: action of rennet on casein (pressed cheeses, blue-veined cheeses)
- Lactic coagulation cheeses: acidification by fermentation (fromage frais)
- Mixed coagulation cheeses: combination of the two mechanisms (Camembert, Brie)

❖ **Manufacturing technology :**

1. Milk preparation: standardization, optional homogenization, heat treatments
2. Coagulation: addition of ferments, rennet or other coagulating enzymes
3. Curd processing: cutting, stirring, heating if necessary
4. Draining: moulding, pressing for certain varieties
5. Salting: in bulk, dry or brine
6. Refining: controlled conditions (time, temperature, humidity) with specific microbial development

Cheese-making involves complex biochemical transformations:

- Proteolysis: protein degradation
- Lipolysis: fat hydrolysis
- Glycolysis: carbohydrate metabolism
- Deacidification: consumption of lactic acid

These reactions contribute to the development of the texture and aromas characteristic of mature cheeses.

### 5.3 Butter and cream

❖ **Cream:** Emulsion of fat in water obtained by centrifugal skimming of milk. It can undergo various treatments:

- Standardization (fat content: 12-55%)
- Homogenization (emulsion stabilization)
- Heat treatment (pasteurization, UHT)

- Fermentation (sour cream)

❖ **Butter:** Water-in-fat emulsion (16-18% water in 80-82% fat) obtained by churning cream. The production process includes :

1. Physical ripening: fat crystallization at low temperature
2. Biological ripening (optional): fermentation by lactic acid bacteria
3. Churning: phase inversion of the emulsion
4. Kneading: eliminates residual buttermilk and distributes water evenly
5. Packaging

Variants include :

- Salted butter (0.5-2% salt)
- Low-fat butter (39-41% fat)
- Concentrated butter or ghee (>99% fat)

Butter has special nutritional characteristics: it is rich in vitamins A, D, E and K, and contains easily digestible short-chain fatty acids.

**5.4 Fermentation process control**

Fermentation control is essential to guarantee the quality and consistency of fermented dairy products:

❖ **Selection of microbial cultures**

- Mesophilic ferments (*Lactococcus*, *Leuconostoc*): 20-30°C
- Thermophilic ferments (*Streptococcus thermophilus, Lactobacillus*): 40-45°C
- Refining ferments (*Penicillium, Geotrichum, Brevibacterium*)
- Probiotics (*Lactobacillus acidophilus, Bifidobacterium)*

❖ **Optimization of fermentation parameters**

- Temperature and time
- Initial and final pH

- Redox potential
- Medium composition (dry matter content, inhibitors)

❖ **Online control**

- Continuous pH measurement
- Titratable acidity analysis
- Viscosimetry
- Near infrared spectroscopy
- Metabolic activity monitoring ($CO_2$) production, $O_2$consumption)

Recent developments include cultures with defined metabolic activity, protective cultures against pathogens and automated fermentation control systems.

## 6. Milk processing: unfermented products

### 6.1 Ice cream

Ice creams are complex emulsions, aerated and frozen. Their manufacture involves:

1. **Formulation**: blend of ingredients (milk, cream, sugars, emulsifiers, stabilizers, flavourings)
2. **Pasteurization:** 80-85°C for 20-30 s
3. **Homogenization:** 15-20 MPa to reduce fat globule size
4. **Maturation:** 4-5°C for 4-24h for fat crystallization and protein hydration
5. **Simultaneous foaming and freezing**: incorporation of air (30-120% overrun) and rapid freezing (-5 to -7°C)
6. **Curing:** freeze at -35/-40°C to reach a final temperature of -18°C

The quality of ice cream depends on the complex structure developed during the manufacturing process:

- Ice crystals (25-30%)
- Air bubbles (50%)
- Partially coalesced fat globules (5-15%)

- Concentrated, viscous aqueous phase

Common defects include large ice crystals (granular texture) and shrinkage during storage. Current research is focusing on the use of natural cryoprotectants and the reduction of sugar and fat content.

**6.2 Infant milk**

Infant formulations aim to be as close as possible to the composition of breast milk:

1. **Modification of the protein fraction**
    - Reduction in total protein content
    - Adjusting the casein/serum protein ratio
    - Enrichment with α-lactalbumin
    - Partial hydrolysis to improve digestibility
2. **Modification of the lipid fraction**
    - Partial substitution of milk fat
    - Incorporation of vegetable and fish oils
    - Addition of long-chain polyunsaturated fatty acids
    - Structuring triglycerides
3. **Carbohydrates**
    - Lactose as the main carbohydrate
    - Addition of prebiotic oligosaccharides (FOS, GOS)
4. **Micronutrients:** iron, zinc and vitamin enrichment in accordance with nutritional recommendations

Production generally includes:

- Mixing and dissolving ingredients
- High-pressure homogenization
- Heat treatment (UHT or sterilization)

- Spray drying
- Inert atmosphere packaging

Recent innovations include the incorporation of bioactive compounds (lactoferrin, probiotics) and the development of specific formulations for particular needs (premature babies, allergies).

### 6.3 Whey and whey derivatives

Whey, a by-product of cheese production, is now valued for its nutritional and functional properties:

❖ **Primary treatment**

- Pasteurization or microfiltration
- Clarifying and degreasing
- Concentration by evaporation or membrane techniques
- Demineralization (ion exchange resins, electrodialysis)
- Spray drying

❖ **Derivative products**

1. **Whey powders**: simple, demineralized or deproteinized
2. **Protein concentrates (WPC**): 35-80% protein
3. **Protein isolates (WPI**): >90% protein
4. **Individual proteins:** β-lactoglobulin, α-lactalbumin, lactoferrin
5. **Lactose:** food, pharmaceutical
6. **Lactose derivatives:** lactulose, lactitol, lactobionic acid

Whey proteins have excellent functional (solubility, foaming, emulsification, gelation) and nutritional (rich in essential amino acids, digestibility) properties. They are used in numerous food applications (dairy products, bakery products, prepared dishes) and nutraceuticals (sports supplements, clinical nutrition).

### 6.4 Caseins and caseinates

Caseins can be extracted from milk by..:

- **Acidic route:** precipitation at pH 4.6 (isoelectric point)
  - Chemical acidification (HCl, $H_2SO_4$)
  - Biological acidification (lactic acid fermentation)
- **Enzymatic pathway:** action of rennet on casein κ

Acid caseins are converted to caseinates by neutralization with bases (Na, K, Ca), improving their solubility and functional properties.

- **Applications**
  - Food industry: dairy products, bakery, confectionery
  - Glues and adhesives
  - Edible coatings and films
  - Nutritional supplements
  - Encapsulation vectors for bioactive compounds
- **Functional properties**
  - Emulsifying power
  - Water retention capacity
  - Gel and film formation
  - Thermal stability

Casein phosphopeptides are being studied for their calcium transport properties and bioactive effects.

## 7. Impact of processes on nutritional quality

### 7.1 Effects of heat treatment

Heat treatment induces various biochemical changes affecting the nutritional value of milk:

❖ **Protein**

- Serum protein denaturation: 5-15% in HTST pasteurization, 70-80% in UHT, >90% in sterilization
- Formation of complexes between serum proteins and caseins
- Maillard reactions: blocking available lysine
- Formation of lysinoalanine and other neoformed compounds

❖ **Vitamins:** Sensitivity varies according to vitamin and treatment

- Thermolabile vitamins: $B_1$, $B_6$, $B_{12}$, C, folates
- Thermostable vitamins: A, D, E, K, $B_2$
- Vitamin losses: 10-20% in HTST pasteurization, 20-50% in UHT, >50% in sterilization for certain vitamins.

❖ **Minerals**

- Partial precipitation of calcium and phosphate
- Reduced calcium bioavailability

❖ **Lactose**

- Formation of lactulose (heat treatment indicator)
- Maillard reactions with proteins
- Isomerization (epimerization)

The severity of changes increases with the intensity of heat treatment, progressively affecting nutritional and functional properties.

**7.2 Consequences of non-thermal processes**

Non-thermal technologies generally offer better preservation of nutritional quality:

❖ **Microfiltration**

- Preservation of native vitamins and enzymes
- Protein and fat retention

- Reduced soluble calcium losses

❖ **High pressure**

- Preservation of water- and fat-soluble vitamins
- Moderate serum protein denaturation
- Preservation of essential amino acids
- Potential improvement in protein digestibility

❖ **Pulsed electric fields**

- Minimal impact on vitamins and bioactives
- Preserving the functional properties of proteins
- Maintaining organoleptic characteristics

❖ **Pulsed light and UV**

- Limited effect on proteins and carbohydrates
- Potential lipid oxidation
- Possible degradation of certain vitamins ($B_2$, A)

These technologies enable us to produce "fresh-like" products that combine microbiological safety with the preservation of nutritional qualities.

**7.3 Improving nutritional profiles**

Technological innovations aim to improve the nutritional profile of dairy products:

❖ **Enrichment**

- Vitamins (D, A)
- Minerals (calcium, magnesium)
- Omega-3 fatty acids
- Fibre and prebiotics
- Phytosterols

❖ **Reduction of unwanted elements**

- Fat content
- Cholesterol
- Lactose
- Sodium

❖ **Specific processes**

- Selective microfiltration
- Fractionation and recombination
- Encapsulation of bioactive compounds
- Fermentation with specific probiotic strains
- Enzymatic hydrolysis (lactose, allergenic proteins)

These approaches make it possible to develop functional dairy products that meet consumers' specific nutritional needs.

**8. Analytical methods for quality control**

**8.1 Physicochemical analysis**

❖ **Overall composition**

- Fat: Gerber method, Rose-Gottlieb, infrared spectroscopy
- Proteins: Kjeldahl, infrared spectroscopy, colorimetry
- Lactose: enzymatic methods, HPLC, infrared spectroscopy
- Dry matter: drying, infrared

❖ **Protein characterization**

- Electrophoresis (SDS-PAGE, IEF)
- Chromatography (HPLC, GPC)
- Spectroscopy (fluorescence, circular dichroism)
- Immunoassays (ELISA)

❖ **Lipid characterization**

- Chromatography (GC, HPLC)
- NMR spectroscopy
- Analytical indices (peroxide, TBA, p-anisidine)
- Differential Scanning Calorimetry (DSC)

❖ **Physical parameters**

- pH and titratable acidity
- Density
- Freezing point
- Viscosity and rheology
- Zeta potential
- Particle size (light scattering)

These methods can be used to characterize the composition and functional properties of dairy products, ensuring their compliance with specifications.

**8.2 Microbiological analysis**

❖ **Microbial enumerations**

- Total flora: non-selective media (PCA)
- Psychrotrophic flora
- Coliforms and *E. coli*
- Coagulase-positive staphylococci
- Lactic acid bacteria
- Yeasts and molds

❖ **Pathogen detection**

- *Salmonella* spp.
- *Listeria monocytogenes*

- *Bacillus cereus*
- *Cronobacter sakazakii* (infant formula)

❖ **Analytical techniques**

- Conventional cultivation methods
- Immunological methods (ELISA, immunofluorescence)
- Molecular methods (PCR, real-time PCR)
- Biosensors
- Flow cytometry
- MALDI-TOF MS

❖ **Detection of microbial spoilage**

- Enzyme activities (lipases, proteases)
- Volatile compounds of microbial origin
- pH and acidity

These analyses are essential to guarantee the microbiological safety and stability of dairy products during storage.

# CHAPTER III: MEAT PRESERVATION AND PROCESSING METHODS

Meat is a highly perishable foodstuff due to its composition (rich in water, proteins and lipids), which makes it an excellent substrate for microbial development. Without appropriate preservation methods, it deteriorates rapidly, leading to considerable economic losses and presenting major health risks.

Meat preservation and processing represent major challenges for the food industry. These processes aim to extend the shelf life of meat products while preserving their nutritional and organoleptic qualities, as well as developing new products to meet consumer expectations.

## 1. Biochemical and microbiological characteristics of meat

### 1.1. Meat composition and structure

Meat is mainly made up of muscle, connective and adipose tissue. Its average composition is as follows

- Water: 65-80
- Protein: 16-22%.
- Lipids: 1.5-13%.
- Carbohydrates: <1
- Minerals: 1-1.5%
- Vitamins: in varying quantities

This nutrient-rich composition makes meat a particularly suitable medium for microbial growth. In addition, its post-mortem pH (generally between 5.4 and 5.8) and high water activity (aw > 0.98) provide favorable conditions for many microorganisms.

### 1.2. Alteration mechanisms

Meat spoilage is the result of several phenomena:

1. **Microbiological alteration**: development of bacteria (Pseudomonas, Acinetobacter, Enterobacteriaceae), yeasts and molds, leading to undesirable organoleptic changes.

2. **Biochemical alteration**: lipid oxidation leading to rancidity and the production of foul-smelling volatile compounds.
3. **Enzymatic alteration**: the action of endogenous enzymes (proteases, lipases) causes changes in texture and flavor.

The rate of weathering depends on intrinsic factors (pH, water activity, redox potential) and extrinsic factors (temperature, atmosphere, handling).

### 1.3.Factors influencing conservation

The main factors affecting meat preservation are :

- **Temperature**: the most decisive factor, directly influencing the speed of biochemical reactions and microbial growth.
- **pH**: affects protein stability and microbial growth.
- **Water activity (aw)**: its reduction limits microbial development.
- **Oxidation-reduction potential**: influences the type of microorganisms able to grow.
- **Presence of additives or preservatives**: may specifically inhibit certain alteration reactions.

Controlling these factors forms the basis of the various preservation technologies.

## 2. Traditional preservation methods

Traditional meat preservation methods have developed empirically over the centuries. They are based on three main principles: the removal of water, the addition of preservatives and heat treatment.

### 2.1.Salting and brining

Salting uses sodium chloride (NaCl) to reduce the water activity of the meat and exert a specific antimicrobial action. There are two main techniques:

- **Dry-salting**: direct application of salt to the surface of the meat, used for dried meats and cured meats.
- **Brining**: immersion of meat in a saline solution, sometimes enriched with spices, sugars or nitrites/nitrates.

The preservative action of salt is explained by :

- Osmotic dehydration of microbial cells
- Disruption of microbial enzyme systems
- Reducing oxygen solubility in the aqueous phase

Effective concentrations are generally between 2% and 10% salt, depending on the product.

**2.2.Drying**

Drying consists in eliminating part of the water available in the meat, thus reducing the water activity (aw) to values below 0.80 for certain products. Dehydration is achieved by natural or controlled evaporation.

Traditional techniques include :

- Air-drying (hot, dry climates)
- Sun drying (especially for biltong in South Africa)
- Drying in ventilated chambers (a more controlled technique)

Critical drying parameters are temperature, relative humidity and air speed. Drying too quickly can lead to surface hardening, which impedes subsequent evaporation (crusting).

**2.3.Smoking**

Smoking involves exposing meat to smoke produced by the incomplete combustion of wood, generally hardwoods such as beech or oak. This technique combines several conservative effects:

- Antimicrobial effect due to phenolic compounds, aldehydes and organic acids
- Antioxidant effect thanks to phenolic compounds
- Partial surface dehydration
- Characteristic flavours

There are different types of smoking:

- Cold smoking (≤ 30°C): mainly for preservation
- Hot smoking (50-85°C): preservative effect and partial cooking

- Electrostatic smoking: modern method using an electric field to deposit smoke particles

However, traditional smoking has the disadvantage of depositing potentially carcinogenic compounds (polycyclic aromatic hydrocarbons), the levels of which need to be monitored.

### 2.4.Fermentation

Meat fermentation relies on the activity of lactic acid bacteria, which convert available sugars into lactic acid, thus acidifying the environment. This process offers several advantages:

- Low pH inhibits undesirable microorganisms
- Production of bacteriocins by certain strains
- Development of characteristic aromatic compounds
- Improved protein digestibility

The best-known fermented products are dry sausages, salamis and certain meats. Fermentation can be :

- Spontaneous: due to naturally occurring flora
- Directed: by addition of selected starter cultures (*Lactobacillus, Pediococcus, Staphylococcus*)

The microbiological safety of fermented products depends on the right combination of acidification, drying and the possible addition of nitrites.

## 3. Modern conservation technologies

Modern meat preservation methods aim to extend the shelf life of products while preserving their nutritional and organoleptic qualities, often with minimal impact on their sensory characteristics.

### 3.1.Refrigeration and freezing

#### a. Refrigeration

Refrigeration (0 to 4°C) is the most widespread short-term preservation method. It considerably slows down enzymatic reactions and microbial development, without stopping them completely.

The critical parameters are :

- Temperature, ideally maintained between 0 and 2°C
- Relative humidity, generally between 85% and 95%.
- Air speed, which influences the surface evaporation rate

For fresh meat, shelf life under refrigeration varies from :

- 2-4 days for minced meat
- 3-5 days for poultry
- 5-7 days for beef, depending on packaging

The cold chain must be maintained from slaughterhouse to consumer to guarantee safety and quality.

**b. Freezing**

Freezing converts available water into ice crystals, effectively inhibiting enzymatic reactions and microbial growth. Recommended temperatures are:

- Quick freezing : -30 to -40°C
- Storage: -18°C minimum

The quality of frozen meat is highly dependent on :

- Freezing speed: rapid freezing forms small crystals that are less damaging to cell structures.
- Temperature fluctuations during storage
- Protection against dehydration (freezer burn)

Despite its advantages, freezing alters some of the meat's properties:

- Water loss on thawing (exudate)
- Texture changes due to protein denaturation
- Long-term lipid oxidation

Shelf life varies from 4 months (minced meat) to 12 months (red meat in pieces) under optimal conditions.

### 3.2.Modified atmosphere packaging (MAP)

Modified atmosphere packaging involves replacing the air in the packaging with a specific gas mixture to inhibit the main mechanisms of spoilage.

**Figure 5:** Modified atmosphere packaging of meat.

#### a. Main gases used

- **Carbon dioxide ($CO_2$)**: bacteriostatic action through acidification of the medium and enzymatic inhibition. Effective concentrations: 20-60%.
- **Nitrogen ($N_2$)**: inert gas used primarily to prevent packaging collapse.
- **Oxygen ($O_2$)**: maintains the bright red color of oxymyoglobin in red meats (concentrations of 70-80% for fresh meat).
- **Carbon monoxide (CO)**: stabilizes red color by forming carboxymyoglobin (limited and regulated use).

#### b. Typical gas mixtures

- Fresh red meat: 70-80% $O_2$, 20-30% $CO_2$
- Poultry meat: 30% $CO_2$, 70% $N_2$
- Cooked meats: 30-50% $CO_2$, 50-70% $N_2$

The advantages of MAP include significantly extended shelf-life (7-14 days for fresh red meat), reduced additives and attractive product presentation. However, this technology requires selectively permeable packaging materials and can encourage the development of pathogenic anaerobic bacteria if the cold chain is broken.

### 3.3.Active and intelligent packaging

#### a. Active packaging

Active packaging deliberately interacts with the product or its environment to enhance its preservation. The main technologies include :

- **Oxygen absorbers**: bags or films containing ferrous compounds that capture residual oxygen.
- **$CO_2$ emitters/absorbers**: regulate $CO_2$ concentration in the packaging.
- **Moisture absorbers**: limit the accumulation of water conducive to microbial growth.
- **Antimicrobial packaging**: incorporates substances such as essential oils, lysozyme or bacteriocins into the packaging film.

These technologies extend shelf life by 50 to 200%, depending on the application.

#### b. Smart packaging

Intelligent packaging provides information on product status through :

- **Time-temperature indicators (TTI**): change color according to cumulative exposure to heat.
- **Freshness indicators**: react to weathering metabolites (biogenic amines, $H_2S$).
- **Leak indicators**: signal a rupture in modified atmosphere packaging.
- **RFID labels**: enable logistics tracking and can integrate temperature sensors.

These systems facilitate quality management throughout the supply chain, and can reduce food waste.

### 3.4.High-pressure treatments

High Pressure Processing (HPP) subjects meat to pressures of 300-600 MPa for a few minutes. This non-thermal technology offers several advantages:

- Effective microbial inactivation without thermal alteration
- Preservation of sensory qualities (taste, color)
- Preservation of heat-sensitive nutrients

- Can be applied to pre-packaged products

HPP acts mainly on :

- Microbial cell membranes
- Cellular enzymes and proteins
- Certain sub-cellular structures

Commercial applications include sliced deli products, marinated meats and prepared meat dishes. HPP increases shelf life by 2 to 5 times compared with conventional methods.

However, this technology can modify certain characteristics of raw meat (partial denaturation of myofibrillar proteins, bleaching due to denaturation of myoglobin) and requires expensive equipment.

### 3.5.Irradiation

Irradiation involves exposing meat to ionizing radiation (gamma rays, X-rays or accelerated electrons) to reduce the microbial load. Depending on the doses applied, a distinction is made between :

- **Radurization** (< 2.5 kGy): reduces weathering flora
- **Radicidation** (2.5-10 kGy): eliminates non-spore-forming pathogens
- **Radiation sterilization** (> 10 kGy): commercial sterilization

Benefits include:

- Efficacy against major food pathogens (*Salmonella, E. coli* O157:H7*, Listeria*)
- Cold treatment (no significant rise in temperature)
- Can be used on packaged and frozen products
- Little change in sensory properties at low doses

Despite its proven efficacy, irradiation faces limited consumer acceptance. In the European Union, its use is restricted and subject to specific labeling. Maximum authorized doses generally vary between 3 and 7 kGy, depending on the country and the product.

## 4. Meat processing

Meat processing encompasses all the processes used to obtain processed meat products from fresh meat. These processes modify the structure and properties of the raw material to develop new organoleptic and functional characteristics.

### 4.1.Ground meat products

#### a. Features and processes

Ground meat products are obtained by grinding meat to varying degrees of fineness, mixed with various ingredients. The main types are :

- **Simple minced products**: minced steak, burger (coarse grain size)
- **Fresh sausages**: minced and seasoned meat, stuffed into natural or artificial casings.
- **Emulsified products**: frankfurters, mortadella (fine granulometry)

Transformation involves several key stages:

1. Mechanical grinding (cutter, chopper)
2. Blend with functional ingredients (salt, phosphates, non-meat proteins)
3. Forming (casing, molding)
4. Heat treatment (cooking, smoking)

#### b. The role of functional ingredients

- **Salt (NaCl)**: extraction of myofibrillar proteins, increased water retention capacity
- **Phosphates**: raise pH, improve binding capacity and tenderness
- **Non-meat proteins**: texture enhancement (soy proteins, caseinates)
- **Texturing agents**: stabilizers (starches, carrageenans, gums)
- **Nitrites/nitrates**: color development, antimicrobial, antioxidant effect

The stability and texture of these products are highly dependent on the formation of a stable protein network and on the water-fat balance.

### 4.2.Brined and restructured products

#### a. Cooked meat

Cooked meat is the result of a process combining brining and cooking:

1. **Brine preparation**: mixture of water, salt, nitrite/nitrate, sugars, phosphates and flavourings
2. **Brine injection**: pressurized introduction of 10-12% brine
3. **Churning**: mechanical massage to promote brine penetration and protein extraction
4. **Molding**: shaping in special molds
5. **Cooking**: generally in stages to a core temperature of 68-72°C
6. **Rapid cooling**: crucial for microbiological safety

The quality of cooked meat depends mainly on :

- Raw material quality (ultimate pH, water retention capacity)
- Protein extraction efficiency
- Controlling cooking parameters

#### b. Restructured products

Restructured products are made from pieces of meat of varying sizes that are bound together to form a cohesive structure. Bonding mechanisms include:

- **Protein binding**: extraction of myofibrillar proteins forming a cohesive gel during cooking
- **Mechanical connection**: entanglement of muscle fibers
- **Additional binding**: use of binding agents such as alginates and transglutaminase

These products make it possible to add value to parts of lesser commercial value by creating high value-added products (restructured escalopes, roasts).

### 4.3.Dried and fermented products

#### a. Dried sausages and salamis

Dry sausages are fermented and dried products, characterized by :

1. **Mixture** of ground meat, fat, salt, nitrite/nitrate, sugars, spices.
2. **Fermentation**: acidification by lactic acid bacteria (pH 4.8-5.4)
3. **Drying/maturation**: controlled dehydration to a weight loss of 30-40%.

The critical process parameters are :

- Temperature and relative humidity during fermentation and drying
- Acidification rate
- Dehydration kinetics

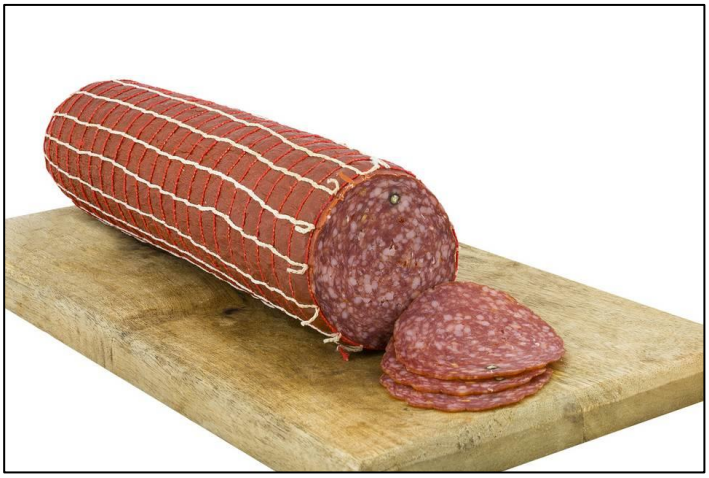

**Figure 6:** Dried salami

Quality and safety depend on hurdle technology: acidification, aw reduction, nitrite action, presence of natural antimicrobial compounds.

**b. Dried meats**

Dried meats include products such as dry-cured meat, Bündnerfleisch, biltong and jerky. Their manufacture involves :

1. **Preparation**: slicing, salting, adding spices
2. **Maturation/fermentation**: development of organoleptic characteristics
3. **Drying**: gradual reduction in aw to 0.85-0.92

**Figure 7:** Dried meat.

The quality of these products is based on a balance between :

- Proteolysis (aroma development)
- Lipolysis (aroma development but risk of oxidation)
- Dehydration (preservation but risk of excessive hardening)

Technological parameters must be adapted to each type of product, according to regional traditions and desired characteristics.

# CHAPTER IV: EGGS AND EGG PRODUCTS: QUALITY, PRESERVATION AND PROCESSING

Eggs are one of the most complete and widely consumed foods in the world. Its culinary and nutritional versatility make it a fundamental component of the human diet. It is also an important raw material for various food industries. This duality, between direct food and processed ingredient, underlines the importance of a thorough understanding of its composition, alteration mechanisms and preservation and processing technologies.

## 1. Egg composition and structure

### 1.1. Physical structure

The hen's egg, a standard reference in the food industry, has a complex, functional structure. With an average weight of 58-60 g, it comprises three main parts: the shell (11%), the albumen (58%) and the yolk (31%).

The shell, composed mainly of calcium carbonate (94%), forms a semi-permeable protective barrier. Its porous structure (7,000 to 17,000 pores) allows gas exchange while limiting microbial entry. It is covered by a protein cuticle that reinforces this protection.

The egg white is divided into four concentric layers of different viscosities:

- External liquid white (23%)
- Thick white (57%)
- Internal liquid white (17%)
- Chalazes (3%), protein cords that hold the yolk in a central position

The yolk is surrounded by a vitelline membrane and has a concentric layered structure with alternating light and dark areas. This organization reflects the yolk formation process in the hen's ovary.

### 1.2. Biochemical composition

#### a. Egg white

The white is made up of 88% water and 12% protein. The main proteins are :

- Ovalbumin (54% of spawn proteins), a phosphorylated glycoprotein with gelling properties
- Ovotransferrin (12%), an iron-chelating protein with antimicrobial properties
- Ovomucoid (11%), protease inhibitor
- Lysozyme (3.5%), an enzyme with antibacterial properties
- Ovomucin (1.5%), a glycoprotein responsible for the white's viscosity

White also contains minerals (0.5%), mainly sodium, potassium and chlorine, as well as traces of water-soluble vitamins.

**b. Egg yolk**

Yellow has a more complex composition:

- Water (51%)
- Lipids (33%), including 65% triglycerides, 28% phospholipids and 5% cholesterol
- Proteins (16%), mainly low-density lipoproteins (LDL, 70%) and high-density lipoproteins (HDL, 16%)
- Minerals (1%), including phosphorus, calcium and iron
- Carotenoid pigments (xanthophylls), responsible for yellow color
- Fat-soluble vitamins (A, D, E, K) and water-soluble vitamins (B)

This composition makes egg yolk an excellent natural emulsifier, thanks to its phospholipids and lipoproteins.

### 1.3. Nutritional value

Whole eggs are a concentrated source of essential nutrients. For an average 60 g egg :

- Energy: approx. 75-80 kcal
- Protein: 6.5 g of high biological value
- Fat: 5-6 g, of which 1.5-2 g saturated fatty acids
- Cholesterol: 200-210 mg
- Micronutrients: vitamins A, D, E, B2, B12, folic acid, choline, selenium, iodine, iron

Egg protein is the benchmark for assessing dietary protein quality, thanks to its balanced amino acid profile and excellent digestibility.

## 2. Assessing egg freshness

### 2.1. Quality criteria

Egg freshness is assessed according to a number of physical and chemical criteria that evolve after laying. These criteria are essential in determining the commercial quality and safety of eggs.

#### a. External criteria

- Shell integrity and cleanliness
- No cracks or splits
- Uniform appearance and color
- Shell strength

#### b. Internal criteria

- Inner tube height (increases with age)
- Yellow index (ratio of yellow height to diameter)
- Haugh units (measurement of white quality based on the height of thick white)
- White pH (increases from 7.6 to 9.2-9.7 with ageing)
- Position of yolk (central in a fresh egg)
- Appearance and mobility of chalazes
- Absence of inclusions (blood or meat stains)

### 2.2. Valuation methods

**a. Non-destructive methods**

1. **Mirage**: Examination of the egg through transparency using a light source. Allows you to observe the size of the inner tube, the mobility of the yolk and the presence of inclusions or cracks.

**Figure 8:** Mirage for eggs.

2. **Buoyancy**: A simple test based on the egg's density, which decreases with age as the inner tube increases. A fresh egg remains at the bottom of a container of water, while an older egg floats.
3. **Acoustic methods**: Analysis of shell vibratory properties, correlated with freshness.
4. **Spectroscopic techniques**: NIR and hyperspectral spectroscopy for non-invasive evaluation of internal parameters.

**b. Destructive methods**

1. **Measuring Haugh units**: calculation based on the height of the thick white and the weight of the egg. $HU = 100 \times \log(h - 1.7w^{0,37} + 7.6)$ where h is the height of the thick white in mm and w is the weight of the egg in g.
2. **Yolk index**: Ratio of yolk height to diameter.
3. **Measuring pH**: The pH of the spawn rises rapidly after oviposition (from 7.6 to 9.2-9.7) due to the loss of $CO_2$.
4. **Microbiological analysis**: Detection of internal bacterial contamination.

**3. Egg alteration**

**3.1. Physico-chemical changes**

The egg undergoes various physico-chemical changes after laying, affecting its quality and functional properties.

**a. Evolution of white**

- **Fluidification**: Progressive degradation of ovomucin, leading to a reduction in the viscosity of the thick white.
- **Alkalination**: pH increase (7.6 to 9.2-9.7) due to $CO_2$ diffusion through the shell
- **Protein modifications**: Partial denaturation and conformational changes affecting functional properties
- **Reduced antimicrobial activity**: Reduced effectiveness of protective systems (ovotransferrin, lysozyme)

**b. Yellow evolution**

- **Weakening of the vitelline membrane**: Decreased resistance and increased permeability
- **Water migration**: Transfer of water from white to yellow, increasing its refractive index.
- **Flattening** : Decrease in yolk index due to water absorption and weakening of the yolk membrane.
- **Lipid oxidation**: formation of volatile compounds responsible for undesirable odors, favored by pH increase

**c. Evolution of the inner tube**

- **Volume increase**: Expansion due to contraction of egg contents and evaporation of water through the shell.
- **Expansion rate**: Approx. 0.4 mm/day at room temperature, influenced by relative humidity and temperature

### 3.2. Microbiological contamination

Eggs can be contaminated in two main ways:

**a. Vertical contamination (trans-ovarian)**

- Infection of the ovary or oviduct before shell formation
- Main pathogens: *Salmonella enterica* serovar *Enteritidis*, *Salmonella Typhimurium*

- Mechanism: colonization of the laying hen's reproductive organs

**b. Horizontal contamination (post-sponing)**

- Microbial penetration through the shell
- Facilitated by: cracked shell, damaged cuticle, condensation on the shell
- Microorganisms concerned: bacteria (*Pseudomonas, Escherichia coli, Staphylococcus*), molds (*Penicillium, Aspergillus*)
- Contributing factors: high humidity, temperature fluctuations, improper handling

**c. Natural defense mechanisms**

Eggs have several antimicrobial barriers:

- **Physical barrier**: shell and shell membranes
- **Chemical barrier**: alkaline pH of the spawn
- **Biological barriers**: antimicrobial proteins in spawn
    - Lysozyme: hydrolysis of bacterial peptidoglycans
    - Ovotransferrin: iron sequestration for bacterial growth
    - Ovomucoid and ovoinhibitor: protease inhibitors
    - Avidin: binding of biotin, an essential cofactor

**d. Factors influencing alteration**

❖ **Environmental factors**

- **Temperature**: Significant acceleration of chemical reactions and microbial growth with increasing temperature
- **Relative humidity**: Influence on water evaporation through the shell
- **Atmospheric gas composition**: $CO_2$, $O_2$ content (oxidation)
- **Light**: Catalysis of lipid oxidation reactions

❖ **Intrinsic factors**

- **Initial shell quality**: thickness, porosity, cuticle integrity

- **Age and diet of the hen**: Influence on egg composition and structure
- **Genetics**: Variations between breeds and lines of hens
- **Herd health**: Impact on vertical contamination

## 4. Egg preservation

### 4.1. Traditional methods

Historically, various methods have been developed to extend the shelf life of eggs in the absence of refrigeration:

**a. Immersion preservation**

- **Liming**: Immersion in a solution of slaked lime (calcium hydroxide), creating a pore-clogging deposit.
- **Water glass**: Immersion in a sodium silicate solution, forming a protective film
- **Oil immersion**: covering the shell with mineral or vegetable oils to limit gas exchange
- **Brine**: Preservation in concentrated saline solution

**b. Dry storage**

- **Burial**: In ash, salt, sand or sawdust
- **Coating**: Application of waterproofing substances (wax, resins, animal fats)
- **Preservation in cereals**: Traditional practice of burying eggs in cereal grains.

These traditional methods, although less efficient than modern technologies, may still be of interest in certain rural areas or as craft techniques.

### 4.2. Modern technologies

Today's egg preservation methods are based mainly on the control of environmental parameters and surface treatments:

**a. Refrigeration**

- **Optimum temperature**: 0-4°C
- **Relative humidity**: 85-90%.
- **Avoid fluctuations**: Prevent condensation on the shell

- **Positioning**: Conservation points down to keep yellow centered

**b. Surface treatments**

- **Washing**: Removal of surface contaminants, followed by rapid drying
- **Modern coating**: Application of edible oils, chitosan or protein solutions to form antimicrobial films
- **UV treatment**: Surface decontamination using ultraviolet radiation
- **Modified atmosphere packaging**: Packaging under inert gases ($N_2$, $CO_2$) limiting oxidation and microbial growth.

**c. In-shell pasteurization**

Developed relatively recently, this technology significantly reduces the microbial load without altering the egg's functional properties:

- Controlled heat treatment (57-59°C for 50-60 minutes)
- 5-log reduction in *Salmonella* without protein coagulation
- Preservation of functional properties (overrun, coagulation, emulsification)
- Increase shelf life to 12-16 weeks under refrigeration

**d. Other emerging technologies**

- **High hydrostatic pressure**: Non-thermal treatment to inactivate microorganisms
- **Pulsed electric fields**: Surface decontamination without affecting internal quality
- **Irradiation**: Effective technology but limited by consumer acceptability
- **Nanotechnologies**: Development of active packaging incorporating antimicrobial nanoparticles

### 4.3. Shelf life

The shelf life of eggs varies considerably depending on storage conditions and treatments applied:

**a. Untreated eggs**

- **Room temperature (20-25°C)**: 7-10 days with optimum quality maintained.

- **Refrigeration (0-4°C**): 4-5 weeks with significant slowdown in spoilage
- **Freezing (broken eggs)**: 6-12 months depending on packaging

**b. Treated eggs**

- **Pasteurized in shell**: 12-16 weeks under refrigeration
- **Asphalt (mineral oil)**: 2-3 weeks longer than untreated eggs
- **Modified atmosphere packaging**: 8-10 weeks under refrigeration

**c. End of shelf-life indicators**

- Inner tube increase > 9 mm
- Haugh units < 60
- Yellow index < 0.35
- White pH > 9.5
- Development of abnormal odors or flavors
- Visible signs of microbial contamination

## 5. Egg products

### 5.1. Definition and classification

Egg products are defined as "processed products resulting from the processing of eggs or their various components or mixtures, or from further processing of these processed products".

**a. Classification by degree of processing**

1. **Primary egg products**: derived directly from the primary processing of eggs
    - Liquid, concentrated or dried whole eggs
    - Liquid, concentrated or dried egg whites (albumen)
    - Liquid, concentrated or dried egg yolks
    - Mixtures of components in different proportions
2. **Special egg products**: undergoing further processing
    - Cooked egg products (canned hard-boiled eggs, pasteurized omelettes)

- Fermented egg products (century eggs)
- Functionally modified egg products (egg whites with increased foaming power)
- Isolated egg fractions (lecithin, lysozyme, avidin)

**b. Classification by physical state**

- **Liquids**: broken, homogenized, pasteurized eggs (original water content)
- **Concentrates**: water content reduced by vacuum evaporation (higher solids concentration)
- **Frozen**: stabilized by rapid freezing (-40°C) then stored at -18°C
- **Dehydrated**: spray-dried, freeze-dried or fluidized-bed dried (water content < 5%)
- **Crystallized**: Obtaining crystalline forms of certain components (lysozyme, ovalbumin).

### 5.2. Industrial applications

Egg products are used in many sectors of the food industry for their functional and nutritional properties:

**a. Bakery-pastry sector (main user)**

- Plumpness and structure of sponge cakes and meringues
- Emulsification in creams and sauces
- Viennese pastry coloring (gilding)
- Frosting in custards and quiches

**b. Pasta industry**

- Natural coloring agent
- Improved organoleptic qualities
- Nutritional enrichment

**c. Sauces and condiments**

- Emulsifying properties of yellow (mayonnaises, vinaigrettes)

- Emulsion stabilization
- Texture and smoothness

**d. Meat preparations**

- Binding of ingredients (charcuterie, terrines)
- Stabilizing emulsions (sausages)
- Coating (adherent breadcrumbs)

**e. Non-food applications**

- Pharmaceutical industry: active ingredient carriers
- Cosmetics: natural emulsifiers
- Biotechnology: production of specific proteins (lysozyme, avidin)

Egg products offer several advantages over shell eggs in these applications: standardization, microbiological safety, ease of use and optimized storage.

## 6. Egg product manufacturing

### 6.1. Industrial processes

The industrial production of egg products involves a sequence of unit operations adapted to the specific features of the different egg fractions and the desired end products.

**a. Industrial breaking lines**

The modern egg-breaking facilities can process up to 180,000 eggs per hour and include :

- Automated egg loading and orientation systems
- Optical detection of defects and contamination
- Controlled percussion breaking
- Automatic separation of white and yellow by differential suction system
- In-line filtration of shell residues and membranes
- Automated cleaning and disinfection systems

**Figure 9:** egg-breaking and separating machine.

These installations incorporate continuous quality control (turbidity, color, viscosity) and advanced traceability systems.

**b. Production of liquid egg products**

After breaking and separation, liquid egg products undergo several stages:

1. **Filtration**: Removal of solid particles (membranes, shell fragments)
    - Coarse filtration: vibrating sieves (mesh size 1-2 mm)
    - Fine filtration: static or rotary filters (150-300 µm)
2. **Homogenization**: Product standardization
    - Viscosity reduction
    - Composition standardization
    - Improved stability
    - Pressure: 5-15 MPa for whole egg and yolk
3. **Formulation adjustments**
    - Standardization of dry matter content
    - Addition of salt (0.5-10%) or sugar (5-50%) as cryoprotectants for products intended for freezing
    - Acidification (citric, acetic acid) for stabilization

- Addition of natural antioxidants (tocopherols, ascorbic acid)

4. **Enzymatic desugaring** (mainly for egg white)
    - Glucose elimination by glucose oxidase
    - Prevention of Maillard browning during drying
    - Improving powder stability

**c. Production of concentrated egg products**

Concentration reduces volume and increases dry matter content:

- **Vacuum evaporation**: Partial water removal at low temperatures (45-55°C)
    - Increase in solids concentration from 12% to 22-24% for whole eggs
    - Reduced transport and storage costs
    - Preservation of functional properties
- **Ultrafiltration**: Selective concentration using membranes
    - Retention of proteins and high molecular weight compounds
    - Partial elimination of water and salts
    - Modification of protein/fat/carbohydrate ratios

**d. Production of dehydrated egg products**

Drying produces long-life products with a water content of < 5%.

1. **Spray-drying**
    - Spraying liquid product in fine droplets
    - Contact with hot air (120-180°C inlet, 65-85°C outlet)
    - Very short residence time (5-15 seconds)
    - High yield but moderate impact on functional properties
2. **Freeze-drying**
    - Rapid freezing followed by vacuum sublimation

- Optimum preservation of structure and functional properties
- High cost, reserved for high value-added products

3. **Fluidized-bed drying**
    - Often used as an additional step after atomization
    - Final drying and particle agglomeration
    - Improved solubility and flow properties

### 6.2. Heat treatment

Heat treatment is a critical stage in the production of egg products, with a dual objective: guaranteeing microbiological safety and preserving functional properties.

Pasteurization, the main heat treatment applied to egg products, must be adapted to each type of product because of differences in thermal sensitivity:

1. **Standard pasteurization parameters**
    - Whole egg: 64-65°C for 2-3 minutes
    - Egg yolk: 60-62°C for 3-3.5 minutes
    - Egg white: 55-57°C for 2-3 minutes
2. **Pasteurization technologies**
    - **Batch pasteurization**: Product heated in a stirred tank
    - **Plate heat exchangers**: Continuous system with heat recovery
    - **Tubular pasteurization**: suitable for viscous products (yolks, enriched mixtures)
    - **Ohmic heating**: Passage of electric current, uniform volumetric heating
3. **Impact on functional properties**
    - Partial protein denaturation
    - Reduced foaming power of egg white (30-40%)
    - Weakening of gelling power

- Changes in the emulsifying properties of yellow

## 7. Egg product preservation

### 7.1. Storage methods

Different approaches are used to preserve egg products, depending on their physical condition and intended use.

**a. Preserving liquid egg products**

1. **Refrigeration**
   - Temperature: 0-4°C
   - Shelf life: 2-10 days depending on the nature of the product
   - Limiting factors: initial microbiological quality, break in the cold chain
   - Regulatory requirement: maintain at ≤ 4°C for entire shelf life
2. **Freezing**
   - Rapid freezing (-30°C to -40°C)
   - Storage temperature: -18°C minimum
   - Shelf life: 12-18 months
   - Protection against oxidation: vacuum or inert gas
   - Addition of cryoprotectants: salt (2-10%) or sugar (5-50%) to limit structural damage
3. **Preservation by acidification**
   - pH lowering with organic acids (citric, acetic)
   - Inhibition of microbial growth
   - Extended shelf life of 1-2 weeks under refrigeration
4. **Aseptic packaging**
   - Pasteurization followed by packaging in a sterile environment
   - Multi-layer packaging or HDPE bottles

- Room-temperature storage for certain formulations (salted/sweet eggs)
- Shelf life: up to 3 months at room temperature, 6 months under refrigeration

**b. Storage of dehydrated egg products**

1. **Storage conditions**
   - Temperature: ideally < 25°C
   - Relative humidity: < 65
   - Protection against oxygen: modified atmosphere packaging (nitrogen)
   - Moisture protection: airtight packaging, aluminized bags
2. **Shelf life**
   - Whole egg powder: 12-18 months at room temperature
   - Egg white powder: 18-24 months
   - Egg yolk powder: 12 months (more sensitive to oxidation)
   - Can be extended with refrigerated storage
3. **Stabilizing factors**
   - Enzymatic desugaring: preventing Maillard reactions
   - Antioxidants: tocopherols, ascorbic acid, propyl gallate
   - Anti-caking agents: colloidal silica, tricalcium phosphate

**c. Preserving special egg products**

1. **Cooked egg products**
   - Hard-boiled eggs in brine: shelf life 3-6 months under refrigeration
   - Vacuum-packed hard-boiled eggs: shelf life of 30-45 days at 4°C
   - Pasteurized omelettes: 21-28 days under refrigeration
2. **Fermented egg products**
   - Lactic fermentation: stabilization by lowering pH

- Shelf life 30-90 days depending on formulation
- Specific Asian products (century eggs, pidan): extended shelf life

3. **Specific purified fractions**
   - Crystallized lysozyme: several years at room temperature
   - Extracted phospholipids: sensitive to oxidation, preservation under nitrogen
   - Isolated proteins: freeze-drying and moisture-free storage

### 7.2. Limiting factors

Several factors influence the stability of egg products during storage:

**a. Microbiological factors**

- **Residual flora after pasteurization**: mainly spore-forming and heat-resistant bacteria
- **Post-processing contamination**: major risk for liquid products
- **Development of psychrotrophs**: Pseudomonas, Bacillus cereus (refrigerated products)
- **Resistance to treatment**: formation of biofilms on equipment

**b. Physicochemical factors**

1. **Protein modifications**
   - Progressive denaturation
   - Aggregation during storage
   - Interactions with other ingredients
   - Impact on functional properties
2. **Lipid alterations**
   - Oxidation of unsaturated fatty acids
   - Formation of volatile compounds (aldehydes, ketones)
   - Development of rancidity
   - Faster in dehydrated products (large surface area in contact with oxygen)

3. **Browning reactions**
    - Maillard reaction between proteins and reducing sugars
    - Formation of brown pigments and changes in flavour
    - Accelerated by temperature and dehydration
    - Particularly problematic in dehydrated egg products

**c. Environmental factors**

- **Temperature fluctuations**: accelerating weathering reactions
- **Light exposure**: catalysis of lipid oxidation
- **Ambient humidity**: moisture recovery from dehydrated products
- **Odor transfer**: absorption of exogenous volatile compounds

# CHAPTER V: STORING AND PROCESSING FISH AND SHELLFISH

Seafood is an essential source of protein and nutrients for a large proportion of the world's population. However, fish and shellfish are among the most perishable of all foodstuffs, due to their specific chemical composition and the activity of endogenous and microbial enzymes. This high perishability poses considerable challenges for their preservation and processing.

## 1. Biological characteristics and chemical composition

### 1.1. Fish

Fish have a biochemical composition that sets them apart from other foods of animal origin. This composition varies considerably according to species, habitat, season, diet and physiological stage.

Fish flesh generally contains :

- 65 to 85% water
- 15-20% protein of high biological value
- 0.5 to 25% lipids, with high proportions of polyunsaturated fatty acids (PUFAs), particularly omega-3.
- 0.5 to 1.5% mineral compounds
- Fat-soluble vitamins (A, D, E, K) and water-soluble vitamins (B complex)

Myofibrillar proteins (actin, myosin) make up around 65-75% of total proteins and are responsible for the functional and textural properties of flesh. The sarcoplasmic proteins (15-25%) include enzymes involved in post-mortem alteration reactions. Finally, stromal proteins (mainly collagen) account for around 3-10%.

Lipid content is used to classify fish into :

- Lean fish (<2% lipids): hake, cod, pollack
- Semi-fatty fish (2-8% lipids): sea bream, sea bass, trout

- Fatty fish (>8% lipids): salmon, mackerel, sardines, tuna

This particular composition gives fish their nutritional qualities, but also explains their high susceptibility to spoilage, notably through lipid oxidation and enzymatic proteolysis.

### 1.2 Crustaceans

Crustaceans (shrimps, crabs, lobsters, crayfish) are characterized by ..:

- 75-80% water
- 15-20% protein
- 0.5 to 4% lipids
- 1-2% carbohydrates (mainly in the form of glycogen)
- 1 to 2% mineral compounds, including high levels of calcium and phosphorus

## 2. Post-mortem alteration of aquatic products

### 2.1. Biochemical weathering mechanisms

As soon as the animal dies, a series of biochemical processes is triggered, leading to a gradual deterioration in quality:

#### a) Rigor mortis and resolution

Rigor mortis (rigor mortis) is the first observable post-mortem manifestation. It results from the formation of irreversible actomyosin complexes following ATP depletion. The onset and resolution of rigor mortis are more rapid in fish and crustaceans than in mammals, due to their different energy metabolism and generally lower body temperature.

Ante- and post-mortem manipulation has a considerable influence on this phenomenon:

- Temperature directly affects its duration
- Smaller fish enter rigor faster

#### b) Enzymatic autolysis

Endogenous enzymes, notably lysosomal cathepsins, calcium-dependent calpains and collagenases, progressively hydrolyze myofibrillar and connective proteins, leading to tissue softening. In crustaceans, the digestive enzymes of the hepatopancreas are particularly active and can cause enzymatic melanosis (blackspot) linked to the action of polyphenoloxidase.

**c) Lipid oxidation**

Polyunsaturated fatty acids, abundant in aquatic products, are highly sensitive to oxidation. This chain reaction produces unstable hydroperoxides that break down into volatile secondary compounds (aldehydes, ketones) responsible for the rancid odor. This phenomenon is catalyzed by enzymes (lipoxygenases), metals (heme iron) and light.

**d) Degradation of nitrogen compounds**

The degradation of nitrogenous components by bacteria contributes to the characteristic odour of altered fish. At the same time, deamination of amino acids and degradation of ATP to hypoxanthine generate ammonia and bitter compounds respectively.

**2.2 Microbiological alteration mechanisms**

The microbial flora naturally present on aquatic products is influenced by the aquatic environment. Gram-negative psychrotrophic bacteria generally dominate, with genera such as *Pseudomonas, Shewanella, Photobacterium and Vibrio*.

The rate of spoilage depends on intrinsic (pH, water activity, redox potential) and extrinsic (temperature, atmosphere) factors. The initial bacterial load, influenced by water quality and handling practices, is also a determining factor.

**3. Conventional preservation methods**

**3.1 Cold preservation**

**a) Refrigeration**

Refrigeration (0 to 4°C) considerably slows down enzymatic reactions and microbial multiplication, without stopping them completely. The use of melting ice (0°C) gives a shelf-life of 5-14 days, depending on the species, fishing conditions and post-capture handling.

Refrigeration efficiency is based on :

- Rapid post-capture cooling
- Maintaining a constant temperature
- The right ice/product ratio (usually 1:1)
- The quality of the water used to produce ice

Innovations such as flake ice, liquid ice and ice with natural antimicrobial agents improve cooling efficiency and extend shelf life.

**b) Freezing**

Freezing at temperatures below -18°C enables long-term stabilization by immobilizing free water in the form of ice crystals, thus inhibiting enzymatic and microbial reactions. The quality of frozen products depends on :

- Freezing speed (influencing crystal size)
- Storage temperature (ideally -30°C to limit oxidation reactions)
- Temperature fluctuations during storage
- Protection against dehydration (glazing, packaging)

Protein denaturation and texture alteration can occur during prolonged storage, particularly in the event of temperature fluctuations leading to recrystallization.

**3.2. Drying and salting**

These age-old techniques are based on reducing water activity (aw) below critical thresholds for microbial growth.

**a) Drying**

Traditional sun-drying is still widely practiced in many parts of the world. Modern techniques such as controlled hot-air drying allow better control of parameters and more consistent quality. Drying kinetics generally include :

- A constant-velocity phase governed by surface evaporation
- A decreasing-velocity phase limited by internal water diffusion

Dehydration down to 15-25% residual moisture generally achieves an aw of less than 0.6, ensuring microbiological stability.

**b) Salting**

Salting uses sodium chloride as an osmotic dehydration agent and microbial growth inhibitor. A distinction is made between :

- Dry salting: salt is applied directly to the product

- Brining: immersion in a concentrated salt solution
- Mixed salting: combining the two methods

The salt concentration in the product's aqueous phase must generally exceed 10% to ensure effective preservation. Techniques such as brine injection accelerate salt penetration.

**c) Typical products**

These techniques have given rise to many traditional products:

- Salt cod (bacalao, klipfish)
- Stockfish (salt-free dried cod)
- Salted anchovies
- Nuoc-mâm and garum (fermented fish sauces)

**3.3. Smoking**

Smoking combines several preservative effects:

- Partial dehydration
- Deposition of antimicrobial compounds (phenols, aldehydes)
- Antioxidant effect of phenolic compounds
- Action of salt (in the case of cold smoking preceded by salting)

We distinguish :

- Cold smoking (20-30°C): pronounced preservative effect, lasting from several hours to several days
- Hot smoking (70-80°C): dominant organoleptic effect, partial cooking of the product

Smoke composition depends on wood type, pyrolysis temperature and oxygenation.

**3.4. Fermentation**

Lactic acid fermentation, which is particularly important in Southeast Asia, relies on the activity of lactic acid bacteria that :

- Lowers pH by producing lactic acid

- Produce antimicrobial bacteriocins
- Generate aromatic compounds

The mastery of these traditional fermentations, often empirical, is now the subject of in-depth scientific studies aimed at standardizing processes while preserving their unique organoleptic characteristics.

## 4. Modern preservation technologies

### 4.1. Modified atmosphere packaging

Modified atmosphere packaging involves replacing the air in the package with a specific gas mixture, generally :

- $CO_2$ (30-60%): antimicrobial effect
- $N_2$ (20-40%): inert filling gas, prevents packaging collapse
- $O_2$ (0-30%): color retention for certain products

For aquatic products, mixtures rich in $CO_2$ (40-60%) are generally preferred for their bacteriostatic effect. However, excessive $CO_2$ contents can lead to:

- Increased exudation
- Surface acidification
- Texture alterations

**Figure 10:** Modified atmosphere packaging of fish.

### 4.2 High hydrostatic pressures

High Pressure Processing (HPP) for a few minutes at room temperature or under refrigeration. This non-thermal technology :

- Inactivates microorganisms by destructuring membranes and modifying protein structures
- Preserves sensory and nutritional qualities
- Does not affect covalent bonds, preserving vitamins and aromatic compounds

For aquatic products, pressures of 250-400 MPa are typically applied. HPP is particularly suitable for :

- Decontamination of oysters and other bivalve molluscs
- Extending the life of high value-added products
- Shellfish shelling made easy

However, this technology can induce textural changes and a slight coagulation of proteins, reminiscent of the start of cooking at pressures in excess of 300 MPa.

### 4.3 Irradiation

Irradiation uses ionizing radiation (gamma rays, X-rays or accelerated electrons) to eliminate pathogenic and spoilage microorganisms. Depending on the dose applied, a distinction is made between :

- Radurization (low doses, <1 kGy): reduced microbial load
- Radicidation (1-10 kGy): elimination of non-spore-forming pathogens
- Radappertization (>10 kGy): commercial sterilization

For aquatic products, doses of 1-3 kGy are generally recommended to balance antimicrobial efficacy and preservation of organoleptic qualities. Irradiation can, however, promote lipid oxidation and generate undesirable odors, particularly in fatty products. The combined application of antioxidants and vacuum packaging can mitigate these undesirable effects.

### 4.4. Bioconservation

Bioconservation uses protective microbial cultures or their metabolites to inhibit the growth of undesirable microorganisms. This approach includes :

- The use of bacteriocin-producing lactic acid bacteria
- Application of purified bacteriocins (nisin, sakacin, pediocin)
- The use of plant extracts with antimicrobial properties

Nisin, the only bacteriocin authorized as a food additive (E234), is active against Gram-positive bacteria, including Listeria monocytogenes. Recent research is exploring cocktails of bacteriocins or their combination with other barrier technologies to broaden the spectrum of action.

## 5. Transformation processes

### 5.1. Threading and cutting

Primary processing operations include :

- Heading and gutting
- Coat (for certain crustaceans)
- Threading and trimming
- Unclipping

These operations, traditionally carried out by hand, are becoming increasingly mechanized. Modern equipment incorporates artificial vision and image analysis systems to optimize cutting efficiency and quality. High-pressure water jet technology offers interesting alternatives for certain operations.

### 5.2. Cooking and pre-cooking

Cooking induces several changes:

- Protein denaturation and coagulation
- Enzymatic inactivation
- Destruction of microorganisms

- Development of sensory characteristics

Critical parameters include temperature, duration and cooking medium (water, steam, hot air). For crustaceans, steaming limits the loss of water-soluble compounds compared to cooking in water. Pre-cooking is often used as a preparatory step for canning or freezing.

### 5.3. Appertisation

Heat treatment in metal cans or flexible sterilizable containers remains a major method of long-term preservation. The time-temperature scale aims to achieve a sterilizing value (Fo) generally greater than 3 minutes to guarantee the destruction of *Clostridium botulinum*.

**Figure 11:** Appertized fish

Modern appertizing technologies include :

- Rotary and shaking autoclaves
- Ohmic heating
- High-pressure heat treatment (PATS - Pressure Assisted Thermal Sterilization)

These innovations aim to improve heat transfer, reduce processing times and preserve organoleptic and nutritional qualities.

### 5.4. Freezing and deep-frozen products

Industrial deep-freezing uses a variety of technologies:

- Forced-air tunnels (-30 to -40°C)

- Plate freezers (-40°C)
- Cryogenic freezing with liquid nitrogen (-196°C) or liquid $CO_2$ (-78°C)

Speed of freezing is crucial to limit the size of ice crystals and preserve cellular integrity. Frozen processed products (ready-made meals, breaded products) represent a fast-growing segment, requiring mastery of the functional properties of ingredients and their behavior during freezing-thawing.

# CHAPTER VI: HONEY COMPOSITION AND STORAGE

Honey is a naturally sweet substance produced by honeybees (*Apis mellifera*) from the nectar of flowers or secretions from living plant parts. The bees harvest, transform and combine this material with specific substances they secrete, then dehydrate it and store it in the hive's combs for ripening. Its complex composition gives it remarkable organoleptic, nutritional and therapeutic properties, which are arousing growing scientific interest.

The preservation of honey is another fascinating area of study. Its specific chemical composition enables it to naturally resist many deterioration processes, which explains its remarkable shelf life.

## 1. Chemical composition of honey

### .11 Carbohydrates

Carbohydrates are the major component of honey, representing around 95% of its dry matter. Fructose (38.5%) and glucose (31%) are the predominant sugars, followed by small amounts of maltose, sucrose and other oligosaccharides.

The fructose/glucose ratio is an important parameter that influences several properties of honey, including its tendency to crystallize. A fructose/glucose ratio greater than 1.3 generally indicates a honey that will remain liquid for a prolonged period, while a lower ratio favors crystallization.

Honeydew honeys generally contain more complex oligosaccharides, notably trisaccharides such as erlose and melézitose, which are absent or present in minute quantities in nectar honeys.

### 1.2. Water

The water content of honey generally varies between 15% and 20%, with an average of around 17%. This content is a crucial factor in honey's microbiological stability and preservation. A water content higher than 20% significantly increases the risk of fermentation by osmophilic yeasts naturally present in honey (*Saccharomyces* spp.).

Moisture content depends on a number of factors, including botanical origin, climatic conditions during production, degree of ripening in the hive, and harvesting and storage conditions.

### 1.3. Proteins and amino acids

Although present in small quantities (0.1-0.5%), honey proteins play an important role in its physico-chemical and biological properties. The majority of proteins come from the bees' salivary and hypopharyngeal glands, with a minor contribution from nectar and pollen.

Honey contains around 18 free amino acids, of which proline is generally the most abundant (50-85% of total amino acids). The amino acid profile varies considerably according to the botanical and geographical origin of the honey.

Proline content is considered an indicator of maturity and is sometimes used to detect honey adulteration. A concentration below 180 mg/kg may indicate immature or adulterated honey.

### 1.4. Organic acids

Organic acids account for around 0.5% of honey's composition and contribute significantly to its taste and natural acidity. The pH of honey generally varies between 3.4 and 6.1, with an average around 3.9.

Gluconic acid, formed by the enzymatic oxidation of glucose by glucose oxidase, is the predominant acid. Other organic acids identified include acetic, butyric, citric, formic, lactic, malic, oxalic and succinic.

Organic acid profiles vary according to floral origin, and can be used as a marker for authenticating certain types of honey.

### 1.5. Minerals and trace elements

The mineral content of honey generally varies between 0.1% and 1%, with an average of around 0.17% for nectar honeys and up to 1.5% for some honeydew honeys.

Potassium is the most abundant mineral, accounting for around 80% of total mineral content. Other minerals present include calcium, sodium, magnesium, iron, copper, manganese and zinc.

Mineral composition is strongly influenced by the botanical and geographical origin of honey, making it a useful parameter for determining its origin.

### 1.6. Phenolic compounds and flavonoids

Phenolic compounds in honey mainly comprise phenolic acids and flavonoids. Although present in low concentrations (5-1500 mg/kg), they contribute significantly to honey's antioxidant, organoleptic and therapeutic properties.

The main phenolic acids identified in honey include gallic, p-coumaric, caffeic, ellagic and ferulic acids. Flavonoids include quercetin, luteolin, kaempferol, apigenin, chrysin, galangin and pinocembrin.

The profile of phenolic compounds is strongly linked to the botanical origin of honey, and can serve as a "fingerprint" for its authentication.

### 1.7 Enzymes

The enzymes present in honey come mainly from the hypopharyngeal glands of worker bees, with a minor contribution from nectar and pollen.

The main enzymes include :

- Diastase (α- and β-amylase): hydrolyzes starch into simpler sugars
- Invertase (α-glucosidase): converts sucrose into glucose and fructose
- Glucose oxidase: oxidizes glucose to gluconic acid and hydrogen peroxide
- Catalase: breaks down hydrogen peroxide into water and oxygen
- Acid phosphatase: hydrolyzes phosphoric esters

Enzyme activity is considered an indicator of honey freshness and quality, as enzymes are sensitive to heat and aging.

### 1.8. Vitamins

Honey contains small quantities of vitamins, mainly B group vitamins (B1, B2, B3, B5, B6, B9) and vitamin C. Their concentration depends largely on the honey's floral origin and processing.

Although present in quantities that are not nutritionally significant for human consumption, these vitamins contribute to the overall biological properties of honey.

### 1.9. Volatile compounds

Over 600 volatile compounds have been identified in different types of honey. These substances, although present in very low concentrations, are responsible for the characteristic aroma of each variety of honey.

The main classes of volatile compounds include aldehydes, ketones, alcohols, acids, esters, hydrocarbons and sulfur compounds. Certain specific compounds can be used as markers to identify the botanical origin of honey.

## 2. Factors influencing honey composition

### 2.1. Botanical origin

Botanical origin is probably the most important factor determining the chemical composition of honey. Honeys can be classified into monofloral honeys (derived mainly from one plant species) and polyfloral honeys (derived from several botanical sources).

Monofloral honeys often have distinctive physico-chemical and organoleptic characteristics. For example, acacia honey contains a high proportion of fructose and crystallizes slowly, while rapeseed honey, rich in glucose, crystallizes rapidly.

Honeydew honeys, produced from the secretions of sucking insects (mainly aphids) or the exudations of certain living plant parts, are distinguished from nectar honeys by their higher mineral, oligosaccharide and organic acid content.

### 2.2 Geographical origin

Geographical origin indirectly influences honey composition by determining the flora available to bees, but also through pedoclimatic conditions that affect the composition of nectar and honeydew.

The mineral and trace element content of honey often reflects the composition of the soil in the region of production. For example, honeys produced in industrialized areas may have higher levels of certain heavy metals.

These geographical variations make it possible to use advanced analytical techniques to determine the geographical origin of honeys, which is important for the certification of protected designations of origin and the detection of fraud.

### 2.3 Bee species

Although the majority of commercial honey is produced by the European honeybee (*Apis mellifera*), other bee species also produce honey with different compositions. For example, honeys produced by *Apis cerana*, *Apis dorsata* or stingless bees (Meliponini) have distinct biochemical profiles.

The different subspecies or races of *Apis mellifera* can also influence honey composition through their foraging preferences and specific physiological characteristics.

### 2.4. Climatic conditions

Climatic conditions affect not only the melliferous flora available, but also the composition of the nectar secreted by plants. Higher temperatures can increase nectar's sugar concentration, while relative humidity influences its volume.

Seasonal and annual variations in weather conditions explain why honeys of the same floral and geographical origin can differ in composition from one year to the next.

### 2.5. Beekeeping practices

The methods used by beekeepers to harvest, process and store honey can significantly influence its final composition.

The harvesting period determines the degree of ripening of the honey in the hive, affecting its water content and enzyme activity. Honey harvested prematurely will generally have a higher water content and lower enzyme activity.

Heat treatments applied to facilitate extraction or prevent crystallization can reduce enzymatic activity and increase hydroxymethylfurfural (HMF) content, an indicator of honey freshness and quality.

## 3. Honey preservation

### 3.1. Natural antimicrobial properties

Honey has a number of characteristics that give it remarkable microbiological stability:

- **Osmotic effect**: The high concentration of sugars creates a high osmotic pressure which dehydrates microorganisms by osmosis.
- **Acidity**: The relatively low pH (3.4-6.1) inhibits the growth of many pathogens.

- **Glucose oxidase system**: This enzyme, introduced by bees, catalyzes the oxidation of glucose into gluconic acid and hydrogen peroxide, a powerful antimicrobial.
- **Methylglyoxal (MGO)**: Particularly abundant in Manuka honey, this compound has strong antibacterial activity.
- **Defensin-1**: This antimicrobial peptide, secreted by bees, contributes to honey's antibacterial properties.
- **Phenolic compounds**: The flavonoids and phenolic acids present in honey have demonstrated antimicrobial properties.

### 3.2 Deterioration factors

Despite its natural preservative properties, honey can undergo various alterations during storage:

- **Fermentation**: The main cause of deterioration, fermentation occurs when water content exceeds 20%, allowing osmophilic yeasts to develop. Fermentation products (ethanol, acetic acid) irreversibly alter the organoleptic qualities of honey.
- **Crystallization**: A natural phenomenon caused by the precipitation of glucose in the form of glucose monohydrate. Although it does not alter nutritional quality, it does modify texture and can promote fermentation by releasing water into the liquid phase.
- **Non-enzymatic browning reactions**: The Maillard reaction between reducing sugars and amino acids leads to the formation of HMF and melanoidins, altering the color and taste of honey.
- **Moisture and odor absorption**: Due to its hygroscopic nature, honey can absorb moisture and odors from the environment if its packaging is not airtight.

### 3.3. Traditional preservation techniques

Historically, several methods have been used to preserve the qualities of honey:

- **Storage in airtight containers**: To prevent absorption of moisture and odorous contaminants.
- **Storage in ceramic or glass containers**: These inert materials avoid chemical interactions that could alter the honey.

- **Store at room temperature away from light**: To slow down photochemical and thermal degradation reactions.
- **Mild pasteurization**: Used in certain crops to destroy the osmophilic yeasts responsible for fermentation.

### 3.4. Modern preservation methods

Current techniques for preserving honey aim to preserve its properties while meeting the requirements of the food industry:

- **Controlled heat treatment**: Heating at specific temperatures for defined times to inactivate yeast while minimizing enzymatic losses and HMF formation.
- **Microfiltration**: Removes suspended particles, pollen and yeast without significantly altering the chemical composition.
- **Dehumidification**: Controlled reduction of water content by techniques such as vacuum dehumidification, to prevent fermentation.
- **Modified atmosphere packaging**: Replacement of air by inert gases to prevent oxidation and microbial growth.
- **Non-thermal technologies**: High-pressure treatment, pulsed electric fields or ultrasound to inactivate microorganisms while preserving nutritional qualities.

### 3.5. Standards and regulations

The preservation of honey is governed by various national and international standards that define quality criteria and acceptable practices:

- **Water content**: Generally limited to 20% (18% for heather and industrial honeys).
- **HMF content**: Not to exceed 40 mg/kg (80 mg/kg for honeys from tropical regions).
- **Diastase activity**: Must be at least 8 Schade units (3 for honeys with low natural enzyme content).
- **Reducing sugars**: Minimum 60% for blossom honey and 45% for honeydew honey.
- **Apparent sucrose**: Generally limited to 5% (exceptions for certain monofloral honeys).
- **Water-insoluble matter**: Maximum 0.1% (0.5% for pressed honey).

These criteria are designed to guarantee the authenticity of honey and ensure that preservation methods do not significantly alter its natural properties.

# CONCLUSION

The preservation and processing of foods of animal origin constitute one of the fundamental cornerstones of agri-food technology. Through the comprehensive study of milk, meat, eggs, fish, and honey, this manual demonstrates that each product possesses unique biochemical, microbiological, and technological characteristics that require specific methods of stabilization and transformation. Whether through traditional practices, thermal processes, or cutting-edge technologies, the ultimate objective remains constant: to ensure the safety, quality, and availability of food products while minimizing losses and optimizing nutritional benefits.

The increasing complexity of modern food systems places ever-greater demands on future professionals. Beyond mastering classical preservation techniques, they must integrate innovative approaches that address current and emerging challenges: growing consumer demand for minimally processed foods, the pursuit of natural additives and biopreservation strategies, the imperative for environmentally sustainable processes, and compliance with increasingly stringent international standards. Understanding the delicate balance between microbial safety, sensory acceptability, nutritional value, and economic feasibility is therefore essential for anticipating the evolution of animal production and food industries.

Ultimately, the knowledge and skills acquired through this manual will enable students to adopt a holistic approach to food preservation, establishing connections between fundamental science, industrial applications, and societal expectations. This integrated perspective will prepare them to play a pivotal role in ensuring food security, protecting public health, and promoting innovation in the agri-food sector at both national and international levels.

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