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Course Handout on Technology of Agri-Food Industries (T.I.A.A. 1 and T.I.A.A. 2)

For the use of third-year undergraduate students in Agri-Food Science and Quality Control

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PREFACE

This handout is intended for third-year undergraduate students in Food Science and Quality Control, as part of the TIAA1 and TIAA2 courses. It has been designed to support students in learning the fundamentals of food science and technology, with a focus on dairy products, the sugar industry, fats and oils, beverages, cereal products, fruits and vegetables, as well as meat products. The food industry is a complex and ever-evolving sector where mastering processing techniques, understanding the properties of raw materials, and managing quality are essential challenges. This document aims to provide students with a solid and structured foundation to understand the various food industry sectors, addressing the technological, microbiological, and nutritional aspects of food products.

The objectives of this handout are as follows: to convey fundamental knowledge about raw materials and processing techniques, to facilitate the learning of quality control methods, to develop a global perspective on food industry sectors through concrete examples and case studies, and to prepare students for professional challenges by training them to meet the demands of the food industry market.

The handout is organized into two main parts, corresponding to the two course units:

- **TIAA1**: This section covers dairy products, the sugar industry, fats and oils, and beverages. It explores the characteristics of raw materials, processing techniques, as well as the microbiological and nutritional aspects of these products. Students will find detailed information on milk composition, the various stages of cheese production, sugar production processes, the properties of fats and oils, and beverage manufacturing technologies.
- **TIAA2**: This section focuses on cereal products, fruits and vegetables, as well as meat products. It addresses the structure and composition of cereals, the techniques for transforming them into flours, breads, and pastas, as well as methods for preserving fruits and vegetables. Finally, it covers the structure of muscles, meat processing techniques, and preservation methods for meat products.

Each chapter is illustrated with diagrams, tables, and figures to facilitate the understanding of technical concepts. Concrete examples and case studies are also provided to link theory to industrial practice.

This academic resource serves as an essential tool for students' learning, enabling them to acquire a methodical and rigorous approach to fundamental concepts in agri-food and quality control. It is part of a pedagogical approach aimed at strengthening students' autonomy and developing their critical thinking skills in response to challenges in the agri-food industry.

T.I.A.A 1

Chapter 1 : Milk and Dairy Products

This food group is primarily based on milk and offers a variety of products with diverse organoleptic characteristics. It includes:

- **Milk**: A natural product produced by mammals, which serves as both food and drink, thus of great nutritional importance. The term "milk" without further qualification is reserved for cow's milk.
- **Processed milks**: These are the result of technological treatments aimed at extending their shelf life (e.g., sterilized milk, pasteurized milk, powdered milk, etc.).
- **Modified milks**: These have undergone changes in texture and structure (e.g., yogurts, fresh dairy desserts, etc.).
- **Cheeses**: These include fresh cheeses (e.g., cottage cheese, petit suisse) and aged cheeses (e.g., camembert, roquefort, comté).

This group is essential due to its contribution of animal proteins (comparable to the meat, fish, and eggs group), calcium, and vitamins A, D, and B7.

Note: Fresh cream and butter are also milk derivatives, but they are classified in the fat group due to their high lipid content.

1. Milk

1.1. Organoleptic Characteristics

1.1.1. Color

Milk has a matte white color, mainly due to the fat, carotene pigments (the cow converts β-carotene into vitamin A, which passes directly into the milk), casein, and vitamin B2.

1.1.2. Odor

The odor of milk is characteristic. Indeed, thanks to the fat it contains, milk fixes animal odors. These odors are related to the milking environment, the animal's diet, and the milk's storage.

1.1.3. Flavor

The flavor of milk varies depending on the tasting temperature and the animal's diet. Note: Industrial milks have undergone deaeration, which reduces and homogenizes odors and flavors.

1.2. Physical Properties Determined in Dairy

1.2.1. Density

The density of milk is 1.032 at 20 °C for bulk milk in dairy. Milk thus has a volume and weight almost equal because its density is close to 1. Density is measured with a thermolactodensimeter, which also allows for quick determination of the milk's fat content. Skimmed milk has a higher density, as the density of fat is 0.9. However, in case of dilution, the density decreases.

1.2.2. Viscosity

Viscosity corresponds to a liquid's resistance to flow. It is due to the presence of proteins and fats in the milk. It limits the rise of fats to the milk's surface, decreases when the temperature increases, and increases when the pH is below 6 (as observed in sour creams). Homogenization multiplies the milk's viscosity by 1.2 to 1.4.

1.2.3. Other Physical Parameters

Other physical measurements are performed in dairy, such as specific heat, freezing point, electrical conductivity, and the milk's dry extract, which is 12.5 to 13.5 g/100 ml. It includes all the milk's components except water. The defatted dry extract has an almost fixed composition because milk fat is the most variable component.

1.3. Milk Microbiology, Pollution, and Hygiene in Production

1.3.1. Milk Microbiology

1.3.1.1. Generalities

Even when treated under normal cleanliness and hygiene conditions, milk contains many germs whose rapid development is favored by its temperature at the udder's exit (35 °C) as well as its richness in water and carbohydrates. Therefore, it must be quickly cooled (temperature < 6 °C) to limit this microbial multiplication.

1.3.1.2. Different Germs Present in Milk

► LACTIC ACID BACTERIA

Lactic acid bacteria are responsible for milk acidification by transforming lactose into lactic acid. When milk, left at room temperature, reaches 6 to 7 g of lactic acid per liter, casein (the main milk protein) coagulates, and the milk sours, resulting in "curdled milk."

► VARIOUS SAPROPHYTIC MICROBES

Other various saprophytic microbes develop when the harvest is not well cared for. Among them, Escherichia coli, which is responsible for digestive disorders.

Proteolytic bacteria hydrolyze caseins and give a bad taste to milk. Lipolytic bacteria destroy fats and give a rancid taste to milk.

► PATHOGENIC MICROBES

Some pathogenic microbes may be present, such as Brucella, responsible for brucellosis, the tubercle bacillus, responsible for tuberculosis, and various staphylococci or streptococci, responsible for infections transmitted by mastitis (inflammation of the udder) in cows.

1.3.2. Milk Pollution by Foreign Substances

It can be due to antibiotics used for animal treatment (e.g., during mastitis), leading to the presence of antibiotic residues in milk, or pesticide residues (fungicides, insecticides, etc.), which represent long-term risks of intoxication for humans.

1.3.3. Milk Hygiene in Production

- Milk must come from registered and controlled farms. The herd's animals must be healthy. They must not show any symptoms of contagious diseases transmissible to humans and must not have been treated with substances dangerous to human health. Moreover, the milk must not contain residues of substances such as antibiotics, sulfonamides, mycotoxins, heavy metals, artificial radionuclides at levels exceeding the tolerated limits.
- Additionally, the hygiene of milking, collection, transport, standardization, possible treatments, and personnel must also be controlled through microbiological standards that must be respected.

1.5.2. Obtaining and Preservation of Different Types of Marketed Milk (Figure 1)

1.5.2.1. Liquid Milks or Common Consumption Milks

► RAW FRESH MILK

This is milk that has undergone no preservation treatment except refrigeration on the farm. The mention "raw milk" or "fresh raw milk" must appear on the packaging and is indicated by a yellow band or label. The sell-by date corresponds to the day after milking. Raw milk must be boiled before consumption (as it contains pathogenic germs), stored in the refrigerator, and consumed within 48 hours.

► PASTEURIZED FRESH MILK

Pasteurization is a heat treatment that ensures the destruction of all potentially present pathogenic germs such as Mycobacterium tuberculosis, Salmonella, Brucella, and most bacteria responsible for spoilage. The milk is thus heated between 72 and 85 °C for about 20 seconds and then quickly cooled to +4 °C to stop the development of microorganisms spared by pasteurization and likely to make it "sour." Examples of microorganisms likely to develop: Streptococcus (including Streptococcus thermophilus), micrococci, and all spore-forming bacteria (such as Bacillus and Clostridium). Packaged pasteurized milk must be stored in the refrigerator, and its shelf life from packaging to consumption must be at most J + 7 days, J being the packaging day. However, derogations regarding the expiration date are gradually being granted. Moreover, once opened, it must be consumed within 2 to 3 days. Pasteurized milk is sold in two forms:

- Whole pasteurized fresh milk;
- Half-skimmed pasteurized fresh milk.

► LONG-LIFE MILKS

- These are sterilized milks that ensure the destruction of all microorganisms present in raw milk.
- **Sterilized Milk**

It is produced by simple sterilization, which consists of heating the already packaged milk in sterile airtight containers to a temperature of 115 °C for 15 to 20 minutes and then cooling it. The milk is then free of any microbial flora. Its expiration date is 120 days, and the storage temperature must be a maximum of 15 °C. The packaging must bear the mandatory mention "best before...". Packaging is done in plastic bottles. Once opened, it is no longer sterile and must therefore be stored cold in carefully closed packaging at +6 °C and consumed within 2 to 3 days.

• UHT (Ultra High Temperature) Sterilized Milk

Unlike pasteurization, it is practiced on bulk, unpackaged milk, according to two methods:

- **Direct method or uperization:** pressurized steam is injected directly into the bulk milk to bring it to 145 °C for a few seconds. This prevents the milk from boiling and having a cooked taste. It is then cooled very quickly and packaged aseptically;
- **Indirect method:** the milk is subjected to heat transfer through heat exchangers and is also brought to 145 °C for a few seconds, then cooled abruptly and packaged aseptically. Its shelf life is 3 months at room temperature.

1.5.2.2. Flavored and Gelled Milks

► FLAVORED MILKS

They are made from sterilized milks, skimmed or not, sweetened or not, with added authorized colorants and natural aromatic substances that can be artificially reinforced. These products are therefore often richer in carbohydrates and sometimes in lipids, hence a non-negligible impact on their energy value.

Examples: chocolate or cocoa milks.

► GELLED MILKS

They are obtained by adding gelling agents (e.g., agar-agar, alginates, carrageenans) and stabilizers (e.g., pectins) to flavored milks.

Note: These two types of milk will be used in the production of fresh dairy desserts.

1.5.2.3. Dehydrated Canned Milks

They benefit from a best before date (DLUO).

► PARTIALLY DEHYDRATED UNSWEETENED MILKS OR UNSWEETENED CONDENSED MILKS

They have been deprived of 50 to 55% of their initial water content and have undergone sterilization in containers or, more rarely, UHT treatment. They can be whole, skimmed, or partially skimmed.

• PARTIALLY DEHYDRATED SWEETENED MILKS OR SWEETENED CONDENSED MILKS

They also exist in whole, half-skimmed, or skimmed forms. They do not undergo sterilization because their high sugar concentration strongly limits microbial growth. Thus, they are standardized, pasteurized for a few seconds, then sweetened with a 70% sucrose syrup, and finally concentrated under vacuum and quickly cooled before being packaged. These milks, presented in cans, tubes, or cartons, can be flavored with natural substances reinforced by other flavors. They are sought after by children due to their taste and presentation. They are often consumed as is without rehydration. For these two types of milk, dehydration treatments allow for extended shelf life of over 1 year at room temperature (12 to 18 months). After opening, they must be stored in the refrigerator and consumed within 3 days for unsweetened condensed milk and 8 days for sweetened condensed milk.

► TOTALLY DEHYDRATED MILKS OR POWDERED MILKS

Only the dry extract is preserved: the water content is thus at most 5% of the finished product, their Aw is 0.2, which allows for long preservation. However, they are sensitive to heat and humidity. Storage is up to 1 year in a cool and dry place. However, once opened, it depends on their fat content:

- Whole: 10 days;
- Half-skimmed: 2 weeks;
- Skimmed: 3 weeks. They can be used to enrich the diet (e.g., malnourished individuals).

1.5.2.4. Infant Milks or Growth Milks

- These are powdered milks specially designed to meet the needs of infants and children from 10 months to 3 years. Their legal denomination is "dietary lacteal food for infants."

1.6. Other Mammalian Milks

1.6.1. Sheep Milk: This milk is more viscous and richer than cow's milk, containing 6.4% fat and 5.6% protein. It also has higher levels of lactose, vitamins B1, B2, B12, and minerals.

1.6.2. Goat Milk: This milk, which does not contain β-carotene, has a whiter color than cow's milk. Its composition is quite similar to cow's milk, but its casein content is lower, resulting in a lower yield for cheesemaking. Moreover, its caseins are different from those of cow's milk, giving it non-allergenic properties. However, this milk also contains chlorine, which can cause acidosis in infants.

1.6.3. Buffalo Milk: This is the base ingredient for true mozzarella.

1.6.4. Mare Milk: The mare, like humans, is a monogastric animal. It thus produces milk whose composition is quite close to human milk, unlike that of ruminants. However, it lacks minerals, and its price remains very high.

One can also consume camel milk, which is even poorer in lipids and richer in water in dry environments. It has a stronger taste and is rich in linoleic acid and vitamin C.

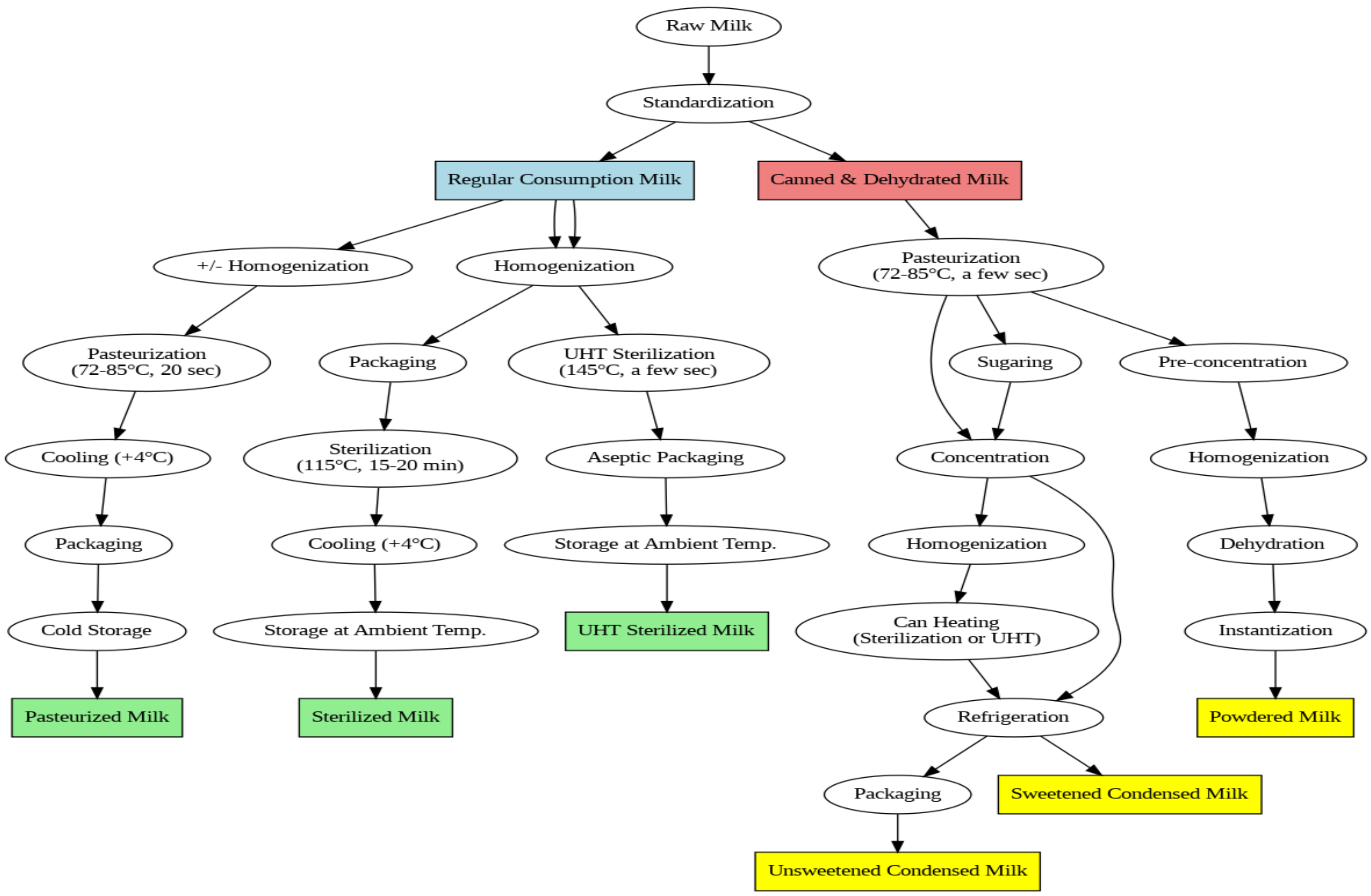

Figure 1 : Different Marketed Milks

2. Fermented Milks

2.1. Definition

Fermented milks" refer to dairy products prepared from skimmed or non-skimmed milks, in liquid, concentrated, or powdered form. They can be enriched with milk components such as milk powder or milk proteins. The milk then undergoes a heat treatment at least equivalent to pasteurization and is inoculated with microorganisms characteristic of each product. The coagulation of fermented milks must not be obtained by means other than those resulting from the activity of these microorganisms, which are mostly "probiotics," i.e., beneficial to health.

2.2. Yogurt

2.2.1. Definition

According to the 1977 definition established by the FAO (Food and Agricultural Organisation) and the WHO (World Health Organisation), yogurt is a coagulated milk obtained by acidic lactic fermentation due to 2 specific ferments: *Streptococcus thermophilus* and *Lactobacillus bulgaricus*, which are naturally present in milk, to the exclusion of any other bacteria.

These bacteria must be found alive at a concentration of 10^7/g of product. They are also thermophilic and degrade lactose into lactic acid starting at 45 °C, the content of which must be at least 0.7% at the time of sale.

Moreover, they live in symbiosis: *Lactobacillus bulgaricus* thus releases amino acids from casein, which will then be used by *Streptococcus thermophilus*, which in turn will release amino acids necessary for the growth of *Lactobacillus bulgaricus*.

2.2.2. General Diagram of Yogurt Production

2.2.2.1. General Diagram of Yogurt Production

Depending on the temperature and incubation time, a more or less acidic and more or less flavored product is obtained. *Streptococcus thermophilus* develops more rapidly and is less acidifying than *Lactobacillus bulgaricus*. They produce more aromas, which are products of their metabolism. To obtain a milder product, the incubation temperature can be increased by 1 to 3 °C or a younger starter can be used for fermentation.

Stirred yogurts are fermented in vats: they will be creamier because the curd is stirred and sieved. On the other hand, traditional yogurts are fermented directly in their pots and have a more compact texture.

Drinking yogurts, which after being stirred are beaten in vats before being packaged. Milk powder improves the consistency. The gelling of fermented milk, which corresponds to the coagulation of casein, is ensured by the action of heat during its heating and acidification obtained during the development of selected lactic bacteria.

Yogurt must not undergo any treatment after milk coagulation other than refrigeration and, possibly, stirring. This cooling occurs when the desired acidity is reached, and the cold limits recontamination by yeasts and molds for which this acidic pH environment is optimal. The expiration date of yogurts is a maximum of 24 days after the production date (Figure 2).

2.2.3. Classification of Different Types of Yogurts

According to Their Fat Content

- *Low-fat yogurts*: less than 1% fat;
- *regular plain yogurts*: minimum 1% fat;
- *whole milk yogurts*: 3.5% fat.

According to Their Flavor

- *Plain yogurts*: they undergo no addition;
- *sweetened yogurts*: they are sweetened with sugar;
- *fruit yogurts*, *honey yogurts*, *jam yogurts*: they undergo an addition of less than 30% of these different products;
- *flavored yogurts*: they contain natural flavors reinforced by a synthetic product.

According to Their Texture

- *Firm yogurts*: these are yogurts coagulated in pots;
- *stirred yogurts*: these are yogurts coagulated in vats and stirred before potting;
- *drinking yogurts*: their texture is liquid.

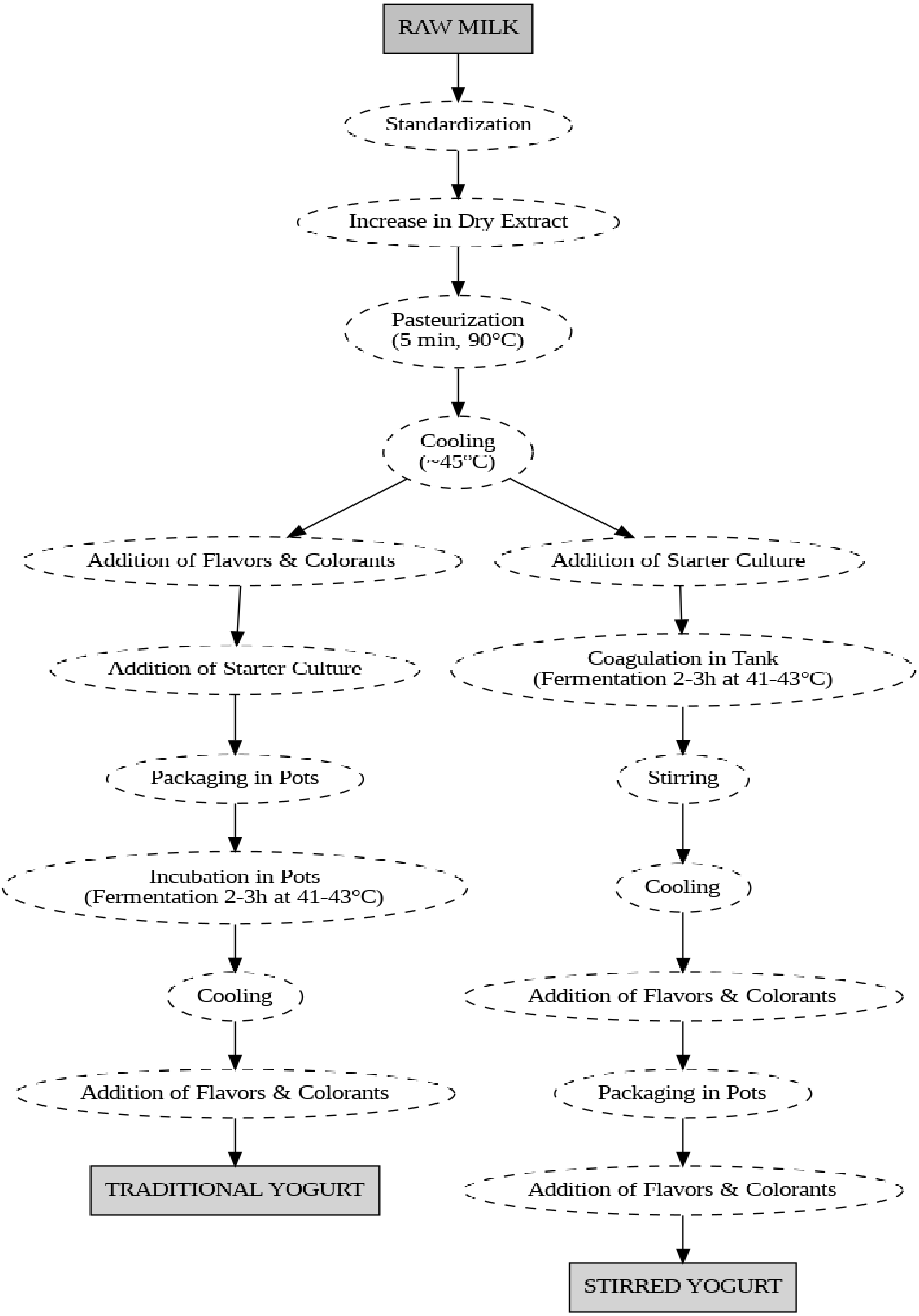

Figure 2 : Types of Yogurts

2.3. Other Fresh Fermented Milks

Their production varies little from that of yogurt, except for the modification of fermentation parameters (temperature, duration). Their quantitative nutritional composition is also close to that of yogurts, but they are not entitled to this denomination. Their flavor varies with the microbial flora used.

• **Milks with *Lactobacillus***

The species acidophilus or casei are used alone or in the presence of other ferments such as *Streptococcus thermophilus*. Some strains of *Lactobacillus acidophilus* or *Lactobacillus casei* strengthen the body's immune properties more effectively than *Lactobacillus bulgaricus*.

• **Milks with *Lactobacillus bifidus*:** Bacteria of the genus Bifidobacterium are commensal of the mouth and distal digestive tract of humans. They are adaptable to the intestinal flora and thus have a regulatory role on digestive transit.

Thus, this type of milk constitutes an effective therapy for diarrhea caused by enteroviruses. Moreover, they have significant activity against enterobacteria and rebalance the digestive flora after antibiotic treatment.

Other Fermented Milks by Heterofermentative Bacteria

The products formed are varied, in addition to lactic acid, the main product of lactose fermentation by homofermentative bacteria.

There are two main types of fermented milks by heterofermentative bacteria:

Kefir: which results from bacterial and fungal fermentations, particularly due to the activity of *Saccharomyces kefir*, which produces alcoholic fermentation. The preparation is foamy due to the presence of CO_2. It contains less than 1% ethanol and 1% lactic acid; **Koumiss**, which is similar to kefir. The milk can be mare, donkey, or camel milk, mixed with cow's milk.

2.4. Concentrated Fermented Milks

They originate from Scandinavian countries. Their commercial name recalls these countries (e.g., Bjorg).

They have a very creamy, velvety consistency, masking their acidity. This is why they are often confused with fresh cheeses due to their viscosity. The total dry extract is 15%, and the fat content is at least 4%.

They are either plain, sweetened, flavored with fruits, cereals, with limited fat content, enriched with vitamins...

3. Cheeses

3.1. Definition of Cheeses

The denomination "cheeses" is reserved for fermented or non-fermented, aged or non-aged products obtained from the following exclusively dairy origin materials: milk, partially or totally skimmed milk, cream, fat, buttermilk. These raw materials are:

- used alone or in mixture;
- coagulated totally or partially before or after draining.

3.1. Cheese Production

6 main steps are used to produce aged cheeses, while only 3 steps are sufficient to obtain fresh cheeses.

3.1.1. Inoculation with Specific Flora

The milk is inoculated with a specific microbial starter, which will represent a population of about 10^6 cells/g of cheese.

Different types of microorganisms are used:

3.1.1.1. Bacteria

LACTIC ACID BACTERIA

- *Lactic streptococci*: they are the most numerous. They produce lactic acid from lactose but also small amounts of aldehydes, volatile fatty acids, which are aroma components.
- ***Lactobacillus***: they participate more significantly in the production of aroma components.
- ***Leuconostoc***: they produce ethanol and organic acids from lactose and diacetyl from citrate. They thus also participate in the constitution of aroma and flavor.

SURFACE BACTERIA

They are brought by the brine. There are two types:

- *Proteolytic bacteria*: they intervene in the transformation of casein and then the digestion of the resulting amino acids. •
- *Lipolytic bacteria*: they participate in the degradation of curd triglycerides with the production of various organic acids.

PROPIONIC BACTERIA

Their concentration increases during the aging of certain cheeses (Emmental). They ferment residual lactose with the production of propionic acid, acetic acid, and CO_2, the accumulation of which is responsible for "holes" in cheeses.

3.1.1.2. Microscopic Fungi

► YEASTS

They produce aroma compounds, especially on the surface.

► MOLDS

They have a very active role in the aging of certain cheeses like blue-veined cheeses and soft cheeses.

There are two types:

- *surface molds*: they are responsible for the white felt of camemberts, brie...;
- *internal molds*: they are responsible for the blue veins of blue-veined cheeses and the internal molds of other cheeses. *Examples: Penicillium roqueforti, P. camemberti*. They have intense lipolytic and proteolytic activity, giving the cheese its organoleptic qualities. Most consume lactic acid, which deacidifies the cheese and contributes to giving it its final texture.

3.1.2. ***Curdling***

Its purpose is to ensure the precipitation of casein through milk curdling. It consists of the coagulation of milk, i.e., its passage from a liquid to a solid state, forming the curd. Thus, after partially or not skimming the milk, the cheesemaker pours it into a copper vat and heats it to about 30 °C. He then adds the agents responsible for coagulation, which occurs after about half an hour.

This coagulation can be obtained in different ways (figure 3):

• By the activity of lactic acid bacteria = lactic or natural curdling

The cheesemaker makes a natural starter from whey (or whey) from the previous day. The bacteria contained in this starter ferment lactose and acidify the milk by producing lactic acid. The milk coagulates as soon as the pH reaches values below 4.6.

• **Action of rennet = curdling by renneting**

Rennet is a liquid secreted by the stomach of young ruminants that contains a proteolytic enzyme that catalyzes the hydrolysis of casein into two fragments:

- a hydrophilic fragment that passes into the whey;
- a hydrophobic fragment that forms a gel.
- Rennet is extracted from the calf's abomasum by maceration in salted water for 4-5 days at 30 °C (this heating accelerates the reactions).
- A brownish solution is then obtained, which is filtered and then stored in powder form
- or left as liquid extracts.

- There are different types of rennet, varying in strength, i.e., the number of liters of milk that 1 liter of rennet can coagulate at 35 °C in 40 minutes. However, more and more, rennet is being replaced by fungal enzymes.
- *Combined action of rennet and lactic ferments*
- Conclusion: depending on the method used, the obtained coagulum or gel has a different texture: uniform gel with the action of rennet alone and friable and spongy (flaky) gelwith the action of lactic ferments.

The choice is thus made according to the desired texture.

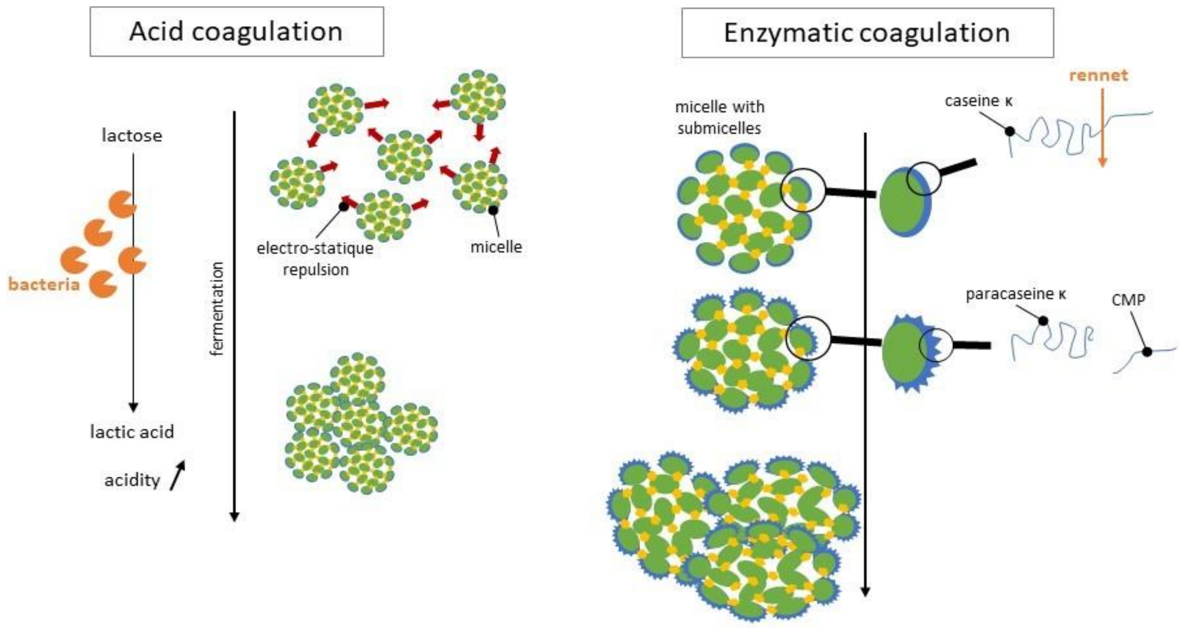

Figure 3 : Biochemical Mechanisms of Acid Coagulation and Rennet Coagulation

3.1.3. Draining

It allows the separation of the curd from the whey, which will then be eliminated. The latter is more or less rich in minerals, soluble proteins, and contains traces of lactose.

The composition of the whey depends on the method of obtaining the curd (lactic bacteria or rennet) and the draining speed. Indeed, draining can be:

- *Slow or spontaneous*: if one wants to obtain fresh cheeses and soft cheeses. In this case, losses in the whey are particularly significant.
- *Accelerated for other cheeses through different steps*:
- cutting: the curd is sliced;

- stirring ensuring agitation of the curd grains;
- pressing the curd;
- optionally, for hard cheeses, "cooking" the curd in the whey (50-55 °C) for an hour. When the grains have the desired consistency, the cheesemaker then transfers the contents of the vat into a perforated mold that allows the whey to drain and the curd to be recovered. A fresh curd + whey is then formed.

3.1.4. Molding

The cheeses are pressed into wooden or other material hooped cloths or taken in perforated molds, which allows obtaining their final shape. A fresh cheese is then produced.

3.1.5. Salting

The cheese can be salted either by spraying fine salt on the surface for soft cheeses or by immersion in a brine bath (- water + salt). Salt plays a triple role:

- it completes draining and will thus contribute to the formation of the rind;
- it regulates water activity (aw) and thus promotes or inhibits the development of microorganisms while regulating enzymatic activities;
- it reveals the cheese's own flavor by influencing the taste and reinforcing the aromas. A salted cheese is then obtained.

3.1.6. Aging or Maturation

This step is more or less long (2 to 3 weeks to over a year) and takes place in a specific place according to the desired cheese: temperature of 3 to 20 °C, controlled humidity, and ventilation. It is thus a period of intense microbial activity that will give the specific taste, color, and texture of each cheese.

3.2. Cheese Classification

3.2.1. Classification of Fresh Cheeses

3.2.1.1. Cottage Cheese

3.2.1.2. Petit Suisse

Currently on the market, there are two types of petit suisse packaging: the 30 g petit suisse (less and less marketed) and the 60 g petit suisse.

3.2.1.3. Salted Fresh Cheeses

Their fat content varies from 0% to 60%. Examples: demi-sel, Carré frais®.

3.2.1.4. Spreadable Cheeses

These are specialties based on fresh cheese or cottage cheese containing various ingredients. Example: Saint-Moret®.

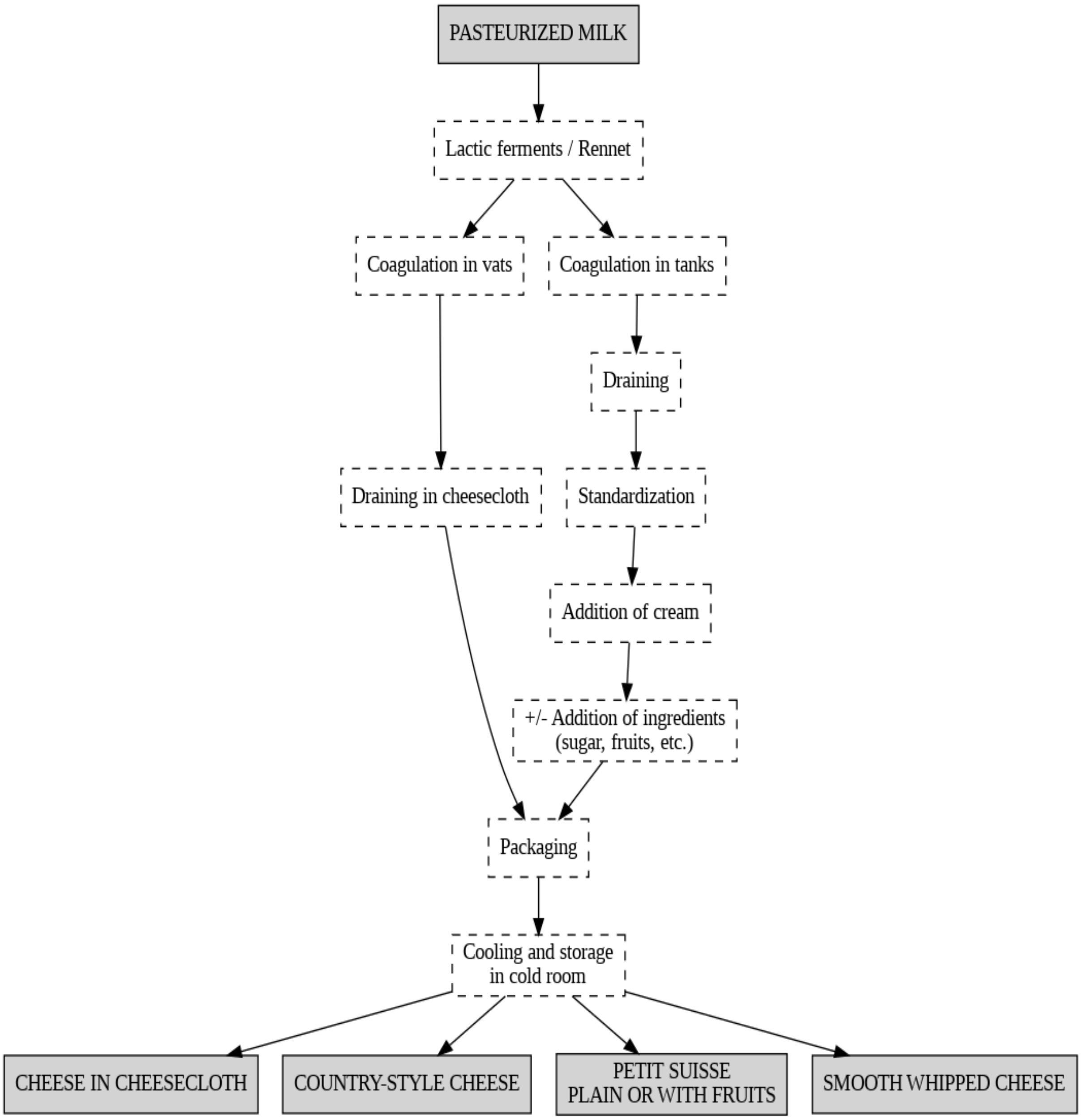

Figure 4 : Steps in Fresh cheese Manufacturing

3.2.2. Classification of Aged Cheeses

3.2.2.1. Soft Cheeses

WITH MOLDY OR BLOOMY RIND

Examples: Brie de Meaux, Brie de Melun, Camembert, Coulommiers, Chaource, Neufchâtel, Carré de l'Est, Saint-Marcellin, Vendôme, Pithiviers, Olivet, Saint-Félicien.

The paste is neither pressed nor cooked and is creamy. These cheeses are made from cow's or goat's milk, raw or pasteurized. The curdling is mixed, the draining spontaneous. Inoculation is done with *Penicillium*, which will give the rind its white felt-like appearance called "bloom."

WITH WASHED RIND

Examples: Maroilles, Munster, Vacherin, Pont l'évêque, Livarot, Géromé, Epoisse, Langres, Mont D'or, Vacherin du Haut Doubs, Rouy, Ossau-Iraty, Abondance.

They are made with raw or pasteurized milk and are voluminous. The curdling is mixed, and the draining is spontaneous. The slowness of aging requires washing the rind to keep it soft, hence their name of washed rind. This washing is done with salted water, which promotes the development of certain proteolytic bacteria, giving these cheeses their characteristic taste and odor. The rind then becomes yellow-orange.

3.2.2.2. Blue-Veined Cheeses

Examples: Bleus (de Bresse, du Haut Jura, des Causses, de Gex, du Vercors, d'Auvergne), Fourme d'Ambert, Fourme de Montbrison, Roquefort, Gorgonzola, Stilton...

The bleus are made with cow's milk, and roquefort with sheep's milk. The curdling is mixed and is inoculated with molds (*Penicillium roqueforti* for roquefort and *Penicillium glaucum* for the bleus) responsible for marbling, which are blue or green veins that give the paste its flavor. To promote the distribution of marbling and also the passage of air (necessary for the development of microorganisms), they are pierced with long needles.

3.2.2.3. Pressed or Semi-Hard Cheeses

WITH MOLDY RIND

Examples: Saint-Nectaire, Tomme de Savoie

WITH WASHED RIND

Examples: St Paulin, Reblochon, Pyrénées, Port Salut, Edam, Gouda, Mimolette, Raclette, Morbier, Cantal, Laguiole, Salers.

The curd is rinsed to reduce acidity, giving them a mild flavor. Then molding and draining. The paste is devoid of holes.

3.2.2.4. Pressed Cooked or Hard Cheeses

Examples: Emmental, Comté, Gruyère, Beaufort, Parmesan.

The renneted curd is heated to 50 °C for 30 minutes, which allows the selection of thermoresistant bacteria.

Molding and draining are very thorough, and aging is long (several months). For some, specific fermentations will occur with the production of carbon dioxide, responsible for the formation of holes or "eyes" dotting the paste.

3.2.2.5. Goat and Sheep Cheeses

Examples: Chabichou du Poitou, Crotin de Chavignol, Pélardon, Rocamadour, Sainte Maure de Touraine, Selles sur Cher, Picodon, Chevrotin, Valençay, Pouligny Saint Pierre, Banon, Brocciu...

These are often local and artisanal products, which is why they are classified somewhat apart.

In this family, we mainly find soft cheeses with bloomy rinds and fresh cheeses. Pressed uncooked cheeses and blue-veined cheeses are rarer.

There are three main types of goat cheeses, differentiated according to their production method:

- **Fresh goat cheeses**: their texture is supple, sliceable, non-sticky, and their taste is neutral;
- **"Lactic" goat cheeses**: these are aged cheeses with a brittle, slightly melting texture, and their taste is typical;
- **"Rennet" goat cheeses**: these are aged cheeses of the camembert type, with a supple, melting, and creamy texture. Their taste is not very typical unless they are made from raw milk.

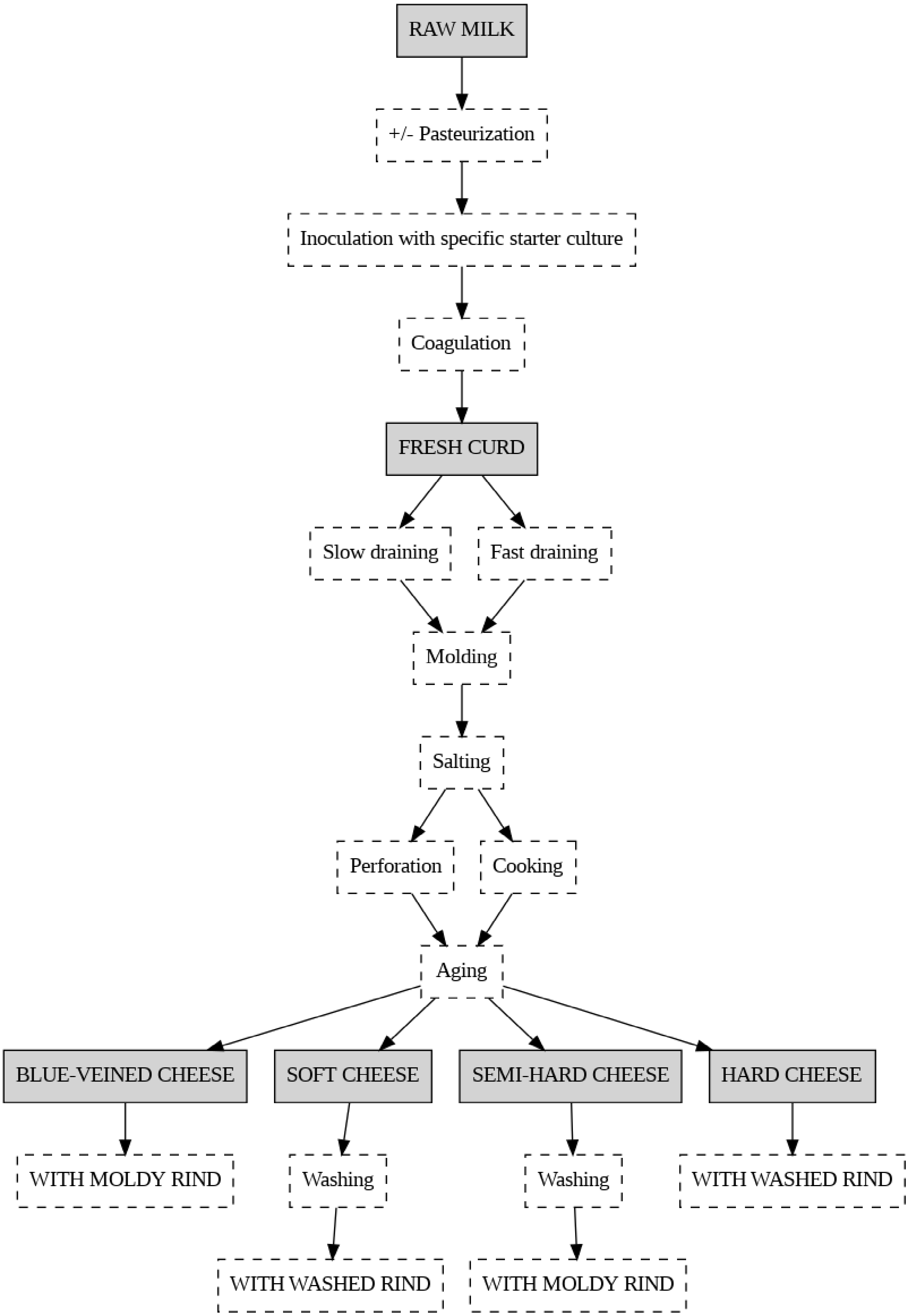

Figure 5 : Production Process of aged cheese

Ice Cream Manufacturing

Ice cream production is a complex process involving physicochemical and biological transformations that influence texture, stability, and sensory quality.

1. Composition and Formulation

The key ingredients in ice cream interact to form a stabilized emulsion with a structured foam that remains solid at subzero temperatures.

1.1. Basic Components

Component	Function
Water (50-70%)	Main solvent, essential for ice crystal formation.
Fat (8-16%)	Provides creaminess, influences mouthfeel and melting behavior.
Sugars (10-20%)	Lowers freezing point, enhances texture and taste.
Proteins (2-4%)	Stabilize the emulsion and increase viscosity.
Emulsifiers (0.2-0.5%)	Facilitate fat dispersion and stabilize air incorporation.
Stabilizers (0.2-0.5%)	Hydrocolloids (e.g., xanthan gum) that minimize large ice crystal formation.

2. Manufacturing Process Steps

2.1. Mixing and Homogenization

Mixing ensures uniform distribution of the aqueous and lipid phases. Homogenization (**50-70°C, 100-200 bar**) reduces fat globule size to **0.5-1 µm**, stabilizing the emulsion.

2.2. Pasteurization

Objective: **Eliminate pathogenic microorganisms** and improve the dispersion of proteins and stabilizers.

- **HTST (High Temperature Short Time) method**: **85°C for 15-30 seconds**
- **LTLT (Low Temperature Long Time) method**: **65°C for 30 minutes**

2.3. Aging

Rapid cooling to **4°C for 4 to 24 hours** allows:

- Partial crystallization of fat, promoting coalescence during freezing.
- Better interaction of stabilizers with water, increasing viscosity.

2.4. Overrun and Freezing

The mix is simultaneously whipped and frozen in an ice cream machine. This step:

- **Incorporates air** (overrun up to 100%), determining ice cream lightness.
- **Lowers temperature to -5°C to -7°C**, forming **micro ice crystals** (~30 µm) for a smooth texture.

2.5. Hardening

Final freezing at **-30°C to -40°C** stabilizes the structure and prevents ice crystal growth. Storage at **-18°C** preserves product quality.

3. Key Physicochemical Properties

Property	Influencing Factors	Effect on Ice Cream
Ice crystal size	Freezing rate, stabilizers	Smaller crystals = smoother texture
Freezing point	Sugar and mineral concentration	Determined by the fraction of free water
Supercooling	Cooling rate	Enables finer structuring
Overrun (%)	Whipping rate, stabilizers	Higher overrun = lighter texture
Melting behavior	Fat and emulsifier composition	Influences sensory perception

Treatment and Utilization of By-Products from Dairy Processing

VALORIZATION OF WHEY

1. Definition of Whey

A pale yellow liquid separated from the curd during cheese production in the draining process.

2. Types of Whey and Their Composition

The type and composition of whey vary depending on the processing conditions or techniques used for casein coagulation.

2.1. Acid Whey: Has a pH below 5 and is synthesized when mineral acids are used for casein coagulation.

2.2. Sweet Whey (pH between 6 and 7): Produced when rennet, chymosin, or other agents are used for casein coagulation.

Acid whey contains less protein and a higher ash content due to protein precipitation from the acid; however, its calcium concentrations are approximately twice those of sweet whey. The presence of high concentrations of acid and salt is a major constraint in the further use of acid whey. Additionally, the characteristics of whey also depend on the type of milk used for production.

	Sweet Whey	Acid Whey
pH	6-7	4-5
Total Solids	63-70	63-70
Lactose	46-52	44-46
Protein	6-10	6-8
Calcium	0.4-0.6	1.2-1.6
Phosphate	13	24.5
Lactate	2	6.4
Chloride	1.1	1.1

Concentration is expressed in g/L, except for pH.

3. Valorization of Whey

3.1. Single-Cell Protein

Single-cell protein (SCP) is defined as dead, dry microbial cells rich in protein (40% to 80% of the dry cell weight) and other nutrients, which are used as supplements in both human and animal nutrition.

Various microorganisms such as yeasts, bacteria, fungi, and algae are used for the production of single-cell proteins. However, among these, yeast is the most commonly used for SCP production due to its ability to grow easily on a carbon source. The bioconversion of whey for SCP production is the most attractive method of whey valorization, where lactose acts as a potential carbon source, used by various microorganisms such as *Kluyveromyces* for biomass production. However, a constraint often arises during the cultivation of these species. During SCP production, at high lactose concentrations, ethanol and other metabolites are produced due to the Crabtree effect under aerobic conditions, which negatively affects product yield.

3.2. Biofuels

The continuous increase in population has led to a rise in the demand for fuels and energy, raising concerns about environmental threats, global climate change, the depletion of fossil fuels, and the inflation of fuel costs. To mitigate these issues, attention has been drawn to the synthesis of biofuels using various agro-industrial wastes. Biofuels are currently emerging as the most sustainable fuels due to their non-toxic, renewable, and biodegradable nature.

3.2.1. Bioethanol

The production of bioethanol from whey is currently attracting attention, where the lactose present can be fermented or hydrolyzed for bioethanol production. Numerous microorganisms have been used for bioethanol production, such as *K. lactis*, *K. marxianus*, *Candida* *pseudotropicalis*, *S. cerevisiae*, *K. fragilis*, and *Torula cremoris*. However, among all these microorganisms, *K. marxianus* is the most suitable for the fermentation process due to its thermotolerance, high growth rate, and metabolic capacity. Many factors such as temperature, pH, substrate concentration, and cell biomass concentration affect the fermentation capacity of these microorganisms.

3.2.2. Biobutanol

Biobutanol is preferred over bioethanol due to several advantages, including its high energy density, low volatility, high boiling point, and hygroscopicity. The traditional route for butanol production involves an anaerobic process known as acetone-butanol-ethanol (ABE) fermentation using *Clostridium* sp., which generates acetone, butanol, and ethanol as final products. To reduce fermentation costs and improve process efficiency, attention has turned to the use of agro-industrial wastes as substrates for this process, including whey.

Whey has been reported as a successful substrate for biobutanol production using the CoA-dependent pathway of *Clostridium acetobutylicum* and *Clostridium beijerinckii* strains due to the presence of lactose.

The metabolic pathway, including enzymes and coenzymes, for butanol production is illustrated in the figure below.

Efforts have been made to improve butanol yield using various biotechnological approaches, including the modification of *Clostridia* sp. through genetic and metabolic engineering and the construction of synthetic pathways for *E. coli* and *S. cerevisiae* strains. Despite the mentioned advances in the field of butanol production from whey, a successful industrial process has not been developed to date due to several issues such as toxicity, low yield, and productivity of butanol, making recovery quite difficult.

3.2.3. Biogas Production

Biogas is a methane-rich gas typically produced through the anaerobic digestion process for the safe treatment and disposal of industrial waste. Numerous studies have been conducted on biogas production using whey as a substrate, where the lactose present in whey is successfully fermented by microbes in the absence of oxygen. A continuous two-phase system has been successfully developed for biogas and hydrogen production from whey.

Anaerobic digestion is a controlled biological degradation process that allows for the efficient capture and use of biogas for energy production.

Anaerobic digestion is carried out by a consortium of bacteria working together to convert organic matter into biogas and inorganic constituents.

Anaerobic digestion generally occurs in four stages:

(I) Anaerobic hydrolysis, where complex particulate organic substances are converted into monomers such as amino acids, sugars, and long-chain fatty acids (LCFAs);

(II) Fermentation, the process following hydrolysis, during which amino acids and sugars are converted into volatile fatty acids (VFAs);

(III) Acetogenesis, a process during which fatty acids and alcohols are converted into acetate and CO_2/H_2, providing direct precursors for methane formation;

(IV) Methanogenesis includes hydrogenotrophic methanogenesis, during which H2 and CO2 are converted into methane, and acetic methanogenesis, during which acetate is converted into methane by acetate-utilizing methanogens.

Several studies have reported the inefficiency of direct anaerobic treatment of cheese whey due to reactor instability and low biogas productivity and methane yield, likely due to the low pH of whey. Therefore, many researchers have studied the co-digestion of whey with different types of manure.

4. Lactic Acid

Lactic acid is a versatile organic acid with major applications in the food, pharmaceutical, and chemical industries. The availability of lactose in whey and the presence of other essential nutrients for microbial growth make whey a suitable substrate for lactic acid production.

Additionally, supplementing whey with various nutrients such as yeast extract, peptone, molasses, corn liquor, lactose, vitamins, minerals, and amino acids is useful for increasing lactic acid yield.

Microbial species, namely lactic acid bacteria, are responsible for fermenting sugars into lactic acid. Important attributes of these species include efficient carbohydrate fermentation as well as substrate phosphorylation. In general, there are two fermentation pathways for lactic acid bacteria depending on their fermentation characteristics. Lactic acid bacteria species are classified into three groups (homolactic fermenters, facultative heterolactic fermenters, and obligate heterolactic fermenters).

5. Enzyme Production

Whey has been widely used as a substrate due to its high nutrient content and low cost. Although the production of various industrially important enzymes has been achieved from whey, much work focuses on the production of β-galactosidase. Different bacterial, yeast, and fungal strains have been studied for enzyme production.

Yeasts have been extensively studied for β-galactosidase production. *K. marxianus* has been reported as effective in β-galactosidase production.

Additionally, a study showed protease production using two mold species, namely *A. tamarii* and *Penicillium pinophilum*.

Amylase is one of the most important enzymes used in the brewing, detergent, textile, pharmaceutical, and food sectors. Combinations of soybean flour, wheat bran, and whey have proven to be effective substrates for amylase production (4257 U/mL) with *Bacillus amyloliquefaciens*. Another microorganism, *Anoxybacillus beppuensis* JF84, produced thermostable amylase in cost-effective substrates such as whey and sugarcane bagasse supplemented with whey.

6. Prebiotics

Prebiotics can be defined as non-digestible food ingredients that enhance the activity or growth of resident microflora in the colon and have beneficial effects on host health. Any food can be considered a prebiotic if it:

(1) Resists gastric acidity,

(2) Resists hydrolysis by gastrointestinal enzymes,

(3) Undergoes fermentation by colonic microflora and stimulates the activity or growth of beneficial bacteria in the colon.

Among these, the synthesis of galactooligosaccharides (GOS) and lactulose has been achieved from whey.

GOS: Composed of at least 210 galactose molecules and a terminal glucose molecule linked by β-glycosidic bonds. GOS synthesis is achieved by the transgalactosylation activity of the β-galactosidase enzyme in a kinetically controlled reaction using lactose as a substrate.

In addition to GOS, whey has been used for lactulose production.

Lactulose (4-O-β-galactopyranosyl D-fructose): A disaccharide composed of galactose and fructose. Lactulose production can be achieved either by lactose isomerization using different catalysts such as sodium or calcium hydroxides, phosphates, borates, or by the enzymatic biotransformation of lactose into lactulose.

7. Biopigments

Given the toxic and hazardous effects of synthetic pigments on humans, animals, and the environment, interest has grown in the production of natural pigments using microorganisms, called biopigments. Researchers have shown great interest in producing biopigments from whey using various microorganisms belonging to the genera *Aspergillus*, *Penicillium*, *Monascus*, etc. Whey can be used as a potential substrate for the production of red pigment by *Monascus* through submerged fermentation.

Among yeasts, the species *Rhodotorula* is considered the most suitable microorganism for carotenoid production from whey.

Another yeast, *Xanthophyllomyces dendrorhous*, has been explored for carotenoid production using hydrolyzed whey through simple aerobic fermentation.

8. Polysaccharides

Microbial polysaccharides are natural biopolymers that are ubiquitous in nature and have important applications in various industrial sectors. Due to their rheological and biological properties, polysaccharides have been used as gelling agents, thickeners, and stabilizers. Additionally, they have been reported to have potential health benefits such as anti-inflammatory, antitumor, and antimicrobial activities. Although microbial polysaccharide production has been performed on various substrates, the use of cost-effective substrates such as whey not only improves polysaccharide production but also minimizes production costs. Among the microorganisms used for polysaccharide production, *Zunongwangia profunda* (for exopolysaccharide (EPS) production), *Leuconostoc mesenteroides*, and *Xanthomonas campestris* (for xanthan gum production) are notable.

9. Bacteriocins

Bacteriocins are antimicrobial protein substances typically synthesized by Gram-positive or Gram-negative bacteria and have antagonistic activity against each other or against other closely related bacterial species. Some examples of bacteriocins extracted from different microbial species include nisin (*Lactococcus* sp.), pediocin (*Pediococcus* sp.), lactocin (*Lactobacillus* sp.), etc.

Bacteriocin production is influenced by process conditions and the type of fermentation medium, primarily the presence of carbohydrates, nitrogen sources, amino acids, proteins, minerals, and vitamins. Several studies have been conducted on bacteriocin production from MRS media; however, due to the high production cost, studies are now focusing on the use of low-cost media for production, such as molasses and corn syrup, soy milk, and whey.

10. Bioactive Peptides

Whey contains a multitude of different biologically active proteins or peptides, representing 15% to 22% of the total milk proteins and having high biological values compared to other dietary proteins. The main whey proteins include immunoglobulin-G, bovine serum albumin, α-lactalbumin, β-lactoglobulin, and glycomacropeptides, as well as others with potent bioactivities.

Almost all proteins are naturally present in whey, except for glycomacropeptide, which is produced from casein during the first step of enzymatic cheese production.

Whey proteins are known for their diverse functional properties due to their physical, chemical, and structural characteristics.

The industrial production of whey protein hydrolysates containing bioactive peptides involves various processing steps. These are:

(1) Fractionation of solids for the removal of fats, lactose, and minerals,

(2) Enzymatic hydrolysis of whey proteins using either:

(a) Commercial enzymes of animal origin such as pepsin, pancreatin, and trypsin,

(b) Plant enzymes such as papain and bromelain,

(c) Bacterial and fungal proteases;

(3) Post-hydrolysis treatment such as filtration, centrifugation, and various chromatographic techniques;

(4) Spray drying of the product;

(5) Packaging.

Chapter 2: Sugar Industry

1. Sugar or Sucrose

In regulations, the term **sugar** refers to products obtained in sugar factories and refineries from sacchariferous plants, meaning plants rich in sucrose.

1.1. Production of White Sugar

1.1.1. Sugar from Sugar Beet

There are 3 varieties of beets:

- *Garden beet*: a common vegetable with red flesh;
- *Fodder beet*: used to feed livestock, with red or white flesh;
- *Sugar beet* with white flesh, containing 16 to 18% sugar per 100g of beet. This variety stores the sugar synthesized by its leaves (through photosynthesis) in its roots. It is this variety that is used in the production of white sugar.

The following steps are necessary:

► WASHING, STONE REMOVAL, WEEDING, AND CUTTING INTO COSSETTES

The beets are harvested and transported to sugar factories. They are washed to remove impurities (stones, straw, and soil) and cut into cossettes, which are thin strips of beet. The shape of the cossettes allows:

- A larger surface area for sugar extraction;
- A thin thickness to reduce the time for sugar diffusion into the juice.

► DIFFUSION

The cossettes are placed in large horizontal cylinders and exposed to hot water at 75°C flowing counter-currently. This step allows the diffusion of sugar through the cell walls of the cossettes into the hot water via osmosis.

A dark blue or black impure diffusion juice is collected, with the following composition:

- Water: 84%
- Sugar: 13-14%
- Impurities: 2-3%

Impure sugar ~ 15%

In parallel, the exhausted cossettes, called pulp, are obtained and used for:

- Animal feed;
- Production of industrial pectins;

- Extraction of other dietary fibers (lignin, cellulose) and incorporation into "fiber-enriched" food products.

► PURIFICATION

- Liming: The sugary juice is purified using lime milk, which precipitates some impurities and forms insoluble salts with them.
- Carbonation: The limed juice is heated to 80-85°C and exposed to carbon dioxide. This transforms the lime into insoluble calcium carbonate, forming a granular precipitate that is easily removed by filtration.

► FILTRATION

The calcium carbonate precipitate containing impurities is separated from the clear sugary juice by filtration. A clear, pale yellow purified juice is obtained, containing:

- 12 to 13% sucrose;
- 86% water;
- 1% impurities.

► VACUUM EVAPORATION

The purified sugary juice passes through evaporation boilers and becomes concentrated. A dense, brown-yellow syrup is obtained, containing about 60-65% sucrose.

► CRYSTALLIZATION

To induce sugar crystallization, the syrup must be concentrated to supersaturation, meaning it is brought beyond its solubility limit. Concentration and crystallization are carried out under vacuum in large boilers at a temperature close to 80°C (to avoid caramelization).

A "massecuite" is obtained, consisting of **clearly visible crystals of pure sugar** and some impurities concentrated in the mother liquor.

► MIXING

The massecuite is poured into a mixer and cooled, allowing the crystals to continue growing at the expense of the mother liquor in which they are immersed and from which they must be separated.

► CENTRIFUGATION

The massecuite is sent to centrifugal dryers, which separate the slightly yellow sugar crystals from the mother liquor and remaining impurities. **First-grade sugar** is obtained.

This sugar is then washed, making it very white, i.e., completely free of any traces of mother liquor, but it remains hot and moist.

However, the water expelled from the centrifuge still contains a high proportion of sugar: this mother liquor, called "first-grade molasses," undergoes further cooking and centrifugation, yielding **second-grade sugar**, which is more colored and less pure than first-grade sugar. The "second-grade molasses," still rich in sugar, is reintroduced into the production cycle, yielding **third-grade sugar** (or **brown sugar**), which is brown and contains impurities, and a final molasses called "**blackstrap molasses**."

Second and third-grade sugars are usually remelted and reintegrated into the production process for recrystallization.

Blackstrap molasses still contains sugar (about 50% of dry matter), but its extraction would be too costly. Additionally, due to its unpleasant taste, it is used for:

- Alcohol production (e.g., ethyl alcohol used in perfumery, vinegar production, pharmaceuticals, and household products);
- Animal feed production;
- Various industrial microbial fermentations, as it is an excellent substrate (production of glutamic acid used as a condiment, citric acid used as a food additive, antibiotics, baker's yeast, etc.).

► DRYING

The **white crystallized sugar** from the centrifuges is dried with hot air and then cooled. Its moisture content is reduced to less than 0.02-0.04%. It is then weighed and directed to bulk storage silos.

► REFINING

Refineries complement sugar factories by not only purifying second and third-grade raw sugars but also packaging and marketing sugars for direct consumption in various forms.

1.1.2. Sugar from Sugarcane

Sugarcane is a tropical plant that contains sugar in its stem. Unlike sugar beet, where sugar is extracted by diffusion, sugarcane sugar is recovered by crushing.

Different steps are involved in producing cane sugar:

► EXTRACTION OF "VESOU" OR CANE JUICE

- *Cutting and crushing the cane*

"Cane cutters" chop the cane into very short and small pieces.

The prepared cane is crushed and pressed increasingly hard, allowing the collection of a sugary juice called "vesou," which contains 10 to 18% sucrose.

The fibrous or woody residues obtained after crushing are soaked in water to dissolve as much sucrose as possible and are then used as fuel for the boilers of sugar factories or refineries.

- *Screening and filtration*

This reaction gradually transforms the sucrose solution into a mixture of glucose and fructose, which hinders crystallization and has two possible outcomes:

- *Production of white or "agricultural" rum* obtained by distilleries that only produce rum;
- *Extraction of cane sugar and the use of residual molasses and mother liquor for the production of industrial rum.* Industrial rum is thus produced by sugar factory distilleries.
- *Sugar extraction*

After being purified, decanted, and filtered, the vesou is evaporated and concentrated to the consistency of a syrup. It is then recooked until spontaneous crystallization of sucrose occurs. The **sugar crystals** are then separated from the mother liquor and dried.

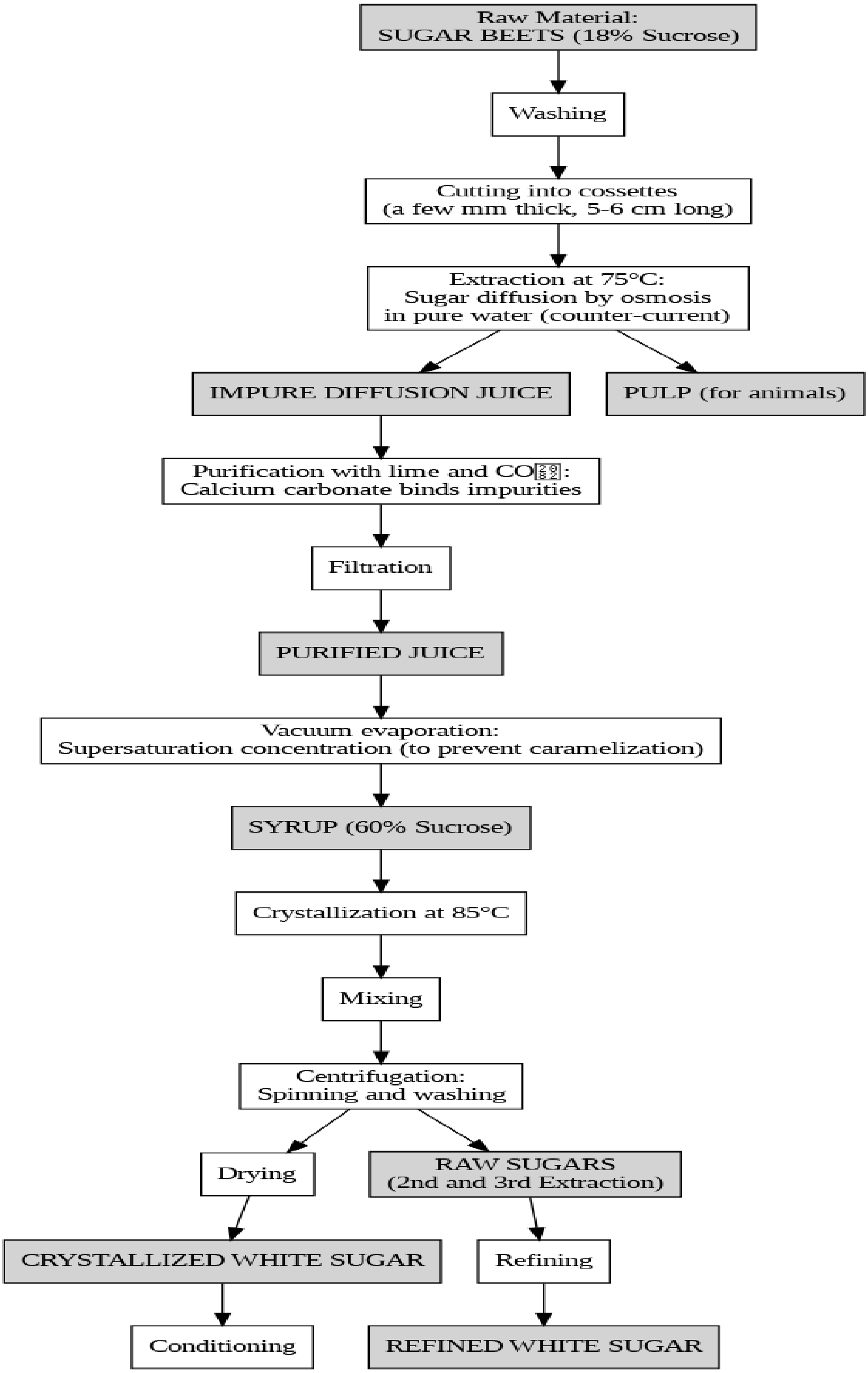

Figure 1 : Production of Sugar

Chapter 3 : Dietary Fats

1. General Information

Dietary fats, as the name suggests, are foods with a very high lipid content that are insoluble in water. They represent the "visible" lipids in the diet because they are intentionally added. They are thus opposed to the **constitutive lipids** of foods, which are an integral part of the product. Their extraction can be done from the following raw materials:

- Animal adipose tissues:
  - Tallow (fat from ruminants),
  - Goose fat, duck fat,
  - Lard (melted pork fat),
  - Marine animal oils (e.g., cod liver oil);
- Oilseeds: peanut oil, sunflower oil, rapeseed oil, soybean oil, grape seed oil, walnut oil, hazelnut oil, safflower oil, palm kernel oil (extracted from the kernel of the oil palm);
- Cereal germ: corn oil, wheat germ oil;
- Pulp of oleaginous fruits: palm oil (extracted from the pulp of the oil palm fruit), copra oil (extracted from the pulp of mature coconuts), olive oil;
- Milk: cream and butter.

1.1. Classification of Fats

1.1.1. Classification by Origin

Origin	Fats
Animal	Butter Cream Beef fat (tallow), goose fat, duck fat, lard Shortening (refined and hydrogenated fats) based on animal fats suitable for deep frying Marine animal oils
Vegetable	Oils for seasoning Oils for frying and seasoning Vegetable margarines
Mixed	Standard margarines based on vegetable oils and fish fats Margarines and shortening for pastries

1.2.2. Classification by Consistency at Room Temperature

The physical properties of fats depend directly on their chemical composition in fatty acids, which influences their consistency.

Thus, the melting point is the temperature at which a fat liquefies. Consequently:

- The more double bonds there are, the more liquid or fluid the fat is at room temperature;
- The more saturated fatty acids are present, the more solid or concrete the fat is at room temperature.

Fluid Fats	**Oils: Peanut Rapeseed Soybean Safflower Cottonseed Corn germ Grape seed Walnut Hazelnut Sweet almond**
Concrete Fats	Oils: Palm Palm kernel Copra
	Vegetable margarines Butter Lard Beef fat, goose fat, duck fat, poultry fat Shortening Common margarines

2. Study of Different Dairy and Vegetable Fats

2.1. Cream

2.1.1. Definition

Cream is the product of centrifugal skimming of milk. It is thus an emulsion of fats in water, meaning that the fat particles are dispersed as droplets in the aqueous phase.

The term cream is also reserved for products obtained from milk containing at least 30% fat.

2.1.2. Manufacturing Steps (figure 1)

2.1.2.1. Centrifugal Skimming

Milk is skimmed using a centrifugal separator that allows it to rotate very quickly inside a tank, resulting in the formation of two phases:

- A heavy phase due to the concentration of denser lipids that gather in the center and form the cream;
- A light phase consisting of the other elements that move to the walls of the tank and constitute skimmed milk or "whey" (rich in proteins and minerals), which is reserved for other food uses or animal feed.

The cream obtained is liquid and smooth since its lactic acid content is still low, but depending on how close to the center of the rotation axis it is collected, it will be more or less rich in fat.

2.1.2.2. Pasteurization

Except for raw cream, pasteurization involves a high-temperature heat treatment between 85 and 90 °C for 15 to 20 seconds while preserving the organoleptic qualities of the cream.

It thus causes:

- Destruction of pathogenic germs and most saprophytic germs;
- Destruction of lipases, factors of rancidity;
- Formation of sulfur compounds that oppose lipid oxidation;

- Subsequent control of the lactic maturation of the cream.
- **2.1.2.3. Inoculation with Lactic Ferments and Maturation**

This step is carried out between 12 and 18 °C. Lactic ferments allow the cream to mature, which acidifies, thickens, becomes suitable for possible foaming, and develops new aromas (notably the formation of diacetyl).

2.1.2.4. Other Steps

- Cooling and packaging.
- Storage in a cold room between 0 °C and +6 °C.
- Commercialization.

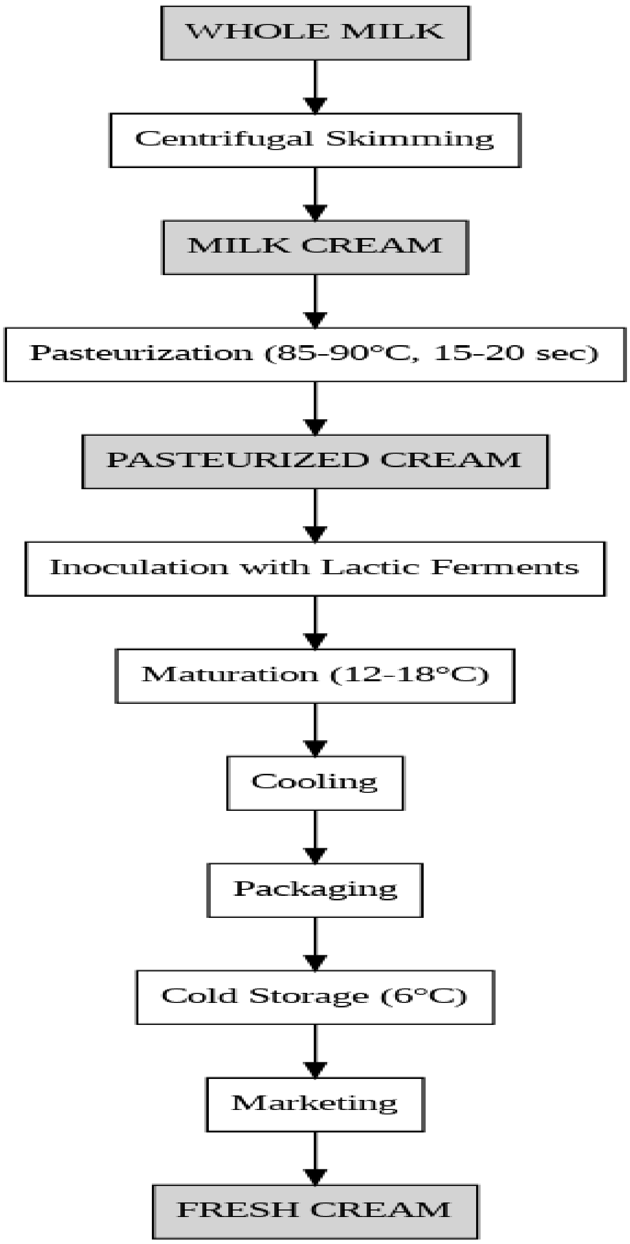

Figure 1 : Production Process of Cream

2.1.3. Denominations

2.1.3.1. Raw Cream

This is the cream obtained just after skimming, which has not undergone any specific heat treatment (except cooling). Its consistency is liquid (during the first few days) and its flavor is smooth.

The term "raw" is mandatory on the labeling, and its fat content is generally higher than that of other creams.

2.1.3.2. Pasteurized Liquid Fresh Cream

It has not been inoculated or matured and therefore retains its fluid and smooth texture, but it is quite fragile. It is rarely marketed except for restaurants under the name "crème fleurette," even though this name is generic and not legal. It is highly appreciated for its ability to foam, meaning to be whipped to incorporate air, making it light and voluminous up to the stage of whipped cream.

It differs from regular liquid creams by the fact that it is only pasteurized and not sterilized. Being more fragile, it is increasingly less used.

2.1.3.3. Pasteurized Thick Fresh Cream (or Matured)

After pasteurization, if a thick cream is desired, maturation is carried out. As we have seen earlier, this process involves cooling the cream to "crystallize" part of the fat (physical maturation) and then inoculating it with lactic ferments taken from particularly aromatic creams (biological maturation) with a high acidity level.

Thus, from smooth and liquid, the cream becomes thick, acidic, and its flavor becomes more pronounced.

Note: the term "thick" does not necessarily mean a higher fat content since a thick cream can be light.

2.1.3.4. Sterilized Cream (Liquid)

Once packaged, raw cream is sterilized at 115 °C for 15 to 20 minutes and then cooled. Since sterilization does not allow inoculation, it remains liquid. However, this process develops a "cooked" or caramel flavor in the milk, which explains the current preference for UHT cream.

2.1.3.5. UHT Cream (Liquid)

Raw cream is sterilized at 150 °C for 2 seconds and then quickly cooled. The organoleptic, nutritional, and functional qualities are thus preserved. Packaging is done aseptically.

2.1.3.6. Whipped Cream

This is a whipped cream containing at least 30% fat.

2.1.3.7. Light Cream

The strength of skimming determines the fat content. Therefore, the separator is adjusted according to the desired fat percentage. Thus, light cream contains at least 12% fat but less than 30%, and this percentage must be specified on the packaging.

Light cream can be thick or liquid but must be pasteurized or sterilized.

They should also be distinguished from "dairy preparations based on light fresh cream with reduced fat content," whose stability is ensured by certain additives such as modified starch.

2.1.3.8. Double Cream

It is often believed that the term "double" applies to a cream particularly rich in fat, whereas it is simply a synonym for "thick." It is therefore simply a matured, thickened cream. This is why it should not be confused with certain creams very rich in fat, intended for cooking and pastry, with a fat content of around 40%.

2.1.3.9. Whipped Cream or Cream for Whipping

This product consists of cream or light cream, in a proportion of at least 75%. The addition of certain products is allowed, such as sucrose, lactic ferments, natural flavoring substances, milk proteins. The foaming rate (ratio between the volume of whipped cream ready for sale and the initial volume) varies between 2 and 3.

The term "whipped cream" applies to a whipped cream containing at least 30% fat.

2.1.3.10. Pressurized Cream

It is always pasteurized or sterilized, and its foaming rate and composition are similar to that of cream for whipping, except for stabilizers, whose addition is limited to 0.1%. It is packaged under pressure by injecting a neutral gas, the release of which causes foaming.

2.2. Butter

2.2.1. Definition

Butter is a dairy product of the water-in-fat emulsion type, obtained exclusively from milk fat after churning and maturation of milk cream. It must contain at least 82% butterfat, a maximum of 16% water, and no more than 2% non-fat dry matter.

Note: the term butter can also be used for certain products such as anchovy butter, peanut butter... In this case, the products must contain at least 10% milk fat.

2.2.2. Different Manufacturing Steps (figure 2)

- **Skimming of milk**: it allows obtaining cream, the raw material of butter.
- **Possible pasteurization of the cream.**

- **Rapid cooling of the cream**: it is done between 10 and 15 °C and allows regulating the activity of the microbial flora, the crystallization of the fat that had melted due to heating, and avoiding the appearance of a "cooked" taste.
- **Inoculation with lactic ferments**: the pasteurized cream is inoculated with 3 to 5% of a starter of selected lactic bacteria from cream or butter with a particularly fine flavor. The lactic ferments used are:
  - Aromatic lactic streptococci (e.g., *Streptococcus diacetylactis*)
  - Acidifying lactic streptococci (e.g., *Streptococcus cremoris*);
  - Heterofermentative lactic streptococci, which are also aroma producers (e.g., *Betacoccus citrovorus, Betacoccus paracitrovorus*).
- **Maturation of the cream**: the cream is matured for 6 to 15 hours in an acidic pH, in the presence of oxygen, and at a temperature between 14 and 16 °C. There is then the formation of lactic acid and diacetyl (by oxidation of the citric acid in the milk) which give a "nutty" flavor. The purpose of maturation is to thicken the cream, facilitate churning, and ensure the greatest possible development of the aroma.
- **Cooling**: it is done at a temperature of 12 °C or lower and perfects the crystallization of lipids.
- **Churning or butyration**: it allows the transformation of cream into butter. The cream is placed in a mobile stainless steel churn with a rough inner surface, which allows the formation of "butter grains." Churning thus corresponds to vigorous and repetitive agitation of the butter, causing an inversion of the emulsion phases (figure 3). Thus, there is an incorporation of gas which, under the influence of movement, creates a compression of the fat globules. The membrane of these globules then bursts and releases the fat, which fuses and forms the butter grains, releasing buttermilk or whey. The latter is a liquid consisting of the rest of the initial milk, including casein, lactose, water, minerals... It thus has the composition of fermented skimmed milk. The butter grains are surrounded by aqueous droplets containing the non-fat part of the butter. Their diameter must be controlled and should not be too small, which would reduce the organoleptic qualities of the butter, nor too large, which would favor rancidity.

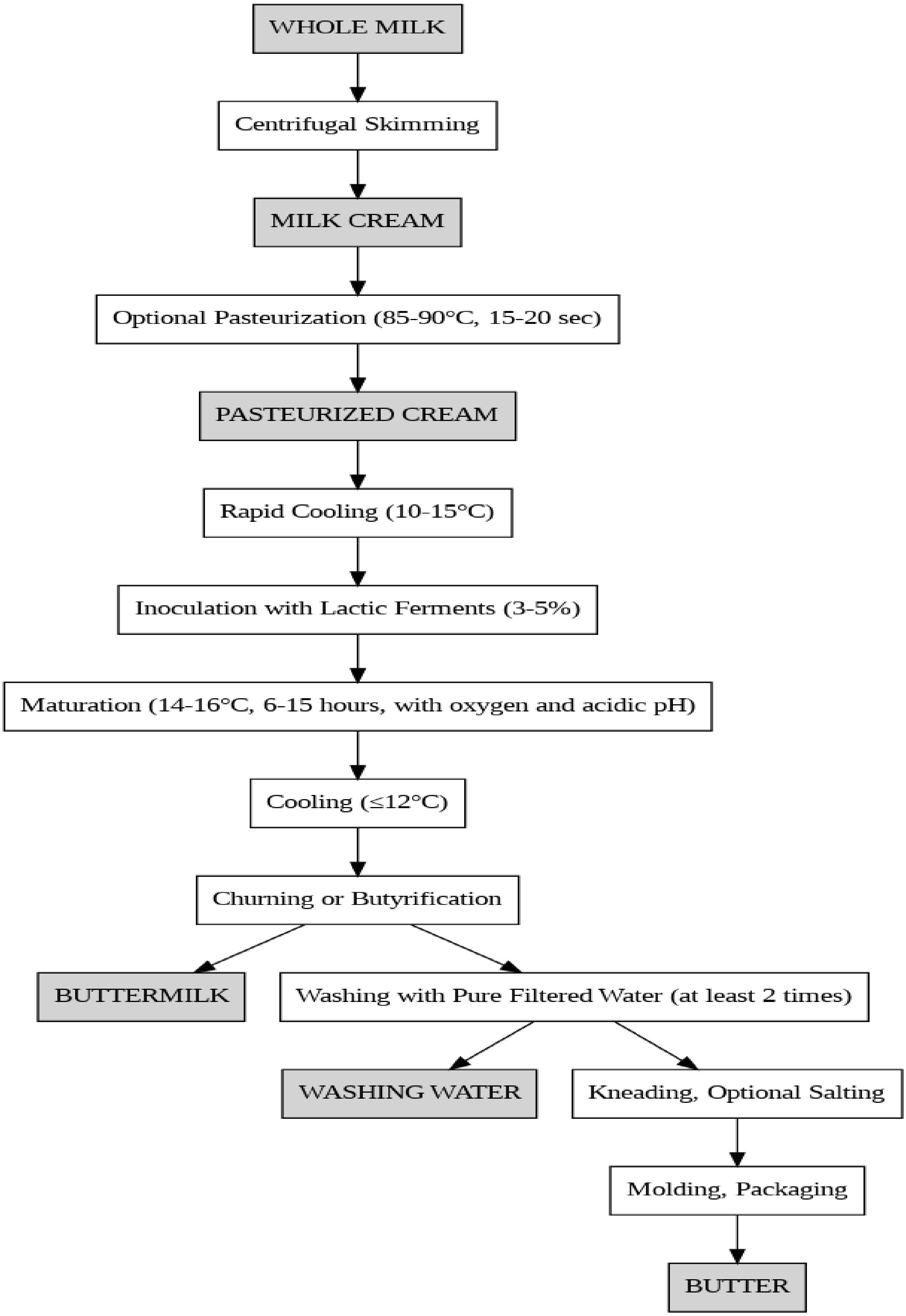

Figure 2 : Steps in Butter Manufacturing

- **Washing of the grains**: washing is done with pure filtered water to avoid contamination of the butter. It also allows removing any remaining buttermilk that could still be retained by the butter grains, which would make the butter unsuitable for storage and reduce its organoleptic qualities by maintaining the acidic taste of the cream. At least two washes are performed.
- **Removal of washing water**: it allows obtaining the butter itself.
- **Kneading**: kneading perfects the fusion of the butter grains and evenly distributes the remaining water (no more than 16%) in the butter mass so that the product reaches a satisfactory humidity.
- **Salting**: it is done at this stage if salted or half-salted butter is desired.

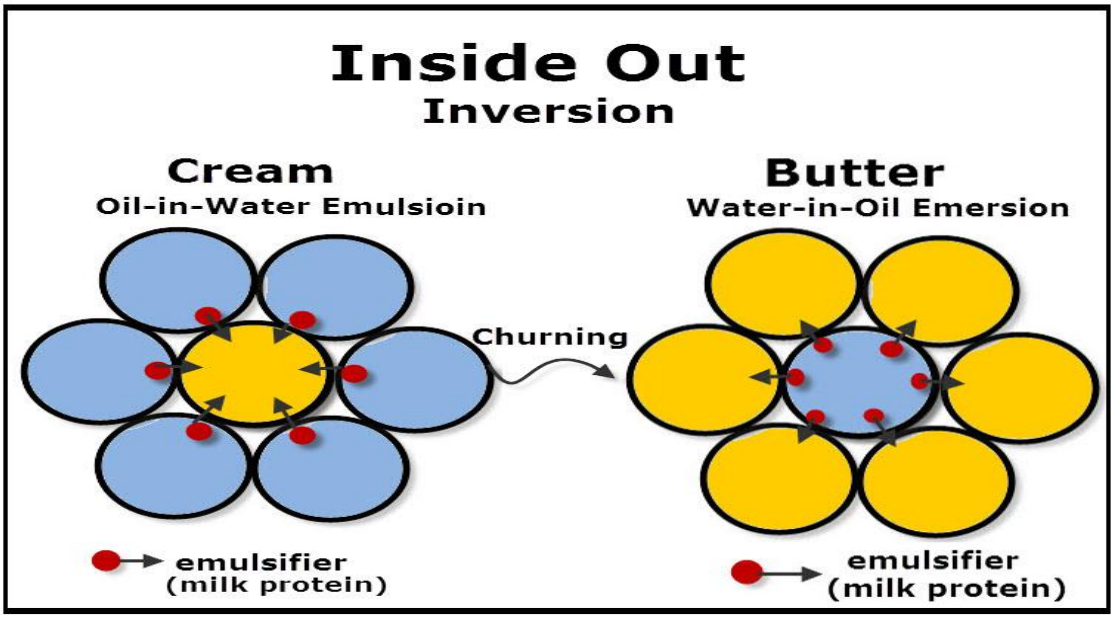

Figure 3 : Cream and Butter Emulsion

2.3. Vegetable Edible Oils

2.3.1. Classification of Oils

2.3.1.1. Based on Their Use

There are thus two categories of oil:

- "Vegetable oil for frying and seasoning" if the linolenic acid content is less than or equal to 2% and if this oil is not discouraged under certain heating conditions.
- "Vegetable oil for seasoning" if the linolenic acid content is greater than 2%.

2.3.2. Classification Based on Labeling

Denominations	Definitions
"Virgin oil of..."	Edible oil from a single seed or fruit Pure oil extracted and clarified by mechanical means Oil neither refined, nor bleached, nor neutralized by chemical means
"Oil of..."	Refined edible oil from a single seed or fruit
"Vegetable oil..."	Blend of edible vegetable oils

2.3.2. Obtaining Vegetable Edible Oils

2.3.2.1. Obtaining Refined Edible Oils (figure 4)

► CLEANING

Seeds or fruits stored in silos still contain foreign bodies (stones, soil...). They are therefore cleaned using sieves and powerful vacuum cleaners.

► HULLING OF SEEDS

It allows the separation of the shell from the kernel.

► GRINDING AND ROLLING

The seeds or fruits are reduced using roller mills.

► COOKING

It is done at a temperature of about 100 °C. The heat weakens the plant cells and dilates them to facilitate the subsequent release of oil from the paste. It also allows the destruction of certain thermolabile substances that harm the quality of the oil.

► TRITURATION

Pressing

The seeds are pressed progressively to obtain an oil still loaded with solid particles. These will then be removed by passing through centrifuges or filter presses. A crude pressed oil is thus obtained.

Extraction by a solvent

The solid particles remaining after pressing are called "cake." They still contain 10 to 15% oil, which will be extracted using a solvent such as hexane. After removal of the solvent by evaporation, we obtain:

- A **crude extracted oil** that will be mixed with the previously obtained crude pressed oil;

- "De-oiled" or "desolventized" cake, which is a product rich in proteins that will be used
- as raw material for animal feed or as fertilizer.

► REFINING

Its purpose is to maintain or improve the organoleptic characteristics of the obtained oils by making them perfectly clear, stable, and odorless. It is based on three basic principles:

- *Insolubilization (action of making insoluble);*
- *Adsorption (penetration of a liquid into a solid);*
- *Distillation (partial vaporization of a liquid and condensation of the formed vapors to separate them).*

Refining thus includes different strictly regulated treatments:

✓ ***Demucilagination or degumming***

The principle used is insolubilization by solutions at various pH levels. It is carried out by washing the oil with slightly acidified steam or with added phosphates. It then allows the elimination of **waxes** and **mucilages** (gelling substances) that would cause deposits in bottles during storage and foaming in frying baths.

There is also the elimination of carbohydrates, proteins, and part of the chlorophyll and phospholipids.

✓ ***Neutralization or deacidification***

The principle used is still insolubilization. It is done by adding soda, which combines with free fatty acids to form a neutralization paste (insoluble soaps) that is separated by centrifugation. The oil thus formed is called neutral oil.

There is thus the elimination of free fatty acids but also of resins (mixture of fatty acids and hydrocarbons) and residual phospholipids that could be responsible for an unpleasant taste.

✓ ***Washing and drying***

The neutralized oil is then washed with water to remove any trace of insoluble soaps. These washes are followed by dehydration under vacuum at about 90 °C. Dried oil is thus obtained.

✓ ***Decolorization or bleaching***

The principle used is that of adsorption. It is done using decolorizing earth or active charcoal on which pigments (chlorophylls) and other coloring substances dissolved in the oil and harmful to its color and conservation are adsorbed. There is, however, the elimination of carotenoids. The oil thus obtained is called decolorized oil.

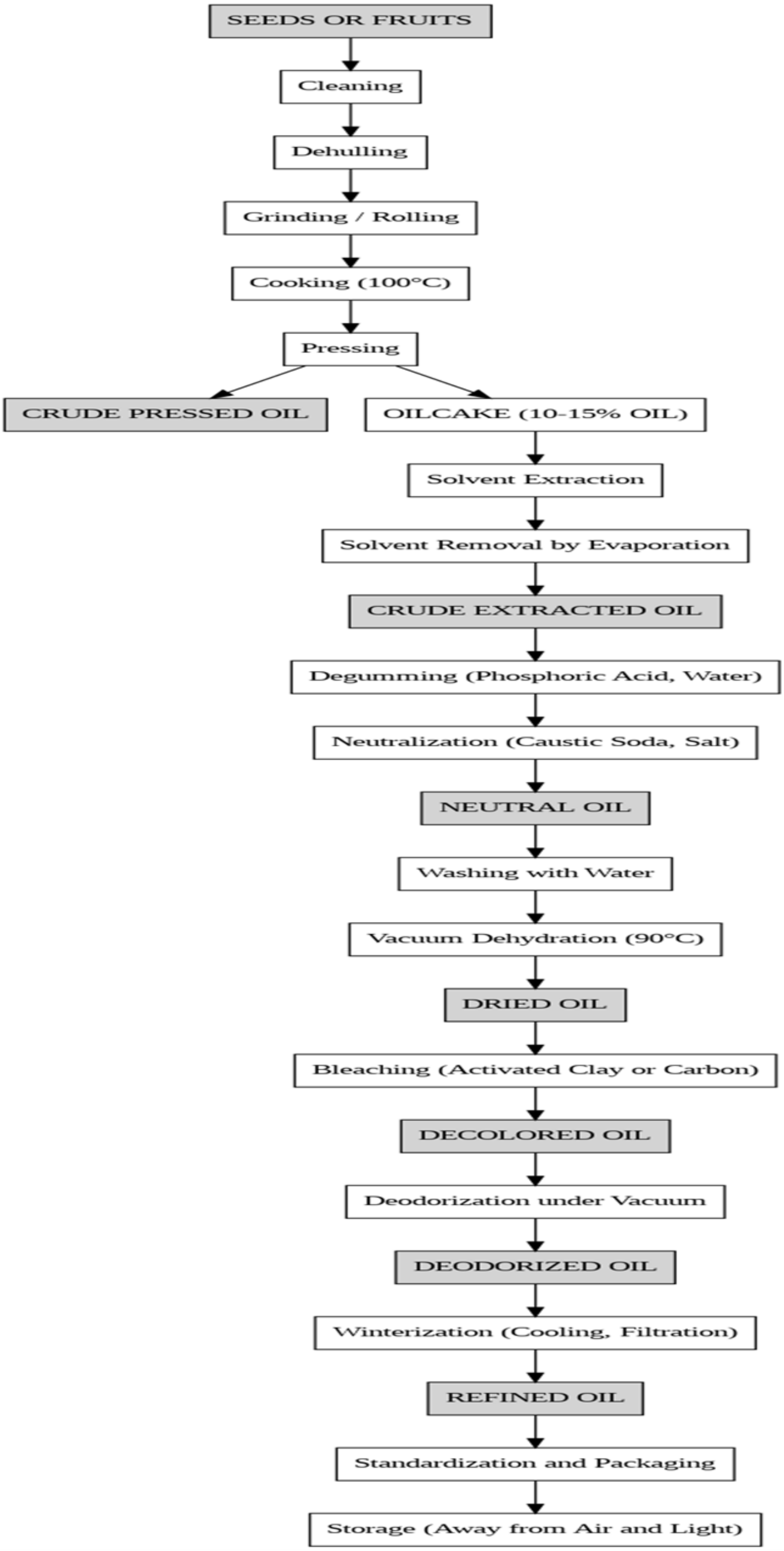

Figure 4 : Oil Refining Process

- ***Deodorization***

The principle of distillation is used. There is the elimination of all substances responsible for unpleasant tastes or odors such as residual free fatty acids, decomposition products, peroxides, pesticides. These substances being volatile, they can be eliminated by heating the oil to 204-246 °C under vacuum, which avoids oxidation and polymerization of the oil. A deodorized oil is thus obtained, but this step also eliminates about 30% of tocopherols.

- ***Refrigeration***

The oil is cooled, which eliminates triglycerides with a high melting point (saturated fatty acids, trans fatty acids). It is then filtered, removing these concrete products, and a **refined oil** is obtained.

Refining allows the use of less controlled raw materials while increasing the extraction yield. However, there is the elimination of provitamins A, tocopherols (30%), and vegetable sterols, but they can, in some cases, be added back to refined oils.

2.3.2.2. Obtaining Virgin or Natural Oils: The Example of Virgin Olive Oil (figure 5)

Ripe olives composed of 40% oil are pressed, yielding:

➢ *A liquid phase (composed of oil and vegetable water) from which "virgin olive oil" is extracted by centrifugation;*

➢ *A paste that still contains 6 to 15% oil, which will then undergo a second hot pressing to yield a simple "olive oil" that is more acidic and thus of lower quality, as well as a second residue called "pomace."*

The pomace is subjected to solvent extraction (generally hexane) and will thus provide "pomace oil," which is very acidic, very colored, and has a very pronounced taste.

Olive oil and pomace oil will then both be refined.

To obtain the best possible virgin oil, the raw material must therefore be of high quality, its storage must be short, and it must be protected from heat and light.

Note: the denomination "pure olive oil" corresponds to a blend of virgin olive oil and olive oil. The acidity of an oil is due to the fact that during the storage of fruits or seeds, lipases hydrolyze part of the lipids and release free fatty acids. This acidity will thus be a criterion of the quality of the raw material used and the organoleptic quality of the obtained oil.

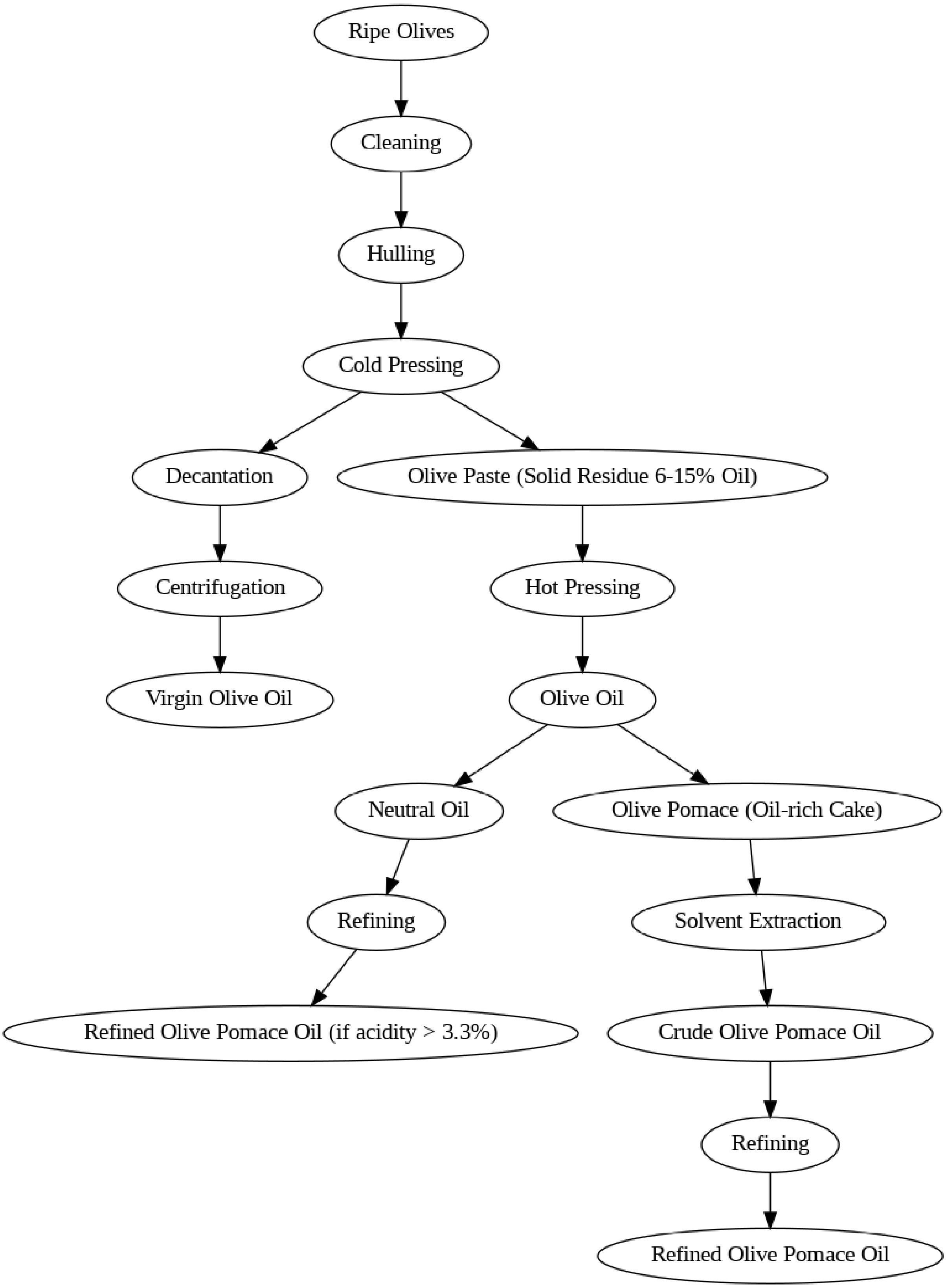

Figure 5 : Production Process of olive oil

2.3.3. Other Authorized Treatments

Their purpose is to modify the physicochemical properties of fats to broaden their uses.

2.3.3.1. Fractionation

It allows the separation of a fat into two phases with different melting points. Example: separation of a fat into a liquid oil and a solid fraction with a higher melting point than the original fat. This technique is mainly used for animal fats or concrete oils such as palm oil.

2.3.3.2. Hydrogenation

It reduces the unsaturation of fats by the chemical fixation of hydrogen on the double bonds of glycerides.

Examples: hydrogenated pork or horse fats for frying, hydrogenated copra fat (vegetaline), hydrogenated oils for margarines.

The consequences are as follows:

Positive Consequence

Partial and sometimes total saturation improves the stability of the fat by making a liquid oil solid or a concrete fat even more solid, which increases their melting point.

Negative Consequence

More or less extensive hydrogenation can also saturate essential fatty acids and thus reduce their content. This is why this technique has been the subject of much research, and we can now distinguish:

non-selective hydrogenation, still widely used, which saturates most polyunsaturated fatty acids;

selective hydrogenation, more recent, which saturates only linolenic acid (responsible for the fragility of oils) but preserves linoleic acid well. However, it can modify polyunsaturated fatty acids by geometric isomerization, transforming them into trans fatty acids, which lose part of their nutritional properties.

2.3.3.3. Interesterification

It consists of modifying the structure of triglycerides by random molecular rearrangement of fatty acids on glycerol. It can be done on a single fat (it is then called randomization) or on a blend of two fats. It thus improves the melting point without modifying the content of essential fatty acids. There is therefore a modification of the physical and rheological properties (viscosity, fluidity) of fats, which improves their use.

Example: improvement of the melting of a fat.

This technique is often used in addition to hydrogenation to optimize the consistency of a fat.

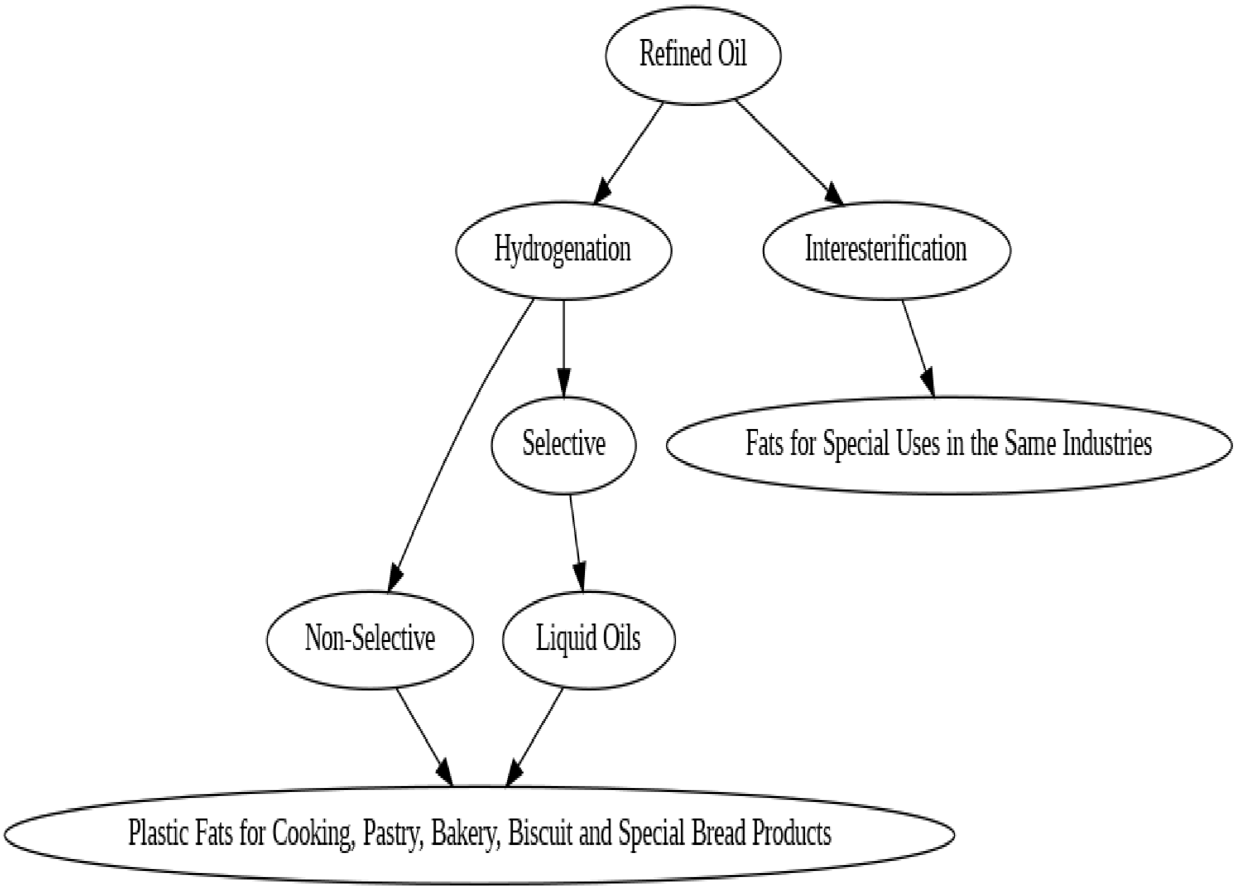

Figure 6 : Authorized Treatments of oil

2.4. Margarines

2.4.1. Definition

Margarines are designated as all food substances other than butter, regardless of their origin and composition, that have the appearance of butter and are prepared for the same use as the latter.

2.4.2. Analysis of Constituents

Margarine is an emulsion stabilized by additives (e.g., lecithins) and obtained by blending:

- Fats that constitute the fat phase and whose content must be at least 80% and at most 90%;
- Water that constitutes the aqueous phase and whose content must be 16%.

2.4.2.1. Constituents of the Fat Phase (82%)

It is composed of different fats and allows obtaining a concrete fat: ►FATS OF VEGETABLE ORIGIN

These include:

- Liquid or fluid oils at 15 °C, particularly from peanuts, rapeseed, cottonseed, corn, soybeans, sunflowers;
- Concrete oils melting between 15 and 40 °C, obtained from coconuts (copra), oil palm (palm and palm kernel).

►FATS OF ANIMAL ORIGIN

These include:

Hydrogenated fish oils;Lard; Dairy fats (up to 3%).

2.4.2.2. Constituents of the Aqueous Phase (16% maximum)

It is composed of:

- ✓ Water (bacteriologically pure);
- ✓ Reconstituted skimmed or whole milk from powdered milk inoculated with specific bacteria producing certain aromas. The aqueous phase thus undergoes directed fermentation, leading to the formation of lactic acid acting as a natural antiseptic and giving it aromas identical to those of milk.

2.4.2.3. Other Constituents (2%)

These include:

- ✓ Salt, in small quantities, to enhance flavor;
- ✓ Starch (cornstarch...);
- ✓ Glucose or lactose, which promote the browning of foods during cooking and thus Maillard reactions;
  Emulsifiers whose role is to facilitate the dispersion of the aqueous phase in the fat phase (in fine droplets). Thus, soy lecithins, mono and diglycerides, stearic, palmitic, oleic, or linoleic acids are used;
- ✓ Additives such as:
- Diacetyl for margarines without milk,
- Preservatives that prevent the development of molds and yeasts,
- Antioxidants that slow down oxidation responsible for rancidity. The most used is tocopherol and its derivatives.

Note:

➢ **Some margarines contain only vegetable oils (100% hydrogenated sunflower oil, for example).**

2.4.3. Manufacturing

The essential steps to remember are:

✓ Blending of fats at a temperature identical to the highest melting point;

✓ Addition of water or milk or water and milk;

✓ Addition of secondary components (additives);

✓ Blending of ingredients;

✓ Emulsification, i.e., maturation using dosing pumps and mixers;

✓ Cooling to about 15 °C, which causes the crystallization of lipids;

✓ Kneading, which gives the margarine a better consistency and greater homogeneity;

✓ Packaging;

✓ Storage at a temperature of about +4 °C.

2.4.5. Different Margarines

2..4.5.1. Table Margarines or Spreadable Margarines

Generally based on polyunsaturated oils, they have a very soft and spreadable texture. They are also fine in taste and are particularly suitable for raw uses.

2.4.5.2. Cooking Margarines

They are composed of both vegetable and animal oils. Several varieties are marketed:

•**Standard margarines**: these are low-end margarines, rich in saturated fatty acids, composed mainly of animal fats and fish oils;

•**Premium margarines**: they are intended for fine cooking. They can contain butter (up to 10%), have a pleasant flavor, and resist well to cooking (sautéed meats, meunière fish, for example);

•**Frying margarines**: they withstand deep and repeated frying well;

•**Vegetable margarines**: they are composed entirely of hydrogenated vegetable oils (sunflower, corn, for example). They are rich in essential fatty acids and thus contribute more to dietary balance. They have a soft, spreadable texture and can be used for cooking;

•**Dietetic margarines**: they have a high content of essential fatty acids and are sometimes enriched with vitamins A and E. They can be presented without sugar, without milk, and without diacetyl. They are suitable for cold or cooking uses;

•**Margarines intended for pastry**: they are adapted to different uses in professional pastry and thus have properties specific to them. Examples: margarines with a light and airy structure for the manufacture of creams, very malleable margarines used for making puff pastry...

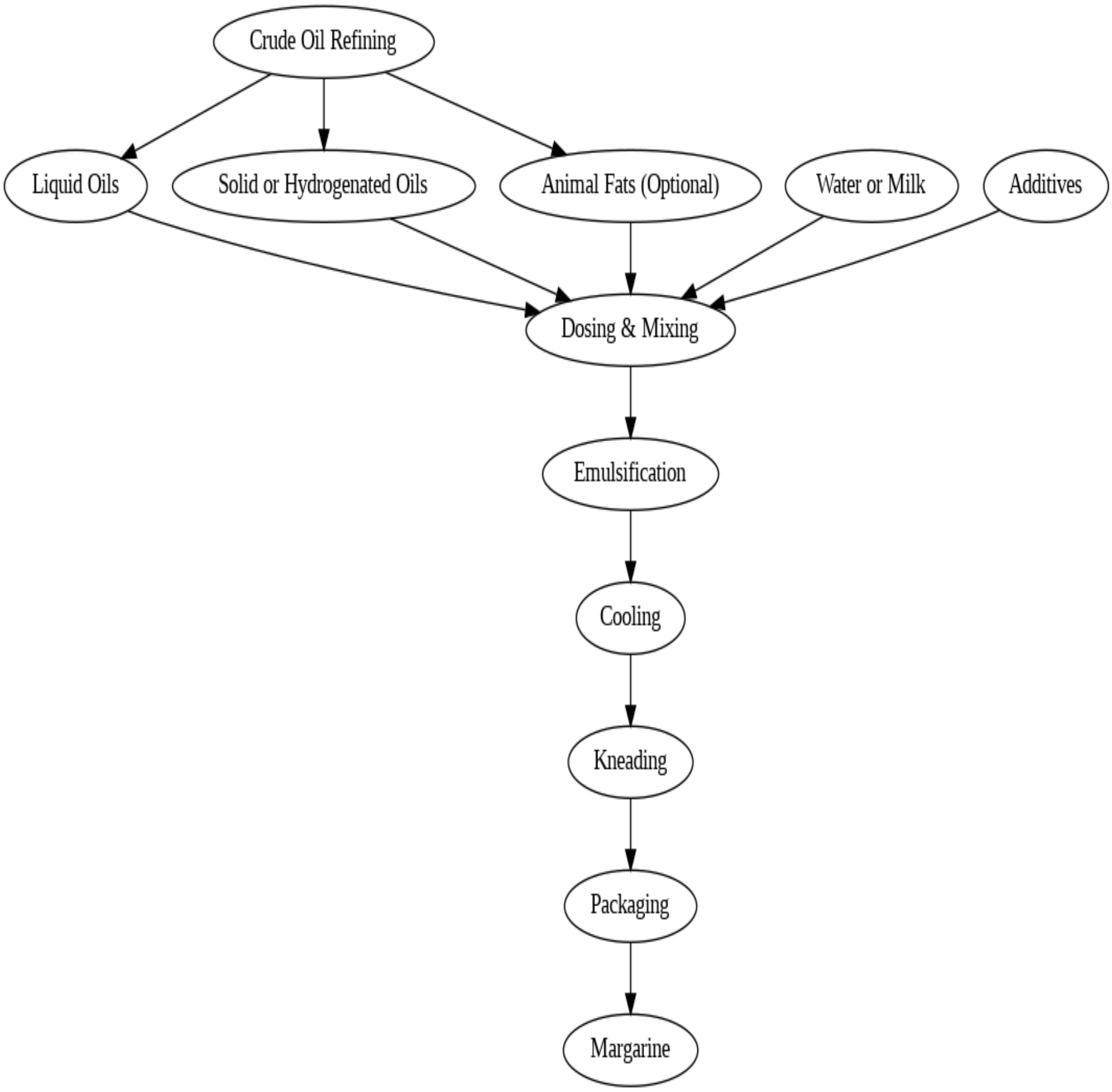

Figure 7: Production Process of Margarine

Chapter 4 : Beverages

1. Fruit- or Vegetable-Based Beverages

Under European Regulation No. 2003-838, fruit juices are classified into three categories: fruit juice, fruit juice from concentrate, and nectar.

1.1 Fruit Juice

The general CODEX standard (CODEX STAN 247-2005) defines fruit juice as the non-fermented but fermentable liquid extracted from the edible part of healthy fruits, which have reached the appropriate degree of ripeness and are fresh or preserved under healthy conditions in accordance with the relevant provisions of the Codex Alimentarius Commission.

Some juices can be obtained from fruits containing seeds, pits, and skins that are not usually incorporated into the juice, although parts or components of seeds, pits, and skins that cannot be removed by good manufacturing practices are accepted.

The juice is obtained by appropriate processes that preserve the essential physical, chemical, organoleptic, and nutritional characteristics of the fruit from which it is derived. The juice may be cloudy or clear and may contain aromatic substances and volatile compounds, provided they come from the same fruit species and are obtained by appropriate physical means. Pulp and cells obtained by appropriate physical means from the same type of fruit may be added.

A single juice is obtained from one type of fruit. A mixed juice is obtained by blending two or more juices or juices and purees from different types of fruits.

1.2 Fruit Juice from Concentrate

The general CODEX standard (CODEX STAN 247-2005) defines fruit juice from concentrate as the product obtained by reconstituting concentrated fruit juice with the water extracted during concentration, and by restoring the flavors and, if applicable, the pulp and cells lost during the production process of the juice in question or from fruit juices of the same species.

The added water must have appropriate characteristics, particularly in terms of chemical, microbiological, and organoleptic properties, to ensure the essential qualities of the juice.

The resulting product must have organoleptic and analytical characteristics at least equivalent to those of an average type of juice obtained from fruits of the same species

1.3 Concentrated and Dehydrated Fruit Juices

The general CODEX standard (CODEX STAN 247-2005) defines concentrated fruit juice as the product obtained from fruit juice of one or more species by the physical removal of a determined portion of the water content. When the product is intended for direct consumption, this removal is at least 50%.

The general CODEX standard (CODEX STAN 247-2005) defines dehydrated fruit juice as the product obtained from fruit juice of one or more species by the physical removal of almost all the water content.

1.4 Fruit Nectars

The general CODEX standard (CODEX STAN 247-2005) defines fruit nectar as:

These are products made from fruit juice or concentrated fruit juice or fruit purée or concentrated fruit purée or a mixture of these product with the addition of water and often sugar or honey.

The addition of sugars and/or honey is allowed in a quantity not exceeding 20% by weight relative to the total weight of the finished product.

In the case of producing fruit nectars without added sugars or with low energy value, sugars may be completely or partially replaced by sweeteners, in accordance with Directive 94/35/EC of the European Parliament and Council of June 30, 1994, concerning sweeteners intended for use in food products.

b) by derogation from point a), fruits such as banana, papaya, guava, pomegranate, and apricot may be used, individually or in a mixture, to produce nectars without the addition of sugars, honey, and/or sweeteners.

1.5 Authorized Ingredients

The addition of vitamins and minerals may be authorized during the production of fruit juice, subject to Directive 90/466/EEC. The addition of sugars and lemon is allowed in fruit juices according to specific standards. For example, to correct the acidic taste of a fruit juice, the amount of added sugars cannot exceed (in dry matter) 15 $g.L^{-1}$ of juice; for sweetening purposes, the sugar concentration must not exceed 150 $g.L^{-1}$. Carbon dioxide as an ingredient is allowed. Another example, ascorbic acid is a widely used additive in juice production due to its antioxidant properties. This vitamin adds value and protects the color of the juices.

1.6 Authorized Substances and Tolerated Thresholds

The regulation specifies that:

✓ The fruit will not retain more water from washing, steaming, or other preparatory operations than is technically unavoidable.

✓ Fruit juices and fruit nectars must have the color, aroma, and flavor characteristic of the juice of the fruit variety from which they are obtained.

✓ The final product must be healthy and suitable for human consumption, so various control points must be in place with strict standards regarding the maximum limits set by the Codex Alimentarius Commission for pesticide residues and other contaminants.

1.7 Authorized Treatments

Mechanical extraction processes, physical processes (such as microwave heating), and water extraction processes are authorized for the production of fruit juices. The addition of pectolytic, proteolytic, hemicellulase, or amylolytic enzymes is permitted to facilitate the extraction process. However, the use of cellulolytic enzymes (cellulases) is not authorized under European regulation (2009/106/CE, 2009), effectively prohibiting juices obtained through liquefaction. Inert filtration, precipitation, and adsorption aids are also tolerated, in accordance with community directives concerning materials intended to come into contact with foodstuffs.

2.1 Preparation of Fruits: Selection, Washing, Calibration

Upon arrival at the factory, the fruits, assumed to be picked at the right maturity, are generally stored for a few days under conditions that limit their deterioration. The storage time depends on the fruit: apples can be stored for up to a week on concrete areas in piles not exceeding 1 meter, citrus fruits for 5 to 6 days. Small red fruits are very fragile and are processed immediately upon arrival to avoid fermentation, or they are frozen for later processing.

The fruits are selected at the entrance to the pressing line, and damaged and/or out-of-spec fruits are removed. For example, the flotation test allows healthy apples to be sorted in hydraulic channels. By this principle, a first selective sorting is carried out. The fruits are then automatically washed and calibrated to match the size of the pressing systems. The pre-treatment of fruits varies according to each species: apples and pears are reduced to cossettes using graters. Citrus fruits are only calibrated. Stone fruits are pitted, either by rotary pitters or in pulpers after an initial steam heat treatment. These process steps are well defined. One of the processes for extracting the pit from plumsinvolves heating the plums to 90°C in a heat exchanger tube and leaving them for 20 minutes in a tank. Then, the fruit preparation for pressing is completed by pitting in a pulper.

2.2 Juice Extraction

2.2.1 Generalities on Pressing

Fruit pressing is a juice extraction technique that relies on the fruit's cellular structure and the applied forces. The juice is stored in microscopic compartments called vacuoles, located inside the fruit cells. Each cell is surrounded by a rigid wall composed of pectins, cellulose, and hemicelluloses, which help maintain the fruit's integrity. To release the juice, these cells must be disrupted, creating a pulp made up of cell wall fragments and liquid.

Factors Influencing Juice Extraction

The pressing process depends on several parameters:

- **Pulp Characteristics:** The thickness, porosity, and mechanical resistance of the pulp influence how easily the juice can be extracted.
- **Juice Properties:** The viscosity and density of the juice determine how it flows once released from the cells.
- **Applied Pressure:** Excessive or too rapid pressure can lead to the formation of a compact layer of residues (pomace), which blocks juice drainage and reduces pressing efficiency.

2.2.2 Presses and Extractors

Presses and Extractors in Fruit Processing

In the industrial processing of fruit pulps, different types of presses and extractors are used to extract juice efficiently. The two main categories of presses are **batch presses** and **continuous presses**, while citrus fruits require **specialized extractors** due to the presence of essential oils in their skin.

Batch Presses

Pack Presses

Pack presses are mainly used for small-scale juice production, particularly for apples. These presses use **hydraulic pistons** to extract juice by pressing fruit between packs. While effective for small quantities, their **low productivity** has led to their disappearance from modern industrial factories.

Basket Presses

Basket presses are more versatile and can process almost all plant materials. They consist of a **large basket with grooved drains**, a **fixed flange**, and a **movable piston**. The pressing mechanism allows juice to flow through the drains, while the rotation of the press body enhances extraction. This method results in juice with **low sediment levels**, making it preferable for high-quality juice production.

Continuous Presses

Belt Presses

Belt presses operate continuously, making them **more suitable for large-scale juice production**. They work by progressively increasing pressure on the fruit pulp as it moves through a **series of rollers and cloths**. The juice is collected through a drainage system, while residues are automatically discharged. Unlike batch presses, belt presses do not require manual reloading, ensuring **higher efficiency**. To maintain hygiene and operational performance, the cloths are cleaned using **beaters and spray jets**.

Citrus Extractors

Brown Extractors

For **citrus fruit processing**, specialized extractors are used to prevent contamination of the juice with essential oils from the peel. Brown extractors first remove essential oils before pressing the fruit. The extraction process involves **cutting the fruit into halves**, placing them in cavities, and applying **controlled pressure** to avoid crushing the seeds, which could release bitter compounds.

FMC Inline Extractors

The **FMC inline extractor**, responsible for over **55% of global orange juice production**, separates juice from essential oils using a **suction system**. This ensures that the juice remains pure and free from unwanted flavors, improving its quality and taste.

2.3 Technologies to Aid Pressing

2.3.1 Physical Treatments to Aid Pressing

2.3.1.1 Mechanical and Physical Action

Yield Improvement in Apple Pressing

During apple processing, the addition of water plays a key role in optimizing juice yield. Two methods are commonly used:

1. **Basket presses (raking and water addition)**: Water is added during raking, which facilitates juice extraction.
2. **Belt presses (pomace remixing)**: After the first pressing, the apple pomace is remixed with water before being pressed again. This technique significantly increases the yield. For example, a first pressing may yield **82%**, while remixing can increase this to **90%** (Hartmann, 1993).

The Flash Détente™ Technique

Flash Détente™ is a technology initially developed for the **pre-fermentation treatment of wines**. Its principle involves a **rapid heat treatment**, followed by cooling under vacuum, allowing for more effective extraction of **compounds from grape skins** (anthocyanins and tannins).

This technique has been extended to **citrus fruits** and **tropical fruits** (such as mango) to enhance **pulp and essential oil extraction**. The process involves several steps:

1. **Blanching**: The fruit is heated to deactivate enzymes responsible for juice degradation.
2. **Vacuum application (30 mBar)**: The sample is placed under intense vacuum, lowering the **boiling point of water to around 30°C**.
3. **Instant evaporation**: A portion of the water **instantly evaporates**, causing **micro-cellular breakdown** and improving the extraction of **flavors and nutrients**.

The evaporated water, rich in aromatic compounds, can be reintroduced into the final product to **preserve the fruit's sensory qualities**.

Application of Flash Détente to Mango and Nectars

When applied to mango processing, **Flash Détente™** offers several advantages:

- **Increased consistency and viscosity** of mango purée.
- **Enhanced color intensity**, allowing for higher dilution ratios in nectars.
- **Improved stability**: Nectars produced after dilution show slower phase separation.
- **Enzyme inhibition**: Blanching prevents enzymatic degradation (polyphenol oxidase, PME), reducing product deterioration.
- **Reduced cloudiness**: Higher viscosity minimizes sedimentation in nectars.

2.3.1.2 Combination of Processes, Aid to Pressing

In addition to enzymatic treatments, modern technologies such as **Pulsed Electric Fields (PEF) and Microwaves** can be applied during maceration to enhance juice extraction efficiency.

Pulsed Electric Fields (PEF) in Juice Extraction

Pulsed Electric Fields (PEF) is a technique that applies short electrical pulses to fruit pulp to **increase cell membrane permeability**. This enhances the release of intracellular compounds such as **polyphenols and antioxidants**, which are beneficial for both juice yield and quality.

- **Effect on Apple Pulp**:
    - Applying a PEF of **3 kV/cm** to apple pulp improves the extraction of **polyphenols and antioxidants**.
    - While the overall juice yield remains similar to traditional maceration, **PEF-treated pulp results in higher nutrient extraction** than untreated pulp.

    - When **PEF is combined with a temperature of 60°C**, it effectively **inactivates polyphenol oxidase (PPO)**, the enzyme responsible for apple juice browning.
- **Effect on Grapes**:
    - Pre-treating **grapes** with **PEF** facilitates **juice extraction** by **enhancing grape deformation**, making pressing more efficient and increasing yield.

Microwave Pre-Treatment for Juice Extraction

Microwave technology has also been explored as a method to improve juice extraction efficiency. The use of microwaves during fruit maceration **increases cell permeability**, which facilitates the **release of juice and polyphenols**.

- **Effect on Apple Purée**:
    - Microwave pre-treatment of **apple purée** at **2450 Hz** during maceration before juice extraction was tested at three different temperatures: **40°C, 50°C, and 60°C**.
    - The treatment significantly **increased juice extraction yield** compared to conventional maceration without microwaves.
    - Additionally, it improved **polyphenol transfer**, enriching the juice with beneficial antioxidant compounds.
- **Sensory Impact**:
    - Despite the improvements in yield and polyphenol extraction, **sensory analysis revealed no significant differences** in taste or aroma between microwave-treated and non-treated juices.

2.3.2 Enzymes to Aid Pressing

The main treatment to aid fruit pressing involves the use of cell wall degrading enzymes. With different intensities and specificities of action, it is distinguished: enzymes to aid pressing, clarification enzymes, enzymes to aid maceration mainly for nectar production, and liquefaction enzymes. Maceration and pulp liquefaction aim to shred and tear the fruits and improve juice flow. Each fruit has a specific amount of pectin, hemicellulose, and cellulose. The ratio of these polysaccharides will be important in choosing the concentration and incubation time of the exogenous enzyme to use.

2.3.2.1 Enzymes Used for These Treatments

Pectins are the main source of water retention in fruits. Without the use of enzymes, insoluble pectins have a gelling effect and cause juice retention during pressing. This is why commercial enzymes used in juice production are mainly pectolytic enzymes.

The use of pectinases addresses two main issues: the dissolution of protopectin and the degradation of soluble pectins. Different enzymatic actions exist depending on the type of juice desired: extraction enzymes, liquefaction enzymes, and maceration enzymes.

The most commonly used enzymes in fruit juice production are pectinases derived from the microorganism *Aspergillus niger*. This fungus can synthesize several pectolytic enzymes, including Pectin Esterases (PE), also known as Pectin Methyl-Esterases (PME), Polygalacturonases (PG), and Pectin Lyases (PL).

Pectolytic enzymes are divided into two groups:

1. **De-esterifying (or saponifying) enzymes**, represented by pectin methyl-esterases (PME), which release methanol and modify the degree of esterification of pectins.
2. **Depolymerizing enzymes**, which can be either endo or exo. Polygalacturonases (PG) act by hydrolysis, while pectin lyases (PL) and pectate lyases (PAL) act by β-elimination, reducing the degree of polymerization of pectins. "Endo" enzymes randomly attack the polymer, whereas "exo" enzymes act progressively from the end of the polymer.

Roles of Pectolytic Enzymes

- **Extraction enzymes** are used to increase juice yield from pressed pulps. They mainly contain pectolytic enzymes such as PME, PG, and PL.
- **Maceration enzymes**, primarily used for nectar production, have high PG activity and low PME activity. They partially hydrolyze the pectins in the middle lamella, dissociating the cells while keeping the walls intact. The resulting juice is viscous and contains a suspension of cells.
- **Liquefaction enzymes** hydrolyze the cell wall, causing cell rupture and the release of vacuolar and cytoplasmic juices. These enzymes include a mixture of PG, PME, and cellulases, which attack all levels of the cell wall, ultimately leading to its complete breakdown. This technique is particularly useful for fruits without specialized pressing equipment or for extracting cellular components that remain trapped in the pulp.

Impact of Methanol in Fruit Juices

The use of PME leads to the release of methanol through the hydrolysis of pectin methyl esters. However, methanol is an undesirable and highly regulated substance due to its toxicity. In freshly pressed juices, methanol levels range from 1.14 to 6.67 mg per 100 mL. After three hours of storage, these levels increase, reaching up to 14.82 mg per 100 mL in grape and lemon juices.

The lethal dose of pure methanol is estimated to be between 1 and 2 mL per kg of body weight, and fatalities have been reported at doses as low as 0.1 mL per kg. For this reason, regulations set the maximum allowable methanol content at 10 mg per 100 mL of beverage to distinguish fruit juices from alcoholic beverages. In the case of freshly pressed tomato juice, methanol levels can quickly reach the regulatory limit. Fortunately, heat treatment significantly reduces methanol release by inactivating PME.

2.3.2.2 Choice of Enzymes and Combined Activities

Enzymatic treatment is particularly necessary for juice production from small red fruits, such as blackcurrants and raspberries, which are rich in pectins. The mechanical processing of these fruits results in highly viscous juices, where the pulp forms a semi-gelled structure that makes juice extraction difficult. Pectolytic enzymes break down this structure, improving juice flow. Similarly, overripe fruits require enzymatic treatment, as prolonged storage alters the composition of pectins, cellulose, and hemicelluloses. This leads to reduced elasticity and cell cohesion, causing the pulp to completely collapse under mechanical pressure, preventing proper drainage and juice extraction. In apples with advanced maturity, enzymatic treatment can increase juice yield by up to 10%.

For liquefaction treatments, the degree of pectin methylation in the fruit must be considered. For example, apple pectins are approximately 90% methylated, making a combination of pectin methyl-esterase (PME) and polygalacturonase (PG) the most effective enzymatic preparation. These enzymes are added to the pulp at concentrations between 40 and 200 g/t, with an incubation period of 30 to 60 minutes at an optimal temperature of 30–50°C.

Studies have demonstrated the effectiveness of enzymes in improving juice extraction. For instance, liquefying apricot, plum, and mango pulp using PME and PG showed that juice yield is influenced by incubation time, temperature, and enzyme concentration. In apricot pulp, maximum yield (82%) is achieved with a 0.5% enzyme concentration at 45°C for 4 hours, while in mango, a 0.9% concentration at 45°C for 6 hours results in a maximum yield of 59%. Without enzymatic treatment, mango juice extraction is nearly impossible, and apricot juice yield remains at only 17%.

Additionally, the inclusion of pectin lyases in an enzymatic preparation containing PG and PME further facilitates nectar production from plum pulp. This highlights the critical role of tailored enzymatic treatments in optimizing juice yield and quality across various fruit types.

2.3.2.3 Stabilization of Cloudiness

In cloudy juices, it is essential that the opalescence remains homogeneous to preserve their organoleptic qualities, such as color and mouthfeel. This cloudiness is due to the presence of suspended particles composed mainly of pectins, proteins, lipids, hemicellulose, and cellulose. The primary risk of cloudiness destabilization is the spontaneous clarification of the juice during storage. If natural enzymes are not inactivated, the action of pectin methyl-esterase (PME) causes the soluble pectins to gel into calcium pectinate. This process traps suspended particles, and the retraction of the gel through syneresis expels a clear serum, giving the juice an undesirable biphasic appearance.

To prevent this destabilization, several measures can be taken. The addition of calcium chelators could prevent the formation of calcium pectinate and thus stabilize the cloudiness, but their use is prohibited in juices. Therefore, it is necessary to intervene during the processing stage by either inactivating PME or degrading soluble pectins.

In the case of carrot juice, complete PME inactivation requires heat treatment for 10 minutes at 70°C or 5 minutes at 80°C. The application of high-intensity pulsed electric fields can also inactivate PME and reduce juice viscosity, with an effectiveness comparable to a heat treatment of 90°C for 30 seconds in watermelon juice.

Another alternative is the use of ultrasound, which has proven effective in orange juice. An ultrasound treatment of 1500 W with alternating pulses every 5 seconds ensures total PME inactivation and improves juice stability. These various techniques provide suitable solutions to maintain the quality and uniformity of cloudy juices throughout their shelf life.

2.3.2.4 Clarification

Clarification is the process of destabilizing cloudiness in juices, which results from the presence of pectic colloids in pseudo-solution and suspended particles stabilized by insoluble pectins. Larger elements, such as cellular debris or cell clusters, do not contribute to this cloudiness.

Initially, clarification was done through simple decantation, but membrane filtration became a key innovation in the 1960s and 1970s. However, without pectinase treatment, clogging issues arise. After enzymatic treatment, filtration is necessary to remove precipitated particles. The final clarity, yield, and flow conditions depend on the filtration type, juice composition, and enzymatic extraction method.

Role of Enzymes in Clarification

Clarifying enzymes are applied to raw juices after pressing to produce clear, stable, and visually appealing juices. Pectin-rich juices tend to be viscous and slightly opaque due to colloidal particles. Pectins increase viscosity and prevent particle aggregation by maintaining electrostatic stability.

The primary role of clarifying enzymes is to break down soluble pectin macromolecules, destabilizing the colloidal equilibrium. These enzymes consist mainly of pectin methyl-esterase (PME) and polygalacturonase (PG). PME breaks ester bonds, allowing PG to cleave the $\alpha(1\rightarrow4)$ bonds between galacturonic acid residues. As a result, particles can flocculate through electrostatic interactions with proteins, leading to sedimentation. This process also prevents excessive viscosity and gelation during juice concentration and filtration.

For juices with highly esterified pectins, such as apple juice, PME or pectin lyase (PL) is needed to enhance PG efficiency. PG activity is ineffective when the degree of methylation (DM) exceeds 75%, but its effectiveness increases as DM decreases. Conversely, PL cleaves pectins between methylated galacturonic acid residues but becomes less effective as DM decreases. In juices with low-esterified pectins, such as grape juice, PG alone is sufficient for clarification.

Additional Techniques for Clarification

In protein-deficient juices, flocculation can be enhanced by adding external proteins, typically gelatin. However, excessive protein addition can lead to cloudiness during pasteurization or storage due to interactions with polyphenols. This issue can be corrected using bentonite, a hydrated aluminum silicate that helps remove excess proteins.

After liquefaction, juices still contain pectins and neutral polysaccharides that resist standard pectolytic enzymes. These compounds accumulate, making clarification more difficult. To address this, researchers have identified a new class of pectinases, rhamnogalacturonanases, which break down complex pectin structures into smaller oligomers.

Innovative methods, such as pulsed electric fields, have also been explored for juice clarification. For example, applying a pulsed electric field at 500V/m in lemon juice improves clarity, eliminates pectins, and enhances long-term stability. These advanced techniques contribute to more efficient and effective juice clarification while preserving quality.

2.4 Microbiological Decontamination Processes

2.4.1 Pathogenic Microorganisms and Decontamination Treatments

Fruit juices generally pose a low microbiological risk due to their naturally low pH, which inhibits the growth of many pathogenic bacteria. However, contamination incidents have occurred, especially in unpasteurized juices, where harmful microorganisms like *E. coli* O157:H7 have been detected. Ensuring microbiological safety is crucial to maintaining juice quality and extending shelf life.

Pasteurization and Its Variants

The most common method to eliminate microorganisms in juices is pasteurization. Traditional pasteurization involves heating bottled juice gradually to around 90°C, ensuring that the product reaches 82–85°C. While effective, this method requires long heating and cooling times, which can alter the juice's flavor, color, and nutritional quality. High temperatures may also cause browning reactions and lead to the formation of undesirable compounds, although some of these compounds exhibit antioxidant properties.

To reduce heat exposure, flash pasteurization was developed. This method rapidly heats the juice to 95–97°C before filling it into glass bottles. The closed bottles retain enough heat (82–85°C) to self-pasteurize, after which they are quickly cooled. This process significantly reduces the intensity of heat treatment while ensuring microbiological safety.

Another approach is cold aseptic filling, where juices are sterilized through flash pasteurization and immediately cooled before being filled into pre-sterilized packaging. This technique requires strict hygiene measures to prevent recontamination but is widely used by juice manufacturers whose packaging materials cannot withstand high temperatures.

For even shorter heat treatment times, ultra-high-temperature (UHT) pasteurization is used. This method rapidly heats juice to temperatures above 100°C, sometimes reaching 130°C, for just a few seconds before cooling. For example, orange juice can be pasteurized in only three seconds at 107°C. This approach minimizes thermal damage, preserving the juice's original taste and nutritional value.

Alternative Decontamination Methods

Consumer demand for minimally processed juices has led to the development of non-thermal decontamination techniques that maintain freshness while ensuring microbiological safety.

- **High-Pressure Processing (HPP)**: This method relies on applying extremely high pressure (e.g., 350 MPa for 5 minutes at 40°C) to inactivate pathogens like E. coli and Salmonella. While effective at eliminating bacteria, HPP does not inactivate pectolytic enzymes, which may lead to phase separation in juices during storage.
- **Pulsed Electric Fields (PEF)**: A promising non-thermal technique, PEF applies short bursts of high-voltage electricity to inactivate microorganisms without affecting flavor,

color, or nutrients. When combined with natural antimicrobials like citric acid, PEF shows enhanced efficiency in eliminating pathogens while preserving juice quality.

These innovative decontamination methods address consumer preferences for fresher, less heat-treated juices while maintaining food safety. The choice of technique depends on factors such as juice composition, storage requirements, and regulatory standards.

2.4.2 Validity of Decontamination Processes

Validation of Microbiological Decontamination

The effectiveness of a microbiological decontamination process is assessed by measuring the concentration of targeted microorganisms before and after treatment. The goal is to significantly reduce the presence of the most resistant pathogenic microorganisms to ensure consumer safety. According to FDA regulations, an effective decontamination process must achieve at least a **5-log reduction** in pathogen levels, meaning a 100,000-fold decrease. This reduction must be maintained throughout the juice's shelf life.

If a chemical antimicrobial agent is used, it must be approved by the FDA for this specific application and classified as **GRAS (Generally Recognized As Safe)** to ensure its safety for human consumption.

2.4.3. Packaging of Decontaminated Juices

Once decontaminated, juices are packaged either as **individual consumer products** or in **bulk containers** for further processing.

- **Individual Packaging:** Includes bottles, cartons, and other retail-ready formats.
- **Bulk Packaging:** Used for juices that will undergo further processing or be repackaged by manufacturers. These may be stored in:
    - Aseptic or frozen barrels
    - Large aseptic containers (e.g., 1000-liter bins)
    - Tanks or tanker trucks for transportation

Bulk juices typically require **re-pasteurization** before final packaging to ensure microbiological stability. This step is crucial to prevent contamination and maintain product safety before reaching consumers.

3. Carbonated beverages

3.1. Sodas

Sodas are carbonated beverages made of water and carbon dioxide, with the addition of fruit juice, fruit concentrate, fruit pulp, or natural fruit extracts, and generally sugar.

3.1.1. Different Types of Sodas

► COLA SODAS

These sodas contain plant extracts. They can be caffeinated (15 mg/100 ml) or caffeine-free. The coloring agent used is caramel.

Examples: Coca-Cola®, Pepsi-Cola®.

► TONIC SODAS

These are made from carbonated water, citrus essential oils, or plant extracts. **Examples:** Fanta®, Sprite®.

► BITTER SODAS

"Bitter" means "bitter" in English. These sodas are made from citrus juice, citrus extracts, or plant extracts.

Example: Schweppes®.

3.2. Unsweetened Carbonated Beverages

These drinks consist of sparkling or carbonated water with added plant extracts (fruits, aromatic plants).

Examples: Badoit® lemon/orange/grapefruit/mint. Their energy contribution is negligible.

4. Manufacturing Technology of Carbonated Beverages:

Bottled beverages go through a complex production process before reaching consumers. This process involves several critical stages, each requiring careful quality control to ensure safety and consistency.

The first step is **water treatment**, as water is the primary ingredient in beverage concentrates. It must meet strict quality standards and be free from contaminants or microorganisms. Each production facility has a dedicated water treatment system, with continuous monitoring at different stages to maintain purity.

Next, the **preparation of simple syrup** involves dissolving sugar in treated water to create a uniform solution. This step ensures that the beverage has the correct sweetness level and texture.

The **preparation of the finished product** follows, where additional ingredients such as fruit concentrates, flavors, preservatives, and acids are mixed with the syrup to achieve the desired taste and composition. Strict quality control measures are applied to verify that the final mixture meets product specifications.

The final stage is **bottling**, where the beverage is packaged in bottles, cartons, or cans. The packaging materials, such as plastic, glass, or metal containers, are carefully inspected to ensure they meet hygiene and durability standards.

Throughout the entire process, ingredients and materials undergo rigorous testing, sampling, and analysis. Only those that pass quality control checks are used in production. This guarantees that the final product is safe for consumption and maintains its intended taste, appearance, and shelf life.

4.1. Water Treatment:

The objective of water treatment in beverage production is to obtain water with the necessary chemical and physical properties to ensure the microbiological safety and quality of the final product. This involves eliminating impurities that could affect the taste, appearance, or stability of the beverage.

4 .1.1. Water Extraction and Storage

Groundwater is drawn through boreholes and stored in a tank to maintain a continuous supply before undergoing treatment.

4.1.2. Filtration

a) Sand Filtration – Water passes through layers of sand and gravel to trap solid impurities larger than 50 microns.

b) Cartridge Filtration – This step removes smaller particles (between 10 and 1 microns) to protect subsequent treatment processes.

4.1.3. Reverse Osmosis (Demineralization)

A semi-permeable membrane allows only water molecules to pass through while blocking unwanted dissolved salts and impurities, ensuring high water purity.

4.1.4. Activated Carbon Filtration (Dechlorination)

Chlorine and organic contaminants are removed to enhance water taste and safety while reducing potential microbial contamination.

4.1.5. Polishing Filtration (Fine Particle Removal)

A polishing filter eliminates any remaining fine particles, ensuring further refinement of the water quality.

4.1.6. Storage of Treated Water

After filtration, the purified water is stored in dedicated tanks before moving to the final purification stage.

4.1.7. Disinfection

a) Chemical Disinfection (Chlorination) – Chlorine-based compounds are added to neutralize bacteria and pathogens.

b) Ultraviolet (UV) Disinfection – UV light sterilizes the water without the use of chemicals, preventing microbial growth.

1.8. Softening (Hardness Reduction)

Calcium and magnesium ions, responsible for water hardness, are removed using ion-exchange resins that replace them with sodium ions to prevent scaling in production equipment.

Each of these steps ensures that the water used in beverage production meets the required safety and quality standards, providing a clean and consistent base for the final product.

4.2. Preparation of Carbonated Beverage

Once the water has been treated, the next stage in beverage production takes place in the syrup room. This process is divided into two main steps:

- **Preparation of White Syrup** (basic sweetened syrup)
- **Preparation of Finished Syrup** (flavored syrup)

4.2.1. Syrup Room (Preparation Room)

The syrup room is where the syrup for the beverage is prepared. This involves mixing water, sugar, and other essential ingredients to create the base of the drink.

4.2.2.Preparation of White Syrup

The first stage in syrup preparation consists of mixing sugar and treated water in specific proportions to create a uniform, sweet base.

a) Dissolution

Crystallized sugar is mixed with treated water in a stainless steel tank equipped with an agitator. The process takes between 16 and 20 minutes at a temperature of 75°C to 80°C, achieved by injecting live steam. The production of hot syrup serves two key purposes:

- It accelerates the dissolution of sugar.
- It ensures the thermal treatment of the syrup, reducing microbial contamination.

b) Filtration

Once dissolved, the syrup undergoes filtration to remove any solid impurities or foreign particles that may be suspended in the mixture.

c) Pasteurization

The filtered syrup is then subjected to **flash pasteurization** for two minutes at a temperature between 78°C and 85°C. This process eliminates bacteria, germs, and other microorganisms, ensuring microbiological safety.

d) Cooling

After pasteurization, the syrup is rapidly cooled to **15°C** using a **plate heat exchanger** where it circulates against cold or glycolated water at **4°C**. This cooling step is crucial because:

- It prevents the evaporation of flavoring agents, ensuring a consistent taste.
- It minimizes foam formation when the beverage is later filled into bottles or cans.

This white syrup serves as the foundation for the final flavored syrup, which will later be carbonated and bottled.

4.2.3. Preparation of Flavored Syrup

At this stage, all essential ingredients of the beverage are incorporated, except for dilution water and carbon dioxide (CO_2). The process consists of two main steps: **emulsion preparation** and **finished syrup formulation**.

a) Emulsion Preparation

Emulsion is the process of combining water-based and oil-based ingredients to ensure uniform distribution of flavors in the beverage. This involves multiple steps:

- **Aqueous Phase Preparation**:
  - Starch is mixed with water in preparation tanks.
  - Potassium sorbate is added to prevent the growth of yeasts and molds.
  - In a separate tank, citric acid is introduced to enhance the acidity and flavor of the drink.
  - This phase is usually prepared the day before production.
- **Oily Phase Preparation**:
  - Citrus oils (such as lemon or orange) are mixed in a special unit.
- **Mixing of Phases**:
  - On the production day, the aqueous and oily phases are combined in a mixing tank.
  - An agitator is used to blend the mixture, but further homogenization is required for a smooth and stable emulsion.
- **Homogenization Process**:
  - A **multi-tooth mixer** reduces the size of oil droplets to 0.3 µm, improving the stability of the emulsion. A specific additive is also introduced at this stage.

- The mixture is then passed through a **high-pressure homogenizer** (300 bars), which further reduces the particle size to 0.1 µm. This ensures product stability for up to **six months**.
- Due to the mechanical action, the temperature rises from **25°C to 31°C**, requiring a second homogenization pass for final refinement.

- **Final Handling**:
  - The homogenized emulsion is cooled to **23°C** and transferred to a **3,500L storage tank** if it meets stability requirements.
  - Any remaining emulsion is stored in a cold room at **5°C** to preserve its quality.

b) Preparation of Finished Syrup (Flavored Syrup)

This step involves incorporating all the necessary components of the final beverage except water and CO_2. The process begins with **transferring the white syrup** into a preparation tank. Then, the following ingredients are carefully added in a specific sequence and quantity:

- **Flavors** – Provide the characteristic taste of the beverage.
- **Concentrates** – Enhance the intensity of the flavor.
- **Acidulants** – Adjust the acidity for a balanced taste.
- **Colorants** – Ensure the desired visual appearance.
- **Preservatives** – Maintain product stability and shelf life.

Once all ingredients are thoroughly mixed, the flavored syrup is ready for the final dilution and carbonation stages.

4.3. Preparation of the Finished Product (Mixing)

Once the flavored syrup is prepared, it undergoes the **mixing process**, where it is combined with water and carbonated to create the final beverage. This stage includes **deaeration, syrup mixing, and carbonation** to ensure the drink meets the required taste, texture, and fizziness.

A. Water Deaeration

Before mixing, the water must be **deaerated** to remove dissolved gases (mainly oxygen) that can affect carbonation and beverage stability. This is done in a **deaeration tank**, which operates under negative pressure using a **liquid ring vacuum pump**.

- Water enters the tank from the top and is dispersed through a **spray ball**, increasing its surface area.
- This setup allows for efficient gas removal by exposing the water to the vacuum, making carbonation more effective in the next stage.

B. Water and Syrup Mixing

Once deaerated, the water is mixed with the flavored syrup. The mixing unit ensures **precise dosing** of each component based on the beverage formulation.

- **Mechanical Mixing**: Uses a **dosing pump** to regulate the syrup-to-water ratio.
- **Electronic Mixing**: Utilizes **flow meters** (magnetic for water and mass flow for syrup) to achieve precise measurement and consistency.

This step guarantees that the beverage maintains its intended sweetness, flavor concentration, and uniformity.

C. Carbonation

Carbonation is the process of dissolving carbon dioxide (**CO_2**) into the liquid to create a fizzy texture. The carbonation system injects **CO_2 directly into the beverage** under controlled pressure.

- The **static mixer** ensures thorough blending of the syrup and water while breaking CO_2 bubbles into finer particles, promoting better absorption into the liquid.
- This step enhances the drink's fizziness, mouthfeel, and overall sensory appeal.

D. Storage and Stabilization

After carbonation, the finished beverage is stored in a **stabilization tank** that is kept under **CO_2 pressure** to prevent gas loss. This ensures the drink maintains its carbonation level until the bottling process.

Once stabilized, the beverage is transferred to the **filling unit**, where it will be packaged into bottles or cans for distribution.

5. Bottling:

Bottling is a critical step in the production of beverages, especially carbonated drinks, where several processes must be followed to ensure the quality and safety of the final product. Here is a detailed explanation of each step:

5.1. PET Bottling

5.1.1. Bottle Rinsing

PET bottles for carbonated beverages, when blown on-site, are directly filled on an aseptic line. Unlike other types of containers, these bottles do not require full washing, but rather rinsing. This process involves injecting sterile or simply potable water, sometimes chlorinated or non-chlorinated, into the bottle. The water is then drained before filling. The rinsing ensures that the bottles are free of contamination before being filled.

5 .1.2. Filling and Bottling

Filling bottles is carried out using a method called "isobaric filling," which is specifically used for carbonated drinks. This process involves maintaining a pressure higher than the saturation pressure of the dissolved gas in the liquid, both in the filler tank and the container being filled. This creates an undersaturation state, which helps to fill the bottle without losing gas. The process takes place in four phases:

- **Pressurizing** the container before filling.
- **Filling under pressure**, where the liquid flows by simple gravity.
- **Stopping the filling** once the bottle is full.
- **Depressurizing**, which releases excess gas.

5.1.3. Capping

Capping involves sealing the bottles after they are filled. There are different capping systems based on the type of cap used. The screw capping system is suited for PET bottles. Plastic caps are secured with a tamper-evident band and are placed by simple pressure, ensuring the product remains sealed.

5.1.4. Labeling

Labeling is a crucial step for providing information to consumers and enhancing the product's marketing appeal. Plastic labels are applied to the bottles, and they contain important information such as:

- Product name
- Lot number
- Composition and nutritional value
- Shelf life
- Net quantity
- Manufacturer’s contact information (phone number, address, email)

5 .1.5. Coding and Packaging

After filling and capping, the bottles go through a date coder where information such as the manufacturing date, time, factory code, production line, and lot number are laser-inscribed. This ensures product traceability. The bottles are then passed to a packaging machine for packing into cartons or other types of packaging.

5.1.6. Storage

Finished products must be stored in an appropriate environment with controlled temperature, humidity, and light. This ensures that the product's quality is maintained until distribution.

5.2. Can Bottling

Cans, made of aluminum or tin-plated steel, are also widely used for packaging carbonated beverages. The canning process is similar to the bottling process.

Before filling, cans must go through a rinser to remove dust and any foreign bodies inside. Once cleaned, they are sent to the filler to be filled.

After filling, foam removal is carried out using a shower of water. This prevents air from entering the can, which could cause the product to oxidize. Finally, the can passes through a seamer, which seals it securely.

This process ensures that cans are filled correctly, sealed safely, and ready for storage or distribution.

T.I.A.A 2

Chapter 1: Cereal Products

Cereal-derived products are foods whose main raw material comes from cereals. In botany, cereals refer to various plants of the grass family, whose grains are used in both human and animal nutrition.

There are 13 types of cereals, including wheat, corn, rice, oats, buckwheat, rye, barley, sorghum, millet, quinoa, triticale, spelt, and einkorn. Cereal products have always held an important place in human nutrition. Indeed, they represent a significant source of energy, mainly in the form of complex carbohydrates. Additionally, they contribute to meeting our needs for plant proteins, certain vitamins (notably those in the B group), and plant-based dietary fibers.

1. Wheat and Its Drivatives

Wheat comes in two distinct species :

- Soft wheat, also known as common wheat (*Triticum aestivum*)
- Durum wheat (*Triticum durum*), which is not suitable for bread-making but is used in the production of semolina and pasta.

1.1. The Wheat Grain

1.1.1. Structure of the Wheat Grain (figure 1)

1.1.1.1. External Appearance

The wheat grain has a length ranging from 6.5 to 8.5 mm and a diameter between 3 and 4 mm.

1.1.1.2. Internal Structure

► THE BRAN

It constitutes about 17% of the total weight of the grain and is composed of several distinct layers:

- The pericarp: a layer characterized by thick-walled cells, with poor digestibility due to its cellulose and lignin content.
- The seed coat: containing the pigments responsible for the yellow-brown color of the grain.
- The hyaline layer: made up of transparent cells.
- The protein layer or "aleurone" layer: a part rich in proteins, vitamins (containing nearly a third of the B1 and B2 vitamins and two-thirds of the B6 and B3 vitamins in the grain), minerals, lipids, cellulose, and lignin.

► **THE ENDOSPERM OR KERNEL**

Representing 80% of the grain's weight, the kernel is bounded at its lower part by the germ. It is a white, friable substance, mainly composed of starch granules (representing 70% of the total starch) surrounded by a network of gluten (a natural protein) but is relatively poor in minerals.

► **THE GERM**

Constituting 3% of the total weight of the grain, the germ is rich in vitamins and lipids. It consists of two main parts: the embryo and the scutellum, which surrounds the embryo, protecting it and providing nourishment.

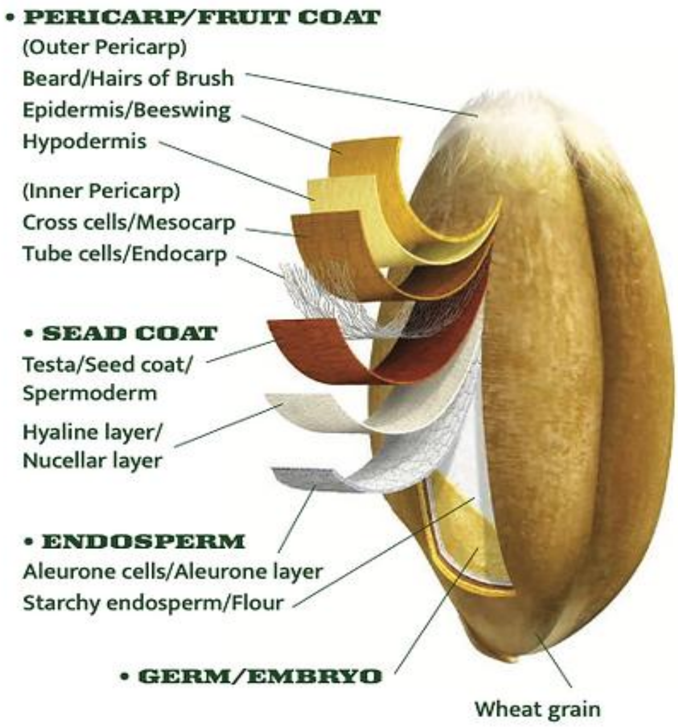

Figure1 : Structure of the Wheat Grain

1.1.2. Chemical Composition of the Wheat Grain

1.1.2.1. Water

The wheat grain contains about 13.5% water. This low water content allows it to be stored for long periods while avoiding the development of microorganisms, particularly molds.

1.1.2.2. Carbohydrates

► **DIGESTIBLE CARBOHYDRATES**

The wheat grain contains about 61% digestible carbohydrates, including:

- **Complex carbohydrates: starch**

This component constitutes the majority of carbohydrates, representing 59% of them, distributed as follows: 25% amylose and 75% amylopectin. Starch is mainly present in the kernel, with a higher concentration in the center than at the periphery. In contrast, the bran and germ have a low starch content. Thus, the whiter the flour, the richer it is in starch and the higher its digestive utilization coefficient (CUD).

- Simple carbohydrates (2%)

These compounds include glucose, fructose, sucrose, and raffinose (tribuloside). They are mainly located in the germ and the protein layer of the bran.

► NON-DIGESTIBLE CARBOHYDRATES: DIETARY FIBERS

PLANT-BASED DIETARY FIBERS (FAV)

The wheat grain contains 9.5% FAV. Plant-based dietary fibers are mainly found in the bran.

1.1.2.3. Proteins

Proteins represent 12% of the total weight of the wheat grain. They are divided into two distinct categories: soluble proteins (albumins and globulins) and insoluble proteins (prolamins and glutelins).

Some insoluble proteins, such as gliadin and glutenin present in the kernel, form what is called gluten:

- Gliadin: it is responsible for the extensibility of the dough, promoting its viscous flow during bread-making, for example. It is also involved in gluten intolerance, known as celiac disease. This condition is characterized by general malabsorption, leading to diarrhea and steatorrhea, responsible for long-term malnutrition. The only effective treatment is the exclusion of wheat, rye, barley, and oats. For this reason, these four cereals are excluded from pediatric flours intended for infants aged 1 to 4 months.
- Glutenin: it gives the dough its elasticity. Gluten from durum wheat is poorly extensible, making it unsuitable for bread-making.

1.1.2.4. Lipids

Wheat grains have a low lipid content, representing only 2% of their total weight. These lipids are mainly located in the germ and the protein layer. However, their qualitative composition is remarkable, as more than half of these lipids are polar. During dough kneading, they bind to proteins and carbohydrates, thus promoting water retention, extensibility, and elasticity of the dough.

1.1.2.5. Minerals

► CALCIUM AND PHOSPHORUS

The concentrations of calcium and phosphorus are as follows:

- Calcium: 35 mg/100 g;
- Phosphorus: 400 mg/100 g.

Indeed, in cereals, particularly wheat, a large proportion of phosphorus (about 75% in the wheat grain) is present in the form of phytic acid, also known as phytates. This substance has the particularity of binding to bivalent cations such as Ca2+, Zn2+, Mg2+, or Fe2+, forming insoluble salts that are not absorbed by the body.

However, phytic acid is mainly concentrated in the grain's outer layers. Therefore, the milling process allows for the removal of a large part of it, about two-thirds, thus promoting better mineral absorption. Moreover, certain enzymes called phytases are capable of releasing these cations trapped in insoluble salts, although they remain inactive in an environment too poor in water. Their action occurs mainly during dough fermentation and at the beginning of baking.

Regarding the mineral content of wheat, it should be noted that magnesium is present at 140 mg per 100 g, in the form of Mg2+, making it subject to interaction with phytic acid, resulting in low absorption.

As for other minerals, here are their concentrations per 100 g:

- Sodium: 3 mg
- Potassium: 435 mg
- Iron: 5 mg (in non-heme form, less well absorbed by the body)
- Zinc: 4.1 mg

Copper: 0.6 mg

- Selenium: 100 µg

Regarding vitamins, we observe:

- Absence of vitamin C
- Vitamin B1: 0.41 mg/100 g, with two-thirds found in the scutellum and the remaining third in the protein layer.
- Vitamin B2: 0.1 mg/100 g, with a very low concentration, half of which is located in the kernel.
- Vitamin B3: 4.7 mg/100 g, with two-thirds located in the protein layer.
- Vitamin B6: 0.5 mg/100 g, with moderate concentrations.
- Vitamin B9: 50 µg/100 g, in modest amounts.

As for fat-soluble vitamins, only vitamin E is present in the wheat grain, with a concentration of 2.5 mg/100 g, mainly located in the germ, which is the richest part in lipids.

1.1.2.7. Plant-Based Dietary Fibers (FA V)

Plant fibers, present notably in the bran of cereals, such as bran, wholemeal bread, are rich in insoluble fibers such as lignin, cellulose, and hemicellulose. They play a crucial role in regulating intestinal transit and contribute to the prevention of colon cancer.

1.2. Wheat Flour

1.2.1. Definition

Wheat flour is the product obtained by milling the kernel of soft wheat that has been cleaned and freed from impurities industrially.

1.2.2. Obtaining Wheat Flour

1.2.2.1. Cleaning

Wheat, often contaminated with impurities, is cleaned using separators to remove large impurities, then using sorters to remove foreign particles. Next, the scourers remove the hairs at the end of the grain and dust the median groove, ensuring industrially pure wheat. Finally, the grains are moistened to facilitate cleaning, soften the bran for future removal, and increase the friability of the grains to facilitate grinding.

1.2.2.2. Milling

The milling of flour aims to separate the kernel from the bran and germ, then reduce the kernel into particles fine enough to obtain flour. It takes place in three stages, the first of which is grinding, carried out using grooved rollers rotating in opposite directions and at a small gap, allowing the grains to be shredded to obtain a coarse mixture called "dough."

Next, this dough undergoes a sieving process through a series of **plansifters (figure 2),** superimposed sieves that oscillate to facilitate filtering. These plansifters are divided into several categories:

- The upper sieves, which retain the coarsest particles;
- The intermediate sieves, where medium-sized particles, called semolina, are stopped;
- The lower sieves, where a small amount of flour is already collected.

The semolina can be classified in two ways:

- According to their size: coarse semolina, medium semolina, fine semolina, and the finest particles called fines.

- Regardless of their size: white semolina, if they come from the heart of the kernel, and dressed semolina, if they come from the peripheral part of the kernel with some bran still attached.

It should be noted that all these semolina (except the fines) will undergo a sifting process completed by breaking. The largest particles are then sent back to a second grinder, similar to the first but with closer rollers, thus producing a second dough which will again be sieved.

This process is repeated about five times. The final residue is called the refuse, which constitutes the bran. Each plansifter provides a certain amount of flour, added to that already collected, called milling flour, representing 20% of the total flour.

Figure 2 : Plansifters

The second stage consists of **sifting and breaking.**

Sifting aims to separate the semolina according to their weight and size. The **sifters (Figure 3),** similar to plansifters, are traversed by an upward air current that sucks up the bran particles still attached to the semolina. The residues thus recovered are called blowings. The heavily dressed semolina are sent back to grinding while the less dressed ones undergo breaking.

Breaking aims to reduce the size of the semolina by crushing them between two smooth rollers. Then, they are sieved and the final residue of breaking is a grayish waste called second break, composed of bran, germ debris, and kernels.

The flattened semolina are designated as groats. At the end of these two stages, another small amount of flour is obtained, representing 23% of the total flour. At this stage, all the peripheral parts of the grain have been removed.

Figure 3 : Sifters

In the third stage, called **reduction,** the groats and fines are treated by reducers, smooth rollers rotating in opposite directions, to crush them and produce flour. Then, the mixture is directed to plansifters, and the intermediate refuse is again subjected to reducers. This process is repeated for 10 passes. The final residue is a white powder called white break.

The flour from reduction represents 33% of the total flour produced.

1.3. Bread

1.3.1. Definition

The term "bread" refers to the product obtained by baking a kneaded dough made from a specific mixture:

- Wheat flour
- Potable water

- Salt
- Fermentation agent

Legislation governs the proportions of these ingredients:

- 100 parts of flour
- 60 to 70 parts of water (depending on the type of bread)
- 2 parts of salt
- 1 to 2 parts of fermentation agent (yeast or sourdough)

1.3.2. Raw Materials

The flour

High-quality flour is essential for bread-making. It must come from healthy wheat and meet precise criteria for moisture, granulometry, and impurity content.

For white bread, type 55 flour is generally used, obtained from an extraction rate of 74%. This flour is said to have "good baking value."

Water

The water used must be potable, non-calcareous, and weakly chlorinated to not hinder fermentation.

It plays a crucial role in hydrating gluten and starch, thus promoting the mobility of flour constituents and the biochemical reactions necessary for bread-making.

Water plays a crucial role in the cohesion of the dough by binding the flour particles together.

Salt, although not essential, offers several advantages:

- Improvement of the taste and flavor of the dough
- Improvement of the mechanical properties of the dough: better handling and elasticity
- Facilitation of the rise and maintenance of the dough's shape

Fermentation agents allow the dough to rise and give it its airy structure.

Sourdough is a natural fermentation agent resulting from the slow fermentation of flour and water.

It contains bacteria and yeasts that transform the natural sugars in the flour into carbon dioxide and alcohol.

Sourdough gives bread a unique taste and a denser, moister texture than yeast bread. However, its preparation is more complex and takes more time.

Baker's yeast is a simpler and faster fermentation agent to use.

It is composed of microscopic fungi that transform the sugars in the flour into carbon dioxide and alcohol.

Baker's yeast allows for lighter and airier bread than sourdough bread. It is also easier to dose and ensures a more consistent result.

Chemical Reactions

Alcoholic fermentation is a chemical reaction that takes place in the presence of yeast.

This reaction transforms glucose (sugar) into ethyl alcohol (ethanol) and carbon dioxide (carbon dioxide).

Reaction equation:

$C_6H_{12}O_6$ (glucose) --> 2 C_2H_5OH (ethanol) + 2 CO_2 (carbon dioxide)

Fermentation plays a dual essential role in bread-making:

1. Dough rising: The carbon dioxide (CO2) produced by fermentation is responsible for the dough rising. It creates alveoli that give the bread its airy and spongy structure.

2. Flavor development: Fermentation also allows for the development of complex flavors in the bread. The microorganisms present in the yeast and sourdough transform the natural sugars in the flour into a variety of aromatic compounds.

Intermediate fermentations: There are techniques that combine yeast and sourdough to create intermediate fermentations. These techniques are often used for country bread, as they allow for a bread with a richer flavor and a more rustic texture.

Additives in Bread

To correct flour deficiencies and improve bread properties.

Types of additives:

- **Bean flour (1%)**
  - Strengthens the gluten network and dough elasticity
  - Whitens the crumb
  - Increases the emulsifying power of the flour
  - Provides lipids and proteins
- **Soy flour (0.5%)**
  - Similar effects to bean flour
- **Soy lecithins (E322) (0.3%)**
  - Soften the dough
  - Delay staling
  - Slow down oxidation

- **Mono and diglycerides of fatty acids (E471)**
    - Similar effects to lecithins
- **Wheat malt, malt extract, and barley malt**
    - Provide amylases to correct flour deficiencies
    - Transform starch into fermentable sugars
    - Improve fermentation and browning of the crust

Gluten Gluten enriches the dough with additional proteins, improving its technological quality.

Vinegar, Acetic Acid, and Lactic Acid These ingredients play an antioxidant role, increase the flexibility of the dough, and are completely eliminated during baking.

Ascorbic Acid (or Vitamin C) It is used to whiten and ferment the dough but is eliminated during baking.

1.3.4. Bread-Making

1.3.4.1. Different Stages

► **Kneading** This stage allows for mixing all the components of the dough.

The incorporation of air (and thus oxygen) promotes the formation of new chemical bonds between the different ingredients, giving the dough its plasticity. Part of the water binds to the gluten, while the rest serves as a solvent and lubricant, giving the dough some mobility.

During dough kneading, the disulfide bonds of gluten proteins connect with each other, forming a three-dimensional network. Disulfide bonds are covalent bonds that form between two sulfur atoms. They are found in many proteins, including those in gluten. These disulfide bonds give gluten its strength and elasticity.

This network gives the dough its structure and its ability to retain gases, which gives the bread its moist and elastic texture.

Disulfide bonds are also responsible for gluten's ability to retain water. This is crucial because water allows the dough to rise and the bread to remain moist.

People suffering from celiac disease or gluten sensitivity cannot digest the disulfide bonds in gluten. This can cause inflammation and damage to the small intestine.

If you are forbidden to consume gluten, you must avoid all foods containing wheat, barley, rye, and triticale. Many other foods are also processed with gluten, so it is essential to read food labels carefully.

► **First Fermentation or Proofing** The dough is left to rest in a vat or kneading machine at a temperature of 20-25 °C to allow the yeast to act. The yeast performs alcoholic fermentation using the residual sugars in the flour (from the degradation of starch by amylases). The higher the flour extraction rate, the greater the amount of carbohydrates. Therefore, CO2 is produced, allowing the dough to begin to rise, becoming tenacious and more elastic. Moreover, the gluten forms a network preventing the carbon dioxide from escaping from the dough. Proofing is also an important stage in the formation of the bread's flavor (aroma and taste). Indeed, propionic acid, pyruvic acid, flavoring aldehydes, and ketones are formed, as well as small amounts of acetic acid and lactic acid, which are also flavor enhancers.

► **Dividing the Dough into Loaves** The loaves are of identical weight, and this stage is carried out using a divider-weigher.

Note: After kneading, the dough must be "relaxed" for a certain time. This step is necessary because kneading, being a mechanical operation, can reduce the dough's flexibility.

► **Shaping or "Turning" the Loaves** This stage consists of giving each loaf the desired shape depending on the type of bread desired (baguette, épi, boule, couronne, etc.). It is carried out using a "shaper." During this stage, there is still production of fermentable sugars (glucose + maltose) thanks to the action of amylases on starch, which will undergo the second fermentation.

► **Second Fermentation or Final Proofing** This stage also takes place in a thermostated chamber (20-25 °C). The yeast still uses the fermentable sugars to produce CO_2 in large quantities. Retained by the elastic and continuous film of the gluten network, this CO_2 then opens a multitude of small alveoli that make the dough swell more and more. The lower the flour extraction rate, the more the gluten network stretches under the pressure of CO_2. The volume of each loaf is thus tripled, and there is again production of many aromas.

► **Superficial Incision of the Loaves** Small incisions are made on the top of the loaves using a blade. These incisions aim to avoid unsightly tears in the crust under the very strong pressure of CO2 and under the action of heat during baking. They also allow for beautiful ridges called golden and crispy grignes, which are an important element of "good bread."

► **Baking the Loaves** The loaves are placed in an oven heated to 230 °C for 15 to 30 minutes (depending on the shape and weight of the bread). Humidity is regulated by injecting steam, which prevents the bread from drying out and allows for the formation of a golden and shiny crust. Under the action of heat, the loaves continue to swell, the crumb forms, the outside dries, hardens, and colors to give the crust.

► **Resting or Cooling** After baking, the bread is left to cool for a variable time depending on its shape and weight. The steam and CO_2 then diffuse through the crust and are gradually replaced by ambient air.

1.4. Bread Staling

Bread staling is a phenomenon that generally occurs between 12 and 24 hours after the bread is taken out of the oven. This process is characterized by an unpleasant change in the organoleptic properties of the bread. More precisely, the crust becomes soft and elastic due to the migration of water towards it, while the crumb, on the contrary, dries, hardens, and its taste changes.

This change is mainly due to a migration of gluten towards starch, leading to a recrystallization of starch. Starch then loses its amorphous form and returns to its crystalline form, a phenomenon known as "starch retrogradation." This results in a decrease in the digestibility of the bread, which can affect its nutritional value.

However, simple reheating can temporarily restore a softer structure to stale bread.

To slow down the staling process, it is recommended to wrap the bread in a cotton cloth and preferably store it in a relatively humid place, such as the vegetable drawer of the refrigerator. It is also interesting to note that "large bread" stales less quickly than baguettes.

1.5. Biscuit Products

1.5.1. Ingredients Biscuits, whether savory or sweet, are mainly composed of:

- Flour
- Fats (the quantity varies according to recipes)
- Sugar
- Egg: its foaming properties are used in meringues, ladyfingers, boudoirs, and genoise, while its emulsifying and binding properties are used in many products such as madeleines and cakes.

They may also contain various other ingredients such as:

- Milk (it makes the biscuit softer and creamier)
- Honey
- Dried fruits
- Fruits
- Chocolate…

The dough rising is ensured either by biological yeast (as for crackers) or by baking powder, also called chemical yeast. The latter contains bicarbonates, ammonium carbonate, acidic elements that, when heated and dehydrated, react with each other and release CO2, thus allowing the dough to rise.

Unlike biological yeast, baking powder brings a significant amount of sodium (~ 12 g of sodium/100 g). It is therefore strongly discouraged during sodium-controlled diets. Moreover, it has no nutritional interest and can destroy a large part of vitamin B1, already insufficient in white flours.

1.5.2. Biscuit Manufacturing

The biscuit manufacturing process includes three main stages:

1.5.2.1. Kneading and Shaping

- Hard and semi-hard doughs (example: petit-beurre): laminating and cutting using molds following the desired shape.
- Soft doughs (example: boudoirs): depositing in molds for baking.
- Liquid doughs (example: wafers): conveyed through piping to a wafer oven.

1.5.2.2. Baking Baking is carried out in tunnel ovens and is generally very fast, taking on average about 5 minutes.

1.5.2.3. Cooling

Cooling is done in a cooler.

1.5.2.4. Decorating, Coating, Filling

These stages include decorating, coating, and filling the biscuit.

1.5.2.5. Packaging and Storage

Dry biscuits have low water activity (aw = 0.3), which protects them against microorganisms. However, they must be stored away from moisture to maintain their quality. Moreover, their components are sensitive to oxidation reactions and light, so it is crucial that the packaging is adequate to preserve their freshness and flavor.

1.6. Pastry and Viennoiserie Products

1.6.1. Pastry Products Pastry products, precursors of biscuits, are a mixture based on flour and water, enriched with fats, eggs, milk, often sugar, sometimes fruits, or other ingredients such as alcohols, flavors, and possibly fruits and prepared creams. These products constitute an excellent culture medium for microbes, especially when they contain egg-based cream fillings. They are therefore a frequent cause of Collective Foodborne Illness (TIAC), often due to salmonella or Staphylococcus aureus. This is why, in collective catering, it is recommended to use egg products during their manufacture and to strictly respect storage temperatures (< 3 °C). Moreover, their relatively high water content further limits their shelf life.

1.6.2. Viennoiserie Products

This category includes various small breads, croissants… which are sold in bakeries and consumed in some "fast food." Moreover, their high fat content makes them susceptible to rancidity.

1.7. Pasta Products

1.7.1. Semolina

1.7.1.1. Definition and Manufacturing Process

Semolina is a coarse, granular flour made from **durum wheat (*Triticum durum*)**. Durum wheat is distinct from soft wheat (Triticum aestivum) in several ways:

- **Grain Shape**: Durum wheat grains are more elongated and harder than soft wheat grains.
- **Protein Content**: Durum wheat has a higher protein content, which contributes to its strength and elasticity, making it ideal for pasta production.
- **Endosperm Composition**: The endosperm of durum wheat is richer in **gluten**, **lipids**, **minerals**, and **vitamins** (10 to 20% more than soft wheat). The starch in durum wheat is also of a different quality, which gives the grains a granular texture even after milling. This granularity is crucial for the texture and cooking quality of pasta.

Manufacturing Process of Semolina:

1. **Cleaning**:
    - The durum wheat grains are cleaned to remove impurities such as dirt, stones, and other foreign materials. This ensures that the final product is pure and safe for consumption.
    - The cleaning process involves the use of separators and sorters to remove large and small impurities, respectively.
2. **Milling**:
    - The cleaned grains are then milled using **grooved grinders**. Typically, **seven grinders** are used in the milling process.
    - The milling process breaks down the grains into smaller particles, separating the endosperm (the starchy part) from the bran and germ.
    - The result of this process is a mixture of **semolina** and **flour**. The semolina is the coarser part, while the finer particles are classified as flour.
3. **Sieving**:
    - The milled particles are sent to **sifters** (sieves) where they are separated based on size.
    - The semolina is classified according to its **granulometry** (particle size):

- **Large Granulometry Semolina**: Used for making soups and cereal dishes.
- **Medium Granulometry Semolina**: Known as "cooking semolina," it is used for making **couscous**.
- **Fine Granulometry Semolina**: This is the type used for making **pasta**.

4. **Yield**:
   - From the milling process, **60 to 65% semolina** and **12 to 15% flour** (called **durum groats**) are obtained. The remaining portion consists of bran and germ, which are often used for animal feed or other purposes.

1.7.2. Pasta

Pasta Value refers to the ability of semolina to be transformed into high-quality pasta. This value is determined by two main aspects: **visual quality** and **culinary quality**.

Visual Quality:

- **Color**: High-quality pasta should have a uniform **amber yellow** color. Any spots or black dots are considered defects and can indicate impurities or improper processing.
- **Pitting**: Pasta should not have **pitting**, which are small holes or dark spots caused by imperfections in the semolina or issues during the manufacturing process.
- **Appearance**: The pasta should be **smooth** and **regular**, without cracks or breaks. A smooth surface ensures even cooking and a pleasant texture.

Culinary Quality:

- **Tenacity**: Pasta should be **tenacious**, meaning it should hold its shape during cooking without becoming too soft or mushy. This is particularly important for pasta dishes that require al dente texture.
- **Stickiness**: After cooking, pasta should not stick together. Stickiness can be a sign of poor-quality semolina or improper drying.
- **Water Absorption**: Pasta should absorb enough water to cook evenly and thoroughly. Proper water absorption ensures that the pasta is cooked to perfection, with a firm yet tender texture.

Factors Influencing Pasta Value:

- **Durum Wheat Quality**: The quality of the durum wheat used is crucial. Factors such as **protein content**, **gluten quality**, and **grain vitreousness** (the glassy appearance of the grain) significantly impact the final pasta quality.

- **Manufacturing Process**: The way the pasta is made also affects its quality. The **type of milling**, **kneading**, **extrusion**, and **drying** processes all play a role in determining the pasta's texture, appearance, and cooking properties.

Importance of Pasta Value:

- **Marketing**: Pasta with good pasta value is more marketable because it has a better appearance, texture, and taste. Consumers prefer pasta that cooks well and has a pleasant mouthfeel.
- **Cooking and Digestion**: High-quality pasta is easier to cook and digest. It retains its shape and texture during cooking, providing a better eating experience.

1.7.2.2. Manufacturing Stages

Unlike bread-making, pasta manufacturing does not involve fermentation or baking. The process is divided into three main stages:

1. Pasta-Making:

- **Mixing**: Semolina is mixed with water to form a dough. The mixing is done in a **vacuum vat** to avoid the formation of air bubbles, which can affect the pasta's texture and appearance.
- **Kneading**: The dough is kneaded to develop the gluten network, which gives the pasta its elasticity and strength.
- **Shaping**: The dough is then shaped into the desired pasta forms. There are several methods for shaping pasta:
    - **Extrusion**: The dough is pushed under pressure through **dies** (molds) to create specific shapes like **spaghetti**, **macaroni**, **shells**, etc.
    - **Laminating**: This method is used to create flat pasta such as **noodles**, **lasagna**, and **tagliatelle**.
    - **Laminating and Imprinting**: For more complex shapes like **butterflies**, **alphabets**, and **stars**, the dough is laminated and then pressed into molds.

2. Drying:

- **Drying Process**: The shaped pasta is dried in **tunnels** where hot and humid air circulates. The drying process reduces the moisture content of the pasta to about **12.5%,** which allows for long-term storage without the risk of spoilage.
- **Impact on Nutrients**: Drying can lead to a decrease in the content of certain nutrients, such as **lysine** (an essential amino acid) and some **vitamins** (notably vitamins B and

B2). The cooking process can further reduce these nutrients, so it's important to handle the drying process carefully to minimize nutrient loss.

3. Packaging:

- **Final Step**: Once the pasta is dried, it is packaged for distribution. Proper packaging is essential to protect the pasta from moisture, which can affect its quality and shelf life.
- **Storage**: Pasta should be stored in a cool, dry place to maintain its quality. Properly packaged and stored pasta can last for months or even years without losing its texture or flavor.

2.Rice

2.1. Généralités

Rice is a grass belonging to the Oryza family, which includes about twenty different species. It is the primary food resource in the most disadvantaged regions of the world, particularly in Asia, Latin America, and Madagascar. In France, rice consumption is relatively low,averaging 3.5 to 4 kg per person per year (figure 4).

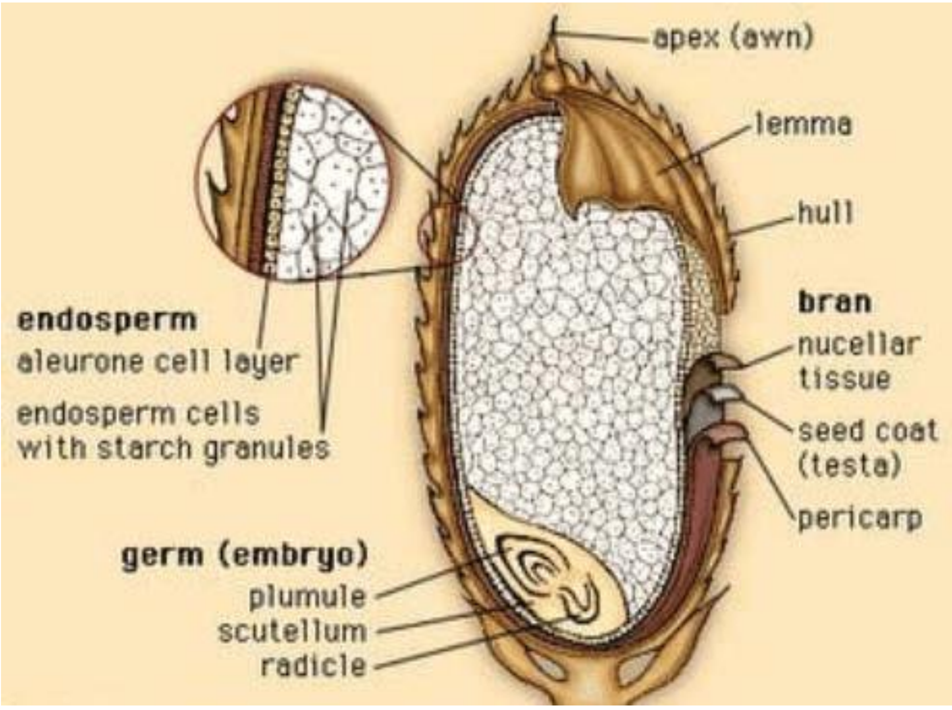

Figure 4: Cross-section of a paddy rice grain.

2.2. Classification

Two main subspecies of rice are cultivated, differing in the shape of their grains:

- **Indica rice (round-grain or common rice)**

- Length: < 5.2 mm
- Diameter: < 2 mm
- Rich in linear starch (amylose), which tends to make it sticky when cooked.
- Ideal for dishes requiring a creamy texture, such as soups and desserts (rice pudding, rice cakes, risotto).

- **Japonica rice (long-grain or "luxury" rice)**
    - Length: > 6 mm
    - Diameter: > 2 mm but < 3 mm
    - Rich in branched starch (amylopectin), it remains firm and does not stick when cooked.
    - Used for appetizers or side dishes (steamed, Creole, or pilaf-style rice).

Although the nutritional value of these two types of rice is similar, round-grain rice is often considered "ordinary," while long-grain rice is perceived as more "luxurious," which is not always justified.

2.3. Rice Milling

Rice milling involves a series of processes to make it suitable for consumption (figure 5).

- **Different types of rice obtained during milling**
    - **Paddy rice**: Raw rice harvested with all its husks, unsuitable for consumption, and used as seed.
    - **Cargo rice (brown or hulled rice)**: Rice with the husks removed, retaining a thin layer of bran rich in minerals, B vitamins, and fiber. It takes longer to cook and is often sold as **brown rice**.
    - **Milled rice (white rice)**: Processed rice, polished to retain only the endosperm, losing much of its nutrients.
    - **Polished rice**: Further polished milled rice, removing the aleurone layer, which is rich in proteins, minerals, and vitamin B1.
- **Consequences of milling**
    - Milling reduces the fiber, vitamin, and mineral content, increasing digestibility but decreasing nutritional value.
    - White rice, although lower in protein than wheat flour, is qualitatively superior, making it a good choice for people with chronic kidney disease who require limited protein intake.

- The loss of minerals and vitamins during milling explains the prevalence of beriberi in populations consuming only polished rice.

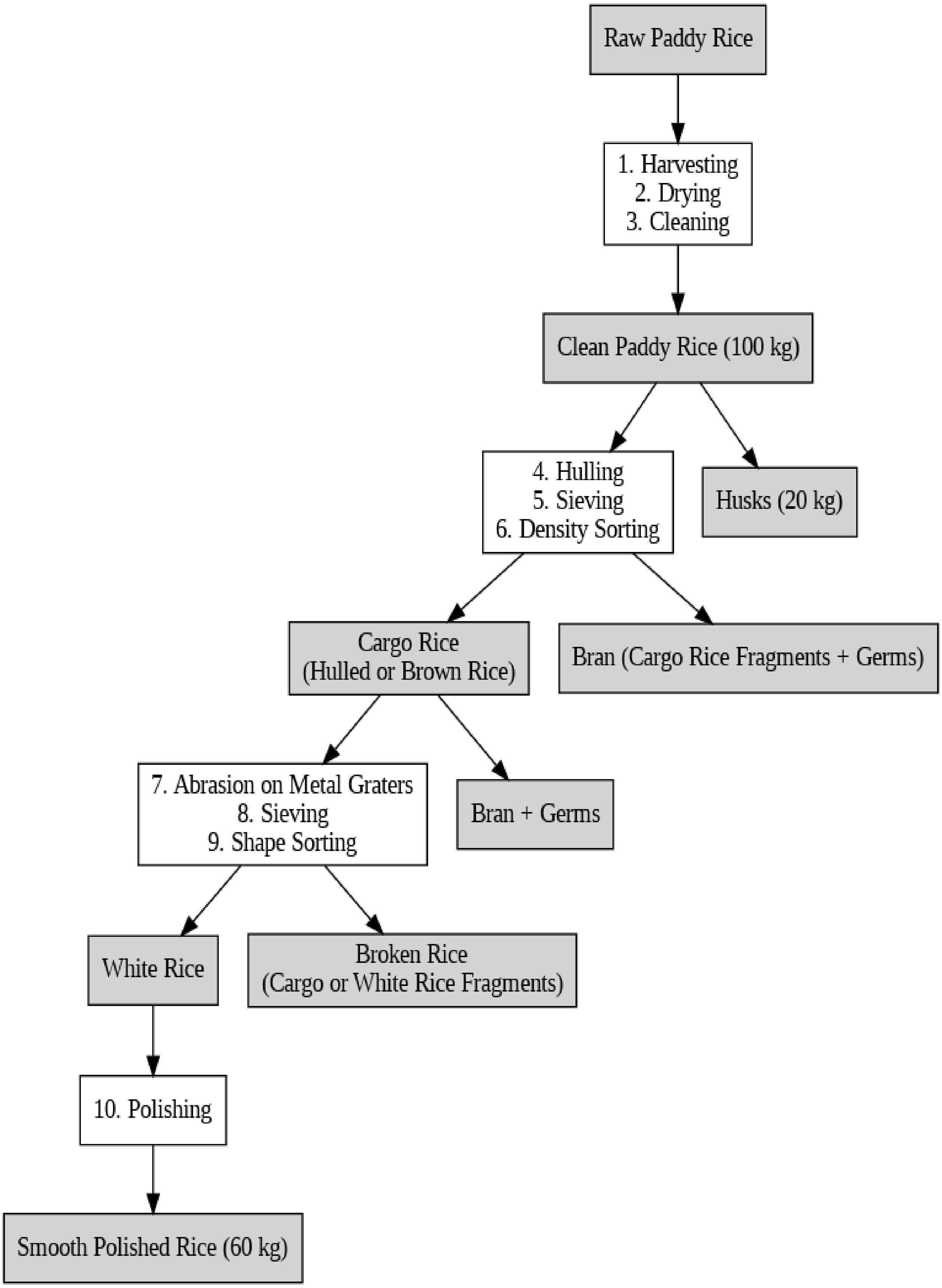

Figure 5 : Rice milling

2.4. Different Forms of Commercial Rice (figure 6)

1. **White rice**
    - The most common form, often polished and devoid of its husks.
2. **Parboiled rice (long or "non-sticky")**
    - Treated with steam before hulling, which helps retain some nutrients.
    - Parboiled rice is richer in B vitamins and minerals and sticks less when cooked.
3. **Precooked rice (or "quick rice")**
    - Precooked with steam and then dehydrated, reducing cooking time to about 10 minutes.
    - Less flavorful than parboiled rice.
4. **Glazed rice**
    - Coated with a talc and glucose suspension to improve appearance.
    - Requires washing before cooking to remove the unpleasant taste.
5. **Oiled rice (or "camolino rice")**
    - Coated with camelina oil, but it tends to go rancid quickly.
    - Less commonly used today.
6. **Other specialty rices**
    - **Wild rice (*Zizania aquatica*)**: An aquatic cereal from North America, rich in proteins, minerals, and vitamins.
    - **Glutinous rice**: An Asian variety that is particularly sticky.
    - **Aromatic rices**: Such as basmati and Thai rice, known for their pronounced flavors.

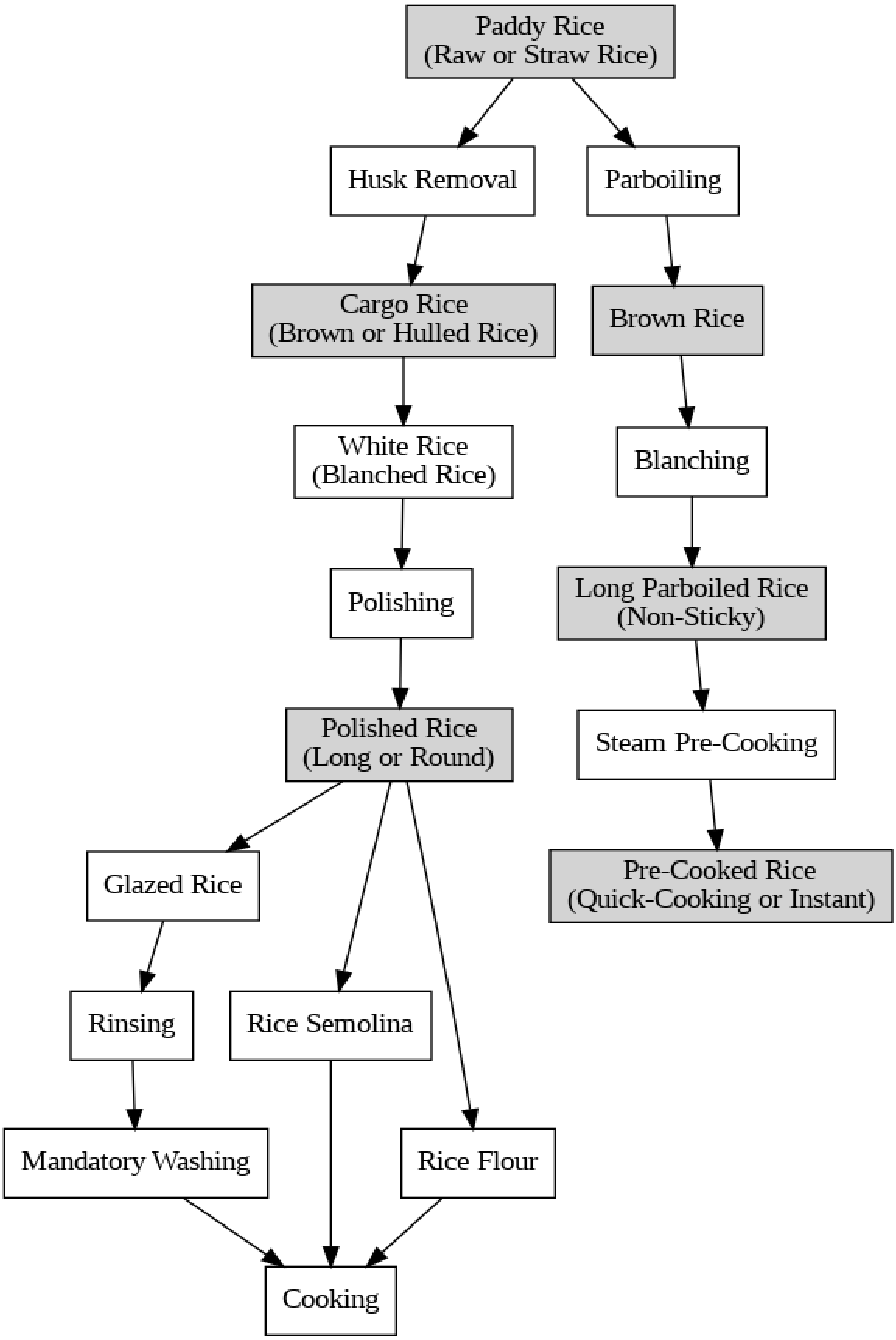

Figure 6 : Different Forms of Commercial Rice

2.5. Nutritional Value of Rice

- **Proteins**: 6.5%, primarily glutelin. The limiting factor is lysine.
- **Carbohydrates**: 78%, mainly starch.
- **Fats**: Low content.
- **Vitamins and minerals**: Brown rice is richer in B vitamins, magnesium, phosphorus, and fiber compared to white rice.

Rice is a versatile grain used in a wide variety of savory and sweet dishes. It is also the base for products like rice noodles, syrup, wine, vinegar, and rice flour, which is used in Asian alcoholic beverages such as sake. White rice is particularly valued in therapeutic diets for its digestibility and anti-diarrheal properties. Round-grain rice, although stickier, is richer in amylopectin, making it more digestible. However, rice does not contain gluten, making it unsuitable for bread-making.

3. Corn

- **Structure of the corn kernel**
  - The corn germ is five times larger than that of wheat.
  - The central endosperm is floury and used for making corn flour, while the peripheral endosperm is used for semolina.

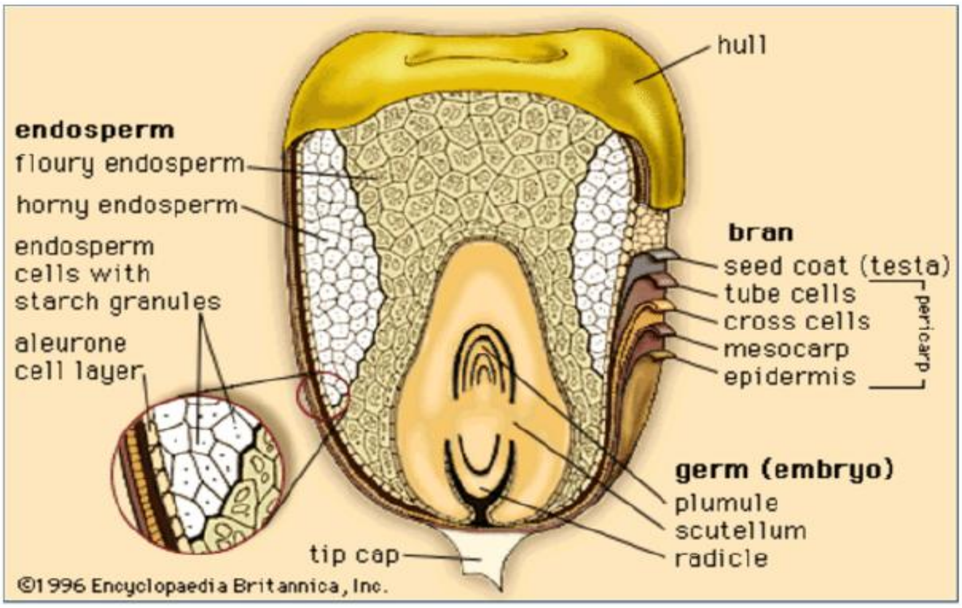

Figure 7 :Cross-section of corn grain

- **Nutritional value of corn**
    - Proteins: 12%
    - Carbohydrates: 63%
    - Fats: 4%
    - Corn is rich in amylopectin, making it quickly digestible.
    - It has two limiting factors: lysine and tryptophan, the latter being a precursor to vitamin PP. A deficiency in tryptophan can lead to pellagra, an endemic disease caused by excessive corn consumption.
- **Milling in semolina production**
    - Corn milling is challenging due to the variable size of the kernels.
    - The germ, rich in fats, must be removed to prevent rancidity.
- **Forms of commercial corn (figure 8)**
    - **Popcorn** and **corn flakes**: Made by heating the kernels, causing them to expand.
    - **Polenta**: A cornmeal dish, precooked and ideal for those with gluten intolerance.
    - **Cornstarch**: Used as a thickening agent in sauces and creams.
    - **Corn oil**: Rich in linoleic acid, used for seasoning or frying.
    - **Corn starch**: Used in sausages, pastries, confectionery, and baby food.
    - **Fresh corn**: Eaten as boiled or grilled cobs.
    - **Canned corn**: Sold as kernels.

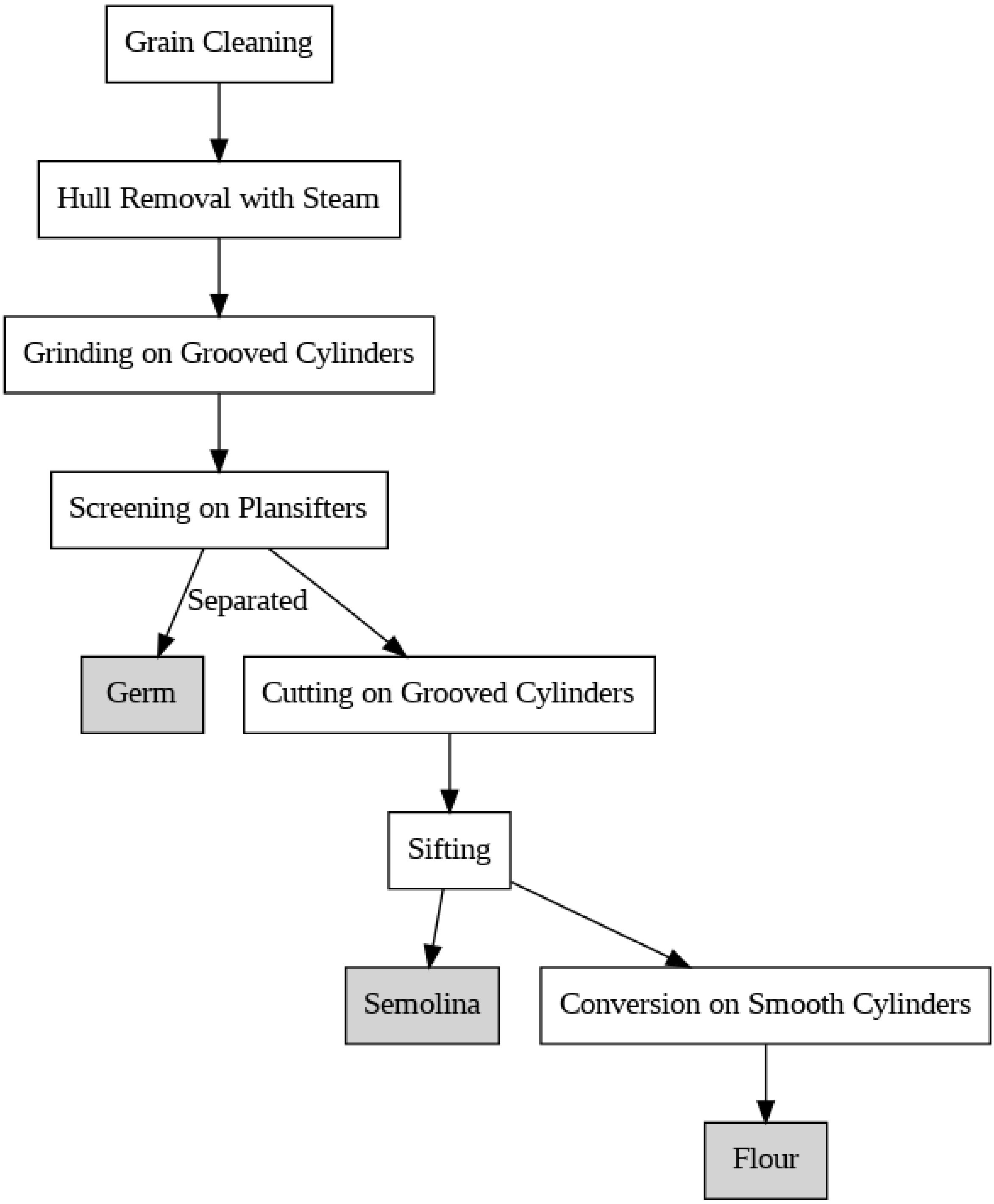

Figure 8 : Forms of commercial corn

Chapter 2 : Fruits and Vegetables

1. Classification of Vegetables and Fruits

1.1. Classification of Vegetables

Vegetables are edible plants, and different parts of the plant are consumed depending on the species.

- **Root Vegetables**: Includes carrots, turnips, celeriac, salsify, radishes, black radishes, beets, parsnips, rutabagas, etc.
- **Stem Vegetables**: Includes asparagus, celery, Swiss chard, kohlrabi, heart of palm, rhubarb, cardoon, bamboo shoots, fennel, samphire, etc.
- **Tuber Vegetables**: Includes potatoes, sweet potatoes, cassava, Jerusalem artichokes, crosnes, yams, etc.
- **Bulb or Pod Vegetables**: Includes leeks, garlic, onions, shallots, scallions, etc.
- **Squash and Cucurbits**: Includes pumpkins, squash, zucchini, pattypan squash, cucumbers, gherkins, etc.
- **Leafy Vegetables**: Includes spinach, sorrel, green cabbage, red cabbage, Brussels sprouts, Chinese cabbage, various lettuces (romaine, butterhead, iceberg, endive, chicory, arugula, watercress, dandelion, nettle, etc.), vine leaves, and green herbs.
- **Flower Vegetables**: Includes cauliflower, broccoli, artichokes, etc.
- **Fruit Vegetables**: Botanically, these are fruits but are consumed as vegetables. Includes tomatoes, eggplants, bell peppers, avocados, olives, etc.
- **Peas and Beans**: Includes green beans, yellow beans, peas, snow peas, etc.
- **Dried Vegetables**: Includes flageolet beans, fava beans, lentils, split peas, etc.
- **Sprouts**: For example, "bean sprouts" which come from the germination of mung beans.
- **Mushrooms**: Classified separately as they are non-chlorophyllous plants.
- **Seaweed**: Although not true vegetables, they are often referred to as "sea vegetables" due to their similar culinary use.

1.2. Classification of Fruits

- **Fresh or Juicy Fruits**: Represent 95% of fruits. They are also called juicy fruits and are characterized by their high water content.
- **Starchy Fruits**: Includes chestnuts and marrons.

- **Oily Fruits**: Includes avocados, coconuts, and olives.
- **Oilseeds**: Includes almonds, hazelnuts, walnuts, peanuts, pine nuts, sunflower seeds, sesame seeds, etc.
- **Dried Fruits**: Fruits that have been dehydrated, such as raisins, figs, apricots, mangoes, papayas, apples, bananas, plums, etc.

2. Ripening

Vegetables and fruits reach their optimal flavor and texture when they are "ripe." Ripening mainly occurs in fruits and involves a series of chemical and enzymatic reactions that allow:

- **Sugar Formation**: Sugar content increases at the expense of starch, which is gradually replaced by sucrose, then partly by fructose and glucose.
- **Aroma Formation**: Through the synthesis of aromatic compounds.
- **Vitamin Formation**: For example, vitamin C is synthesized during ripening.
- **Pigment Changes**: Chlorophyll is degraded, revealing carotenoids and anthocyanins synthesized during ripening. The fruit then turns yellow or red.
- **Decrease in Acids and Tannins**: Enzymatic action reduces acidity, increasing the overall sugar/acid ratio. The fruit becomes sweeter, especially as the amount of astringent tannins decreases.
- **Softening of Fibers**: Hemicelluloses in cell walls regress. Additionally, pectins are solubilized and depolymerized, contributing to the softening of the plant.

These changes depend on climate (temperature, sunlight, rainfall). Fruits also release ethylene, a gas that plays a crucial role in ripening. Ripening can be delayed after harvest by exposing fruits to a CO2-enriched atmosphere and lowering the temperature, which reduces ethylene production.

Example: Bananas harvested green in the islands are ripened in mainland "ripening rooms." However, the optimal ripening state is very short. The organoleptic qualities of fruits decline rapidly due to a decrease in sugars and changes in plant fibers. To extend storage time, fruits are harvested before full ripeness and immediately refrigerated to delay ripening.

3. Contamination of Plants

3.1. Contamination by Microorganisms

Plant spoilage is caused by two types of microorganisms: phytopathogenic microorganisms that attack the plant before harvest (leading to the use of pesticides) and saprophytic microorganisms that develop after harvest, especially if the plant has been damaged.

- **Phytopathogenic Flora**: Composed of fungi and bacteria, transmitted through seeds and the environment, particularly soil contaminated by crop residues. Fungi cause rot that affects specific parts of the plant, while bacteria cause soft rot by releasing pectinolytic enzymes, promoting fermentation.
- **Saprophytic Flora**: Depends on the environment and can come from air, soil (telluric contamination), or water. Contaminants can include parasites (Helminths and Protozoa), pathogenic bacteria (*Salmonella*, *Listeria*, *Yersinia*), or enteroviruses, particularly hepatitis A and E and poliovirus.

Note: Healthy, undamaged products are generally less spoiled. Damage promotes the growth of latent microorganisms, such as fungi. Fruit ripeness also corresponds to a phase of tissue fragility due to increased degradation enzymes and decreased antiseptic compounds.

3.2. Contamination by Chemical Residues

These contaminants come from natural phenomena and environmental contamination (accidental radioactivity, farming techniques). Regulations specify acceptable levels of chemical residues such as metals, arsenic, pesticides, or nitrates in fruits and vegetables.

Example of Nitrates: The nitrate content in a plant depends on the species, variety, climate, and farming methods. It decreases as the plant reaches full maturity. However, since commercial plants are never fully mature, the nitrate content in the vegetables we consume can remain high. Leafy and root vegetables accumulate the most nitrates, making peeling particularly important. Nitrates themselves do not seem to be directly toxic except in very young children and pregnant women. They are absorbed and eliminated by the kidneys. However, they can be reduced to nitrites by enzymes secreted by the plants themselves or by bacteria that develop on the plants after harvest. Nitrites can cause methemoglobinemia in very young children, characterized by the transformation of hemoglobin into methemoglobin, causing dyspnea and dizziness.

Nitrites can also lead to the formation of carcinogenic nitrosamines. Therefore, the WHO's acceptable daily intake of nitrates is 3.65 mg/kg of body weight, and vegetables represent a significant portion of this intake. Blanching removes 20-40% of nitrates, and boiling in water removes 40-50% if the cooking liquid is not consumed. Organic farming can reduce nitrate content in vegetables by 30-50%.

4. Preservation of Plants

4.1. By Positive Cold: Refrigeration

4.1.1. Refrigeration Applied After Harvest: Pre-Cooling

Cold extends the storage time of plants after harvest. However, this preservation method must be adapted to each plant based on its ability to tolerate refrigeration and the stage of development at the time of cooling.

- **Packaging**: Plays a protective role and can be airtight or perforated to optimize preservation. Before packaging, plants may undergo treatments (washing, fungicide treatment, chemical treatments, ionization, wax coating) that must be communicated to the consumer. Harvesting and transportation should be done as quickly as possible before packaging, as long as the ambient temperature remains high, respiration and metabolic processes continue.
- **Pre-Cooling**: Cools plants as soon as possible to limit nutritional losses and slow or prevent microbial growth. Different methods are used: cold air flow, immersion in cold water, direct contact with whole or crushed ice.
- **Storage Conditions**:
    - **Storage Temperature**: Chosen specifically for each plant (0 to 10°C), with programmed temperature regimes to optimize preservation.
    - **Storage Duration**: Depends on the plant and storage temperature.
    - **Humidity**: Must be regulated to avoid being too dry (preventing wilting) or too humid (preventing microbial growth).
    - **Atmospheric Gas Composition**: Must also be controlled to prevent enzymatic browning, fermentation, and excess ethylene that accelerates ripening. Preservation in a modified atmosphere is possible.

4.1.2. Refrigeration Applied at Home

Some vegetables such as winter squash, garlic, onions, and potatoes can be stored at room temperature. However, most should be refrigerated immediately after purchase in the refrigerator's vegetable drawer, which is adapted with less cold and more humid air than the shelves, preventing dehydration.

4.2. Preservation of Vegetables by Blanching

Blanching vegetables is a preliminary step to canning, freezing, and dehydration. It involves subjecting the raw vegetable to high temperature for a few minutes, depending on its nature and size.

4.2.1. Advantages of Blanching

- Destroys oxidizing enzymes, fixing colored pigments, preventing enzymatic browning, limiting subsequent vitamin C loss, and maintaining organic compounds.

- Surface sterilizes the food.
- Softens the vegetable by acting on dietary fibers, facilitating packaging.
- Eliminates gases, reducing oxidation-reduction reactions and removing excess unpleasant gaseous components (e.g., with cabbage).
- Promotes subsequent dehydration or rehydration.

4.2.2. Disadvantages of Blanching

- Causes loss of rigidity in the vegetable during dehydration.
- Gives a "cooked" flavor to fresh products.
- Converts some chlorophyll into brown or olive-green pheophytin.
- Responsible for the loss of aromatic compounds: hence, onions are generally not blanched.
- Causes loss of water-soluble vitamins (average 25% loss of vitamin C).

4.2.3. Blanching Methods Used

- **Water Blanching**: Time and temperature are adapted to each vegetable. Calcium salts may be added to firm pectins; pH is raised to block chlorophyll color (at the expense of vitamins B and C); sulfites are added to prevent enzymatic browning, limiting vitamin C oxidation but destroying vitamin B.
- **Steam Blanching**: Longer and more expensive but results in less mineral loss. However, losses of vitamins C, B1, E, and beta-carotene are similar to water blanching.
- **Microwave Blanching**: Seems to preserve nutritional elements well, but results vary slightly.

4.3. Preservation of Vegetables by Canning

4.3.1. Definition

Canning is a method of preserving perishable food based on two combined techniques:

1. Packaging in a container that is airtight to liquids, gases, and microorganisms.
2. Heat treatment to destroy or completely inhibit enzymes, microorganisms, and their toxins. The goal is to prevent spoilage and make the food unfit for consumption.

4.3.2. Technology

- **For Vegetables**:
    1. Washing and preparation.
    2. Peeling, trimming, paring, and sizing.
    3. Blanching.
    4. Canning: Vegetables are placed in a covering liquid (containing salt).

5. Preheating to a temperature above 60°C to expand the contents and exclude dissolved gases before sealing. This removes as much oxygen as possible, better preserving vitamin C.
6. Sealing the cans.
7. Canning at a temperature above 115°C in large autoclaves, cooking and sterilizing the food.
8. Rapid cooling to prevent overcooking.
9. Storing canned goods at room temperature.

- **For Fruits**:
  1. Washing.
  2. Peeling, trimming, paring, and sizing.
  3. Canning with added sugar syrup.
  4. Preheating.
  5. Sealing.
  6. Canning at a temperature above or equal to 85°C.
  7. Cooling.
  8. Storing canned goods in syrup at room temperature.

4.3.3. Nutritional Value Changes

For vegetables, there are no changes in macronutrients. For fruits, carbohydrate content increases (from an average of 12% to about 16%). Regarding vitamins:

- Vitamin C is lost by about 50% in vegetables and up to 90% in fruits.
- Other vitamins are lost by about 20%. Regarding minerals: Since they are water-soluble, they are largely found in the juice. It would therefore be wise to consume the juice.

4.4. Preservation of Vegetables by Freezing

4.4.1. Definition

Freezing is an ultra-rapid freezing method that forms small ice crystals, preserving cell walls. Frozen foods are thus very similar to fresh foods. This method differs from conventional freezing, which involves slower cooling and the formation of large ice crystals that can damage cell walls, making foods soft upon use. It is important to note that freezing does not destroy microorganisms but simply stops their growth. It also slows enzymatic reactions responsible for unpleasant flavors and color loss. Frozen products are not sterile and must be free of pathogenic germs. Freezing is primarily a means of preserving vegetables for a long period at a temperature of -18°C or lower.

4.4.2. Technology

1. Washing and preparation of the product.
2. Peeling, trimming, paring, and sizing.
3. Blanching.
4. Cooling.
5. Possible addition of sugar (for fruits) and/or citric acid and/or ascorbic acid, which are antioxidants preventing browning.
6. Freezing: The freezing process must be conducted to quickly pass through the maximum crystallization zone and reach a temperature below -18°C as soon as possible.
7. Storage at a temperature generally below -18°C. The lower the temperature, the longer the storage life.
8. Thawing: Can be direct (cooking the vegetable directly) or indirect (must be done in a cold room at +3°C according to regulations).

4.4.3. Quality of Frozen Products

The quality of frozen products depends on the freshness of the vegetables and the speed of the freezing process. However, there is very little difference from fresh vegetables.

4.4.4. Nutritional Value of Frozen Products

The nutritional value of frozen products is well preserved compared to fresh vegetables. It is therefore an excellent preservation method.

4.5. Preservation of Vegetables by Dehydration

The goal of dehydration is to improve preservation by reducing water content from an initial 88-95% to 5-12%. This technique reduces the water activity (aw).

4.5.1. Technology

- **Vegetables**:
  - Preparation: Washing, sorting.
  - Cutting: Crucial and must be clean and in small pieces.
  - Blanching: For many vegetables, it is replaced by complete cooking so that dehydrated vegetables only require a few minutes of cooking, coinciding with rehydration time.
  - Drying: Vegetables are gradually exposed to increasingly dry air flow.
  - Packaging.
  - Storage.
- **Fruits**:

- To prevent browning, fruits are blanched with small amounts of sulfur dioxide (E220).
- They are then dried by desiccation, either naturally in the air or forced by hot air in a tunnel.

4.5.2. Nutritional Value Changes

- **Vegetables**: The nutritional value is almost identical to fresh vegetables if treated immediately after harvest, as they are never consumed as-is but always rehydrated.
- **Fruits**: Carbohydrate content, which averages 12%, increases to about 60-70% (close to that of jams). The energy value then reaches 1,150 kJ/100 g (275 kcal/100 g). Constituents are thus concentrated by about 4 times, except for oxidizable ones like vitamin C, which is completely destroyed during this process. Magnesium and potassium content is high. Dried fruits are also rich in fiber (laxative properties) and thus have a low glycemic index. They can be used as snacks for athletes.

4.6. Preservation by Sugar Concentration: Jams

The industrial production of jam involves a series of automated and controlled steps to transform fresh fruits into a stable, high-quality final product. The main steps of the process are:

Reception and Sorting of Fruits:

- Fresh fruits are received in bulk or in packaging and visually inspected for quality and freshness.
- They are then sorted by ripeness, variety, and absence of defects.
- A conveyor system transports the fruits to the next steps.

Washing and Drying:

- Fruits are thoroughly washed with potable water to remove impurities and pesticide residues.
- A rotating brush system or powerful water jets may be used for washing.
- Excess water is removed by air drying or spinning.

Preparation of Fruits:

Fruits may undergo different preparation steps depending on their type and the desired texture of the jam:

- Some fruits, like strawberries, may be cut into pieces.
- Others, like apples, may be peeled, cored, and diced.
- Fruits with large pits, like peaches, may be pitted.

Cooking:

- Prepared fruits are mixed with sugar and possibly other ingredients like pectin, lemon juice, or spices.
- Cooking is usually done in large stainless steel vats under vacuum or at atmospheric pressure.
- Temperature and cooking time vary depending on the type of fruit and the desired texture of the jam.
- A mechanical mixer prevents the fruits from burning and ensures even cooking.

Evaporation and Concentration:

- The cooked jam may undergo an evaporation step to reduce water content and increase sugar concentration.
- This results in a thicker texture and better preservation.
- Evaporation can be done under vacuum at low temperatures to preserve fruit quality.

Filling and Sterilization:

- Hot jam is filled into pre-sterilized glass jars or bottles.
- Filling can be automated using dosing machines.
- Filled jars are then hermetically sealed.
- For optimal preservation, jars undergo a high-temperature sterilization step, usually above 100°C.

Labeling and Quality Control:

- Sterilized jam jars are labeled with required information, such as ingredient list, production date, and expiration date.
- A final quality control check ensures the absence of packaging defects and compliance with quality standards.

Storage and Distribution:

- Labeled jam jars are stored under appropriate temperature and humidity conditions before being distributed to retailers and consumers.

4.7. Preservation of Vegetables by Freeze-Drying

Freeze-drying, or cryodesiccation, is a dehydration technique at very low temperatures under vacuum, transforming the water in vegetables from solid to vapor without passing through the liquid state, a phenomenon called sublimation.

The technology includes the following steps:

1. Preparation: Washing, sorting.

2. Cutting.
3. Blanching.
4. Rapid freezing at about -35°C, preserving cell integrity and solidifying water.
5. Dehydration under vacuum: Water content can be reduced to as low as 1%.

Practical examples of this method include mushrooms, fruit juices, and coffee. Note that rehydration often results in more water being absorbed than the original fresh product contained. For example, 10 kg of fresh vegetables can yield 1 kg of dehydrated vegetables, which can then be rehydrated to yield 11 kg of vegetables.

4.8. Preservation of Vegetables by Fermentation

Fermentation is another method of preserving vegetables and fruits through controlled fermentation.

4.8.1. Sauerkraut

Sauerkraut technology involves placing cabbage in anaerobic conditions and subjecting it to lactic acid fermentation. The end of gas release indicates the end of fermentation. Fermentation is controlled by salt, which:

- Inhibits the growth of certain microorganisms due to its acidifying properties.
- Promotes the proliferation of other species like *Leuconostoc mesenteroides*, *Lactobacillus*, and *Streptococcus*, which consume glucose and produce lactic acid, responsible for the sour taste of sauerkraut.

The nutritional value of cabbage is altered by fermentation. Cabbage is very rich in B vitamins and contains some vitamin A. When transformed into sauerkraut, its vitamin B1 content is significantly increased, and vitamin C content is barely changed as fermentation occurs almost completely in the absence of air. Fermentation also seems to have beneficial effects on gut flora. Sauerkraut can be sold sterilized in cans or as fresh sauerkraut.

4.8.2. Olives

- **Green Olives**: Undergo debittering by treatment in an alkaline solution followed by lactic acid fermentation in a saline medium. Note that green olives are olives that have not reached maturity.
- **Black Olives**: Prepared similarly to green olives. However, they are sometimes simply canned after debittering without undergoing fermentation.

4.9. Preservation of Vegetables by the 4th Range Technique

4.9.1. Different Ranges of Vegetables

Vegetables can be classified into six ranges or categories based on their presentation:

1. **1st Range**: Fresh vegetables as-is.
2. **2nd Range**: Canned vegetables.
3. **3rd Range**: Frozen vegetables.
4. **4th Range**: Fresh, raw, ready-to-use vegetables that have been peeled, cut, or otherwise prepared.
5. **5th Range**: Cooked, vacuum-sealed, ready-to-use vegetables: pasteurized or sterilized under modified atmosphere.
6. **6th Range**: Freeze-dried vegetables.

4.9.2. Preparation of 4th Range Products

1. Cooling: By cold air for leafy vegetables; in a cold room with humid atmosphere for root vegetables and cabbages.
2. Washing.
3. Brushing.
4. Peeling.
5. Quick dip (0 to 2 seconds) in a chlorinated bath: Reduces microbial population; prevents enzymatic browning.
6. Rinsing with potable water and adding antioxidants (citric acid, L-ascorbic acid): Reduces phenol browning; lowers pH, negatively affecting bacteria.
7. Thorough spinning.
8. Packaging: Use of an appropriate gas; use of appropriate film with packaging that allows the vegetable to continue breathing.
9. Storage at a temperature below 4°C.
10. Transport at a temperature below 4°C.
11. Distribution at a temperature below 4°C.

The shelf life (DLC) of these products is a maximum of one week, and the storage temperature must be between 0 and +4°C.

4.9.3. Nutritional Value of 4th Range Products

Vitamin C loss is high, especially for leafy vegetables (nearly 75% loss), but carotenes and vitamin E are well preserved. However, these products allow consumers to expand their choices.

4.10. Treatment of Vegetables and Fruits by Ionizing Radiation

Food irradiation is a treatment technique aimed at sanitizing food products and/or extending their shelf life. It does not replace current preservation methods but rather complements traditional techniques such as refrigeration or cooking.

This process involves exposing food to different types of radiation:

- Gamma radiation
- X-rays
- Accelerated electron beams

It is important to note that there is no nuclear risk associated with the food (no possibility of radioactive contamination), and irradiated products are not toxic to consumers. Radiation simply breaks down molecules, releasing free electrons that, in turn, ionize other molecules.

The effects of irradiation, whether positive (improving hygienic quality, extending shelf life) or negative (bad odors), depend on the "dose" of radiation applied, measured in gray (Gy), where 1 Gy = 1 joule per kilogram of food (Table 1).

Depending on the dose, the following can be achieved for each food:

- **Inhibition of germination:** 0.04 to 0.10 kGy
- **Inability of insects to reproduce:** 0.03 to 0.20 kGy or their death: 1 to 3 kGy
- **Partial or total destruction of microbial load:** 1 to 4 kGy
- **Destruction of pathogenic germs (equivalent to pasteurization):** 1 to 6 kGy (radurization)
- Sterilization: 15 to 50 kGy (radappertization)

In 1980, the WHO concluded, after study, that irradiating food up to an average dose of 10 kGy posed no toxicological risk. This maximum dose of 10 kGy was therefore adopted for food treatment. Higher doses will only be used for sterilizing industrial equipment.

Authorization for irradiation is based on a positive list specifying the method and dose used for different types of products, fresh or stabilized (dried - frozen).

Table 1 : Optimal Dosing of Ionizing Radiation for the Treatment of Vegetables and Fruits

Process-Dose	Fresh Products	Stabilized Products (Dried - Frozen)
Anti-Germination (0.05-0.15 kGy)	Potatoes, onions, garlic	/

Disinfestation (0.5 - 3 kGy)	Citrus fruits, papaya	Dried vegetables, dried fruits, cereals
Delayed Ripening (1-3 kGy)	Strawberries, raspberries, papaya, mango	-

This preservation method offers several advantages: it limits the use of food additives, allows treatment of products in their packaging, and avoids the use of heat.

Chapter 3: Meat Products

1. Definitions of Meat Products

Meat products represent all edible parts of warm-blooded animals.

Meat

This includes all edible parts from certain terrestrial animals and birds, excluding fatty parts and products from certain animals (milk and eggs).

Butcher's Meat

This includes all striated muscles covering the skeleton after skinning and evisceration.

Offal

These are products from the tripe industry. They form a diverse group containing smooth muscles (set of tripe), organs (liver, gizzards, heart, lungs, testicles, udders, sweetbreads, kidneys, tongue, etc.), and nervous tissues (brain, spinal cord).

By-products

These represent other edible parts of the animal, such as the head, tail, feet, snout, ears, etc.

Charcuterie

This includes all processed products (curing) and preparations made from minced meat (pork, lamb, beef, veal, etc.), enriched with fats, spices, and herbs, which may or may not be cooked.

Poultry

This includes all domestic birds.

2. Structure of Skeletal Muscle

Muscles are composed of muscle fibers, which are attached to bones by tendons, and connective tissue. The latter surrounds the muscle fibers and contains blood vessels, nerves, and adipose tissue.

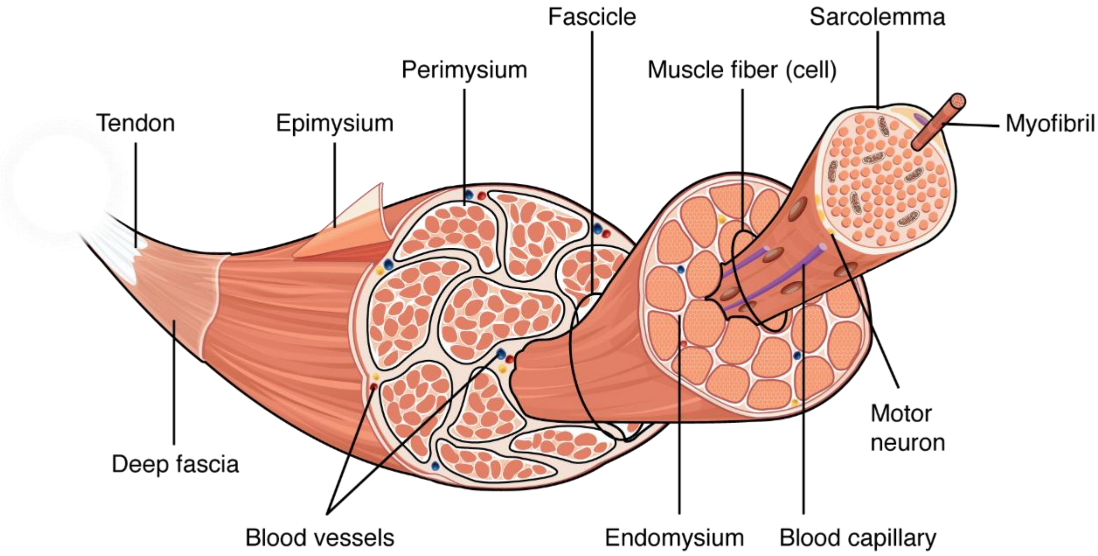

Figure 1 : Structure of Skeletal Muscle

2.1. Muscle Fibers

Muscle fibers are organized into bundles; they are large cells containing fibrils, called myofibrils, aligned in parallel and responsible for muscle contraction. They are stained by a pigment: myoglobin, which serves as an oxygen reserve for the cell in anticipation of contraction. The bundles of muscle fibers are wrapped by the perimysium. The muscle fibers are wrapped by the endomysium.

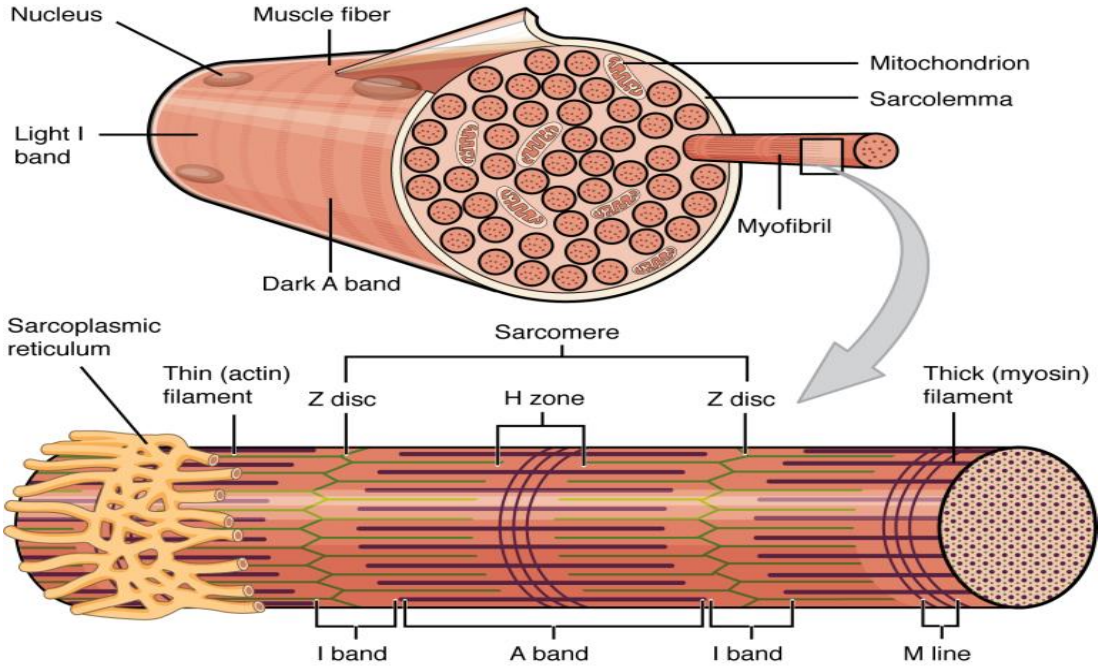

Figure 2 : Muscle Fibers

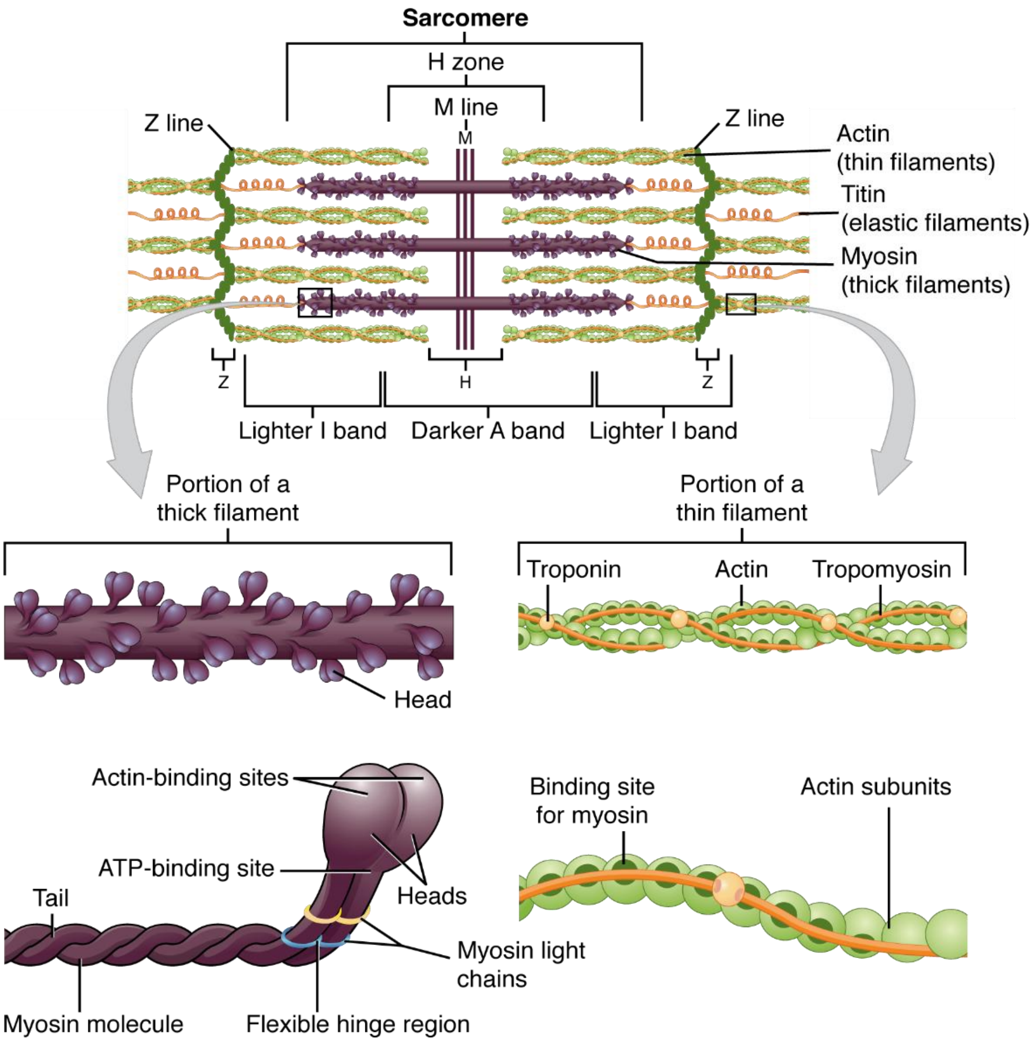

Figure 3 : The sarcomere

2.2. Connective Tissue

Connective tissue, also known as perimysium, is a structure that gathers muscle fiber bundles and plays an essential role in muscle nutrition. It is composed of four main elements:

- **Collagen**: It constitutes 80% of the connective tissue and provides resistance and structure to the tissue.
- **Elastin**: It gives the tissue its ability to contract and relax.
- **Fibroblasts**: These are cells that synthesize collagen and elastin, contributing to the formation and maintenance of connective tissue.

- **Ground substance**: Rich in mucopolysaccharides, it contains vascular and nerve branches as well as fat cells. These are distributed harmoniously and diffusely, allowing the formation of "marbling" or the tenderness of the meat.

Connective tissue is visible to the naked eye and defines the "grain" of the meat, i.e., the ratio between the amount of muscle fibers and connective tissue. Thus, the less connective tissue there is, the shorter the fibers and the better the meat.

For example, a meat with a "fine grain" will be smooth and creamy because it contains more muscle fibers than connective tissue. This type of grain is typical of animals with strong musculature, meaning the quality of their meat will be superior.

3. Classification of Different Muscle Proteins

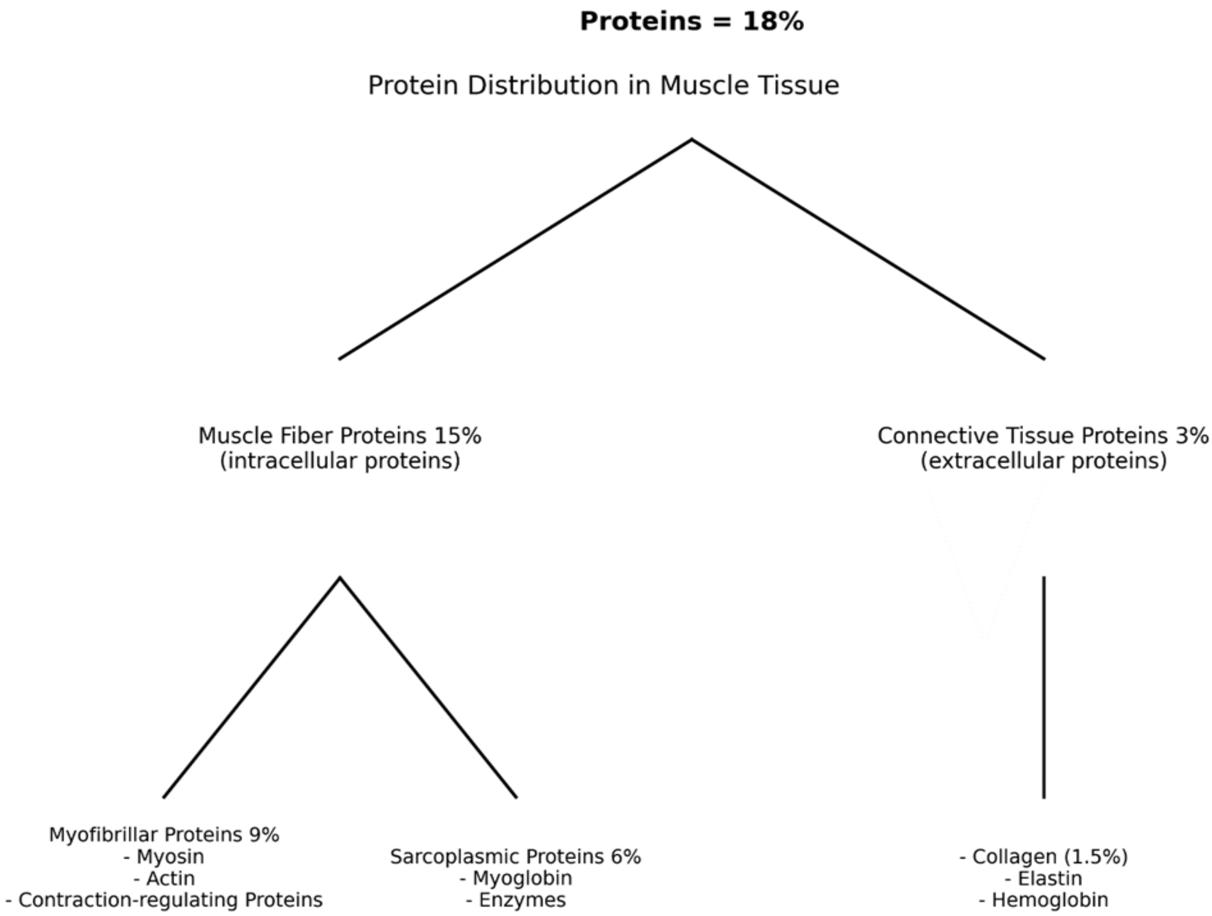

Figure 4 : Different Muscle Proteins

2.1. Collagen

Collagen is the most abundant protein in the animal kingdom, representing 30% of mammalian body proteins. It serves as a rigid element in tissues, contributing to the toughness of meat. The collagen molecule, cylindrical in shape, is formed from tropocollagen proteins. The latter consists of three strands twisted and linked by hydrogen bonds and covalent bonds, the quantity of which increases with age.

Collagen fibrils then aggregate to form collagen fibers, creating a true framework in the connective tissue. This structure gives collagen-containing tissues properties of resistance and elasticity.

Moreover, collagen is exceptionally rich in:

- Glycine: one in three amino acids is represented by glycine;
- Proline and hydroxyproline, which are two other amino acids characteristic of collagen.

TRANSFORMATION OF COLLAGEN INTO GELATIN

During the cooking of meat, collagen can transform into gelatin through hydrolysis. This gelatin is appreciated for its functional and organoleptic properties. When cold, it forms a gel, while when hot, it disperses in water.

3. Classification of Meats

A piece of meat rich in collagen will therefore be rich in gelatin after cooking. Its organoleptic properties will be sought after during cooking, although its biological value is reduced. Without this tenderizing transformation, the meat would be too tough to eat.

Consequently, the meat cuts richest in collagen require longer cooking for the connective tissue to become tender. This is why meats are classified into categories that reflect the anatomical position of the cut on the animal and its collagen content:

- **Category 1**: thighs, buttocks, back. These cuts contain little connective tissue but a significant muscle mass.
- **Category 2**: shoulders and rib regions. These cuts are richer in connective tissue and have a reduced muscle mass.
- **Category 3**: extremities of the limbs, neck, breast, abdominal muscles. These cuts are rich in connective tissue, tendons, bones, and small muscles.

The classification of meats into categories is not necessarily related to their quality, but it determines the appropriate cooking method for each cut:

- For first-category meats, the final internal temperature of the cut should be below 40°C. These meats are generally prepared as grills or roasts.
- For second and third-category meats, it is necessary to cook them at a temperature above 80°C in an aqueous environment. Second-category meats are often used for slightly longer cooking, such as sautéing or braising, while third-category meats are generally cooked for a very long time, as boiled meats or stews.

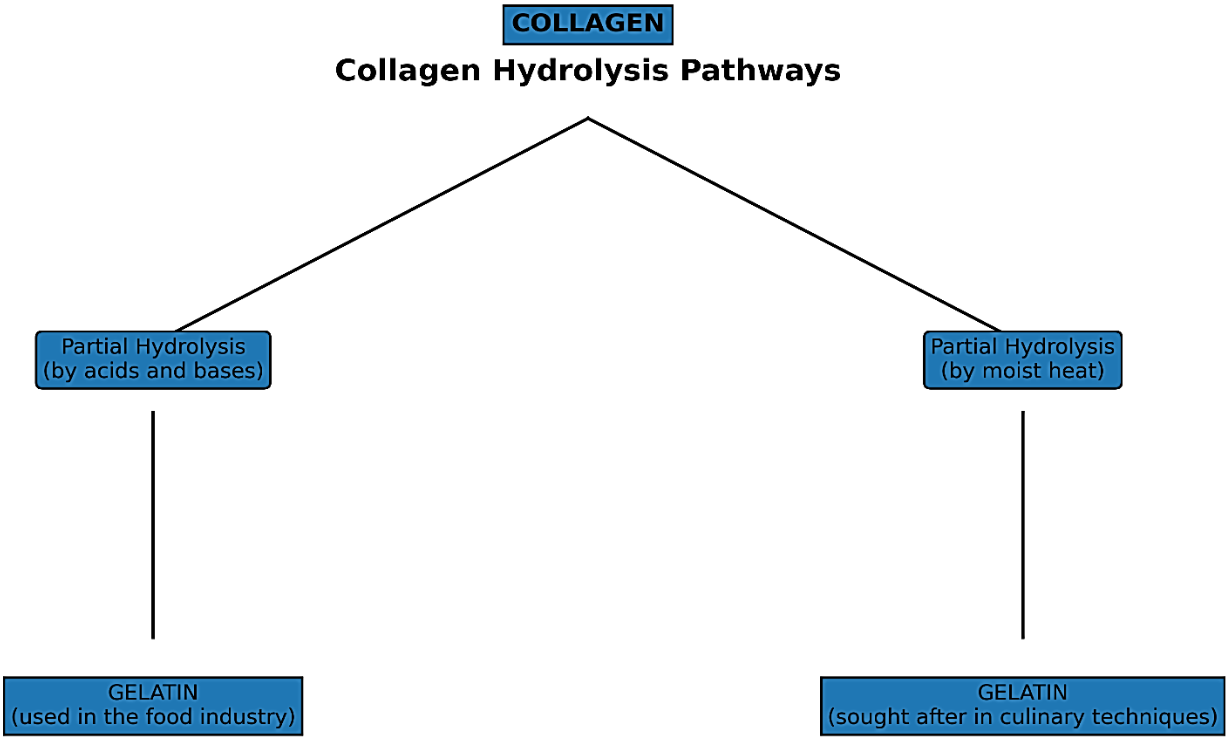

Figure5 : Collagen hydrolysis pathways

4. Transformation of Muscles into Meat

Many changes occur between slaughter and consumption, allowing the transformation of muscle into meat. This is a series of mechanisms that follow one another, affecting different chemical components of the muscle as well as its physical properties.

4.1.1. Transport of Animals

Fatigue and stress in animals have a direct impact on meat quality. The more stressed and fatigued the animals are, the more the quality of the meat deteriorates. Therefore, efforts are made to minimize these factors by reducing the duration of transport as much as possible.

4.1.2. Stabling

This is the waiting period for animals before slaughter. The conditions of this stage have been improved to partially mitigate the effects of group stress, often observed during this phase.

Additionally, animals are subjected to a hydric diet to limit the production of feces, which could be responsible for post-mortem contamination.

4.1.3. Ante-mortem Sanitary Inspection

The health status and general hygiene of the animals are checked, and they must be impeccable.

4.1.4. Slaughter

Slaughter must be carried out under the best hygienic conditions and be as non-traumatic as possible for the animals. It takes place in several stages:

- Anesthesia of the animal;
- Killing by electricity or a metal spike (death is thus instantaneous).
- **Bleeding**: Up to 50% of the blood is removed, which limits bacterial growth. After slaughter, the cessation of blood circulation and bleeding deprive the muscle tissues of oxygen, thus altering cellular metabolism.

Islamic Slaughter, or Halal:

- **Consciousness of the Animal**: The animal must be conscious, therefore not stunned.
- **Throat Slitting**: The animal must be slit widely up to the cervical vertebrae. The ritual sacrificer must pay particular attention to the equipment used for the sacrifice; their knife must be perfectly sharp and cutting.
- **Bleeding**: After throat slitting, a large portion of the animal's blood is removed.

It is important to note that these rules aim to ensure the dignity and respect of animal life, while meeting the dietary requirements of Muslims. Moreover, animal welfare is a major concern in halal slaughter.

- **Skinning**: This step involves the removal of the animal's skin.
- **Evisceration**: This is the process of removing the internal organs of the animal.
- **Splitting**: The animal is cut into two symmetrical parts.
- **Post-mortem Sanitary Inspection with Stamping**: This step consists of a sanitary inspection after the animal's death, followed by stamping to attest to its wholesomeness.
- **Carcass Weighing**: The animal's carcass is weighed.

Table 1 : Major Differences in Halal Slaughter Steps

Steps	Poultry	Cattle
Reception & Animal Welfare	Transported in crates, rested before slaughter	Transported in trucks, kept in holding pens before slaughter
Immobilization	Hung on an overhead conveyor	Immobilized in a rotating or restraining box
Stunning (if used)	Often by electrified water bath (optional in halal)	Stunning by captive bolt (not allowed in halal, but electric shock may be permitted under conditions)
Ritual Slaughter	Manual slaughter by cutting the jugular veins, carotid arteries, and trachea	Same process but requires more precision due to larger size
Bleeding	Takes seconds to minutes	Requires several minutes for complete bleeding
Plucking / Skin Removal	Feathers removed after scalding in hot water	Hide is removed after bleeding and evisceration
Evisceration	Internal organs removed by abdominal incision	Same process but more complex due to the size of the animal
Cooling	Often by water immersion or air chilling	Stored in cold rooms for meat maturation
Cutting & Packaging	Often sold whole or in pieces	Meat is matured before being cut into quarters and packaged

3. Differences in Halal Regulations & Certification

- **Poultry**: Mechanical slaughter is sometimes allowed under certain halal certifications, but human intervention for pronouncing Allah's name remains essential.
- **Cattle**: Slaughter must be strictly manual, ensuring complete bleeding, with irreversible stunning prohibited.

4. Metabolism of Muscle After Slaughter

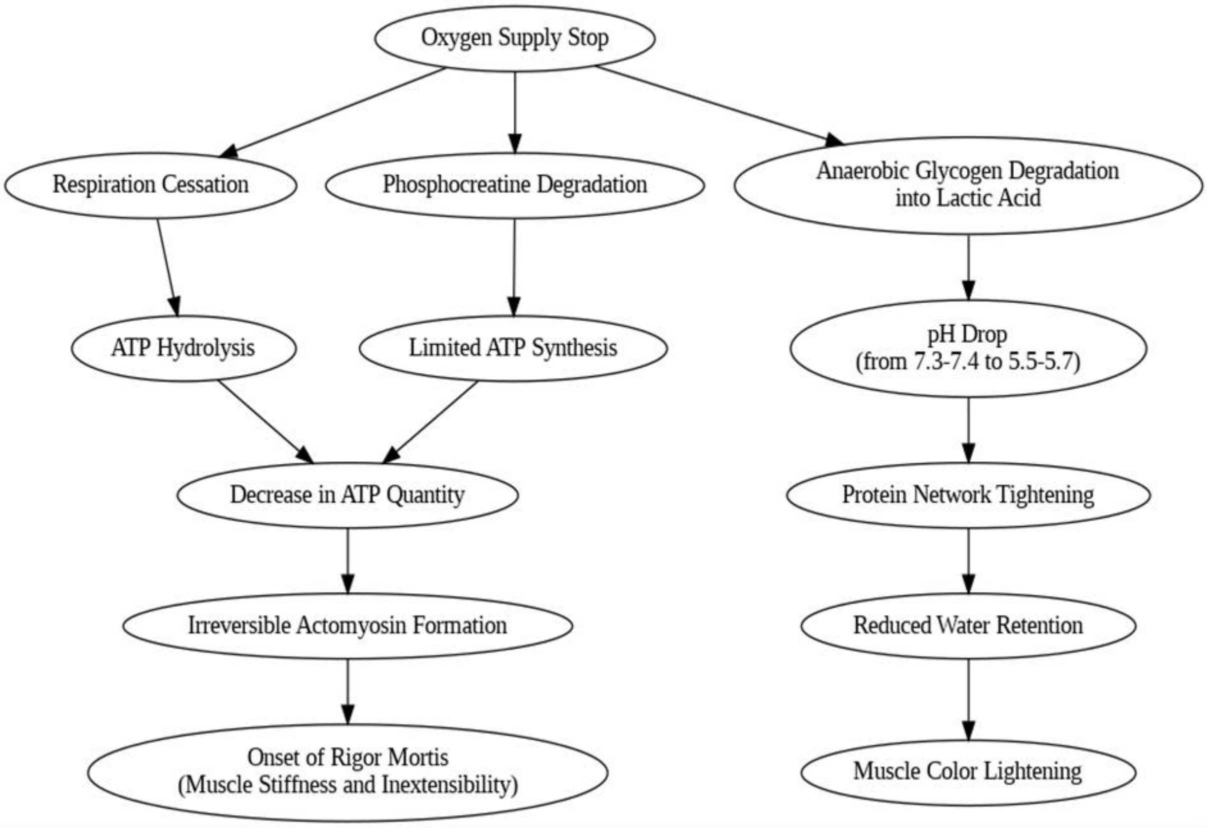

Figure 6 : Metabolism of Muscle After Slaughter

4.1. Cooling and *Rigor Mortis*

Rigor mortis, which occurs 8 to 10 hours after slaughter, is due to the formation of an irreversible actomyosin complex following the depletion of energy-rich compounds (ATP) due to lack of oxygen. Consequently, the muscle contracts, its hardness increases, and the anaerobic degradation of glycogen leads to the formation of lactic acid, which lowers the pH.

Too rapid cooling of the carcass during the rigor mortis phase promotes contraction and reduces the tenderness of the meat. However, cold limits a too rapid drop in pH, which could lead to excessive protein denaturation and the expulsion of a large amount of water, making the meat tough.

Moreover, cold slows the growth of contaminating microorganisms. Therefore, in practice, cooling is adjusted so that the muscle reaches rigor mortis at a temperature between 14 and 19°C.

4.2. Aging

Aging corresponds to the storage of meat in a cold room (15 days to 3 weeks) before commercialization. It corresponds to the resolution of rigor mortis through physical and chemical degradation phenomena in the muscle under the effect of proteolytic enzymes called cathepsins. These enzymes are released and activated in the muscle tissue by the lowering of pH. The meat then begins to tenderize progressively and thus develops its organoleptic qualities. The aging time depends on the volume of the carcass and the storage temperature. From a biochemical point of view, we observe:

- Alteration of the Z-lines of the myofibrils;
- Weakening of the bonds linking the contractile proteins of the muscle fibers. They then become more soluble, which increases the tenderness of the meat;
- Denaturation of sarcoplasmic proteins, particularly myoglobin, which becomes more oxidizable;
- Continued degradation of ATP into IMP (inosine monophosphate);
- Dephosphorylation of IMP, which then transforms into hypoxanthine, the rate of which is a good indicator of aging;
- Release of organoleptic compounds responsible for the flavor and taste of the meat.

Note: The proteins of the connective tissue undergo little modification.

5. Organoleptic Qualities of Butcher's Meat

5.1. Tenderness

Tenderness is defined by the ease with which the meat can be cut and chewed.

Intrinsic Factors Influencing Tenderness

- **Age of the Animal**: The tenderness of the meat decreases with the age of the animal.
- **Quality of the Carcass**: A poor-quality carcass will yield tougher meat.
- **Diet and Fattening State of the Animal**: The fatter the animal, the more tender its meat.
- **Meat Category**: Category 1 meat is more tender than category 2 meat, which is itself more tender than category 3 meat.
- **Position of the Cut on the Muscle**: Tenderness decreases near the tendons.
- **Cutting of the Piece**: A piece not cut along the muscle fibers will be significantly less tender.

Extrinsic Factors Influencing Tenderness

- **Appropriate Use of Cold**: Proper cooling of the meat after slaughter can influence its tenderness.
- **Cooking Adapted to the Meat Category**: The method and duration of cooking, adapted to the meat category, can also affect its tenderness.

5.2. Flavor

Flavor is the result of gustatory and olfactory impressions. The flavor of cooked meat is determined by more than 600 compounds, including non-volatile compounds that contribute to taste and volatile compounds that contribute to odor. The primary precursors of flavor are transformed into intermediate reactants or directly into flavor molecules. This transformation occurs during aging under the action of enzymes and is intensified during cooking.

Most muscle compounds contribute to the aroma:

- Amines and sugars form aromas during cooking through Maillard reactions. However, excessive cooking can produce brown polymers with a strong taste.
- Free fatty acids released by the hydrolysis of triglycerides and phospholipids undergo auto-oxidation, leading to aldehydes and ketones, which are components of flavor. However, in excess, this flavor becomes rancid.

The cooking method also plays an important role:

- Braising accentuates Maillard reactions and lipid degradation.
- Dry atmosphere cooking (grilling, frying) is even more effective.

5.3. Juiciness or Succulence

Juiciness or succulence depends on the lipid content of the meat cut and its ability to retain water. The latter is due to muscle fibers, which, thanks to myofibrils, retain three-quarters of the water in meats.

During the transformation of muscle into meat, when the pH decreases too significantly, the protein network tightens, and water is expelled. Under these conditions, PSE (pale, soft, and exudative) meats are obtained, which then become "fibrous" and therefore unfit for consumption. To avoid this phenomenon, salt is added, which reduces the tightening of proteins. Moreover, during cooking, starting at 40°C, protein denaturation occurs, leading to a decrease in water retention and a decrease in the weight of the meat.

5.4. Color of Meat

The color of meat is determined by that of the muscle, which is itself influenced by the presence of two pigments: myoglobin and blood hemoglobin, although the latter has only a weak influence.

When a piece of meat exposed to air is cut, different transformations of these pigments can be observed. The surface of the meat becomes bright red due to the appearance of oxymyoglobin, which forms upon contact with ambient oxygen. Just below this zone, the meat has a purplish-red color, characteristic of reduced myoglobin, due to the reducing action of the muscle that persists after the animal's death. A few millimeters below, a brown layer is found, the thickness of which varies and increases over time. This layer corresponds to the formation of metmyoglobin, which occurs when oxygen pressure decreases.

Thus, if the meat is left in contact with air for a few hours, it changes from a bright red color to a brown color, due to the development of the metmyoglobin layer.

The color of meat is influenced by diet, pH at slaughter, preservation treatments, and cooking. Iron deficiency makes the meat whiter. A pH between 5.2 and 5.5 gives pale and exudative (PSE) meat, while a pH between 5.5 and 6.3 gives good quality meat. A pH between 6.3 and 6.7 makes the meat dark, firm, and dry (DFD). Preservation treatments can change the color of meat, for example, long refrigeration forms metmyoglobin. Cooking denatures globin starting at 65°C, changing the color of the meat.

Some bacteria producing H2S color globin green, indicating meat spoilage.

6. Contamination of Meat

6.1. Ante-mortem Contamination

Meat can be contaminated by: parasites (tapeworm larvae in beef and pork, non-specific trichinella larvae in pork), pathogenic microorganisms (controlled by veterinary inspections), viruses (unlikely due to vaccinations), and the BSE agent. BSE, an incurable disease of cattle, is linked to an abnormal heat-resistant protein. Creutzfeldt-Jakob disease (CJD) and its variant (vCJD) are similar human diseases. The origin of BSE is unknown, but animal feed is suspected. Preventive measures include securing animal feed, removing specified risk materials (SRM) from human consumption, and monitoring and screening for BSE. No data suggest a risk of BSE transmission through meat consumption.

6.2. Post-mortem Contamination

Carcasses can be deeply contaminated by techniques such as scalding, or superficially by various germs (*Pseudomonas, Acinetobacter, Lactobacilli, Micrococci, Staphylococci, Clostridium, Salmonella, Shigella, Campylobacter, Yersinia,* and yeasts and molds).

- Rapid refrigeration and proper slaughter conditions are necessary to avoid these alterations. The whole muscle is less susceptible to contamination than trimmed or minced meat, which can cause foodborne infections due to various pathogens:
    - *Clostridium perfringens*;
    - *Clostridium botulinum* (which develops mainly in preserved products);
    - *Staphylococcus aureus*;
    - *Salmonella*;
    - Toxic amines produced by the germs themselves.

7. Preservation of Meats

7.1. Fresh Packaged and Refrigerated Meats

Packaging is an effective way to extend the shelf life of meat by protecting it from external contaminants. It is generally used for retail sale.

7.1.1. Film Packaging

- Packaging under film in an atmosphere close to normal under a plastic film impermeable to water vapor, permeable to atmospheric gases (O_2, CO_2). The bright red color of the meat surface is maintained by the formation of oxymyoglobin. Microbial growth is slowed by refrigeration, thus limiting preservation to a few days.
- Packaging under a completely impermeable film with the initial constitution of an internal atmosphere rich in CO_2 by gas injection: modified atmosphere packaging. CO_2 inhibits strict aerobic flora, especially if the packaging is applied shortly after slaughter.

7.1.2. Vacuum Packaging

Vacuum packaging is done under a film completely impermeable to gases and water vapor.

- **Objectives of Vacuum Packaging**: Vacuum packaging has two main objectives: to ensure more effective protection through the use of more resistant plastic films that shrink onto the product, and to extend the preservation of meats by several weeks.
- **Effects of Vacuum Packaging on the Microbial Flora of Meat**: The O_2 pressure is very low as it is consumed by the muscle tissue and bacteria. It is then gradually replaced by CO_2. This selects a particular bacterial flora (lactobacilli) that inhibits the proliferation of other populations, especially those that make up the putrefactive flora. Moreover, the absence of O2 reduces myoglobin, and the meat then takes on a dark red color. Upon opening the package, myoglobin oxidizes again, and the meat regains its bright red color.

7.2. Frozen and Deep-frozen Meats

The meat must be healthy because these processes do not destroy microorganisms but only prevent their proliferation. Moreover, freezing or deep-freezing should not occur too early during the transformation of muscle into meat.

The quality of frozen or deep-frozen meat changes little during storage. It is therefore a good preservation method. However, during thawing, the organoleptic qualities of the meat are altered: water exudation occurs, the color is modified (the meat takes on a dark red color), and the tenderness of the piece increases.

7.3. Canned Meats

Canning is a preservation method by heat that, through sterilization, destroys pathogenic germs. Heat transforms collagen into gelatin, causes swelling of elastin, generates the formation of actomyosin which hardens the meat, leads to the release of disulfide products, and is responsible for browning of myoglobin, which then transforms into ferrihemochrome.

8.Charcuterie Products

Charcuterie products include various preparations based on meat, mainly pork, minced and mixed with fats, herbs, and spices, which may or may not be cooked. Although these products have a bad reputation due to their high fat, additive, and salt content, it should be noted that farming practices have evolved, leading to a reduction in fats in some charcuterie. Moreover, "light" or "reduced-fat" alternatives have emerged, offering products containing up to half less fat, with the use of poultry meat or soy proteins as raw materials. However, the importance of charcuterie, which is an integral part of the gastronomic heritage, should not be overlooked.

8.1.Cachir

The industrial production of cachir (or halal sausage), which is very popular in several Maghreb countries, including Algeria, follows a precise and controlled process to guarantee quality, safety, and compliance with food standards.

8Ingredients Used in the Industrial Production of Cachir:

1. **Beef or Lamb Meat**:
   - Beef or lamb meat is used, often in boneless pieces, which are finely minced.
   - **Weight**: approximately 60-80% of the total recipe.
2. **Beef or Lamb Fat**:
   - Fat is essential to give cachir its soft texture and rich flavor.
   - **Weight**: approximately 20-30% of the recipe.

3. **Wheat Semolina or Flour**:
    - Used as a binder to maintain the shape and texture of the sausage.
    - **Weight**: approximately 5-10% of the recipe.
4. **Spices and Seasonings**:
    - **Paprika**: for color and a mild taste.
    - **Cumin**: for a traditional flavor.
    - **Garlic (powdered or fresh)**: for a strong aroma.
    - **Black Pepper**: to enhance the flavor.
    - **Coriander**: sometimes added for a fresh touch.
    - **Turmeric**: for a golden color and slight bitterness.
    - **Salt**: for seasoning and preservation.
5. **Water or Crushed Ice**:
    - Added to mix the ingredients and reduce the temperature during the manufacturing process.
6. **Food Coloring**:
    - Red coloring (often based on paprika or natural dyes) is used to give cachir its distinctive color.
7. **Casings**:
    - The casings used for stuffing are either natural (cleaned intestines) or artificial (collagen or cellulose).
8. **Additives and Preservatives (optional)**:
    - **Nitrates or nitrites** may be added to extend shelf life and maintain the red color. These additives must be used within the limits permitted by food regulations.

Industrial Manufacturing Process of Cachir:

1. **Reception of Raw Materials**:
    - **Reception of Meat and Fat**: The pieces of meat and fat are received and checked to ensure their quality, freshness, and compliance with sanitary standards.
    - **Storage Temperature**: The meat is stored at a temperature of 0 to 4°C to avoid bacterial proliferation.
2. **Mincing and Preparation of the Filling**:
    - The meat and fat are finely minced in industrial grinders to obtain a homogeneous texture.

- **Temperature**: During mincing, the temperature must be controlled and remain below 4-6°C to avoid bacterial growth and protein denaturation.

3. **Mixing of Ingredients**:
    - Spices, semolina or flour, salt, and ice are added to the minced meat. Ice water or crushed ice is incorporated to cool the paste and obtain a smooth and homogeneous texture.
    - **Temperature**: The mixture must be maintained at a temperature below 5°C to ensure the safety and quality of the product.
4. **Stuffing (Filling of Casings)**:
    - The filling is introduced into casings (natural or artificial) using automatic stuffing machines. This process must be done carefully to avoid air bubbles.
    - The casings are filled to obtain the desired size and shape for each unit of cachir.
    - **Temperature**: During stuffing, the temperature of the paste must be maintained below 5°C to avoid bacterial proliferation.
5. **Cooking (or Pasteurization)**:
    - Cachir is then steamed or cooked in hot water to make it safe for consumption and give it a firm texture. Cooking is done in industrial cookers.
    - **Cooking Temperature**: The cooking temperature generally varies between 75 and 85°C, for a period of 1 to 2 hours. This step allows the meat to be pasteurized, killing pathogenic microorganisms while preserving its texture.
6. **Rapid Cooling**:
    - After cooking, cachir is quickly cooled to stop cooking and avoid bacterial proliferation.
    - **Cooling Temperature**: Cachir must be cooled to a temperature of 3-4°C in less than 2 hours.
7. **Packaging**:
    - Cachir is then packaged as individual sausages, either vacuum-packed or in modified atmosphere (using gases such as nitrogen or carbon dioxide).
    - **Storage Temperature**: The finished product is stored at a temperature of 0-4°C to ensure freshness and food safety.
8. **Quality Controls**:
    - Quality controls are carried out throughout the process to check the texture, color, taste, and microbiological safety of cachir.

- Products are also tested for their salt, fat content, and to detect any contamination.

Processing of Slaughter By-Products and Valorization of the 5th Quarter

The slaughter industry generates a large quantity of by-products which, if not valorized, can pose an environmental problem. However, these by-products, grouped under the term **5th quarter**, can be transformed into useful resources for various industries, including agri-food, pharmaceuticals, cosmetics, and energy. This course presents the main methods of processing and valorizing slaughter by-products.

1. Definition and Composition of the 5th Quarter

The **5th quarter** includes all parts of the animal that do not directly correspond to commonly consumed meat cuts. It consists of:

- **Red offal**: liver, heart, kidneys, spleen, lungs.
- **White offal**: head, feet, tripe, stomach.
- **Fats**: used in the production of food or industrial products.
- **Bones and cartilage**: used for the production of gelatin and animal meal.
- **Blood**: rich in proteins, used in animal feed and the pharmaceutical industry.
- **Skin**: processed into leather for the textile and leather goods industries.
- **Feathers and hair**: transformed into meal for animal feed.

If properly managed, these by-products can be turned into useful and profitable resources, reducing waste and environmental impact.

2. Valorization Channels of By-Products

2.1. Food Valorization

- **Processing of offal** into consumer products (pâtés, sausages, prepared dishes, canned goods, halal charcuterie).
- **Gelatin production** from bones and skin (used in the food industry, especially in candy, yogurt, and dietary products).
- **Use of fats** in the production of cooking oils and margarine.
- **Production of food additives** from certain 5th quarter components, such as phosphates extracted from bones.

2.2. Industrial Valorization

- **Transformation of skins** into leather for the production of shoes, bags, clothing, and furniture.
- **Production of animal meal** from bones, feathers, and fats, used as nutritional supplements in livestock and aquaculture.
- **Production of biofuels and biogas** through anaerobic digestion of organic waste, enabling renewable energy production and sustainable waste management.
- **Use of bone ash** in the glass and ceramics industries.
- **Manufacturing of adhesives and glues** from animal proteins.

2.3. Pharmaceutical and Cosmetic Valorization

- **Extraction of collagen and elastin** from skin and bones for cosmetics, reconstructive surgery, and dietary supplements.
- **Use of blood** for the production of proteins, pigments for the pharmaceutical industry, and derivatives such as hemoglobin.
- **Production of amino acids and enzymes** from by-products for medical and industrial applications.
- **Extraction of calcium and minerals** from bones for dietary supplements.
- **Manufacture of dermatological products** with derivatives from animal fats.

3. Economic and Environmental Impact

3.1. Economic Interest

- Reduction of financial losses by utilizing all by-products, optimizing the profitability of slaughterhouses.
- Creation of new economic opportunities in the agri-industry, chemical, energy, and pharmaceutical sectors.
- Development of an international market for slaughter by-products (gelatin, animal meal, refined fats, etc.).
- Reduction of waste disposal costs, turning an expense into a source of income.
- Encouragement of innovation in processing and extraction methods.

3.2. Environmental Issues

- Reduction of waste and environmental nuisances associated with by-product disposal (odors, soil and water pollution).
- Decrease in greenhouse gas emissions through recycling, sustainable transformation, and renewable energy production via anaerobic digestion.

- Contribution to a circular economy by maximizing the use of resources from slaughtering.
- Conservation of natural resources by substituting some raw materials with recycled by-products.
- Implementation of regulations and certifications to oversee by-product processing and ensure their safe use.

The processing and valorization of slaughter by-products offer sustainable and profitable solutions for optimizing the use of animal resources. The implementation of advanced technologies and appropriate regulations would further improve the efficiency of these sectors while reducing their environmental impact. It is therefore essential to promote initiatives for recycling and transforming by-products within a circular economy perspective.

The future of the 5th quarter relies on technological innovations, increased awareness among industry players and consumers, and a legislative framework supporting these approaches. Collaboration between the agri-food, pharmaceutical, cosmetic, and energy sectors is crucial to developing sustainable and economically viable solutions.

Fishery Products

1. Definition - Classification

These are animal products that humans obtain from the aquatic environment. They include:

- Fish;
- Mollusks;
- Crustaceans.

2. Fish

2.1. Classification by Habitat

Fish can be categorized based on their natural habitat:

- **Freshwater Fish**: bleak, barbel, pike, carp, whitefish, roach, gudgeon, hotu, loach, burbot, char, perch, trout perch, catfish, zander, tench, trout...
- **Saltwater Fish**: shad, anchovy, sea bass, brill, cod (salted and dried cod is called "salt cod" or "morue"), plaice, horse mackerel, hake, conger, bream, haddock (smoked haddock), smelt, swordfish, flounder, halibut, gurnard, herring, pollock, dab, monkfish, sea wolf, mackerel, whiting, grouper, mullet, moray eel, skate, scorpionfish, dogfish,

John Dory, sardine, sole, pouting, tuna (bluefin, albacore, skipjack, yellowfin), turbot, weever...

- **Mixed-Water Fish** (depending on their reproductive cycle): eel, sturgeon, salmon.

2.2. Classification by Skeletal Structure

Fish are also classified based on the nature of their skeleton:

- **Cartilaginous Fish**: These species, the first to appear on Earth, have a cartilaginous skeleton. Examples: sharks, rays, dogfish...
- **Bony Fish**: More evolved, these fish have an ossified skeleton. Examples: anchovy, hake, salmon...

2.3. Classification by Shape

Fish can be grouped into three categories based on their morphology:

- **Round Fish**: pouting, cod, whiting, mullet, hake, horse mackerel, pollock, bass, ling, sea wolf, haddock, monkfish...
- **Long Fish**: eel, conger, sand eel, dogfish, shark...
- **Flat Fish**: plaice, flounder, halibut, dab, sole, turbot, skate...

2.4. Classification by Lipid Content

Fish are also categorized based on their fat content:

- **Lean Fish (< 3% fat content)**: monkfish, whiting, pike, cod, haddock, perch, pollock, skate, burbot...
- **Semi-Fatty Fish (3-10% fat content)**: anchovy, red mullet, bass, dogfish, carp, sardine, swordfish, tuna, mullet, trout...
- **Fatty Fish (> 10% fat content)**: eel, mackerel, herring, salmon...

3. Structure of Fish

3.1. The Edible Part

The edible portion of a fish varies depending on the species and size.

- **Loss During Preparation**: Heading and evisceration result in a loss of 20 to 30% of the total weight, or even up to 55% for large-headed fish.
- **Weight of the Skin**: It represents about 2% of the total weight.
- **Final Yield**: The edible portion generally represents between 50 and 65% of the initial weight, which explains the high cost of fresh fish, especially fillets, due to the waste generated.

Note: In addition to the flesh, it is also possible to consume the eggs and milt (sperm) of the fish.

3.2. The Flesh or Muscle of Fish

Fish flesh, unlike meat, has specific characteristics:

- **Short Muscle Fibers**: Organized into lamellae called myotomes, they make the flesh more tender.
- **Low Connective Tissue Content**: This explains why fish require quick cooking to remain tender.

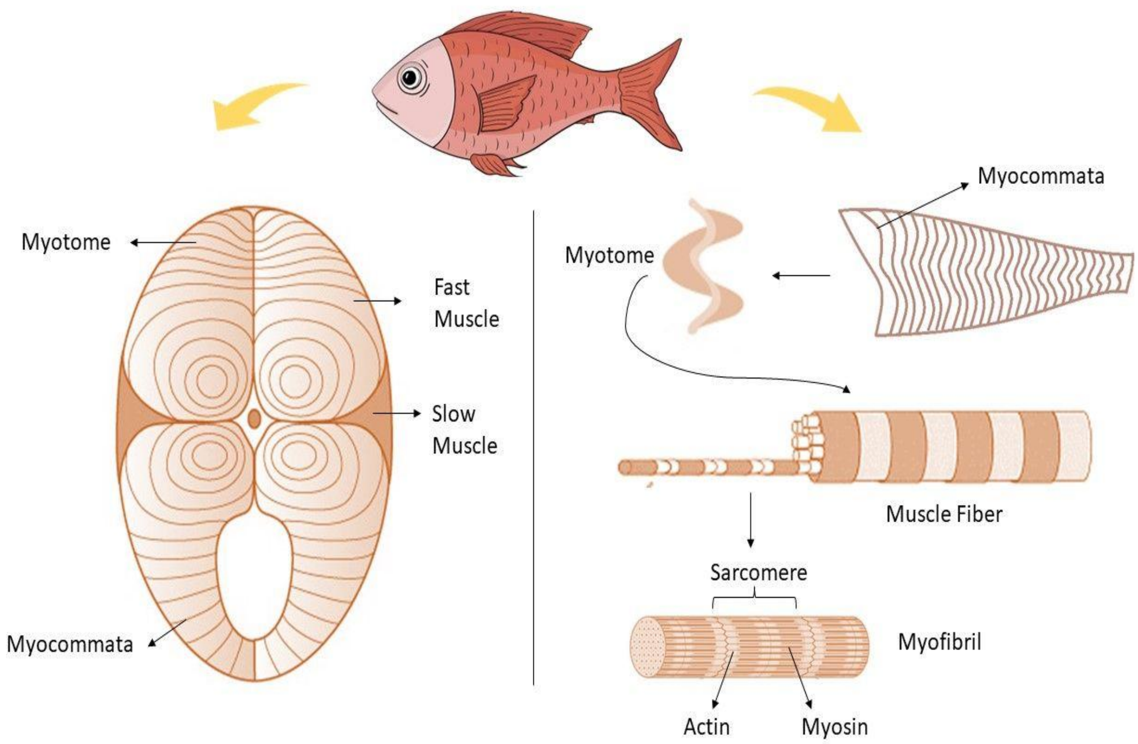

Figure 7 : Muscle of Fish

Two Types of Muscles Are Distinguished:

a) **White Muscles**:

- Present in species living on the continental shelf.
- Little myoglobin and lipids.
- Energy provided by anaerobic glycolysis, as these fish swim little and find their food nearby.

b) **Red or Dark Muscles**:

- Dominant in pelagic species (living in the open sea).
- Rich in blood vessels, lipids, glycogen, and myoglobin.
- Aerobic metabolism, allowing prolonged swimming to search for food.

3.3. Connective Tissue

The connective tissue of fish has the following specificities:

- **Composition**: Mainly collagen fibers with little elastin.
- **Gelatinization Temperature**: It begins to transform at 40°C, a temperature much lower than that of meats (80°C), making the muscle tissue more fragile to heat and technological treatments.

4. Development of Fish Muscle After Fishing

After capture, fish muscles undergo several biological and biochemical stages influenced by fishing, handling, and storage conditions. These stages are crucial for the quality and preservation of the fish.

4.1. Immediate Post-mortem Phase

Initial State:

- The fish is still alive or just caught. The muscles are flexible and relaxed.
- The muscle's energy reserves (glycogen) are still available.

Post-mortem pH Drop:

- The pH decreases rapidly after capture to reach a value of 6.5 to 6.7, due to the small amount of glycogen quickly depleted during the stress of capture.
- This pH remains too high to effectively inhibit microbial proliferation.

Metabolic Process:

- The available oxygen decreases rapidly.
- The muscles switch from aerobic (with oxygen) to anaerobic (without oxygen) metabolism, leading to an accumulation of lactic acid.

4.2. Rigor Mortis

- **Onset**: A few hours after death (depending on temperature and species).
- **Main Characteristic**: The muscles become rigid due to the depletion of energy reserves (ATP) needed to relax the muscle fibers.
- **Duration**:
  - Rigor can last several hours to several days depending on the species and storage conditions (faster at room temperature).

- For example, at 0°C, it can last 1 to 2 days for some species.

- **Impact**:
  - During this phase, the muscle is firm but difficult to handle.
  - Once rigor mortis is resolved, the texture becomes softer, but the fish may be more vulnerable to microbial degradation.

4.3. Resolution of Rigor Mortis

- **Enzymatic Degradation**:
  - Endogenous enzymes (proteases) begin to degrade the muscle fibers.
  - This leads to a gradual softening of the muscles.
- **Factors Influencing Resolution**:
  - Temperature: The higher the temperature, the faster the resolution.
  - Species: Some species resolve rigor more quickly than others due to their muscle composition.
- **Consequence**:
  - Improvement in texture, but the flesh becomes more fragile and more sensitive to degradation.

4.4. Advanced Degradation

- **Trigger**: If the fish is not properly preserved, endogenous enzymes and microorganisms begin to alter the proteins and lipids of the muscle.
- **Visible Signs**:
  - Excessive softening of the muscles.
  - Appearance of unpleasant odors (ammonia, trimethylamine).
  - Discoloration of the flesh.
- **Prevention**:
  - Rapid preservation (refrigeration, freezing) is essential to slow these processes and preserve the quality of the muscle.

5. Quality Control for Fish Safety

5.1. Assessing Chemical Spoilage

As fish deteriorates, it releases a distinct, unpleasant odor caused by the breakdown of proteins or the transformation of nitrogen-based compounds. This odor results from the release of ammonia and volatile amines, such as trimethylamine. To gauge freshness, the level of volatile basic nitrogen (VBN) is measured in each fish. If the VBN exceeds 40 mg of nitrogen per 100 g, the fish is deemed unfit for sale.

Additionally, histamine levels are checked and must remain below a specified limit.

5.2. Evaluating Organoleptic Spoilage

The external appearance of fish changes quickly during storage, reflecting the extent of muscle degradation. Standardized marketing criteria have been established for fresh or refrigerated fish. Freshness is assessed using a rating system, and the average score determines the following freshness categories:

- Extra fresh: > 2.7;
- Freshness A: > 2 and < 2.7;
- Freshness B: > 1 and < 2.

Factors such as the type of product, fishing location, and presentation (whole, gutted, etc.) are also considered.

Practical Tips: When buying fresh, whole fish, pay close attention to the following features:

- Gills should be moist and bright red;
- Eyes should be clear, shiny, and level with the head;
- Skin should be glossy, pearly, tight, and firmly attached to the flesh;
- Flesh should be firm and springy, free of stains or finger marks, and should not easily separate from the bones;
- Scales should be intact, shiny, and firmly attached;
- The belly should not appear swollen or dull;
- The smell should be mild and pleasant (a strong fishy odor indicates poor freshness).

5.3. Detecting Bacterial Contamination

The fish's skin is coated with mucus made up of glycoproteins, which contain free amino acids and trimethylamine oxide.

While the muscle of the fish is sterile, the mucus, skin, gills, and intestinal contents are rich in microorganisms.

After capture, bacteria from the mucus and digestive tract can spread and multiply in the fish's flesh. This process is accelerated by the softening of the flesh caused by natural enzymes (proteases) and a relatively high pH level.

6. Different Fish Preservation Technologies

6.1. Traditional Methods

6.1.1. Salting

Salting is an ancient technique used to extend the preservation of certain fish. It involves increasing their salt content, which limits the development of microorganisms. Common examples include:

- **Cod**, which is salted to about 30%, giving salted cod.
- **Anchovies**, used to produce nuoc-mâm, a fish autolysate obtained by natural enzymatic digestion.
- **Fish eggs**, which are preserved in brine to avoid lipid oxidation.

6.1.2. Smoking

This method, often combined with salting, is used for species such as salmon, trout, herring, and haddock.

- **Objective**: To reduce the water content of the fish, which increases the concentration of nutrients, especially proteins and salt.
- **Result**: A different texture and better preservation due to partial dehydration.

6.1.3. Marinating

Marinating involves immersing the fish in an acidic mixture, such as acetic acid, vinegar, or white wine.

- **Effects**:
  - Destruction of parasites.
  - Denaturation of proteins and tenderization of tissues.
  - Reduction of pH below 4.5, which inhibits pathogenic germs, including *Clostridium botulinum.*
- **Improvement**: Additional heat treatment strengthens the destruction of bacteria (except lactic acid bacteria) and their toxins.
- **Use**: These products are often semi-preserves.

6.2. Canning

Canning involves packaging fish in airtight containers before subjecting it to thermal sterilization. This method is commonly used to produce various canned products:

- **Natural Canned Fish**: fish packed without additives.
- **Oil-Packed Canned Fish**: often used for fish such as sardines or tuna.
- **Tomato or Sauce-Packed Canned Fish**: adding flavors and extending shelf life. Canning factories are generally located near ports to ensure the freshness of the fish before processing.

Note: In some industries, fish are pre-cooked in ovens or steam before being sliced.

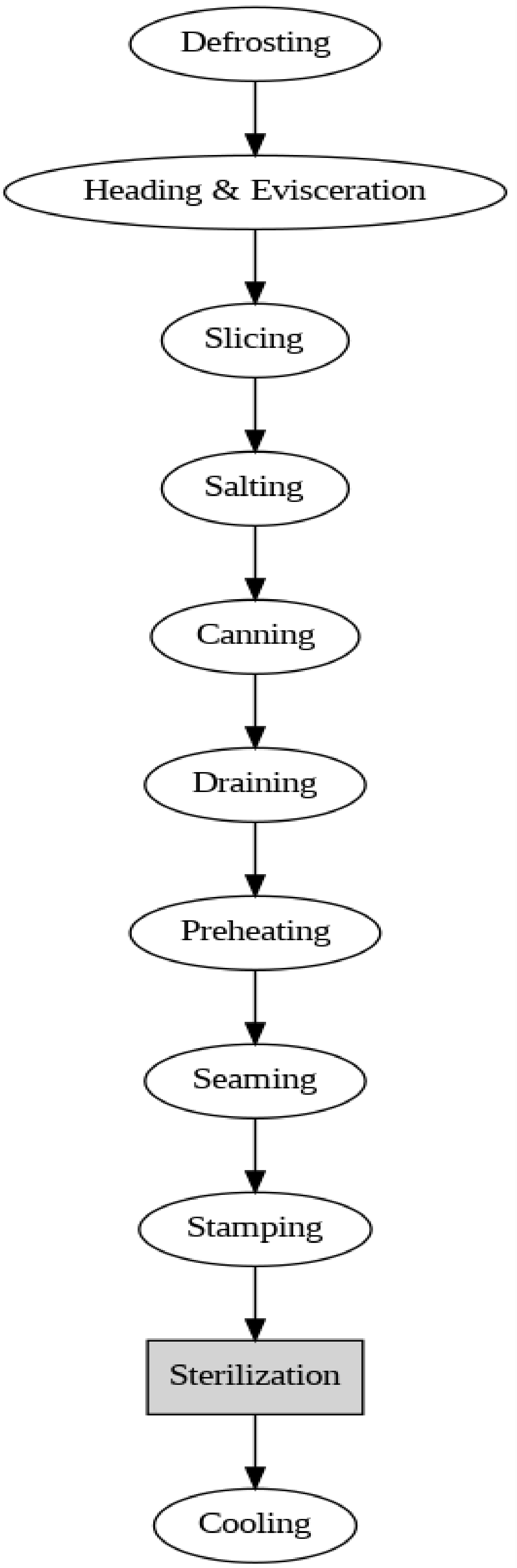

Figure 8 : Fish Processing and Canning Process

6.3. Freezing or Deep-freezing

6.3.1. Varieties of Frozen or Deep-frozen Products

Frozen or deep-frozen fish are available in different forms:

- Whole or headed fish.
- Fish fillets.
- Breaded fillets and breaded squares (the breading can represent up to 28% of the product).
- Fish steaks.
- Fish-based preparations: fritters, croquettes, brandades, gratins, ready meals, etc. **Note**: Fish were among the first foods offered as frozen ready meals and also initiated the development of frozen low-calorie meals.

6.3.2. Manufacturing Steps for Breaded Fillets or Squares

The main steps followed for manufacturing are:

1. Preparation of the fish: washing, sorting, evisceration, and heading.
2. Filleting.
3. Trimming of fillets.
4. Freezing or deep-freezing.
5. Cutting into squares (for square-shaped products).
6. Breading of fillets or squares.

6.3.3. Impact of Freezing or Deep-freezing

6.3.3.1. On Semi-fatty and Fatty Fish

- **Risk of Rancidity**: The quantity and quality of lipids present make these fish more susceptible to rancidity during storage. This limits their shelf life to 1 or 2 months.
- **Lipid Oxidation**: The oxidation products of lipids can react with certain amino acids (e.g., lysine, tryptophan, sulfur amino acids), making them unavailable and thus reducing the nutritional value.
- **Prevention of Rancidity**:
  - Store fish at very low temperatures.
  - Protect them from exposure to oxygen.
  - Avoid the presence of salt, which accelerates auto-oxidation.

6.3.3.2. On Lean Fish

- **Impact on Proteins**: The structure of muscle proteins is particularly sensitive to cold.

- **Better Preservation**: Lean fish rancidify more slowly, so their freezing can be extended (2 to 3 months) without significant loss of quality.

7. Mollusks

Mollusks are invertebrate animals with soft bodies. They are divided into two main categories:

- **Cephalopods** (without shells): squid, cuttlefish, octopus, small octopus...
- **Shellfish** (with shells):
  - **Gastropods** (single shell): abalone, limpet, periwinkle, whelk...
  - **Bivalves** (two-valved shells): mussel, cockle, clam, scallop, oyster, pecten, venus clam, razor shell, ark shell...

8. Crustaceans

Crustaceans are aquatic invertebrates with a hard exoskeleton that molts to allow growth. Most crustaceans live in the sea, although some, like crayfish or grey shrimp, also inhabit freshwater. Common crustaceans include crab, edible crab, pink shrimp, lobster, spiny lobster, Norway lobster, spider crab, velvet crab, prawn...

1.4. Other Aquatic Animals

- **Echinoderms**: sea urchin (also called sea chestnut or sea hedgehog).
- **Protochordates**: sea squirt (or "fig of the sea"), resembling a large brown potato with bright yellow flesh.

Note

The term **"seafood"** refers to a dish composed of mollusks, crustaceans, and echinoderms.

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