People's Democratic Republic of Algeria

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University Mohammed KHIDER, Biskra

Faculty of science and technology

Department of industrial chemistry

Matter : **Agro-food processes**

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This course isintended for 3rd year GP students

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Chapter I : Transformation and conservation processes

Chapter II : General information on separation processes

Chapter III : Reaction Engineering

Chapter IV : Structuring operation

Chapter V : Mechanical and manufacturing operations

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Introduction

Food is an essential part of our lives. The food industry is the basic and important to every nation. It is one of the critical sectors of countrys economy. It plays a crucial role in public health, food safety, food security, social development, and nutrition. Product quality, health, and sanitation issues are major concerns in the food industry [1, 2].

Food industry plays an important role in providing food for human consumption. It satisfies community needs with respect to availability, distribution and quality of food. It is one of the world's most dynamic economic sectors as it changes rapidly. Most problems in the food industry can be solved with technology.

Before starting this course intended for 3rd Process Engineering students in the LMD system; you need to know:

1. Food industry technologies.
2. Components of food industry.
3. Agriculture.
4. Food Processing.
5. Food Distribution.
6. Regulation.
7. Financial Services.
8. Marketing.
9. The main objectives of food processing include.

1. Food industry technologies

Modern food industry uses a wide variety of sophisticated technologies. Agricultural machinery (such as tractor) has practically eliminated human labor in many areas of production. Robots have the potential to transform food processing, food handling, food packaging, and food serving. They have incredibly increased the productivity as compared to the manual production. Block chain can be used to seew here delays and waste occur in the supply chain for food products. Micro wave heating or infra-red energy from a hot surface is widely used in food preparation. Evaporators are used in a number of food processing industries. Metabolic engineering has been used for the production of carotenoids by different yeast cells. Ultra sound is another technique which offers the potential of non-invasive, hygie nicme asurement for the food industry. Nanotechnology has been used in food processing, food packaging, and food preservation. It has the potential to revolutionize agriculture and food systems [3] [2].

The food industry needs to deal with new legislation and increased regulation on environmental issues. The excessive use of fertilizers, pesticides, and food additives may adversely affect the environment and human health. Compliance with regulatory standards is an issue for manyfood manufacturers. As public shifts toward a greener planet, the food industry shoul dimplement green policies. Bringing to market new products in a time lymanner is difficult for many food companies. The process of creating new, relevant products, and moving them through R&D, testing, and marketing to retail takes time. Consumers tastes are fickle and targe ting them is increasingly more crucial. A big challenge facing the food is transparency. Consumers are reading the back of packages now more ever. They want to know what ingredients are going into their products. Their interest for transparency continues to hold food companies accountable. They are becoming more educated on the benefits of healthier choices. Enterprises in the food industry are operating in a highly competitive, global environment and they must constantly engage in product development. They are in a state of change driven by cost of operations. This change is heading for automation solutions that canenable the industry to become more lean and agile [3, 4].

2. Components of food industry

The food industry in it sentirety is not one industry but a collection of several types of industry producing a diverse range of food products. It covers farming, food production, food processing, preservation, packaging, distribution, retail, and catering. The food industry comprises comprise of the following components.

3. Agriculture

This is the process of producing food, feed, fiber, and other desired products. It includes scropfarming, live stock raising, and fish farming. It also entails manu facturing of farmequipment, fertilizers, farmmachinery and hybridseeds to facilitate agricultural production.

4. Food Processing

The majority of agricultural products is seasonal and perishable. Food process in gis used to transform rawing redients into market able food products. It makes some food available all year round. Packaging protects food from the surrounding, extends food shelf life, and increases the quality of food.

5. Food Distribution

This includes transporting, storing, and marketing food products to consumers. The food industry needs a transportation network to connect its numerous parts. A whole saler would pur chase local produce and distribute it to a range of customers and clients.

6. Regulation

There are regulations on food production and distribution to ensure quality and safety. These are restrictions imposed by government authority. There are some regulatory requirements that a food business must meet in order to operate. FDA is responsible for enforcing food laws and regulations.

7. Financial Services

These include insurance and credit to facilitate food production and distribution. Insurance policies cover costly business disruptions commonly seen in the industry. Food accounting professionals work closely with all aspects of food industry to evaluate ideas and opportunities.

Research & Development Research on any aspect of food industry produces relevant information about that sector. The food serving sector has the largest potential of research and development. Research reflections may be on factors influencing consumer behavior, customers' buying choices, formation of attitude, and opinions. Companies need to have adeepunder standing of how consumers behave.

8. Marketing

Marketing is the primary vehicle for promoting information about food. Food marketing describes any form of advert is ingused to promote the purchase and/orconsumption of a food or beverage.

9. The main objectives of food processing include

- Extending the shelf life of food products.
- Preventing contamination of food.
- Facilitating food storage and transportation.
- Converting raw food materials into appealing, sellable products.
- Creating job opportunities for a large number of people.

Chapter I

Transformation and conservation processes

The history of food is closely linked to the evolution of preservation processes. Already, prehistoric man had to work hard to find ways to preserve his food. Today in industrialized countries, food preservation is above all a question of health.

I. Transformation and conservation processes

Table I.1. Conservation techniques.

1 :Brining	2 :Canning	3 :Refrigeration	4 :Pasteurization	5 : Salting	6 : Fermentation
7 :Lyophilization	8 :Sugaring	9 :Freezing	10 :Drying	11 :Smoking	

I.1. Optimization of thermal processes

The treatment of food by heat is today the most important technique of long-term preservation aims, to destroy or completely inhibit very effective microorganisms, enzymes and their toxins. There are several techniques for preserving food by heat treatment, such as pasteurization, canning, cooking and aseptic processes.

I.1.1.Pasteurization

This term comes from Louis Pasteur (1822-1895) and refers to a process of preserving food by heating to temperatures below 100°C followed by sudden cooling (4°C) to destroy certain pathogenic microorganisms which are not eliminated and which it is necessary to slow down the development of germs still present. Pasteurized foods are usually kept cold.

This technique concerns, for example, milk and dairy products, fruit juices, vinegar, honey *(Table 1.2).*

Table I.2. Pasteurization scales [1].

Commodity	Temperature and time required
Milk	30 minutes at 60°C or 15 seconds at 72°C
Creams/Dessert creams	30 minutes at 71°C or 16 to 20 seconds at 82°C
Carbonated drinks based on fruit juice	30 minutes at 66°C
Apple juice	30 minutes at 77°C

I.1.2. Canning

It is a method, invented by Nicolas Appert in 1790, he enclosed vegetables in bottles waterproof which he immersed for a time in boiling water. He observed that his vegetables did not change orin appearance or taste, and could be kept for a long time. This revolutionary process evolved from boxes in tinplate to autoclave pots. This preservation technique is called "appertization" in other words heat sterilization coupled with airtight packaging. The parameters of thetreatment are superior to those of pasteurization and they vary depending on the product between ten minutes to115°C and thirty minutes at 121°C *(Table 1. 3).*

Two operations are important in canning :

1-packaging in airtight containers.

2-heating at high temperatures (110 to 120°C) to destroy micro-organisms and avoid any subsequent bacteriological contamination.

Table 1.3. Appertization scales.

Food	Duration (minutes)	Temperature (°C)
Natural green beans	2 to 4	121
Stewedpeas	10 to 15	121
Sardines in oil	2 to 4	121
Cornedbeef	6 to 4	121
Mushrooms	6 to 10	121

Canning is a heat treatment which aims to destroy all living microbial forms. This preservation process consists of heat sterilizing perishable foods in airtight containers (metal boxes, jars). Preserved foodstuffs of animal or plant origin, perishable, whose conservation is ensured in a container impervious to water, gases and microorganisms, at any temperature below 55°C, are considered preserved.

Figure I.6. Home canning.

I.1.3. Cooking

Cooking is the action of subjecting food to heat with a view to consumption (Table 1.4) Its main objective is therefore the development of the organoleptic characteristics of the product : Improved taste, odor, color and texture. According to the scales applied, the products cooked can be kept in the refrigerator for a few days, and in the freezer for a few weeks.

Various types of cooking are possible :

· Cooking by contact with a solid or solidifying product (meat, eggs, etc.)

· Cooking a liquid or pasty product.

· Cooking by contact with a liquid: boiling and frying.

· Cooking by contact with a gas: in the oven and with steam.

· Cooking by infrared radiation: grills and roasts

Table 1.4.Industry recommended standard cooking temperatures.

Minced meat	
Minced beef/veal	71°C
Minced chicken/minced turkey	80°C
Beef	
Rare	60°C
Average	71°C
Well cooked	77°C
Roasts or rolled beef steaks	71°C
Minute steak	71°C
Poultry	
Whole stuffed chicken, whole stuffed turkey	82°C
Whole chicken – without stuffing	82°C
Whole turkey – without stuffing	77°C
Pieces of chicken or turkey	77°C
Prank call	
Cooked separately	74°C
Eggs and egg dishes	
Egg dishes and sauces, custard	71°C
Leftovers – reheated	74°C

I.1.4. Aseptic processes

Consists of heating the product to a fairly high temperature, between 135°C and 150°C, for a period of time very short, between 1 to 5 seconds. The sterilized product is then cooled and then packaged aseptically.

This process is used for the sterilization of liquid products (milk, fruit juice, etc.) or thicker consistency (dairy desserts, cream, tomato juice, soups, etc.)

I.2. Optimization of refrigeration processes

Refrigeration is a technique of preserving food at low temperatures that stops or slows cellular activity, enzymatic reactions and the development of microorganisms. It extends thus the lifespan of fresh, plant and animal products by limiting their deterioration.

There are three processes that use this technique, refrigeration, freezing and freezing.

I.2.1. Refrigeration

It consists of lowering the temperature of a food to values slightly higher than its freezing point which is between 0°C and 4°C. It allows storage for four to ten days.

Figure I.1. Refrigeration processes.

I.2.2. Freezing

It is a technique of brutal cooling (-35°C -196°C) then freezing at -15°C-18°C. Thanks to this process, the water contained in the cells crystallizes finely, thus limiting cell destruction. You can freeze vegetables, fruits, certain cheeses, butters, eggs, fruit juices, meats, fish products, ready meals, pastries and other desserts. The conversation which may exceed two years. Frozen food packaging must be water vapor and gas tight. (risk of oxidation or odors).

I.2.3. Refrigerated transport

It consists of transporting the products resulting from refrigeration treatment under conditions similar to that of treatment so as not to break the cold chain.

I.3. Dehydration and combined processes

Dehydration is a physical technique for preserving food. It consists of eliminating, partially or totally, the water contained in the food to prevent the development of micro-organisms and block enzymatic activity.
Since ancient times, grains, fruits, meats and fish have been dried in the sun. Later drying was carried out in ovens. Today, foodstuffs are dehydrated by different techniques: hot air dryers, infrared ramp, heating cylinders, fluidization (passage of hot gases through a plate grid).
Depending on the intensity of dehydration, we distinguish:

I.3.1. Drying

Which consists of removing excess humidity by evaporation of water. We end up with food products called dry.

Figure I.2. Drying food preservation.

I.3.2. Smoking

Smoking is one of the oldest preservation methods used since the Paleolithic. It is in addition to salting which consists of subjecting food stuff to the action of compounds gases released during combustion. Smoking meat or fish. It is used for: -Flavoring and coloring.
-Preservation, conservation by antimicrobial effect and modification of the texture of the product.

Figure I.3. Smoking food preservation.

I.3.3. Dehydration-impregnation by immersion (DII)

The dehydration-impregnation by immersion (DII) or osmotic dehydration (OD) is a method able to increase the life time of the food stuffs for the purpose of new and appreciated sensory properties to them. It brings an appreciation to the product, facilitates marketing (conditioning) and thus allows of it, the marketing of products of diversification, which for could change the routine in the mode of consumption of the fruits. Moreover, it is a technique of conservation using lessenergy and which proceeds under transferable technological conditions in country medium, because of the simplicity of their implementation [1] .
In deed, Certain countries of Africa in the south of the Sahara, like Senegal and Cameroun developed techniques of conservation by the osmotic dehydration (OD) of the food stuffs with strong water content during these last years.

The increase in wall and membrane permeability could allow saltpenetration to increase and thereby lead to structural changes. It isalso possible that atincreased osmotic pressure, the viscosity of the salt solution islower and the external resistance to mass transferat the garlic tissue surface is lower, thus facilitating water transfer higher temperatures favor water flow from the fruit to the soaking medium. At 45°C, sliced garlicappears to undergo changes in physical properties such as color.

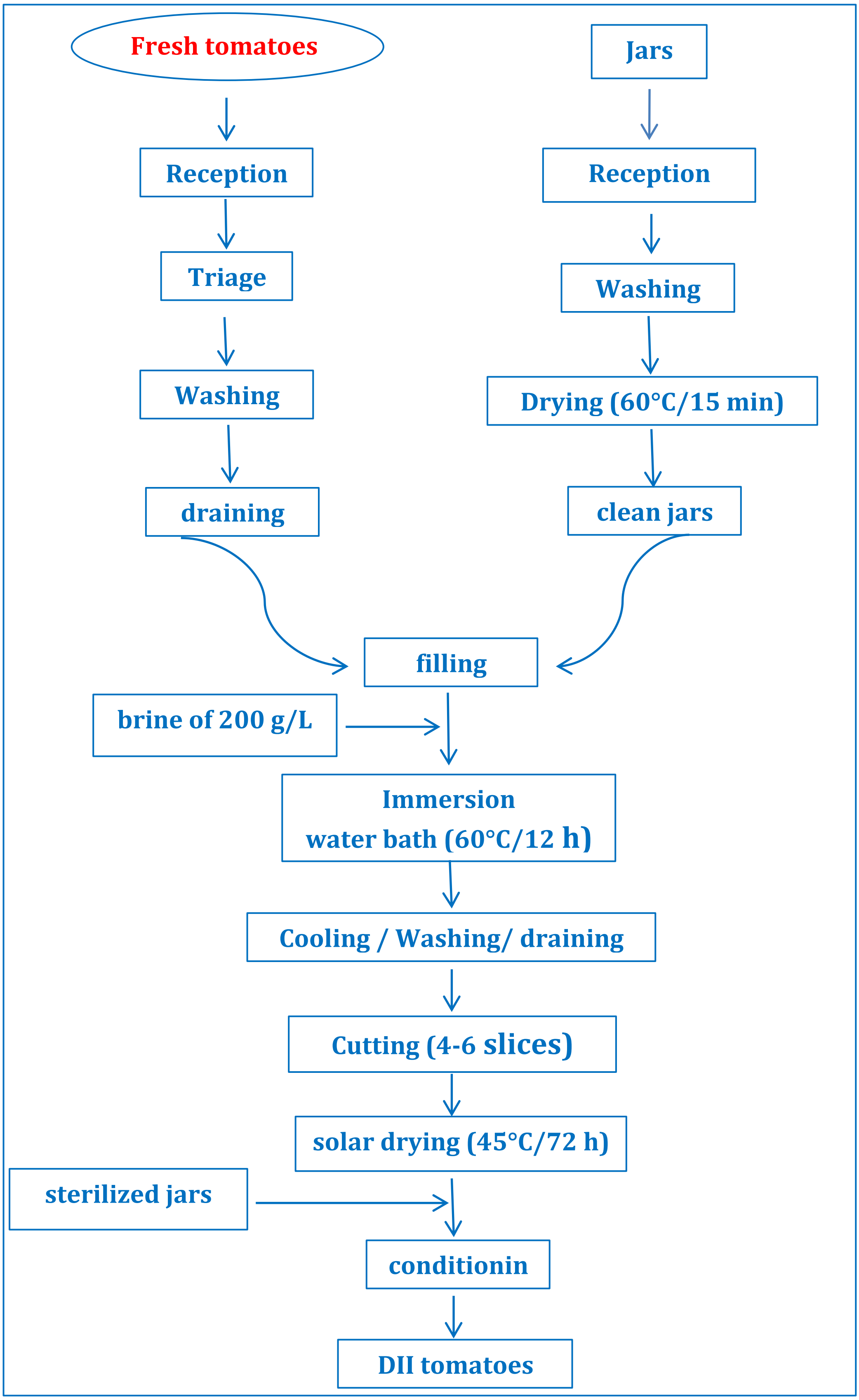


Figure I.4. Production diagram of tomatoes treated by DII.

I.4. A more precise study of these techniques

For centuries, man has sought all means to preserve food stuffs in order to ensure his survival in times of scarcity (end of winter, lower productivity, etc.).

Salting has made it possible to preserve meat and fish when accompanied by drying or smoking. The Romans preserved olives, radishes and other vegetables in brine. The virtues of preserving cold have also been known for a long time: for example, the Romans wrapped fish from the Rhine in snow and ice to transport them to Rome.

Around 1790, Nicolas Appert invented a process for preserving food, using heat and in hermetically sealed containers: appertization. It was, moreover, within the frame work of a competition organized by Napoleon I aimed at rewarding the best process of preserving tinkée food for the armies that the process was really developed after multiple trials.

Currently, new decontamination techniques using soft technology are being developed. They combine a rapid reduction of the microbial flora and the preservation of the organoleptic and nutritional qualities as well as the functionality of foods.

I.4.1. Food preservation techniques

The preservation of foods aims to preserve their edibility and their taste and nutritional properties. In particular, it involves preventing the growth of microorganisms and delaying the oxidation of fats which causes rancidity. Common methods of food preservation are mainly based on a transfer of energy or mass which aim to extend the life of food products (pasteurization and sterilization, drying, osmotic dehydration, refrigeration and freezing) or to transform through chemical reactions or change of state (cooking, fermentation, obtaining a crystallized state, etc.).

I.4.2. Heat preservation techniques

Pasteurization aims to destroy pathogenic and spoilage microorganisms. This heat treatment must be followed by sudden cooling since all the microorganisms are not eliminated and it is necessary to slow down the development of the germs still present. Pasteurized foods are usually kept cold (+4°C). Apart from refrigeration, other means of preservation can be used in parallel to counter the development of surviving microorganisms: addition of chemical preservatives, vacuum packaging, reduction of water activity, etc. This technique concerns, for example, milk and dairy products, fruit juices, vinegar, honey, etc.

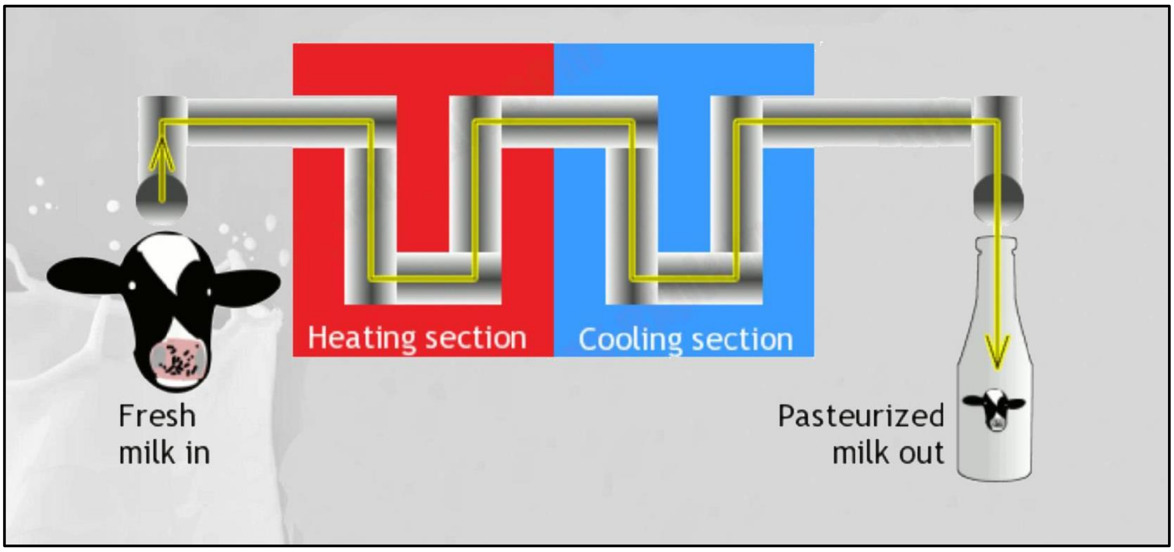


Figure I.5. Milk processing and pasteurization.

Ultra high temperature (UHT) treatment consists of heating the product to a fairly high temperature, between 135°C and 150°C, for a very short time, between 1 to 5 seconds. This process uses either indirect heating in tubular or plate exchangers or direct heating by contact between the product and pressurized water vapor. The sterilized product is then cooled and then packaged aseptically. This process is used for the sterilization of liquid products (milk, fruit juice, etc.) or of thicker consistency (dairy desserts, cream, tomato juice, soups, etc.).

Blanching is a heat treatment which involves immersing food in water heated to close to its boiling point or exposing it to steam for a few minutes. The products thus treated are generally fruits or vegetables before canning to reduce the surface microbial flora and facilitate canning or before freezing to inactivate the enzymes of the food, preserve the natural color and facilitate the bagging the product.

Chapter II

General information on separation processes

II.1. Phase separation

In chemistry, a separation process is a technique or technology which allows for the transformation of a mixture of substances in two or three phases, such as liquid/liquid, solid/solid, or gas/gas, that maybe miscible or immiscible.

II.1.1. Pressing

Pressing is a process by which we extract liquid from a solid by exerting pressure on it. For instance, we use pressing to extract juice from oranges or to extract aromas from crushed flowers. Mechanical forces, hydraulic or pneumatic systems are commonly used to carry out pressing [5].

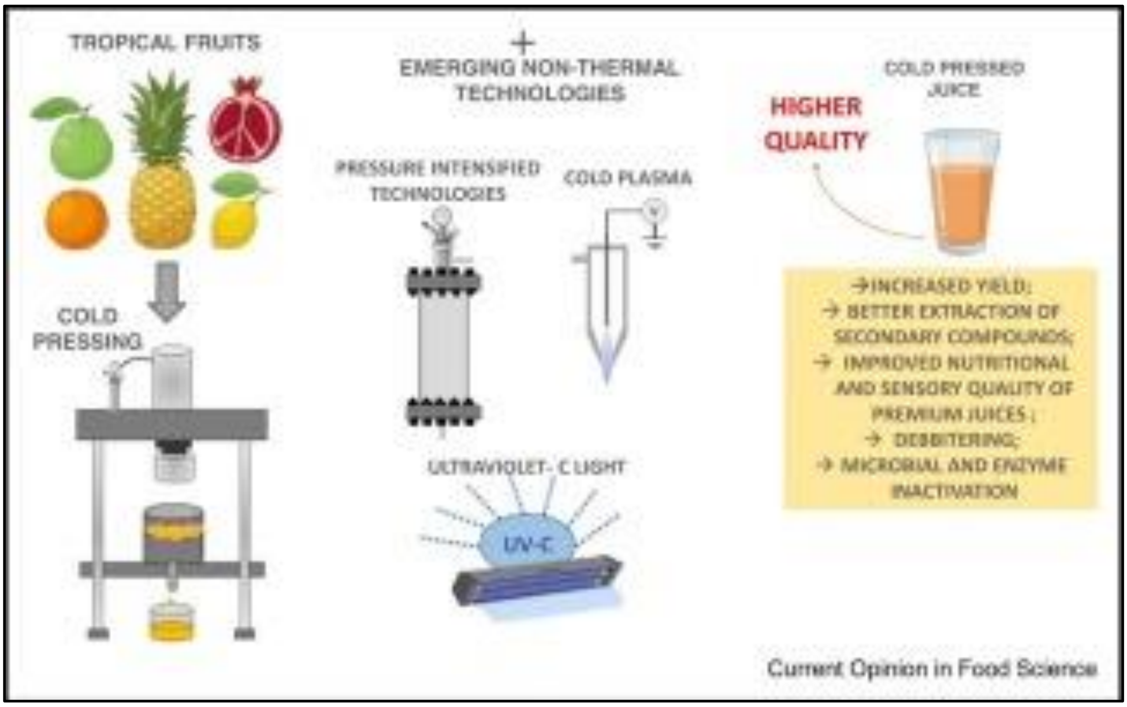


Figure II.1. Presing process.

In the food industry, pressing is used for the extraction of fruit juice, sugar, oil, etc. Pressing is still used for the dehydration of products intended for food consumption.

Consumption of fresh juices is increasing all over the world. According to Food and Agriculture Organization (FAO), in 2020 [5], world production of tropical fruits wasapproximately 25 million tons, about 5.2 million tons more when compared with the previous ten years of production [6]. Figure.II.2. represent the world production of certain products, obtained by pressing.

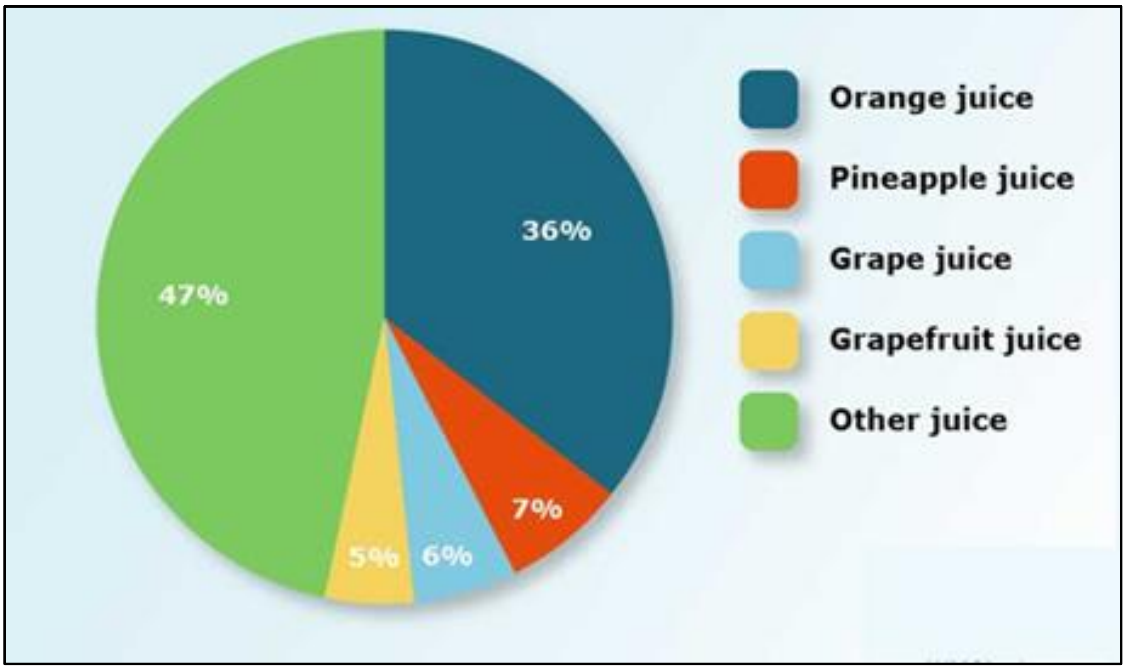


Figure II. 2. Global juice industry: Share of industry value by product type in 2019 in % [6].

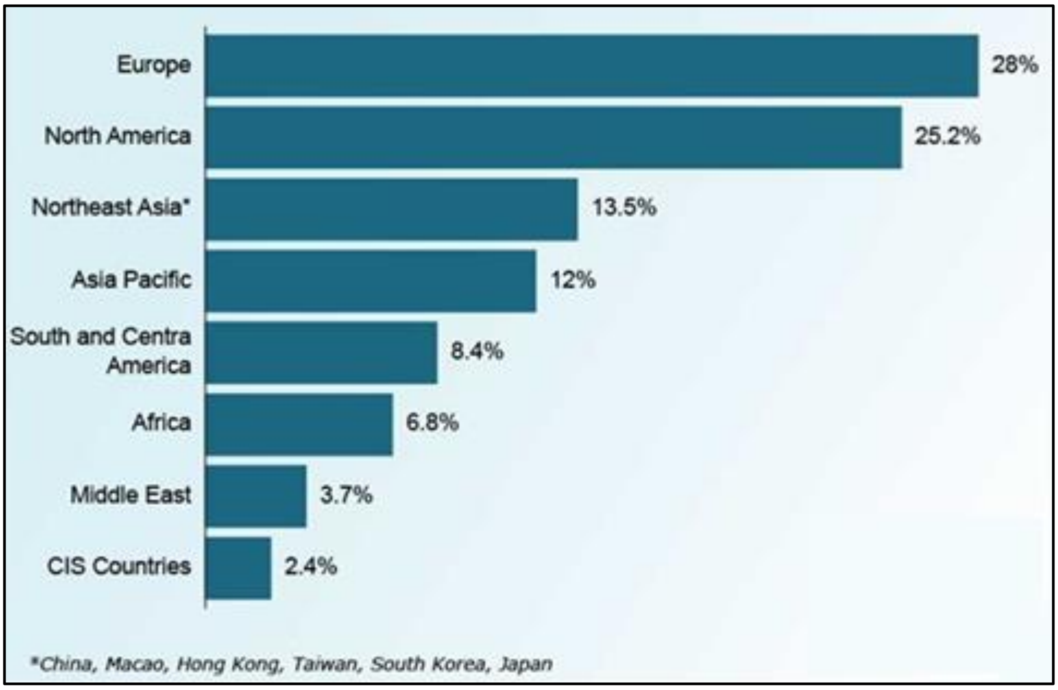
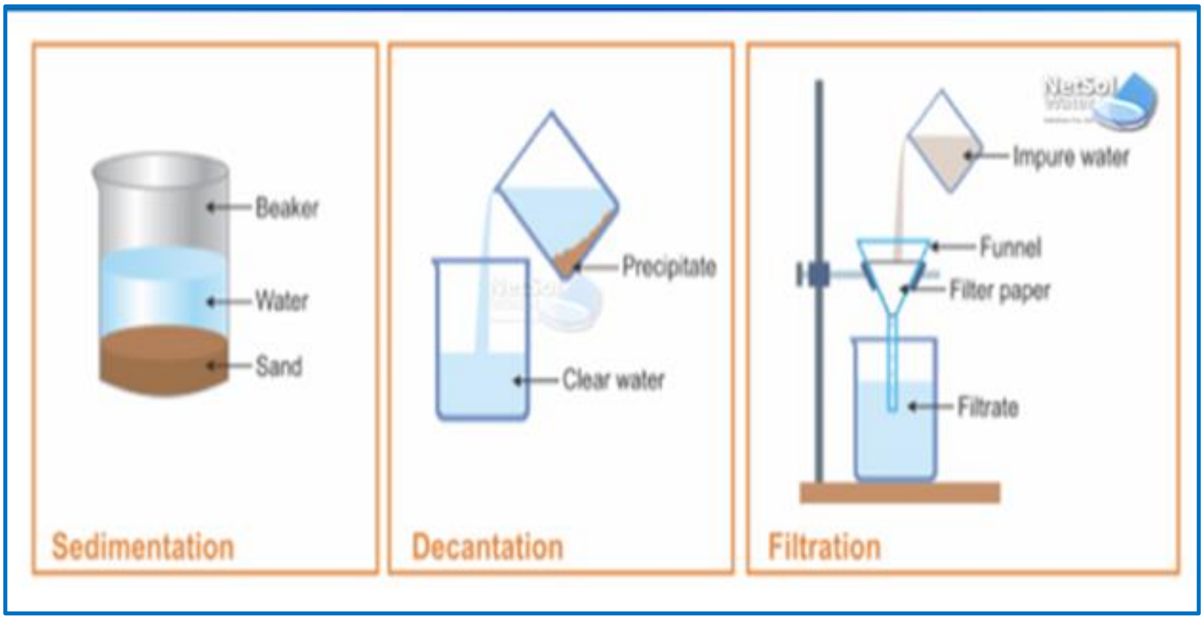


Figure II. 3. Global juice industry: Share of industry value by region in 2019 in % [6].

II.1.2. Decantation

II.1.2.1. Decantation (sedimentation)

It in volves allowing a mixture of different substances to settle naturally until separation occurs (Figure II.4.). This process occurs in the environment, such as when water is mixed with sand or soil [7-9].



Firgure II. 4. Sedimentation, decantation and filtration process.

After stirring, the soil particles disperse in the water. As a result of this, wecan observe the following phenomena

• A layer of soil gradually form sat the bottom of the container. This layer is made up of particles of earth that fallunder the effect of their weight.

• The liquid gradually clears as it contains fewer and fewer particles. The less dense particles are slower to settle to the bottom of the container.

• After a sufficiently long time, the liquid becomes clear again because all the particles have fallen to the bottom of the container.

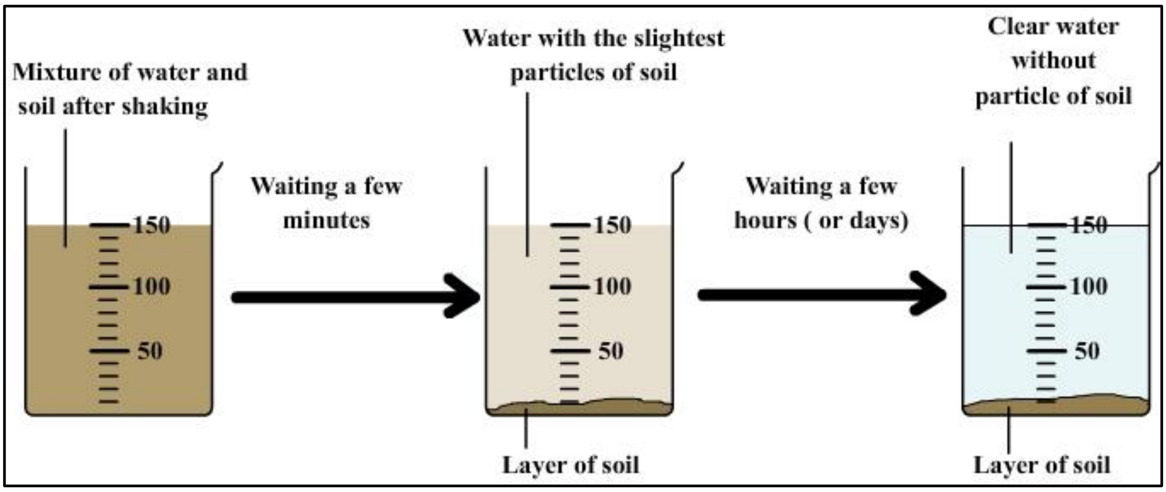


Figure II. 5. Settling of a mixture of water and earth (solid-liquid).

II.1.2.2. The separating funnel (liquid-liquid)

Liquid-liquid extraction is a fundamental experiment in organic chemistry labs that in volves several to picssuch as chemical structure, density, solubility, and acid-base chemistry. This technique is often carried out using a separatory funnel where two liquids are allowed to settle. The liquid with the highest density sinks to the bottom of the funnel, while the liquid with the lowest density rises to the top. Once the two phases are clear lyseparated, we can isolate the components of the mixture. This separation technique can beused, for instance, to separate a mixture of water and oil. As demonstrated in the diagram below, oil floats on water because it has a lowe rdensity than water [10].

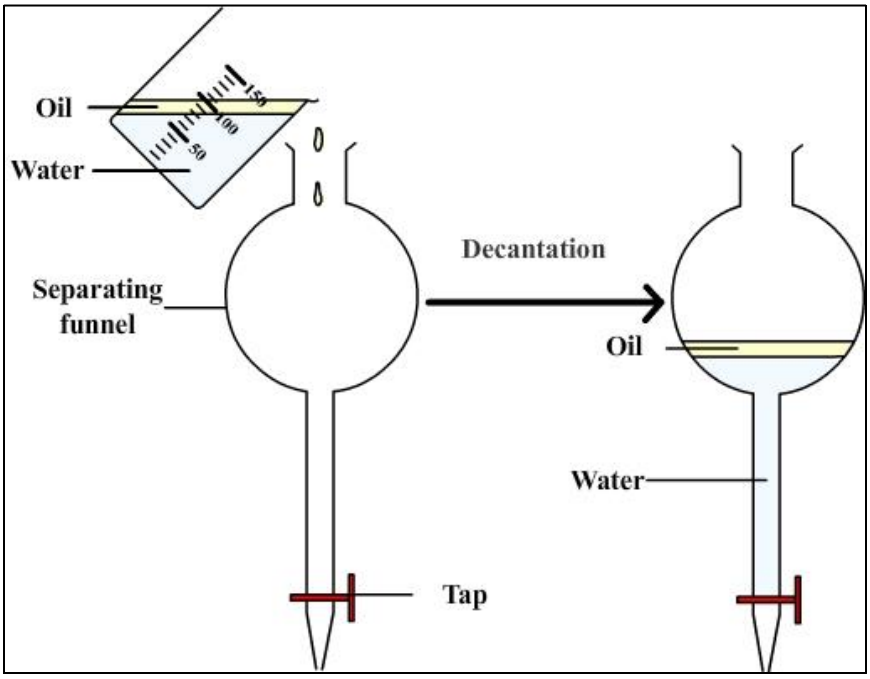


Figure II. 6. Separation of oil and water using a separatory funnel.

II.1.3. Filtration

Filtration is a process in which solid particles in liquids or gases are separated using a filter. The filter only allows the liquid to pass through but blocks the solid particles. This process is carried out using a filter medium such as filter paper. The pores of the filter medium are larger than the solvent particle but smalle rthan the solute particle. Therefore, only solvent particles can pass through, and the solute particle is left on the other side, making the solution free from insoluble solutes. The principle of filtration is based on the difference in particle sizes.

II.1.3.1. Principle of filtration

Filtration is a separation according to the diameter of solid particles of different sizes, which are dispersed in a liquid. The pressure difference forces the liquid to pass through the filter while solid particles remain on the surface.
Two phenomena often accompany filtration:

- The first phenomenon is clogging: The penetration of particles into the gaps (small empty spaces between the parts of the filter) of the filter material causes the phenomenon of clogging. This modifies the porosity and slows down filtration.
- The second phenomenon is adsorption: It results from the electric charge which has the filter material. This induces the retention of certain products by the filter despite their dimensions allow their passage through the pores of the filter.

II.1.3.2. Filtration Process

Filtration is a process that separates particles based on their differences. There are two types of mixtures:

- heterogeneous
- homogeneous.

A heterogeneous mixture is one where the solute particles are unevenly distributed in the solvent phase. For example, sand in water is a heterogeneous mixture. A homogeneous mixture is one where the solute particles are evenly distributed in the solvent phase. A brine solution is an example of a homogeneous mixture, also known as a solution.

To filtera mixture, we use a filtration membrane that only allows particles of a certain size to pass through, leaving the solution at one end free from insoluble solute particles. For instance, if wewant to filters and from water, wecan use a muslincloth or filtration paper as a filtration membrane. We place the membrane at the mouth of the container containing the sand and water solution, and then allow the solution to pass throughit. The membrane only allows water to pass through, thus separating the sand from the sand and water solution.

Figure II.7, show the particles too large to fit through the filter lattice are trapped, allowing smaller particles and fluid to pass through as filtrate.

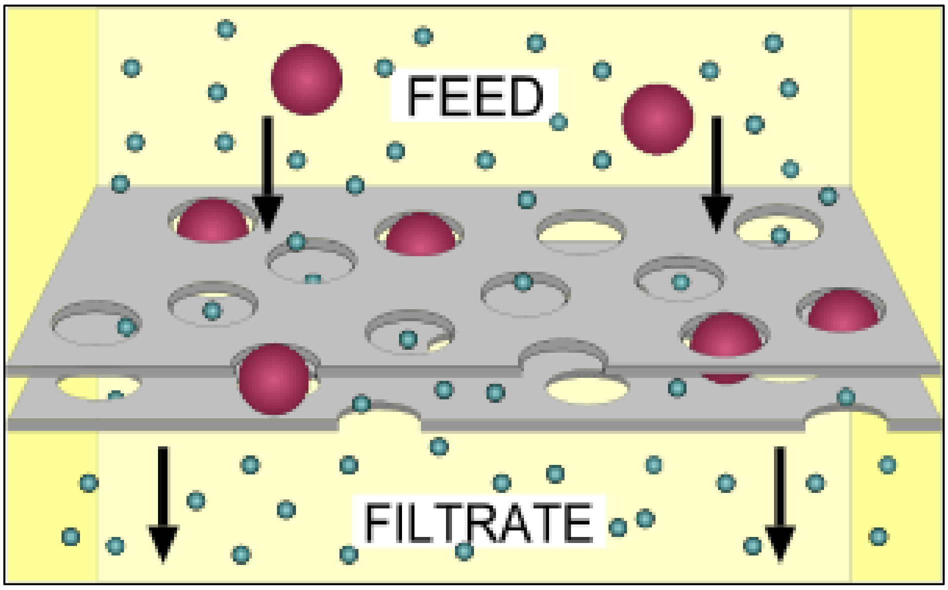


Figure II. 7. Diagram of simple filtration.

II.1.3.3. Filtration methods

Filtration consists of separating the constituents of a liquid-solid mixture by passing through afiltering medium. It is much faster than sedimentation. There are several methods of filtration.

II.1.3.3.1. Gravimetric filtration (gravity filtration)

Gravity filtration is a method of filtering impurities from solutions by using gravity to pull liquid through a filter. Gravity filtration is often used in chemical laboratories to filter precipitates from precipitation reactions as well as drying agents, inadmissible side items, or remaining reactants.
In this method, the laboratory funnel equipped with a filter paper is used (Figure II.8.).

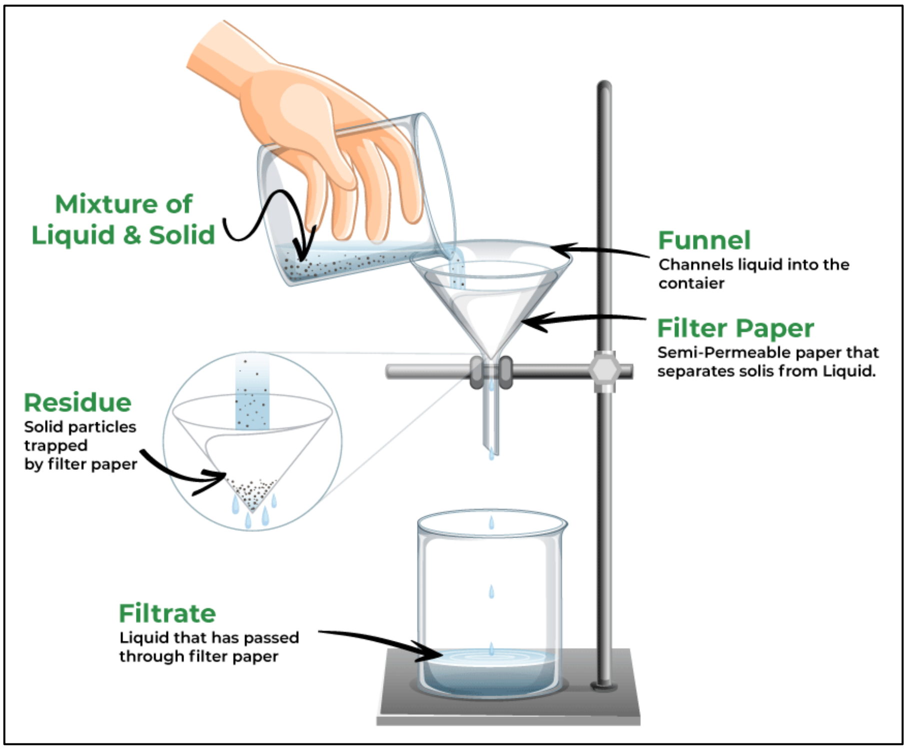


Figure II.8. Gravity filtration.

We caneasily filter any of the solutions, if we have

- Filter medium (Filter Paper)
- Slurry or residue (Fluid with suspended solids)
- Filtration driving force (Pressure, force, gravity, etc)
- Filtration device that holds the filter medium and filtrate.

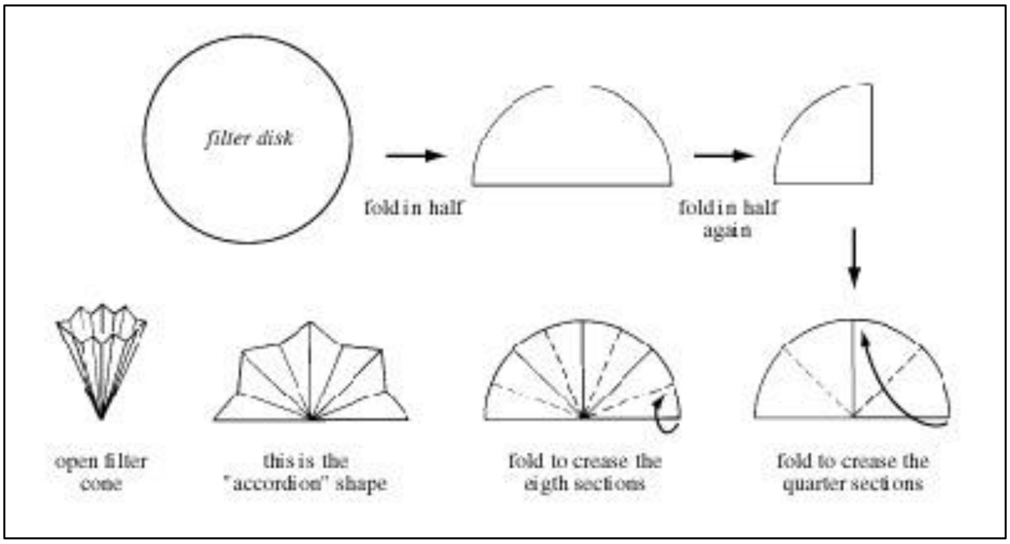


Figure II. 9. Funnel/Filter paper.

Gravimetric filtration has the following disadvantages :
• Filtration is slow.
• The difficulty of recovering the isolated solid phase, especially when it is not abundant.
• The separation is incomplete: the solid retains a significant quantity of liquid.

II.1.3.3.2. Vacuum filtration

The filtration speed is increased by the creation of a depression down stream of the filter material (Figure II.10.). This is the filtration method commonly used for sintered glasses and filter membranes. Special funnels fitted onto a suction flask, in which adepression, are used. The funnel is fitted onto the vial via a rubber cone, which will stick to the flask and funnel when the depression is established.

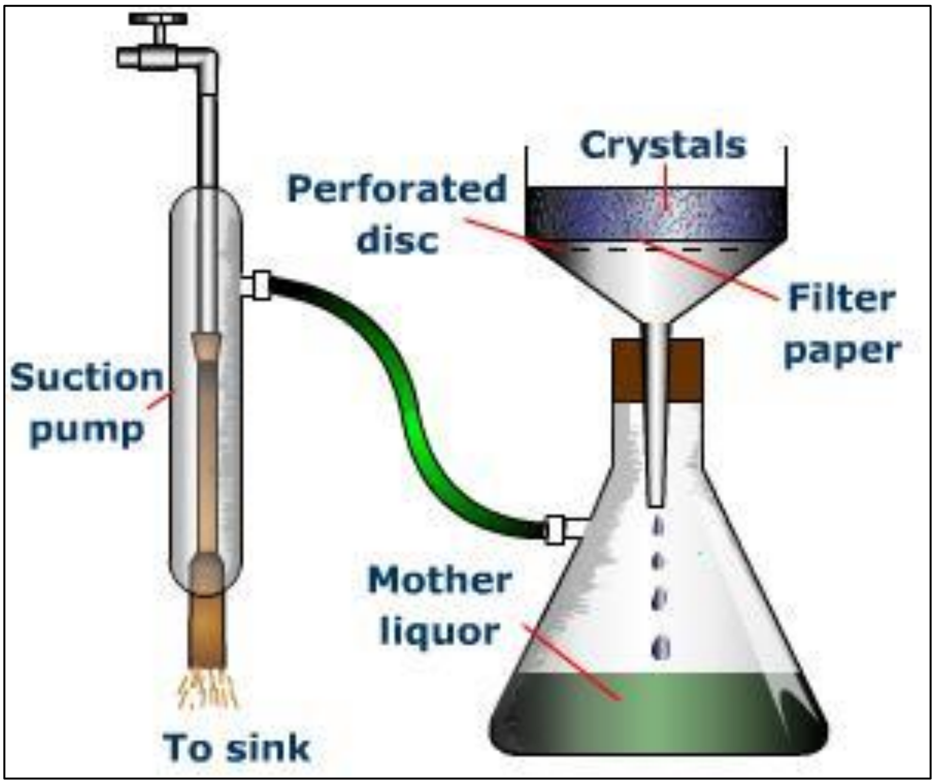


Figure II. 10. Vacuum filtration.

II.1.3.3.3. Pressure filtration

The filtration speed is increased by exerting pressure on the liquid to be filtered by lover of the filtering material represented by a filter membrane (Figure II.11.). Pressure filtration avoids foaming and evaporation of the solvent; it is frequently used in industry. This system of pressure filtration with filter membranes also available in the form of filter cartridges (millipore) adaptable to a practical syringe for the filtration of small volumes of solution to be filtered.

In the laboratory, sterilizing microfiltration using the Swinnex Millipore device is a filtration under pressure. This device is made up of two plastic parts, which are screwed on to each other enclosing a filter membrane.

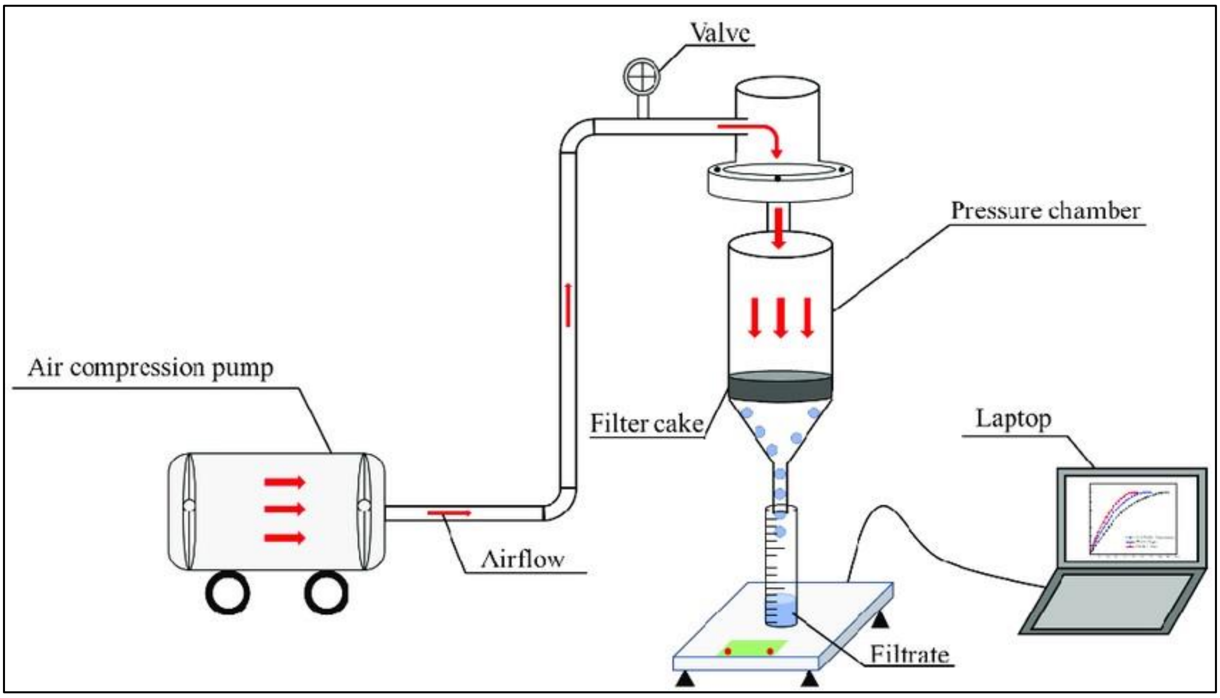


Figure II.11. Pressure filtration.

II.1.3.4. Filtration exemples

Filtration is one of the most important techniques for the separation of mixtures in a laboratory, it is also a common process happening in our every day life like:

- When making coffee, hot water is filtered through the ground coffee and a coffee bean. The filtrateis the coffee in liquid form. Using a tea ball or atea bag (paper filter) for brewing tea is very also an example of filtration example.
- A kidney is a biologica lfilter that is used to filter the human blood.
- Filters with particulate-capturing fibers are commonly used in aquariums.
- During mining, belt filters extract precious metals.
- Sand and permeable rock in the ground filtered the water which is then stored in the aquifer and thenused as ground water.

II.1.3.5. Applications of filtration

Some applications of separation by filtration method are mentioned below.

- Filtration of Tea or Coffee using a Sieve.
- Separation of chalk powder and water from their solution.
- Vacuum cleaners are fitted with filters in order to absorb dust particles.
- Filtration of sand particles from water or chalk powder.
- The waste water treatment plant uses the filtration technique to filter the sewage.

- Filtration techniques are used in the metallurgical process to remove the slag.
- Air filters are used in automobiles and in factories to remove harmful particles from the smoke.
- The treatment of water uses filtration techniques.
- Blood filtering in kidneys is another application of the filtration technique.

II.1.4. Centrifugation

II.1.4.1. Definition

Centrifugation is a process used to separate or concentrate materials suspended in a liquid medium, based on their density under the action of a centrifugal force. It makes it possible to recover a precipitate (pellet) and a supernatant. The mixture to be separated can consist of two liquid phases or solid particles in suspension in a liquid.
Centrifugation uses high rotation speeds (ranging from (6 to 10,000 revolutions per minute).

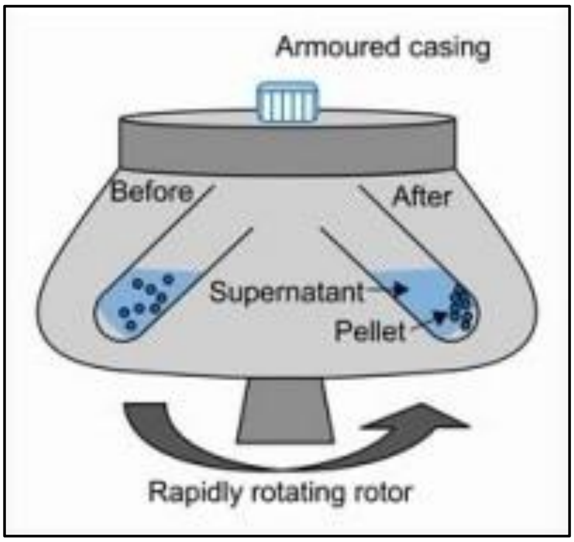


Figure II.12. Centrifugation Theory.

II.1.4.2. Principle

Centrifugation makes it possible to separate constituents of very different size and mass. Contained liquid. The constituents contained in a sample are subject to two forces :
✓ Gravity: It is the force that is exerted from top to bottom.
✓ Archimedes' thrust: This is the force that is exerted from bottom to top.

For a given rotation speed, each rotor has a relative centrifugal forcecentrifugation in x.g (force ofrelative gravity or acceleration) which can be expressed as rotational speed in rotations per minute according to the mathematical conversion formula [11]. This is:

$$g = 1.119 \cdot 10^{-5} \cdot r \cdot N^2 \quad \text{......................(II.1)}$$

where g is the relative centrifugation force, r is the rotor rotation radius (in cm) and N (rotations per minute: rpm) expresses the rotation speed (Figure II. 13.).

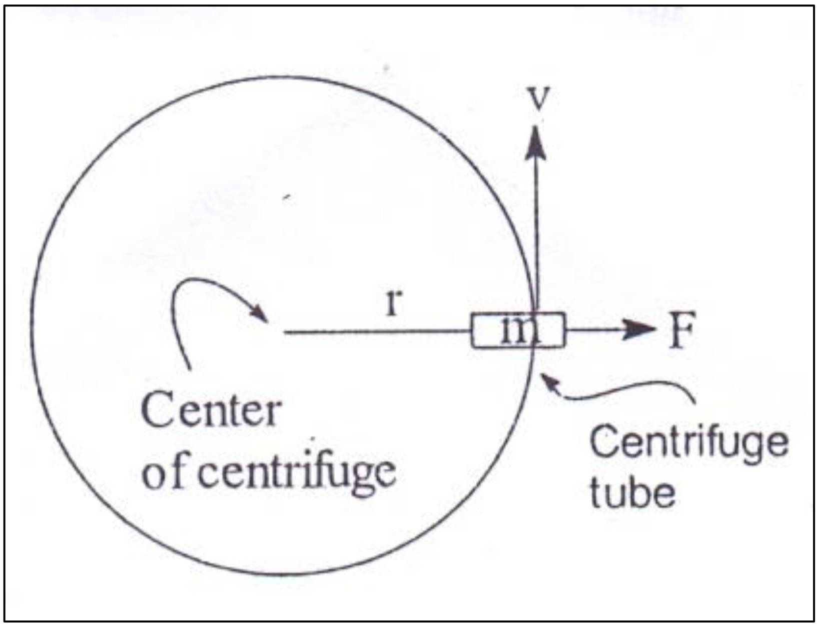


Figure II. 13. Illustration of the principle of Centrifugation.

II.1.4.3. Type of centrifugation

1. Density gradient centrifugation.
2. Differential centrifugation.
3. Ultra centrifugation.

II.2. Separation at the molecular level

II.2.1. Extraction

II.2.1.1. Introduction

Extraction is a process that enables the selective separation of one or more compounds from a mixture based on their physical or chemical properties. Since ancient times, humans have been using various techniques to obtaindyes, perfumes, flavorings, and natural product extracts.

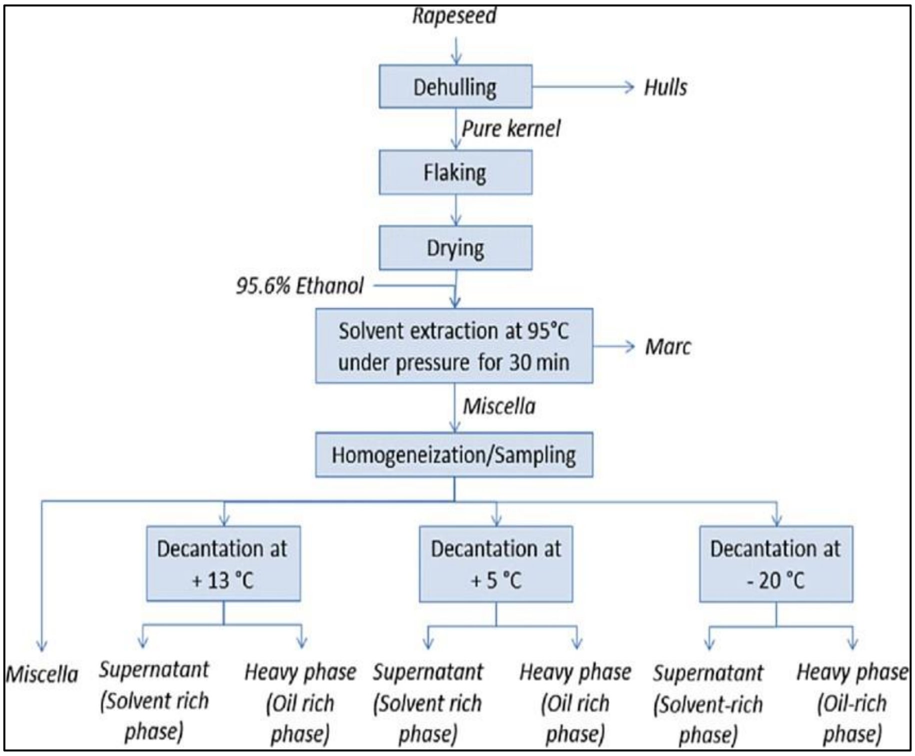


Figure II. 14. Extraction processus.

II.2.1.2. Definitions

Extraction involves transferring a compound from one phase to another:

• From one liquid phase to another liquid phase.

• From a solid phase to a liquid phase.

It is an operation which consists of separating certain compounds of an organism (animal or plant) according tovarious techniques.

II.2.1.3. Expression

The expression "expression method" is reserved exclusively for citrus fruits. As its name indicates, itis a method of extraction by pressure. Contrary to what one might believe, itis not the juice that is extracted here but rather the essence contained in the peel of the citrus fruits. First, the citrus fruits are introduced into a machine called a "pelatrice," wherethey are pressed and their peelpierced with small holes to release their essence - similar to when you squeeze the skin of a tangerine and it releases a littles pritz of perfume. The resulting mixture then passes through a centrifuge in order to separate the fruit juice (the watery part) from the zest essence (the oily part). The advantage of this method is that it does not in volve heating the citrus fruit, which guarantees an ultra-realistic smell.

The extraction of raw materials in perfumery can be done in various ways. One of these methods is called expression, which is an old technique used to extract the essence found in the peel of citrus fruits.

Figure II.15. Bottles of rose essential oil for aromatherapy.

There are several extraction processes for rawmaterials in perfumery :

- Including distillation
- Volatile solvent extraction.
- Expression.
- Enfleurage.
- Head space.
- Extraction by CO_2 or sofact.

Figure II. 16. Expression extraction.

II.2.1.4. Enfleurage

The oldest extraction technique involves imprisoning flowers in a layer of animal fat, which retains their odors. This method, developed in Grasse and dating back to Antiquity, can be done using hot or cold fat.

In the process of cold enfleurage, flower petals are placed on a plate coated with odorless grease. The petals are replaced every 24 to 48 hours to allow the grease to absorb as much of the fragrance as possible. Once the grease is saturated with fragrant molecules, it is heated and mixed with alcohol. The alcohol absorbs the fragrant molecules and is then filtered to obtain what is known as an absolute.

The hot enfleurage technique is similar to cold enfleurage, but is better suited for more resilient flowers. Instead of placing the petals on solid, cold oil, the petals are immersed multiple times in very hot oil to extract a fat rich in scents. This fat is then heated in the same manner as in cold enfleurage, decanted, mixed with alcohol, and filtered to obtain an absolute. However, this technique is now rarely used, mainly due to its use of animal fats. Some perfume companies are working to reinvent the process to make it more ethical

We are being more eco-responsible by using jojoba oil instead of animal fat. The extracts resulting from this technology are obtained without petrochemical solvents, at a very low environmental cost. They enjoy exceptional quality and faithfully represent what nature gives us to feel.

Figure II. 17. Jasmine enfleurage photograph taken by Elise Pearlstine.

II.2.1.5. Liquid-liquid extraction

Liquid-liquid extraction is one of the oldest sample preparation techniques.

It is a fundamental operation of material transfer between two immiscible liquid phases, without heat transfer. This technique makes it possible to extract a substance dissolved in a solvent, using another solvent, called extraction solvent, in which it is more soluble. The initial solvent and extraction solvent should not be miscible (Figure 2.18.).

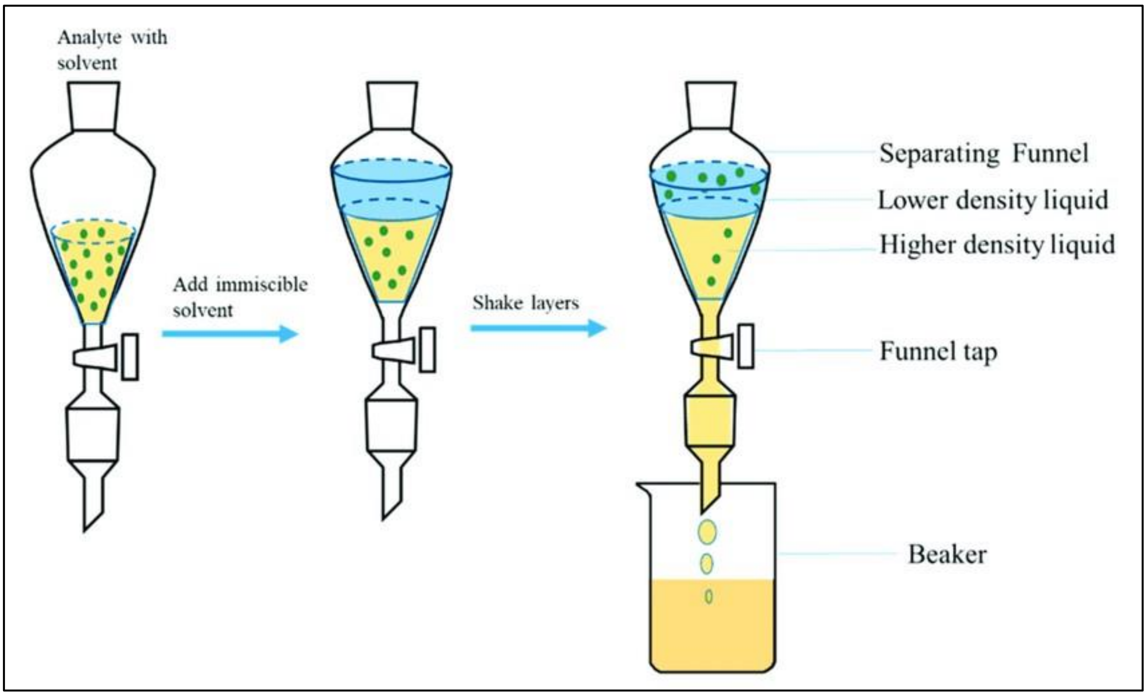


Figure II. 18. The stages of liquid-liquid extraction.

II.2.1.6. Solid-liquid extraction

Solid-liquid extraction is a slow process that involves transferring a substance from a solid into a liquid solvent. Various techniques can be used, including maceration, infusion, and decoction.

- **Decoction**
  Decoction is an extraction method used for extracting water-soluble and thermostable constituents, especially from plants. In thisprocess, the crude plant material is boiled in an open-type extractor with a specified volume of water for a specific duration. Typically, the initial crudedrug to water mass ratio is either 1:4 or 1:16. The volume isthenreduced to one-fourth of its original volume due to boiling and evaporation. Once the extraction iscomplete, the concentrated extract is strained or filtered and canbeused directly or further processed [12].

- **Infusion**
  Infusion involves pouring boiling water over finely ground plants (leaves or flowers) and allowing them to soak to dissolve their active ingredients.

- **Maceration**

Consists of allowing a solid to remain cold in a liquid in order to extract its soluble constituents.

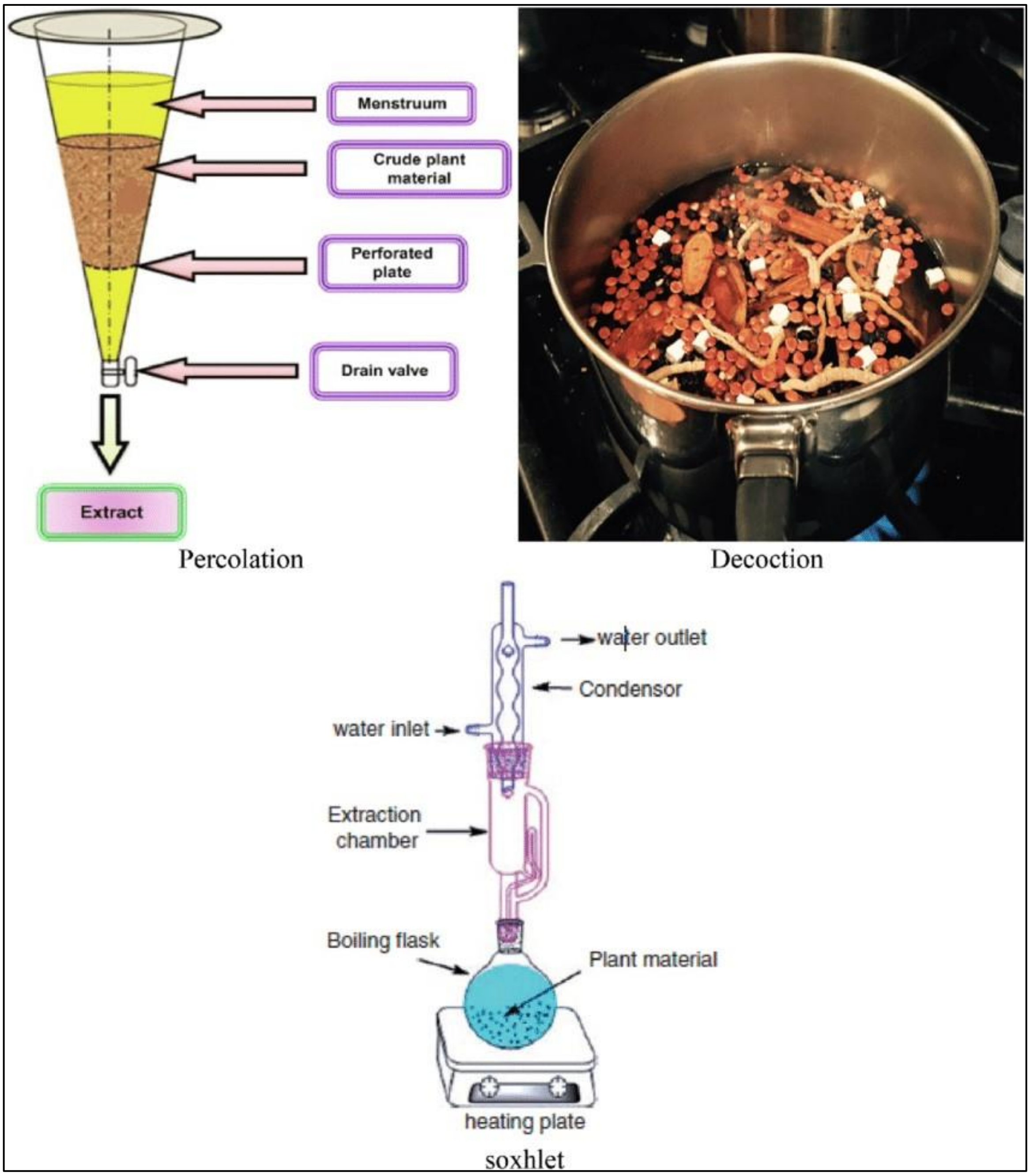


Figure II. 19. Different solid-liquid extraction techniques (decoction, infusion, maceration).

II.2.1.7. Extraction by hydro distillation or steam distillation

Hydro-distillation involves distilling a compound by stripping it with water vapor. This method is widely used for extracting essential oils (Figure II.20.). It includes boiling a mixture of water and a natural product, then condensing the vapors with a refrigerant. The distillate obtained comprises two phases : an aqueous phase and an organic phase, which is the essential oil.

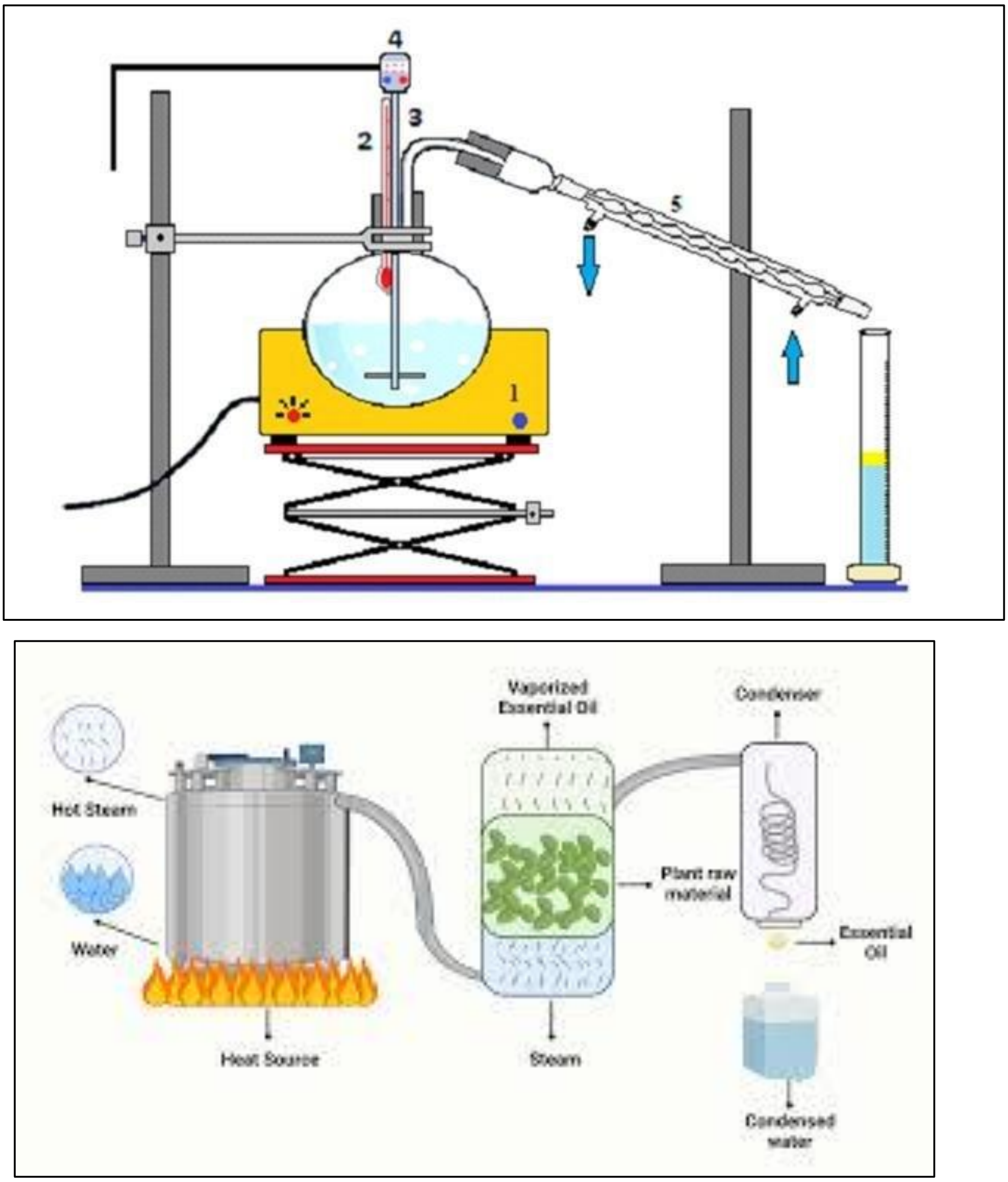


Figure II.20. Extraction by hydro distillation or steam distillation.

II.2.2. Distillation

Distillation is a method used to separate two miscible liquid substances. Through this process, we take advantage of the different boiling points of the substances. The mixture is heated until the boiling point of one of the components is reached. This component evaporates, and its vapors are collected and condensed in another container. The other component, which does not reach its evaporation temperature, remains in liquid form in the original container, Figure II.21.

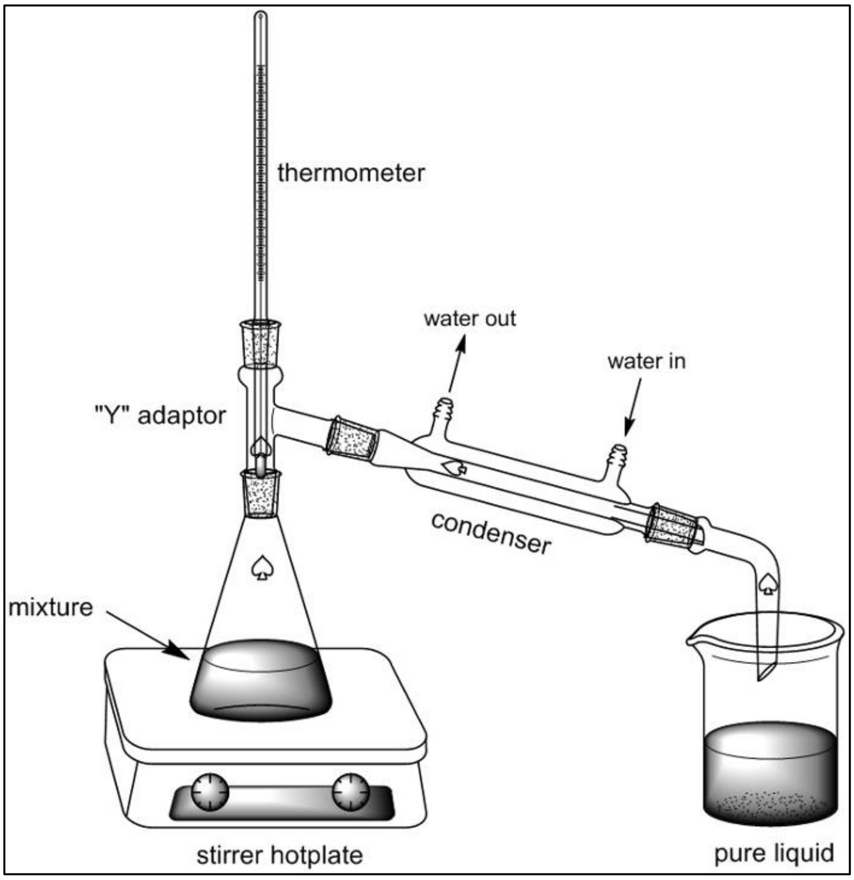


Figure II.21. Distillation process.

The principle of different distillation techniques uses the laws that govern the balance between liquid and vapor of pure substances and mixtures. There are several types of distillation :

- Including distillation under atmospheric pressure.
- Distillation underreduced pressure lowers the boiling point of mixtures. For example, underreduced pressure of 25 mm Hg, the boiling point of mostliquidsdecreases by 100 to 125°C.

II.2.3. Evaporation

Evaporation is a process by which the liquid part of a mixture is eliminated, transforming it intogas.

To do this, the liquid constituent of the mixture can be allowed to evaporate naturally at temperature room temperature, or the process can be accelerated by heating the mixture. Evaporation serves to recover the solid part of a heterogeneous mixture or the solid solute of a solution. It also allows concentrate the solute of a solution into a smaller volume of solvent. (Figure II.22.)

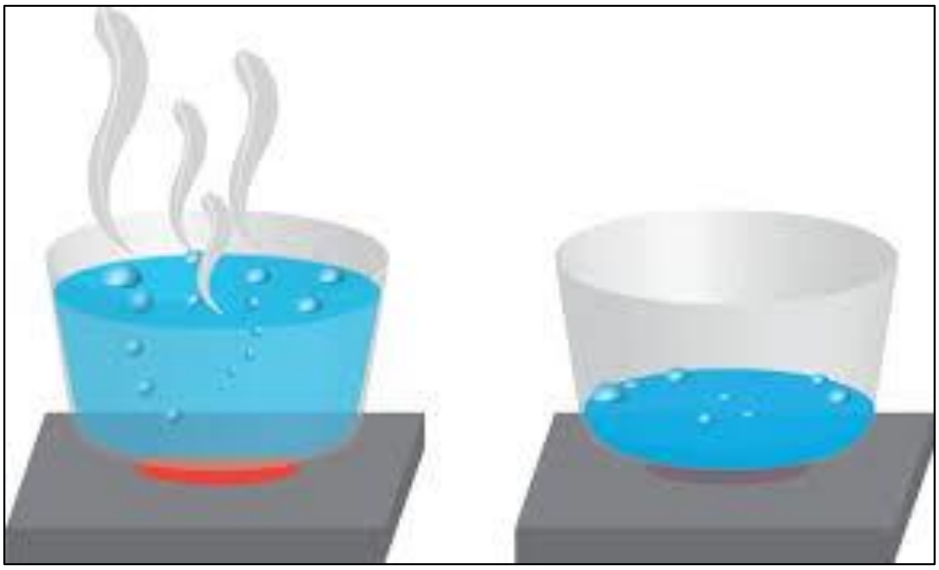


Figure II.22. Evaporation.

II.2.4. Membrane processes

Membrane separation methods are a separation process using as an agent separating a synthetic membrane which is a thin layer of material. The thickness of a membrane can vary between 100 nm and up to just over 1 cm. It allows stopping or passing selective of certain substances dissolved or not in a mixture, between the two environments that it separated [13]. Thepart of the mixture retained by the membrane is called retentate (or concentrate) while that which passes through the latter is called permeate. Separation occurs under the action of a forcetransfer motor according to a defined separation mechanism. The characteristics of the membranes aredetermined by two parameters: permeability and selectivity.

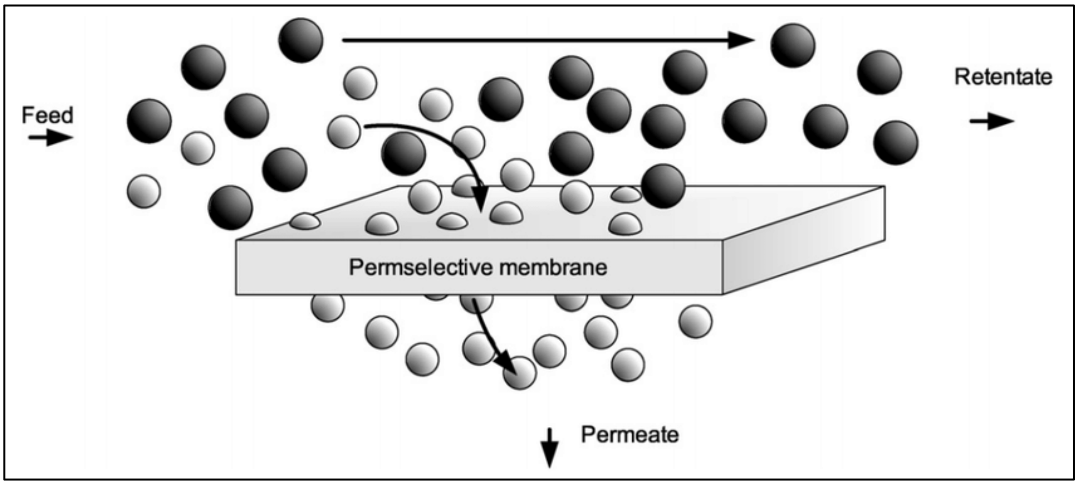


Figure II.23. The schematic of membrane separation.

Example: Reverse Osmosis

Reverse Osmosis, alsoknown as Ultra-Filtration, represents state-of-the-art technology in water treatment. Reverse Osmosis (RO) wasdeveloped in the late 1950's under U.S. Governmentfunding, as a method of desalinatingsea water. Today, reverse osmosis has earneditsname as the mostconvenient and thoroughmethod to filter water. It isused by most water bottling plants, and by many industries thatrequire ultra-refined water in manufacturing. This advancedtechnologyisalsoavailable to homes and offices for drinking water filtration.

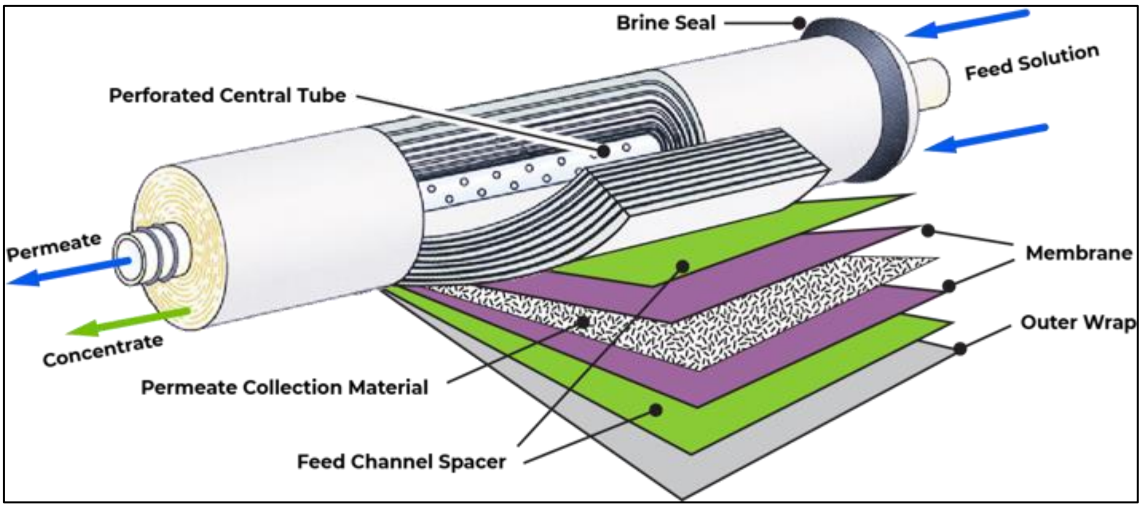


Figure II.24. Reverse osmosisspiral membrane.

Uses dense membranes that allow the solvent (water) to pass through and stop all salts. This technique is used to:
• Desalination of sea water.
• Desalination of brackish water.
• Production of ultra pure water.

Chapter III

Reaction Engineering

III.1. Physico-chemical reaction engineering

III.1.1. Coagulation

The process described is a crucial step in making fermented milks, cheeses, and specific dairy desserts. It causes the casein micelles to become unstable, leading to the formation of a solid product called curd, which primarily consists of insoluble caseins. In cheese making, the curds are separated from the liquid part, called whey.

There are three types of coagulation:

- Acid coagulation resulting from the action of lactic acid bacteria, or the addition of an acid (lactic coagulation).
- Enzymatic coagulation, which uses rennet or other proteolytic enzymes.
- Microbial coagulation, which uses microbial coagulants obtained from molds or bacteria.

Each coagulant has it sown characteristics of sensitivity to pH, temperature and calcium ions. While some can technically beused on all types of cheese, others are more specifically reserved for certain types of production.

Figure III.1. Coagulation of milk to cheese.

III.1.2. Gelation

Gelationis the process of transforming a liquid substance into a solid, gelatinous formusing a gelling agent. This process is used in the modern preparation of various food items such as jams, fruit jellies, and jelly desserts. High polymers from natural sources, such as pectin, agar, alginates, and carrageenan, are comm only used as carbohydrate hydrocolloids for this purpose. In the dairy industry, gelation can occur after heat treatment in products that are rich in dry extract. However, in the case of ordinary milk sterilized at ultra-high temperature for a very short time (U.H.T.), a gel may appear after a long period of storage.

Various gelling agents are used in food, pharmaceutical and non-food industries. These include puddings, desserts, jelly pet food, pharmaceutical gels, and hair gels [14].

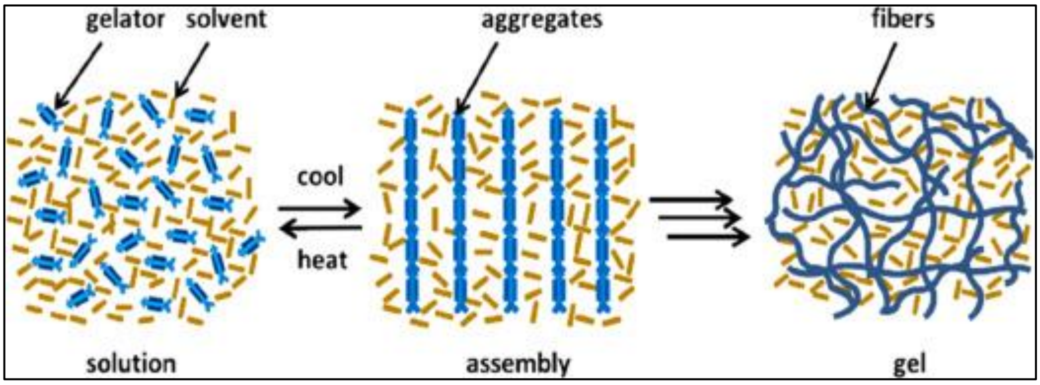


Figure III.2. Schimatic representation of self-assembly of organogelatorsin 3-dime, ensional fiber network [15].

III.2. Biological reaction engineering

III.2.1.Biomass production

Biomass is all organic matter of plant or animal origin (such as meat, milk, and grass) that can be converted into energy. It is used in agriculture and the agri-foodindustry for various purposes [16].

Biomass is used for biofuels, with sunflower, olive, soy, or palm oils serving as the basic raw materials for making biodiesel. Bioethanol is produced from the fermentation of crops such as wheat, corn, beet, or sugar cane. Biomass is also used to produce heat and/or electricity, utilizing crop residues and dedicated productions like olive pomace and vegetable waters as combustibles.

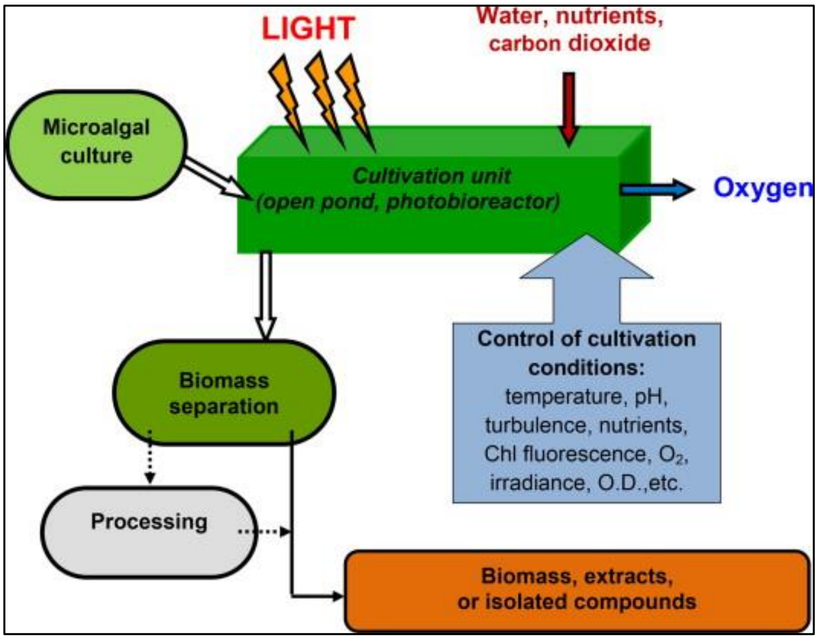


Figure III.3. Biomass production.

III.2.2. Metabolites production

For the production of metabolites, we traditionally differentiate between primary and secondary metabolite production.

III.2.2.1 Primary metabolites

By convention, we describe as primary the metabolites which are part of the vital metabolic pathways of a living (micro) organism: metabolites of energy metabolism and metabolites of the biosynthesis pathways of the elementary building block metabolites. Taking into account the evolutionary history of life, primary metabolites have a "universal" or "common to many species" character.

Examples of primary metabolites of the “physiologically fundamental availability” type

- Biosynthesized essential metabolites (such as amino acids, nucleotides, coenzymes, fatty acids with membrane function, fundamental sugars, and sugar derivatives).
- but also the fundamental precursor intermediate metabolites (citric acid, fumarate, oxaloacetate, 2-ketoglutarate, etc.).

Examples of primary metabolites of the “products of energy metabolism” type

- Ethanol from alcoholic fermentation,
- Acetic acid from acetic respiration...

Consequence of this definition: in a given medium and environmental conditions, if a primary metabolite is synthesized, it is synthesized during all the physiological phases of a bioreactor culture, in the phase of exponential growth, slowdown, biomass plateau. Even if production yields are not the same depending on physiological states!

For example, during an alcoholic fermentation with an excess of fermentable sugars, the yeasts can continue to produce ethanol while the growth is stopped by the high concentrations of ethanol (the yeasts are then maintaining life and maintaining. life implies an operational energy metabolism hence the persistent production of ethanol And finally, if the sugars in the environment remain in excess, it is the toxic effect of the ethanol, the concentration of which will have exceeded a certain threshold. toxic, which will stop the production of ethanol by yeast).

III.2.2.2. Secondary metabolites

Secondary metabolites are those a priori not directly involved in the development or reproduction of an organism. Their absence does not result in immediate death but can limit the survival, fertility or appearance of an organism. This absence may also have no effect. Secondary metabolites are very specific compounds, a priori which appear following the metabolism of unusual nutrient sources, or following defense reactions, or which participate in particular ecological interactions between flora... Thus the production of a given secondary metabolite is limited to a very small number of phylogenetically close species (contrary to the case of primary metabolites) (let us simply cite here the example of antibiotics, typical cases of secondary metabolites). Secondary metabolites have a production which depends very directly on the environmental conditions of culture, on very specific physiological inductions. Frequently, they are synthesized in the plateau phase of biomass (not always!!).

III.2.3. Fermentation

Fermentation and a veryold technique of transformation and preservation are of either animal or vegetable origin (yogurts, cheese, bread, fermented vegetables, etc.) It is a biological process which manipulates microorganisms present in the raw materials serving as substrate. Indeed, fermentation is based on a biochemical reaction which consists of releasing energy from an organic substrate under the action of microbial enzymes and rejecting products of interest for food and industry. Generally this reaction does not involve oxygen (O_2), it there for etakes place in the absence of air (an aerobiosis). It allows food products to be preserved while improving their nutritional qualities and increasing their organo leptic qualities [17].

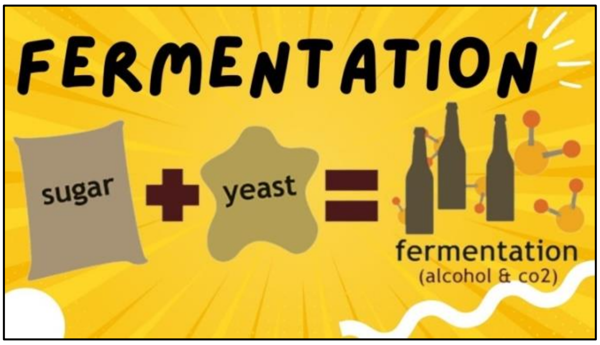


Figure III.4. The fermentation process.

III.2.4. Bioconversion

Bioconversion is a process that utilizes organisms (such as micro-organisms or enzymes) to degrade or convert biomass. In biological conversion, organisms metabolize complex biomass components into simpler compounds, which can be further transformed into biofuels, biochemicals, or other use ful products.
[18].

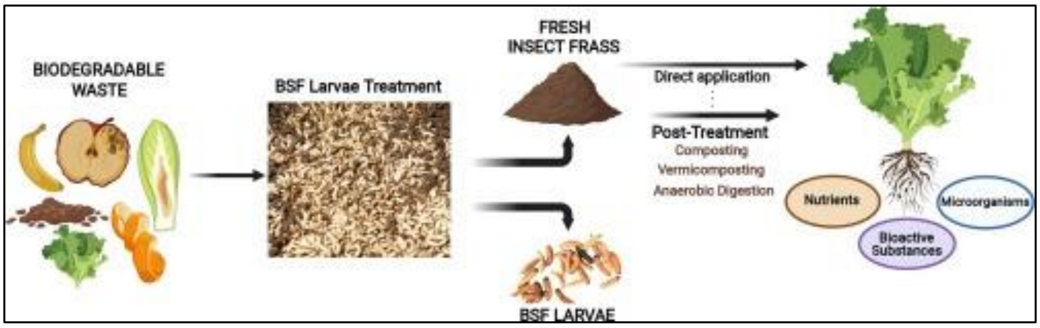


Figure III.5. Frass derived from black soldier fly larvae treatment of biodegradab lewastes.

Chapter IV

Structuring operation

IV. Structuring operation

IV.1. Emulsification

An emulsion is a colloidal dispersion system where larger droplets of the dispersed material (dispersed or discontinuous phase) are dispersed in the dispersion medium. Dispersed liquid materials are dispersed in a liquid dispersion medium without dissolving into each other. The process of forming an emulsion from two liquids is called emulsification. In general, a surfactant (emulsifier), which has both hydrophilic and lipophilic properties, is used to stabilize an unstable emulsified state.

In the case of water and oil, the emulsion takes one of two compositions: Oil-in-Water (O/W), in which water is dispersed in oil, or Water-in-Oil (W/O), in which oil is dispersed in water. Examples of W/O emulsions include dairy products like butter and margarine, and creams in cosmetics. Mayonnaise and fresh cream, and skin cream in cosmetics are O/W emulsions.

In recent years, synthetic techniques have been used to create double emulsions (also called emulsions of emulsions or multiple emulsions), such as W/O/W and O/W/O emulsions. The technologies used to compose and control a variety of emulsions made of non-combining substances are applied in many areas, including cosmetics, food, and pharmaceuticals.

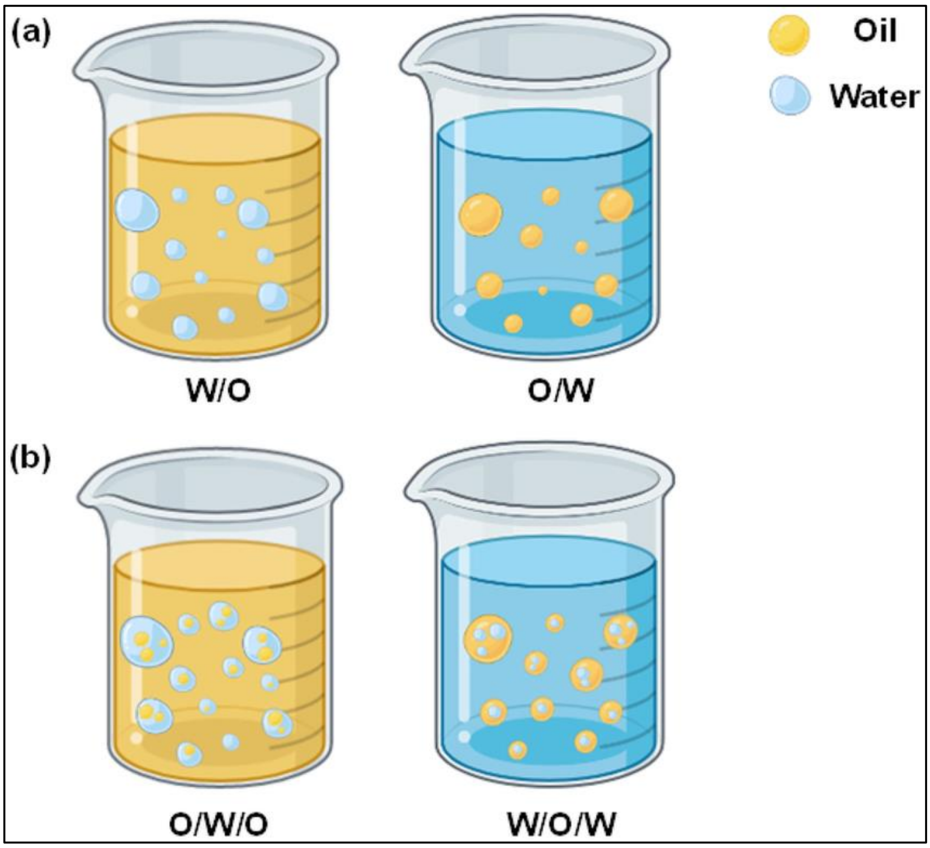


Figure IV. 1. Emulsion types:
(a) Simple emulsion, and (b) multiple emulsion [19].

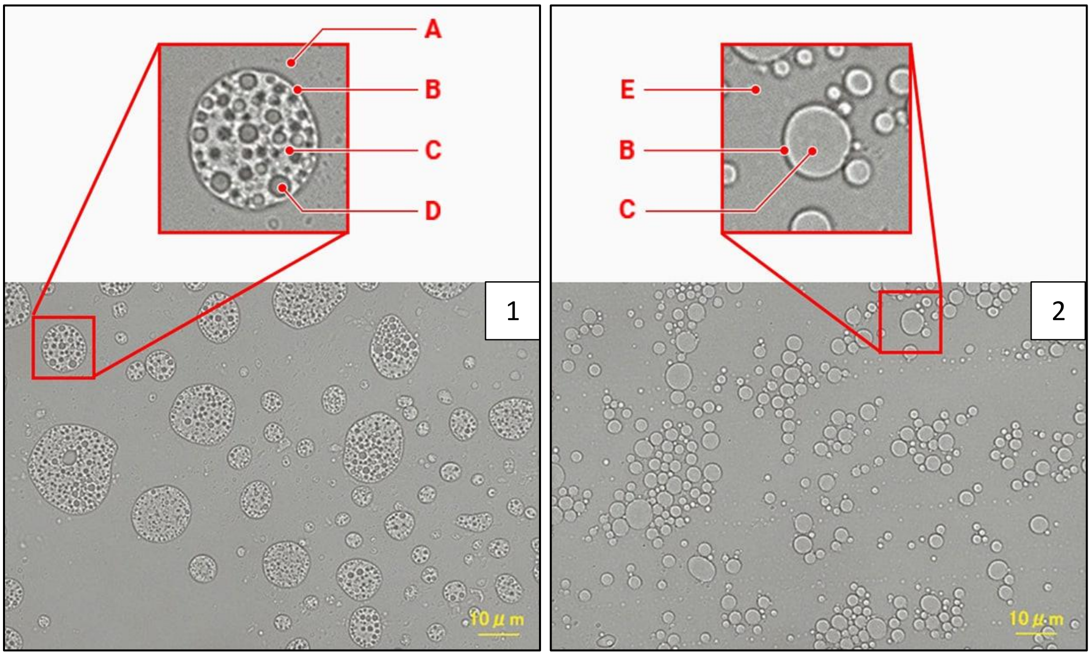


Figure IV.2. Observing emulsions (double emulsions) using a fluorescence microscope BZ-X800 : 1) W/O/W emulsion (x100) and 2) O/W emulsion (x100): A: Outer water phase, B: Oil droplet, C: Oil phase, D: Inner water phase and E: Water phase [20].

IV.1.1. Examples of emulsions

Salad dressing, mayonnaise, and milk (fat-in-water emulsion) and butter (water-in-fat emulsion).

The mixture remains stable thanks to a third ingredient called an emulsifier. The emulsifying agents used in the food industry are: lecithins and the monoglycerides and diglycerides of food fatty acids [21].

Figure IV.3. Fresh And Pure Milk Cream.

IV.1.2. Difference between emulsions and suspensions

A suspension is another kind of dispersion system that has a liquid dispersion medium. The greatest difference between suspensions and emulsions is that the dispersed material is liquid in emulsions and solid in suspensions. Examples of suspensions include muddy water, ink, general paint, and toothpaste. In food, soups and sauces are generally suspensions. When gas is dispersed in a liquid dispersion medium, it is called a foam, some common examples of which are soda, meringue, and shaving foam.

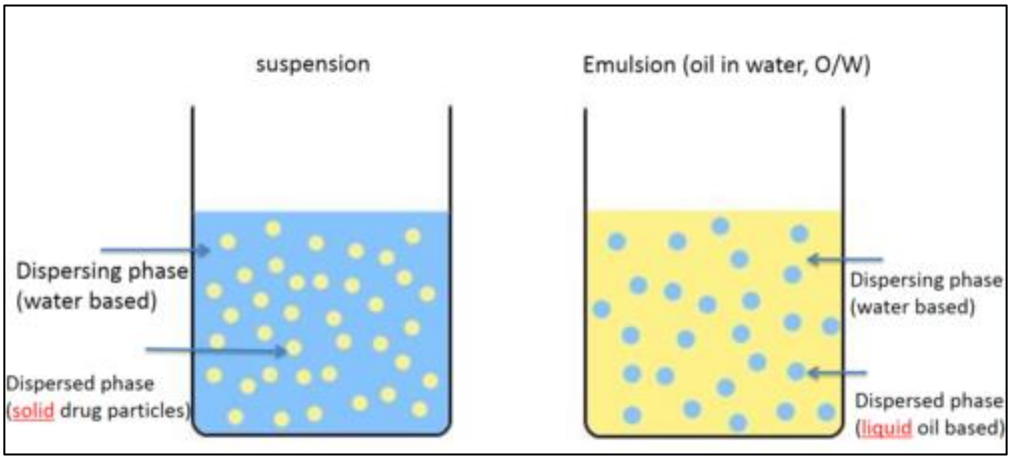


Figure IV.4. Difference between emulsions and suspensions.

IV.1.3. Lecithin

Lecithin is the yellow to brown fatty substances that can be obtained from both plants and animals. Although eggs are still the best whole food source of lecithin, soy lecithin, and sunflower lecithin are the most common varieties [22]. Lecithin can be also found in many other sources, such as cauliflower , whole grains, chickpeas (garbanzo beans), cabbage, organic meat, seeds, liver, split peas, peanuts, milk, and nuts [23].

Commercial lecithin, which is commonly derived from soybeans is often used in food industry as emulsifier in processed goods, like ice creams and salad dressings [24].

Lecithin supplements are usually used for controlling the high cholesterol levels, aid for lactation, and as antiulcer [25]. These lecithin supplements most probably prepared from eggs, sunflower seeds, or soybeans. Although, animal derived lecithin is now used for preparation of supplements but still soybeans is the most important source for lecithin supplements [25].

Sunflower lecithin is not as common as soy lecithin but in many case it is preferred because soybeans are sometimes subjected to genetic modification in mass production but sunflower seeds never subjected to such modification. Moreover, the process of extraction of sunflower lecithin is also gentler and doesn't require harsh chemicals [26].

Figure IV.5. A pile of soy lecithin granules.

Lecithin is a broad term used to describe crude fractions of oil, fat, or egg phospholipids. Although nowadays the term lecithin can be used as a reference to phosphatidylcholine (Figure IV.3); crude lecithin contains other phospholipids, such as phosphatidyl ethanolamine, phosphatidyl inositol, and phosphatidyl serine [27] .

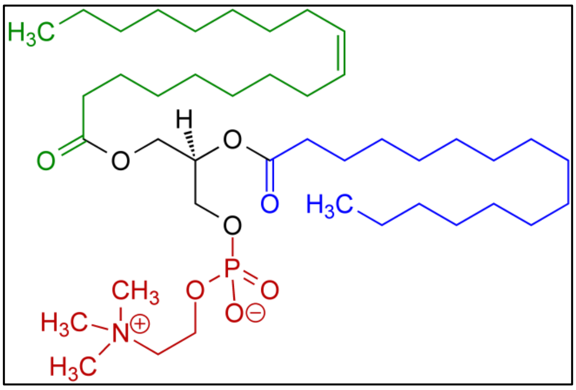


Figure IV.6. Chemical structure of Lecithin: Phosphatidylcholine.

IV.1.4. Simplified structure of lipids and behavior with respect to water

Many fatty substances (oil, butter, milk) are used in cooking. They belong to the chemical family of lipids; lipid is molecule which constitute fat. When cooks prepare sauces, they use lipids, water and form emulsions.

- Triglycerides are lipids from areaction between a triol (glycerol) and three fatty acids (R-COOH) each comprising a long carbon chain. These molecules, often schematized in the form of a three-toothed comb, are apolar because they do not have charged poles.

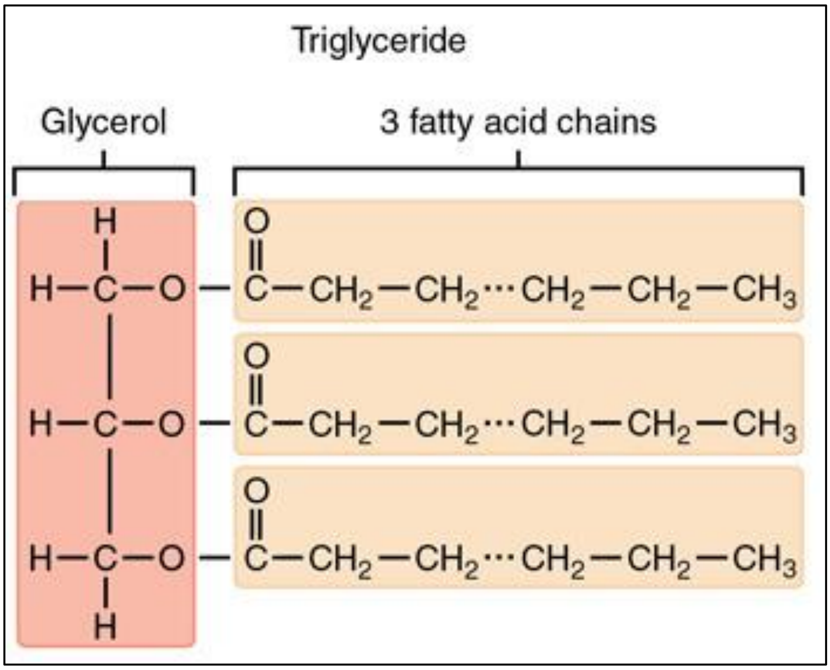


Figure IV.7. A triglyceride structure.

IV.1.5. Surfactant species

Molecules that "love" water and lipids.It is a molecule with a long hydrophobic carbon chain (which does not like water) and lipophilic (which likes lipids) and a hydrophilic polar part: "the head" (which likes water).

In order to preserve an emulsion, it is necessary to add molecules (or ions) which "like" both oil and water, that is to say which are both lipophilic and hydrophilic: these are surfactant species.

Surfactants used in food are part of the category of emulsifiers, whose code is E4xx. They are widely used in baking.

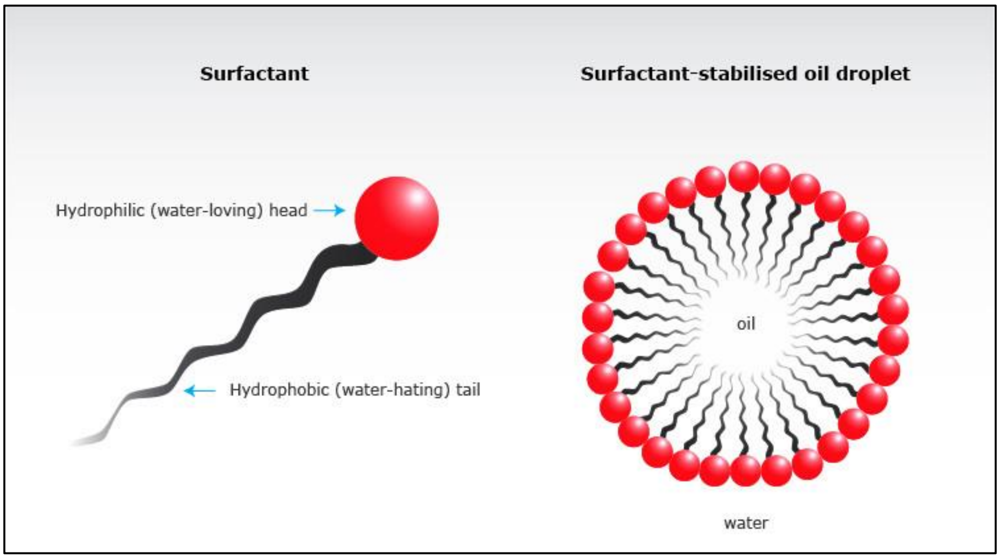


Figure IV.8. Surfactant schematic.

IV.2. Extrusion-Cooking

Extrusion is a process of central importance and widespread application in the food industry. The extensive development of extrusion technology represents one of the most significant achievements in food process engineering in the last fifty years. The expansion of food extrusion technology has been accompanied by considerable research activity that has generated an impressive volume of new knowledge as to the physics and chemistry of the process. Literally, 'extrusion' (from the Latin word *extrudere*) means the action of pushing out.[28]
Extrusion cooking may be defined as a thermomechanical process in which heat transfer, mass transfer, pressure changes and shear are combined to produce effects such as cooking, sterilization, drying, melting, cooling, texturizing, conveying, puffing, mixing, kneading, conching (chocolate), freezing, forming etc.
The extrusion cooking process is used to produce a wide range of products such as breakfast cereals, confectionery, flatbread biscuits, appetizer snacks and pre-cooked infant flour. It is also used for the production of processed cheeses or the manufacture of surimi, the solubilization of pectins and other hemicelluloses, the chemical modifications of biopolymers, the production of thermoplastic starches.

Table IV. 4. Food products obtained by an extrusion process [29, 30].

Characteristics	Products
Extrudedcerealproducts	Cereals Ready-to-eat Expanded snack foods Precooked flour Pasta products Pellets for snacks Bases for instant soups
Extruded fruit products	Fruit leather Fruit bars
Extrudedproteinproducts	Snacks (protein bars) Textured vegetable protein products Restructured seafood Semimoist and expanded pet foods Processedcheeses
Confectioneryproducts	Chocolate Fruit gum Chewing gum

IV.3. Overgrowth

The purpose of this process is to disperse a gas phase, which is not formed in place, into a liquid or pasty material in the form of fine bubbles. The end result is a stable dispersion of gas in a continuous medium [31].

Chapter V

Mechanical and manufacturing operations

V.1. Grinding, Sieving, Flow (especially powders)

Grinding is the process of breaking down a solid into smaller particles to increase its surface area therefore, its reactivity is affected. In chemistry, pharmacy, and the food industry, manual grinding is done using a mortar and pestle, while industrial grinding is done by machines. Grinding is classified into three main families :

✓Coarse grinding.

✓Fine grinding.

✓Ultrafine grinding.

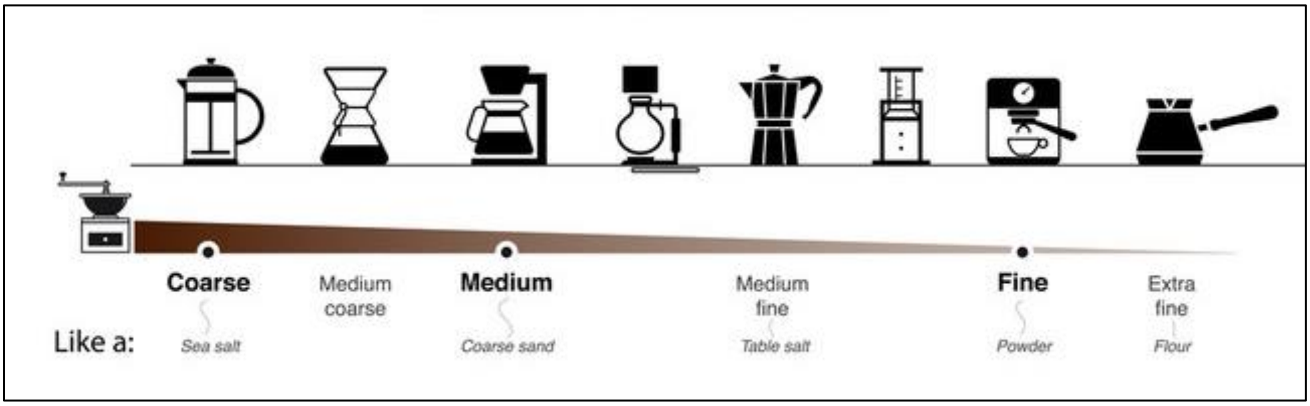


Figure V.1. Coffee grind guide.

V.1.1. The coarse grinding

Large solid materials are first subjected to coarse grinding in order to obtain centimeter-sized pieces. This type of crusher operates by cutting. There are two types: knife grinders, which are used to cut frozen meat, and graters, which are used for processing beets in the sugar industry or potatoes in the starch industry.

V.1.2. The Fine grinding

To achieve the necessary fineness for modern technology, it is often required to grind materials until they reach the point of aggregation or even agglomeration. This can be achieved through the following methods:

- Using a small mill diameter

- Using grinding bodies that are no larger than the minimum size required for breakage

- Keeping the grinding time short

- Applying grinding aids

V.1.3. The Ultrafine grinding

Ultrafine grinding in the submicron range, which spans from 100 nm to 1000 nm, has recently become increasingly important in the development of new functional materials for various industrial applications, including the food industry [32].

V.1.4. The sieving

Sieving involves passing a solid product or suspension through a sieve to separate and possibly analyze the particle size of certain elements, (Figure 5.12). Granulometry involves determining grain dimensions using a sieve, which is a square mesh instrument used for particle size analysis. "Sieve" or "passing" refers to the quantity of material that passes through the sieve, while "refusal" on a sieve refers to the quantity of material that is retained on the sieve.

Figure V.1. Particule size analysis.

V.1.5. Flow

Half of the factories worldwide deal with powders, each with unique characteristics that determine its final quality. These characteristics can be biological, chemical, or physical. In addition to its inherent properties such as composition, particle size, density, and morphology, a powder's behavior is also influenced by its interactions with the environment, especially with air (humidity, temperature, aeration rate). Finally, the handling of the powder will impact its behavior and flowability, including packaging properties, electrostatic charge, and surface morphology.

It's important to consider how well a powder flows before packaging, emptying, transferring, storing, dosing, or mixing it. If a powder doesn't flow well, it can form clumps that may damage equipment. Therefore, it's recommended to study the flow of your powder beforehand. There are several methods to evaluate powder flowability, such as measuring the angle of repose, conducting packing tests (Hausner index, dynamic packing or compression tests), and comparing packing tests. The Jenike test can also be used to quantify flow properties by determining break points that define flow locations.

Conducting these tests allows for the determination of minimum flow diameters, the slope of hoppers, necessary surface conditions, and the installation of flow aid devices if needed. It's important to understand how to qualifyyourpowders.

Figure V.2. Powder flow image.

5.1.6. The cutting

Cutting, or slicing, is a mechanical operation that uses cutting tools to reduce the dimensions of products while controlling their geometry and weight. Food products are increasingly being presented to consumers pre-sliced to make them easier to use. Various techniques are used to cut a wide range of products including soft, chewy, sticky, crumbly, and heterogeneous items.

5.1.7. Packaging and conditioning

Packaging involves placing a food item in direct contact with an envelope or container. It also includes placing one or more packaged food items in a second container. Packaging is an important part of food processing as it helps with handling during transport, storage, and distribution. It ensures that the product is protected against external contamination and air humidity. The packaging must be suitable for the products, solid, clean, dry, waterproof, easy to handle, and stackable. There are various packaging materialsavailable.

- Paper and cardboard, including corrugated cardboard and cardboard (e.g. cereal boxes), which can be recycled, bleached or unbleached.
- Plastic containers such as soft drink, spring water, and food containers are made from various types of polymers including PE, PP, and PET.
- Glass is both transparent and can be colored.

- Metal: Tin cans, metal cans.
- Multi-layer and composite containers, such as milk, juice, and ice cream cartons made from waxed cardboard.
- Wood is used for certain cheese packaging or for certain boxes containing alcohol bottles.

Figure V.3. Packaging and conditioning image.

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