République Algérienne Démocratique et Populaire
Ministère de l'Enseignement Supérieur et de la Recherche Scientifique
Université **A**/**M**ira de **B**ejaia
Faculté des **S**ciences de la **N**ature et de la **V**ie
Département de **S**cience **A**limentaire

Course handout

Fats and Oils in Food Science: Composition, Properties, Processing and Quality Evaluation

Intended for

Master 1

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2025-2026

Preface

Fats and oils play a fundamental role in human nutrition as well as in numerous industrial processes. Their importance is not limited to their high energy value, but also extends to their technological, nutritional, and sensory functions. Indeed, they significantly contribute to the texture, flavor, stability, and preservation of many food products, making them essential components in food science and technology

The study of fats and oils provides a better understanding of their chemical composition, physicochemical properties, and the transformations they undergo during processing, refining, and storage. Such knowledge is essential to control the quality of final products and to ensure their safety for consumers.

In a context where nutritional quality and food safety requirements are becoming increasingly strict, the analysis and control of lipids represent a key field for students, researchers, and professionals in the agri-food sector. This course therefore aims to provide the theoretical and applied foundations necessary for understanding and utilizing lipids in food systems.

Thus, this educational material is designed to serve as a structured reference covering the different aspects of fats and oils, from their origin to their technological and nutritional applications.

Learning Objectives

Understand the basic chemical structure and classification of fats and oils.

Explain the physical and chemical properties of lipids in food systems.

Describe the main extraction, refining, and processing techniques of fats and oils.

Identify the nutritional roles and health implications of dietary lipids.

Analyze the technological functions of fats in food formulation and processing.

Evaluate quality parameters and methods used in lipid analysis.

Introduction

Introduction

Lipids, commonly referred to as fats and oils, represent one of the most important classes of biomolecules in food science and human nutrition. They play a fundamental role in the human diet as a major source of energy, providing more than twice the caloric value of carbohydrates and proteins. Beyond their nutritional function, fats and oils contribute significantly to the texture, flavor, appearance, and overall sensory quality of food products.

From a technological perspective, fats and oils are widely used in the food industry due to their unique physicochemical properties, such as melting behavior, crystallization patterns, oxidative stability, and plasticity. These properties make them essential ingredients in a wide range of food products including baked goods, confectionery, dairy substitutes, and frying media.

Fats and oils originate from both animal and plant sources, with vegetable oils (such as olive, sunflower, soybean, and palm oil) being the most commonly used in industrial applications. However, the composition of fatty acids varies widely depending on the source, which directly influences their nutritional quality and functional behavior.

In addition to their beneficial roles, lipids also present several challenges, particularly related to human health and food stability. Excessive consumption of saturated fats has been associated with cardiovascular diseases, while unsaturated fats are generally considered healthier. Furthermore, lipids are highly susceptible to oxidation, leading to rancidity and loss of nutritional value, which makes their processing and storage critically important.

The fats and oils industry includes several key technological steps such as extraction, refining, modification (hydrogenation, interesterification), and fractionation. These processes are designed to improve the stability, functionality, and safety of lipid-based products while adapting them to specific industrial needs.

The aim of this work is to provide a comprehensive overview of fats and oils, focusing on their chemical structure, physicochemical properties, technological processing, nutritional aspects, and industrial applications in the food sector.

Chapter I

Nutritional importance and benefits of fats

Chapter I: Nutritional Importance and Benefits of Fats

Introduction

Fats, or lipids, are a major class of biomolecules essential for the functioning of the human body. Their role is not limited to a simple energy intake, but extends to complex biological functions including cell structuring, metabolic regulation, intracellular signaling and protection against various physiological aggressions. Recent advances in nutrition and biochemistry have led to a better understanding of their involvement in preventing chronic diseases and maintaining physiological balance.

I. Energy role: metabolic integration and physiological adaptation

Lipids represent the main form of energy storage in higher organisms. In the form of triglycerides accumulated in adipose tissue, they constitute a strategic energy reserve that can be mobilized during energy deficit situations.

Lipid mobilization is based on a process finely regulated by hormones such as glucagon, adrenaline and insulin. Lipolysis releases free fatty acids which are transported to the consuming tissues (muscle, liver) bound to albumin. Once internalized, these fatty acids undergo mitochondrial β-oxidation producing acetyl-CoA, NADH and $FADH_2$.

Under conditions of prolonged fasting or diabetes, excess acetyl-CoA leads to the formation of ketone bodies (acetoacetate, β-hydroxybutyrate), which are an essential alternative energy source for the brain.

This metabolic flexibility gives lipids a central role in the body's adaptation to variations in energy intake.

II. Membrane dynamics and cell organization

Biological membranes consist of a dynamic lipid matrix composed mainly of phospholipids, glycolipids and cholesterol. This lipid bilayer organization is not static but highly dynamic.

The concept of fluid mosaic emphasizes the importance of lipid-protein interactions in the membrane. The nature of the fatty acids (chain length, degree of unsaturation) directly influences bilayer fluidities, permeability and membrane protein activity. Membrane microdomains, called lipid rafts, rich in cholesterol and sphingolipids, play a key role in cell signaling, endocytosis and cell recognition.

III. Lipids and molecular signaling

Lipids are at the heart of cellular communication mechanisms. They act as direct precursors or mediators of many signaling pathways. Among the lipid-derived molecules, we distinguish:

- **Eicosanoids**: derivatives of arachidonic acid, involved in inflammation, immunity and hemostasis
- **Sphingolipids**: involved in apoptosis and cell proliferation
- **Endocannabinoids**: regulate appetite, pain and mood

These lipid mediators ensure rapid and localized communication between cells, which is essential for maintaining homeostasis.

IV. Essential fatty acids: role in inflammation and immunity

Essential polyunsaturated fatty acids (PUFAs), including omega-3 and omega-6, play a key role in regulating the inflammatory response.

Omega-6s (linoleic acid arachidonic → acid) are generally associated with the production of pro-inflammatory mediators. Conversely, omega-3s (EPA, DHA) give rise to anti-inflammatory mediators such as resolvins and protectins.

The balance between these two families conditions the inflammatory state of the body. An imbalance, common in modern diets, is associated with pathologies such as cardiovascular diseases, type 2 diabetes and neurodegenerative diseases.

V. Lipids and gene expression (nutrigenomic)

Lipids are not only energetic substrates; they also act as regulators of gene expression.

Some fatty acids activate nuclear receptors such as PPAR (Peroxisome Proliferator-Activated Receptors) and LXR (Liver X Receptor).These receptors modulate the

expression of genes involved in lipid metabolism, anlagen and the inflammatory response. This role paves the way for nutrigenomics, a discipline that studies the impact of nutrients on gene expression.

VI. Role in the nervous system and neuroprotection

The brain is composed of nearly 60% lipids (in dry matter), which underlines their importance in cognitive functions. Omega-3 fatty acids, especially DHA, are essential for the formation of snaps, bilayer fluidities and neurotransmitter transmission. They also play a neuroprotective role by limiting oxidative stress and neuronal inflammation. Deficiency is associated with disorders such as cognitive decline, depression and neurodegenerative diseases (e.g. Alzheimer's).

VII. Lipids, gut microbiota and immunity

Recent research has highlighted the interaction between dietary lipids and gut microbiota. Fatty acids influence the composition of microbiota, intestinal of permeability and the immune response. Short-chain fatty acids (butyrate, propionate), produced by fiber fermentation, play a key role in gut health and immune regulation.

VIII. Role in the transport of micronutrients and bioactive compounds

Lipids facilitate the absorption not only of fat-soluble vitamins, but also of many bioactive compounds such as carotenoids, lipophilic polyphenols and sterol. They are involved in the formation of chylomicrons, ensuring the transport of these molecules via the lymphatic system.

IX. Chronic disease prevention.

Lipids play an ambivalent role depending on their nature.

IX.1. Beneficial effects:

monounsaturated fatty acids cardiovascular → protection

omega-3 anti-inflammatory → anti-inflammatory effect

phytosterols cholesterol → cholestérol reduction

IX.2. Deleterious effects

trans fatty acids → increased cardiovascular risk

excess saturated fat → dyslipidemias

Chapter II

Natural Lipid-Rich Foods

Chapter II: Natural lipid-Rich Food

Introduction

Lipids are essential macronutrients naturally present in a wide variety of foods and play a fundamental role in human nutrition. Natural lipid-rich foods are characterized not only by their high fat content but also by the diversity of their fatty acid composition and the presence of numerous bioactive compounds. These foods provide a concentrated source of energy and contribute significantly to physiological functions such as cell membrane structure, hormone synthesis, and metabolic regulation. The nutritional value of these foods depends largely on the nature of the lipids they contain, particularly the balance between saturated and unsaturated fatty acids. This chapter aims to present a comprehensive overview of natural foods rich in lipids, focusing on their origin, composition, and nutritional importance.

I. Definition and general characteristics of lipid-rich foods

Lipid-rich foods are generally defined as foods containing a significant proportion of fats, typically exceeding 20% of their total composition. These foods are distinguished by their high energy density, as lipids provide approximately 9 kilocalories per gram, which is more than twice the energy provided by carbohydrates or proteins. In most natural lipid-rich foods, fats are primarily present in the form of triglycerides, which consist of glycerol esterified with three fatty acids. The physicochemical and nutritional properties of these foods depend on the type of fatty acids they contain, including saturated, monounsaturated, and polyunsaturated fatty acids. In addition, these foods often contain minor compounds such as vitamins, sterols, and antioxidants that further enhance their biological value.

II. Plant-based lipid-rich foods

Natural foods of plant origin constitute a major source of dietary lipids, particularly unsaturated fatty acids, which are widely recognized for their beneficial effects on human health. Vegetable oils represent the most concentrated form of lipids in nature, with fat contents approaching 100 percent. These oils are extracted from seeds or fruits such as olives, sunflower seeds, soybeans, and palm fruits. Their composition is dominated by

triglycerides, but they also contain significant amounts of minor components such as tocopherols and polyphenols, which act as natural antioxidants. The fatty acid profile of vegetable oils varies depending on their botanical origin, with olive oil being rich in oleic acid, sunflower oil in linoleic acid, and flaxseed oil in alpha-linolenic acid. These differences influence both their nutritional properties and their stability during storage and processing.

In addition to oils, oilseeds and nuts represent another important category of plant-based lipid-rich foods. These include almonds, walnuts, peanuts, sesame seeds, and flaxseeds, which typically contain between 40 and 70 percent lipids. Beyond their fat content, these foods are also rich in proteins, dietary fiber, and bioactive compounds such as polyphenols. The lipids present in nuts are predominantly unsaturated, contributing to improved lipid metabolism and cardiovascular health. Regular consumption of nuts has been associated with a reduction in low-density lipoprotein cholesterol and an increase in high-density lipoprotein cholesterol, highlighting their protective role against cardiovascular diseases.

Certain fruits also contain significant amounts of lipids, with avocado and olives being notable examples. Avocado is unique among fruits due to its high lipid content, which can reach up to 30 percent. Its lipids are mainly composed of monounsaturated fatty acids, particularly oleic acid, which is known for its beneficial effects on heart health. Similarly, olives are rich in lipids and serve as the primary source of olive oil. These fruits play a central role in dietary patterns such as the Mediterranean diet, which is widely recognized for its positive impact on health and longevity.

III. Animal-based lipid-rich foods

Foods of animal origin also contribute significantly to lipid intake in the human diet. Dairy products such as butter, cream, and cheese are among the most important sources of animal lipids. These products are characterized by a high content of saturated fatty acids, as well as the presence of cholesterol and fat-soluble vitamins such as vitamins A and D. While these nutrients are essential for growth and physiological functions, excessive consumption of saturated fats has been linked to an increased risk of cardiovascular diseases. Therefore, moderation in the intake of these products is recommended.

Meat and animal fats represent another major category of lipid-rich foods. Fats derived from beef and pork, commonly known as tallow and lard, are widely used in both traditional cooking and food processing. These fats contain a mixture of saturated and monounsaturated fatty acids and provide a high energy value. However, their high saturated fat content requires careful consumption to avoid negative health effects associated with excessive intake.

In contrast, fish and marine products are considered particularly beneficial sources of lipids due to their high content of long-chain polyunsaturated fatty acids, especially omega-3 fatty acids such as EPA and DHA. These fatty acids play a crucial role in brain function, inflammation regulation, and cardiovascular health. Fatty fish such as salmon, sardines, and mackerel are therefore highly recommended as part of a balanced diet. Their regular consumption has been associated with a reduced risk of chronic diseases, including heart disease and neurodegenerative disorders.

IV. Minor bioactive compounds in lipid-rich foods

In addition to their major lipid components, natural lipid-rich foods contain a variety of minor bioactive compounds that contribute to their nutritional and functional properties. These include tocopherols, which act as natural antioxidants and protect lipids from oxidative degradation, as well as phytosterols, which have been shown to reduce cholesterol absorption in the human body. Carotenoids, present in certain plant oils and fruits, serve as precursors of vitamin A and contribute to visual health and immune function. Polyphenols, particularly abundant in olive oil, play an important role in reducing oxidative stress and inflammation. The presence of these compounds enhances the overall health benefits of lipid-rich foods and highlights the importance of consuming them in their natural and minimally processed forms.

V. Factors influencing lipid composition

The lipid composition of natural foods is influenced by several factors related to both biological and environmental conditions. In plant-based foods, the fatty acid profile depends on the species, variety, and climatic conditions under which the plant is grown. Temperature, soil quality, and agricultural practices can significantly affect the synthesis of fatty acids and the accumulation of lipids in plant tissues. In animal-based foods, the

diet and living conditions of the animal play a crucial role in determining the composition of fats. For example, animals fed on grass tend to produce fats with a higher proportion of unsaturated fatty acids compared to those fed on grain-based diets. In addition, processing and storage conditions can alter the lipid composition through oxidation and degradation reactions, thereby affecting both nutritional quality and sensory characteristics.

VI. Nutritional and health implications

Lipid-rich foods play a vital role in maintaining human health, but their effects depend largely on the quality and quantity of fats consumed. Unsaturated fatty acids, particularly those of plant origin and marine sources, are associated with numerous health benefits, including improved cardiovascular function and reduced inflammation. In contrast, excessive intake of saturated fats and trans fats has been linked to the development of metabolic disorders such as obesity, dyslipidemia, and cardiovascular diseases. Therefore, it is essential to adopt a balanced dietary approach that emphasizes the consumption of high-quality lipid sources while limiting the intake of less desirable fats.

Conclusion

Natural lipid-rich foods constitute an essential component of human nutrition, providing energy, essential fatty acids, and a wide range of bioactive compounds. Their diversity allows for a balanced and varied diet that supports health and well-being. However, the nutritional value of these foods depends not only on their lipid content but also on the type of fatty acids and associated compounds they contain. A dietary pattern that prioritizes plant-based lipids and omega-3-rich foods, while limiting saturated and trans fats, is fundamental for promoting long-term health and preventing chronic diseases.

Chapter III

The main constituents of fats

Chapter III: The main constituents of fats

Introduction

This chapter focuses on the chemical composition and molecular structure of fats and oils. It explains the structure of triglycerides, fatty acids, and minor lipid components such as phospholipids and sterols. A clear understanding of lipid chemistry is essential for explaining their physical behavior, nutritional value, and reactivity during processing and storage.

I. Definition of fatty substances

Fatty substances are part of a very complex set of organic compounds, the lipids present in animal and plant tissues. These are biomolecules characterized by their:

- Insolubility in water
- Their creamy (oily) feel.
- Solubility in organic solvents (ether, hexane, benzene and chloroform)

They result from the esterification of fatty acids by an alcohol or an amine.

II. Classification

Fats are divided into two groups according to their origins:

- **Fat of vegetable origin:** mainly comes from oilseeds (rapeseed, sunflower, soya, peanut, etc.) and pulps of certain oil fruits (palm fruit, olive, etc.).
- **Fat of animal origin:** which are tallow, lard, bacon, butter, fish oil and aquatic vertebrae.

Fats can also be classified according to their consistency, as follows:

- ***The fluid state*:** oils;
- ***The solid state*:** fats;
- ***The waxy state*:** waxes.

III. Composition of fats

Fats consist of a complex mixture of triglycerides (esters of glycerol and fatty acid) 97 to 99% and unsaponifiable substances, minor constituents 1 to 3%.

A crude fat, as found in the natural state, consists of several essential groups of compounds.

III.1. Fatty acids

Fatty acids are organic molecules consisting of a single functional group: a carboxylic function (monocarboxylic or mono-acid). The rest of the molecule consists of a longer or shorter carbon chain, called an aliphatic chain (Figure 1).

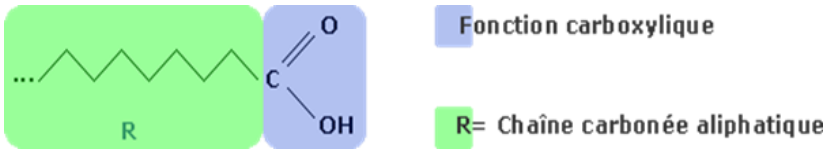


Figure 1: fatty acid structure

Fatty acids are differentiated on the one hand, by the number of carbons, on the other hand, by the presence or absence of establishment (i.e. double bond or ethylenic bond).

Fatty acids are predominant components by weight of triglycerides which represent 90 to 99% of the molar mass. They are generally monocarboxylic with a number of carbon atoms greater than four (4 to 24). The vast majority of fatty acids have an even number of carbon atoms. They can be saturated or unsaturated and more often unbranched.

Depending on the length of its carbon chain, a fatty acid is said to:

- short chain if the number of carbon atoms is ≤ 6
- chain averages if the number of carbon atoms is between 10 and 14
- long chains if the number of carbon atoms is between 16 and 18
- very long chain if the number of carbon atoms is ≥ 20.

There are two types of fatty acids:

a) Saturated fatty acids

Their general formula is $C_nH_{2n}O_2$ or $CH_3(CH_2)_nCOOH$, we distinguish:

- Even-numbered fatty acids (Table I);
- Fatty acids with an odd number of carbons (Table II)

Table I: Saturated fatty acids with even number of carbons.

fatty acids	*Number of carbons*	*Formula*	*Common name*
Botanical	4:0	CH_3-$(CH_2)_2$-COOH	Butyric
Hexanoic	6:0	CH_3-$(CH_2)_4$-COOH	Caproic
Octanoic	8:0	CH_3-$(CH_2)_6$-COOH	Caprylic
Decanoic	10:0	CH_3-$(CH_2)_8$-COOH	Capride
Dodecanoic	12:0	CH_3-$(CH_2)_{10}$-COOH	Laurique
Tetradecanoic	14:0	CH_3-$(CH_2)_{12}$-COOH	Palmitic acid
Hexadecanoic	16:0	CH_3-$(CH_2)_{14}$-COOH	Myristic
Octadedecanoic	18:0	CH_3-$(CH_2)_{16}$-COOH	stearic
Oecosanoic	20:0	CH_3-$(CH_2)_{18}$-COOH	Arachidic
Decasonoeque	22:0	CH_3-$(CH_2)_{20}$-COOH	Butanic
Tetracosanoic	24:0	CH_3-$(CH_2)_{22}$-COOH	Lignocèric
Haxacosanoic	26:0	CH_3-$(CH_2)_{24}$-COOH	Cerotic

Table II: Saturated fatty acids with an odd number of carbons.

fatty acids	*Number of carbons*	*Formula*	*Common name*
Heptanoic	7:0	CH_3-$(CH_2)_5$-COOH	Heptilique
Nonanoic	9:0	CH_3-$(CH_2)_7$-COOH	Pelargaric
Hundecanoic	11:0	CH_3-$(CH_2)_9$-COOH	Undecyl
Pentadecanoic	15:0	CH_3-$(CH_2)_{13}$-COOH	Pentadecelic
Heptadecanoic	17:0	CH_3-$(CH_2)_{15}$-COOH	Margaric

- Nomenclature of saturated fatty acids

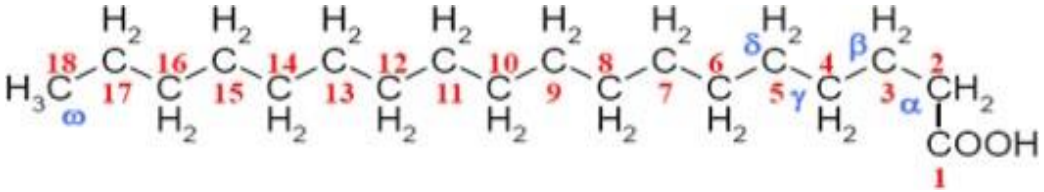
Each saturated fatty acid usually has two names: a common name that often recalls its origin (for example, caproic acid found in goat's milk, its name is derived from the

Latin name "capra" which means goat); and a systematic name describing its structure (number of carbons) (Table III).

Table III: Nomenclature of saturated fatty acids.

Systematic name	**n-[nC] an oic**
	n: indicates that the fatty acid is normal (chain not connected) **[nC]:** number of carbons **year:** indicates that the chain is saturated
Symbol	CN.
	Cn: number of carbons **0:** indicates that the chain is saturated
Common name	Recalls its origin

Example: Stearic acid.



- **Systematic name:** Octodecanoic acid
- **Symbol:** C18:0
- **Common name**: Stearic acid
-

b) Unsaturated fatty acids

These are fatty acids that have one or more double bonds, we distinguish:

- **Monounsaturated or monoenic fatty acids:** their general formula is

$$CH_3 - (CH_2)_X - CH = CH - (CH_2)_Y - COOH \quad \text{with} \quad X + Y = n - 4$$

Their double bonds are in Cis form (the two hydrogens on the same side) or Trans form (the two hydrogens are opposite) (Figure 2).

***CIS* Configuration** ***Trans* Configuration**

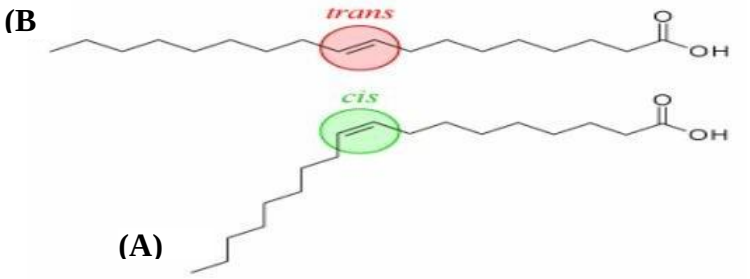


Figure 2: Cis (A) and Trans (B) configuration of unsaturated fatty acids

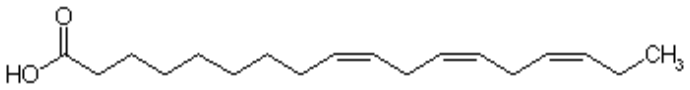
- **Polyunsaturated fatty acids**

They have several double bonds in the same chain. Linoleic acid (omega 6 family) and linolenic acid (omega 3 family) cannot be bio-synthesized by the body (only plants are capable of this). As they are necessary for the functioning of the body, they must be provided by food. We're talking about essential fatty acids.

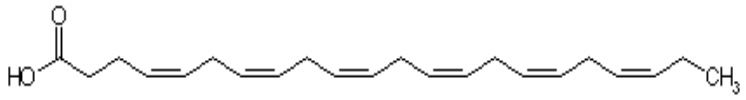
-Nomenclature of unsaturated fatty acids

In the same way as saturated fatty acids, unsaturated fatty acids also have a common name related to their origin and a systematic name describing its structure. Added to this is a nomenclature often used in physiology and biochemistry which is based on the number of carbon atoms, the number of establishments and the position of the first double bond. For example, the fatty acid**: Cx: y w-z** consists of x carbon, y double bond and the first of which is at the **z^{th} position** starting from the side opposite the acid group. There are 3 families of unsaturated fatty acids, the family of **3,** the family of des, the family of figure 3)

- **Family 3:**

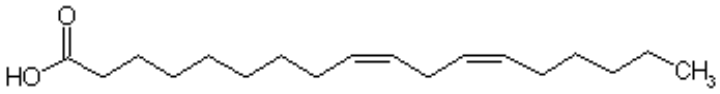


Linolenic acid (18:3 $\Delta^{9,12,15}$ or 3, 6, 9)



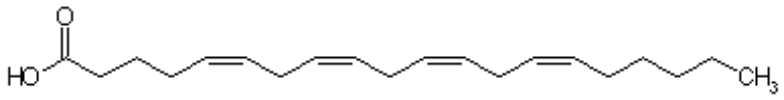
Docosahexaenoic acid (22:6 $\Delta^{4,7,10,13,16,19}$ or 3, 6, 9, 12, 15, 18)

- **Family 6:**



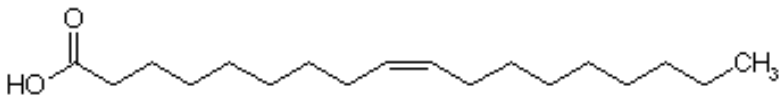
Linoleic acid (18:2 $\Delta^{9,12}$ or 6,9)

Linolenic acid (18:3 Δ $^{6,9,12 \text{ or } 6,9,12}$)

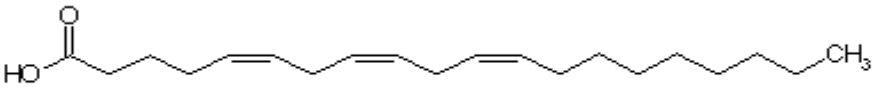


Arachidonic acid (20:4 $\Delta^{5,8,11,14}$ or 6, 9, 12, 15)

- **Family 9:**



Oleic acid (18:1 Δ9 or 9)



Eicosatrienoic acid (20:3 Δ5, 8, 11 or 9, 12, 15)

Figure3: Families of unsaturated fatty acids

- ***Notion of Essential Fatty Acids (EFA) and Indisponsible Fatty Acids (IFA)***

There are two EFA: *linoleic acid* (C18:2, -6) and *alpha linolenic acid* (C18:3, -3). Each of them belongs to a different family; the first is from the omega 6 family and the second is from the omega 3 family. Linoleic acid is mainly contained in Essential fatty acids represent fatty acids that the body is unable to synthesize itself. These fatty acids must therefore be provided by the diet. From them the body is then able to synthesize the other fatty acids, which the body needs to function. These last fatty acids that can be synthesized are called *Essential Fatty Acids*.

Some vegetable oils called vièrges and first cold pressing (peanut oil, evening primrose, sunflower, safflower oils, etc.), in eggs, dairy products, in wild game meat (especially in the liver). Alpha-linolenic acid comes from green plants, certain aquatic plants (e.g. Spirulina), seafood (cold sea fish oils such as salmon, halibut, mackerel, etc.), certain vegetable oils (borage, nut, soybean, flax oils, etc.). The two acids together make up what was once called *Vitamin F.*

III. 2. Glycerides (acyl-glycerols)

They are esters of fatty acids (R-COOH) and glycerol ($C_3H_8O_3$). Their general formula is:

CH2 — COOR1
|
CH — COOR 2
|
CH2 — COOR3

Where R1, R2, R3 are straight chain organic acid radicals with an even number of carbon atoms and generally between 4 and 24. These acids may or may not be saturated.

Glycerol has two primary alcohol functions and one secondary alcohol function. The esterification of one of these functions with a fatty acid gives a monoglyceride. The esterification of two functions by two fatty acids gives a diglyceride and the esterification of three functions forms a triglyceride (which may or may not be homogeneous) (Figure 3).

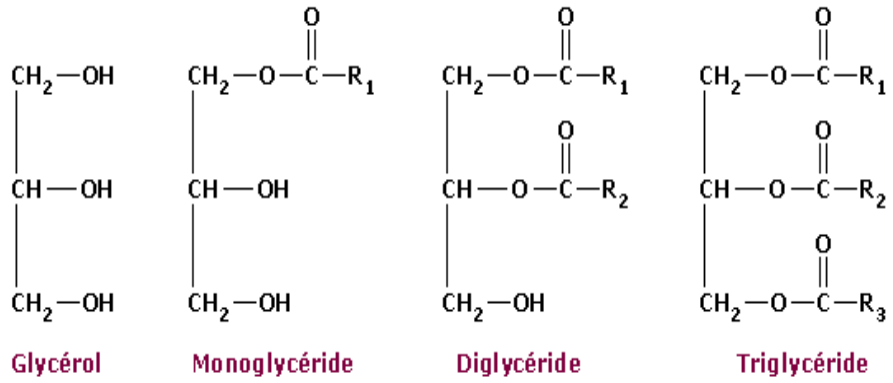


Figure4: Glycerides

- **Nomenclature**

The conventional nomenclature is often replaced by names based on the usual names of fatty acids, possibly followed by the number of the carbon to which each chain is linked (palmityl 1, stearyl 2, oleyl 3 glycerol or tristearin). The names of glycerides are often replaced by abbreviated symbols, a consequence of the characteristic abbreviation association of each fatty acid.

The abbreviations are placed one after the other in the order of the numbering of the strings: palmito1, stearo 2, linoline 3: PSL.

III. 3. Phospholipids (Phosphatides)

These are compounds consisting of a glycerol molecule esterified in position one or two, by fatty acids, and in position three by phosphoric acid which itself can be associated with a nitrogenous alcoholic base or an amino acid.

a) Glycerophosphoric ester

This is glycerol mono phosphate.

b) Phosphatid acids themselves

They are mixed esters of fatty acids and phosphoric acids (Figure 5).

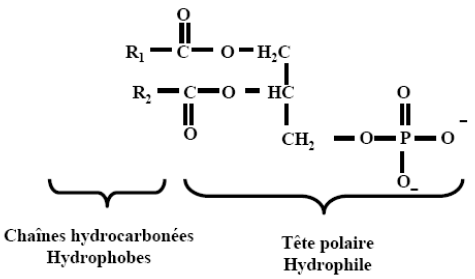


Figure5: General structure of phosphatidic acids

c) Phosphoglycerides

They are 1,2-diglycerides with a phosphoric residue in the 3-position, itself having a hydroxylated amine (choline or ethanol amine) (Figures 6 and 7) or a hydroxyamino acid (serine) (Figure 8).

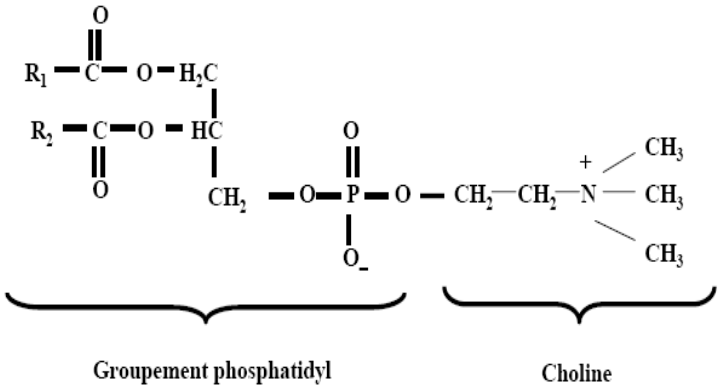


Figure 6: Phosphatidyl-cholines or lecithins

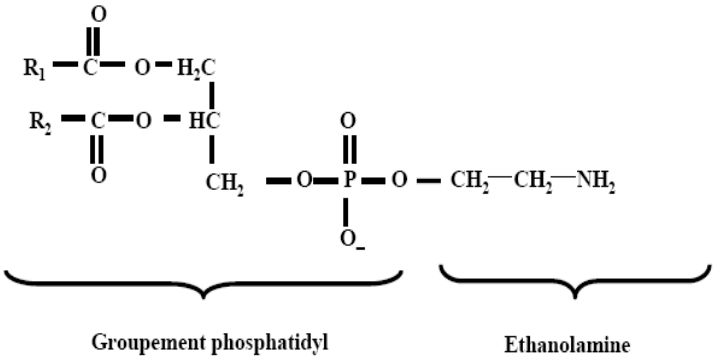


Figure7: Phosphatidyl-ethanolamines or cephalins

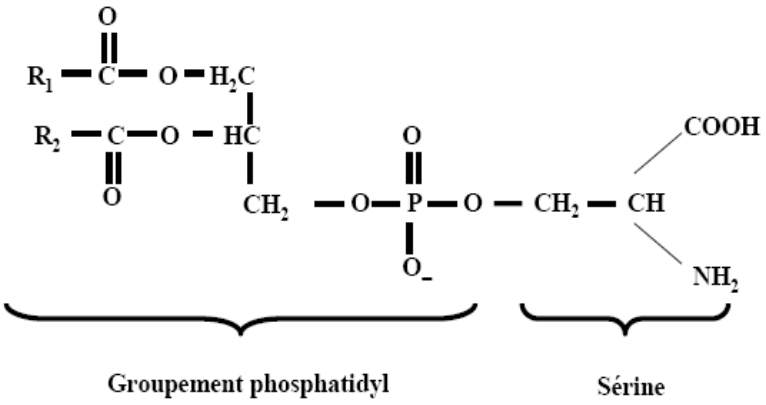


Figure8 : Phosphatidyl-serines

As opposed to triglycerides, glycerophospholipids are polar bodies with two dissociable functions: acid and amine. This explains their essential hydrophilic property. Although they are fatty in nature, they constitute a bridge between the fatty phase and the aqueous phase. They have a high aptitude for the formation of lipoprotein sheets, constituting membranes.

d) Sphingomyelins

These phosphatides are the essential part of mucilages. Some have the property of hydrating and precipitating under the action of phosphoric acid. Here, it is an amide bond that unites the fatty acid with the alcohol (Figure 9).

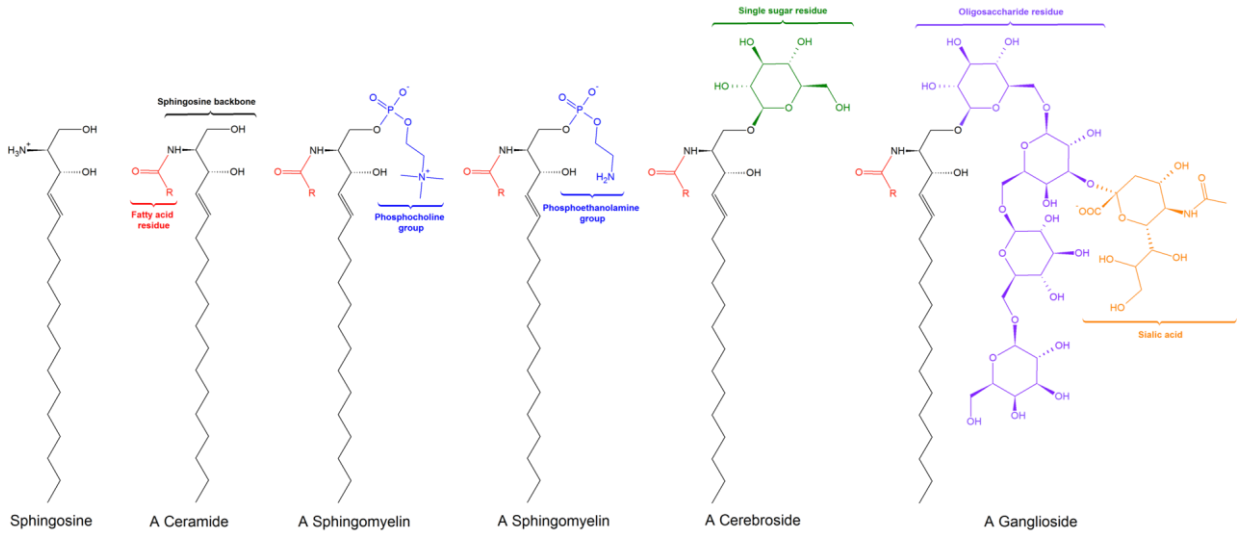


Figure 9: Sphingomyelins

III. 4. Unsaponifiables

The unsaponifiable fraction of a fatty substance comprises the set of constituents which, after basic hydrolysis (saponification), are very sparingly soluble in water and soluble in lipid solvents (hexane and ether).

The proportion of unsaponifiable contained in a fatty substance obviously depends on the biological origin of this fatty substance, the treatments it may have undergone (refining, as well as the nature of the extraction solvent (diethyl ether and hexane), a particularly important factor: in general, the unsaponifiable fraction of an unrefined

liquid has about 0.2 to 2%, the average being around 1%, although there are proportions that can exceptionally go up to 10% (Shea butter). The main unsaponifiables of fats are:

a) Waxes

They are complex mixtures of long-chain fatty acid esters (22 to 30 carbon atoms) and higher long-chain fatty alcohol (C_{18} to C_{30}) found naturally in sunflower, cotton and pure oils.

b) Fat-soluble vitamins

Four vitamins belong to these categories: vitamins A, D, E and K. They are related to lipids by their insolubility in aqueous medium. By definition, vitamins are organic molecules with no energy value, essential for the functioning of the body. Therefore, they must be provided through the diet.

Fatty substances obtained by pressure or by extraction with a solvent may contain a more or less significant amount of fat-soluble vitamins: vitamin A, D, E and K.

Vitamin E is present in all natural lipids, but vitamins A and D are only found in specific fats.

- **Vitamin A or retinol:** Vitamin A1 (retinol), which is a conjugated polyethylinic alcohol derived from the cleavage of B-carotene (provitamin A), is mainly found, in the form of palmitate, in animal fats (butter, liver oil, tallow, lard,etc.). Vegetable oils are devoid of it, while being able to provide B-carotene. Vitamin A has several roles, it has an effect on growth. In the body, retinol comes either from food or from biosynthesis from carotenes of plant origin (Figure 10).

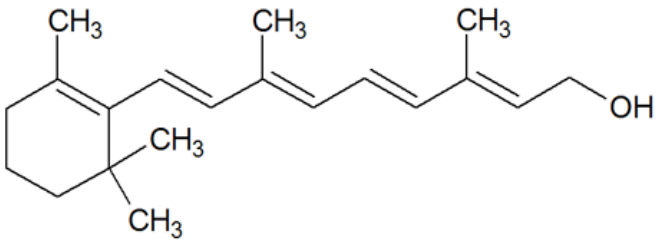


Figure 10: Vitamin A structure

- **Vitamin D or calciferol:** Vitamin D exists in two biologically active forms. Vitamins D2 (ergocalcipherol) and D3 (cholecaciferol) differ only in their side-

chain structure. Vitamin D2 is mainly found in fish oils, butter and animal fats (Figure 11).

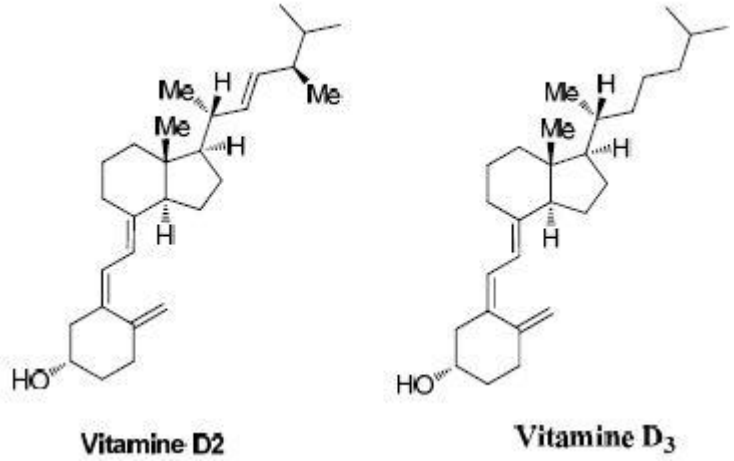


Figure1: Vitamin D structure

- **Vitamin E:** alpha tocopherol is the most active form of vitamin E, it is a powerful antioxidant that protects unsaturated fatty acids sensitive to oxidation. Tocopherols are abundant in crude vegetable oils, some of which disappear during refining, especially during deodorization. They generally represent 200 to 1200 mg/kg of unrefined vegetable oil, fish oils contain 500 to 600 mg/kg or 100 to 200 mg/kg depending on whether they are lean or fatty fish. Although animal fats (beef, sheep, pork) are poor (10 to 20 mg/kg), butter provides significant amounts (20 to 50 mg/kg) (Figure 12).

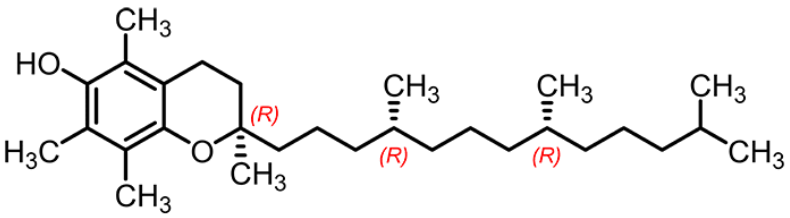


Figure 12: Vitamin E structure

- **Vitamin K:** Vitamin K contains several molecules. The main forms are vitamin K1 (phylloquinone) of plant origin, vitamin K2 (menaquinone) of animal origin. Vitamin K is an anti-hemorrhagic agent that has an important role in blood clotting (Figure 13).

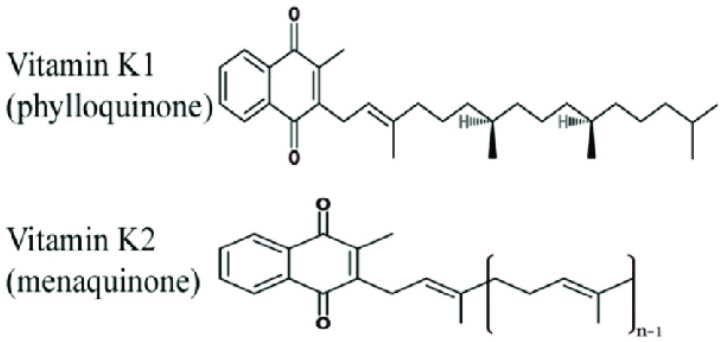


Figure 13: Vitamin K Structure

c) Sterols

They are cyclic compounds, of high molecular weight, with an alcohol function. They are found in the free state or esterified with a fatty acid. It represents 30 to 60% of the unsaponifiable.

In the animal kingdom, the main sterol is cholesterol (Figure 14), in the plant kingdom, we talk about phytosterols and ß-ketosterols.

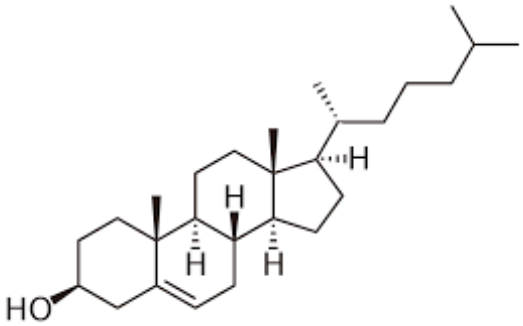


Figure 14: Cholesterol structure

d) Hydrocarbons

The unsaponifiable of natural lipids, always contains a small amount of various hydrocarbons, it is generally of the order of 10% of the unsaponifiable fraction. We find

- Saturated or unsaturated aliphatic hydrocarbons, which have a carbon condensation between 11 and 35.
- Hydrocarbons of triterpene origin.

Squalene, a hrxa-unsaturated hydrocarbon with 30 carbon atoms, is frequently found in plant and animal fats (liver and fish oils, etc.).

e) Carotenes and carotenoids

Carotenes include conjugated aliphatic lycopersenes formed as a result of the dehydration reaction. Carotenoids are tetraterpenes from the evolution of lycopersene; a hydrocarbon with eight unconjugated double bonds and 40 carbon atoms. They contain :

- **Carotenes:** they are synthesized only by plants, with a particularly high content in palm oil (500 to 800 mg/kg). These compounds are often coloured, due to the presence of conjugated double bonds, and contribute to the colouring of vegetable oils. The main carotenes are B-carotene and its isomers (Figure 15).

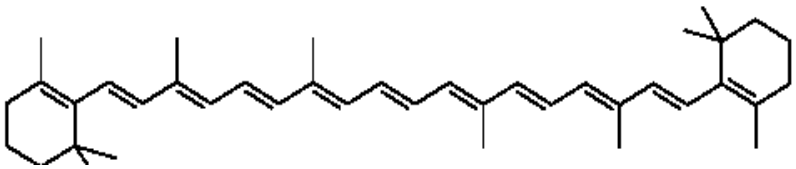
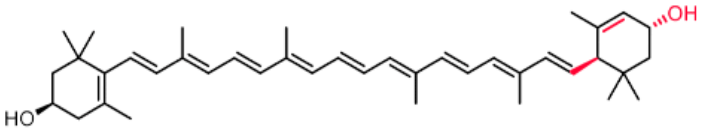
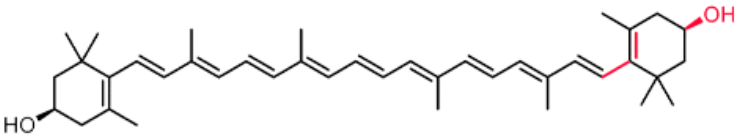


Figure 15: Structure of B-carotene

- **Xanthophylls:** substances that are also coloured, lipophilic and produced only by plants. The main xanthophylls encountered are zeaxanthin from corn oil and lutein (Figure 16).



lutein



Zeaxantine

Figure 16 : Xanthophyll structure

f) Chlorophylls and their derivatives

Chlorophylls a and b are green pigments of plants, they are fat-soluble. The loss of magnesium cations converts them into lipophilic a and b pheophytins (Figure 17).

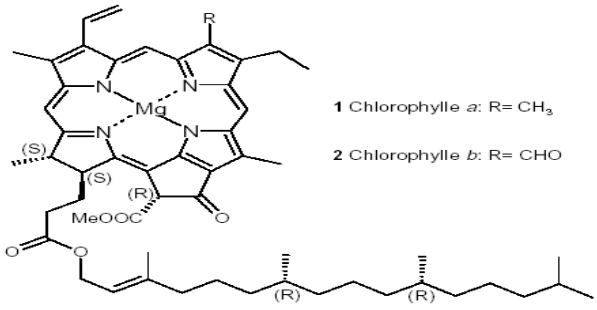


Figure 17: Structure of chlorophyll

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g) Phenolic compounds

Phenolic compounds are specific molecules of the plant kingdom, located in different parts of the plant according to the plant species and the polyphenolic group considered. The basic element that characterizes polyphenols is the presence of one or more 6-carbon phenolic nuclei, to which is directly linked to at least one free hydroxyl (OH) group; or engaged in another function: ether, ester or heteroside**;** In this family of molecules are many substances that can be classified according to their structure into five main groups: phenol acids, flavonoids, anthocyanins and tannins. Polyphenols are synthesized by plants during secondary metabolism in order to defend against environmental aggressions (figure 18 and 19).

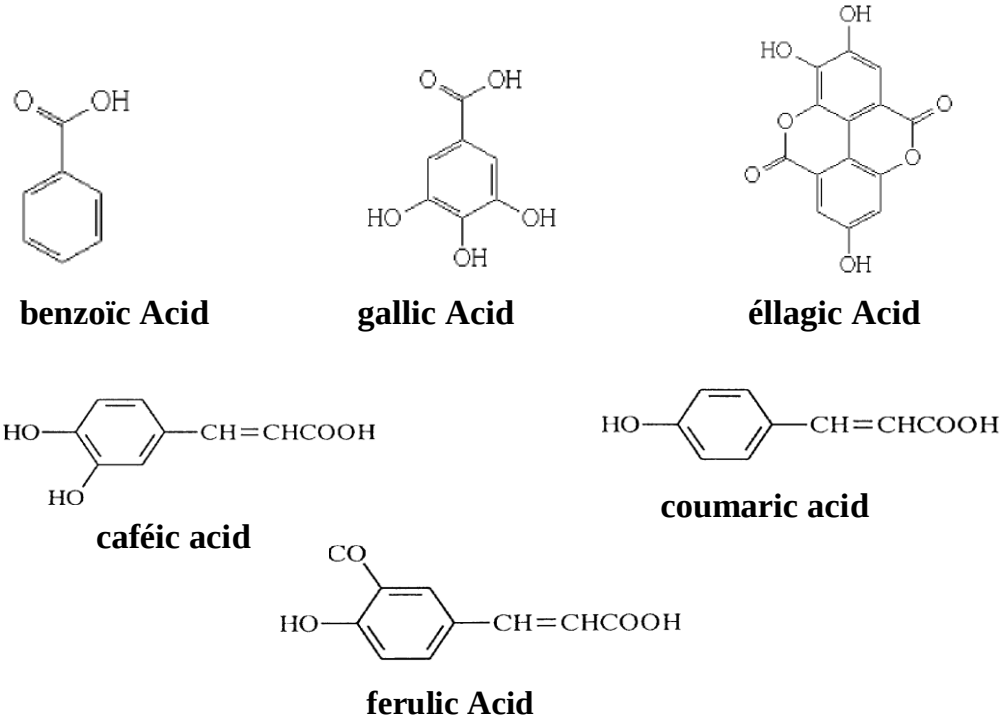


Figure 18 : Structure of somme phénolic acids

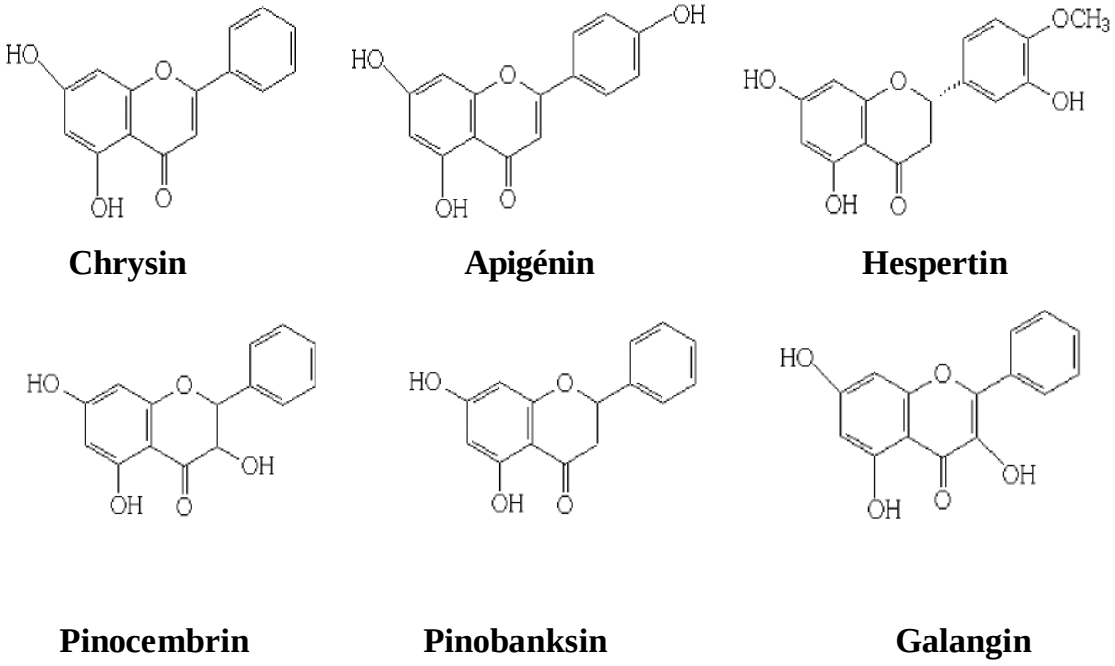


Figure 19: Structure of somme flavonoïds

Conclusion

This chapter has demonstrated that the properties of fats and oils are directly linked to their chemical structure. The type and arrangement of fatty acids significantly influence their nutritional and technological characteristics. This knowledge is essential for understanding the behavior of lipids during industrial processing and food formulation.

Chapter IV

Physico-chemical properties of fat

Chapter IV: Physico-chemical properties of fats

Introduction

This chapter explores the physicochemical properties of fats and oils, including melting point, crystallization behavior, solubility, and oxidative stability. These properties determine the functional behavior of lipids in food systems and influence their industrial applications. Understanding these characteristics is crucial for controlling quality and stability during processing and storage.

I. Physical Properties

I.1.Density

Fatty acids have a lower density than water (reference density), which is why the oil rises to the surface of the water when the emulsion is not stabilized.

II.2. Solubility

Short-chain fatty acids are water-soluble, but as soon as the number of carbon atoms in the chain increases, they become insoluble. They are soluble in organic solvents such as benzene, ether or chloroform. Similarly, the higher the number of double bonds, the lower the solubility.

II.3. Melting point (mp) and boiling point

It is the temperature at which the fat changes from the solid state to the liquid state) At room temperature, fatty acids are in the liquid state if the number of their carbon atoms is less than 10; they are in the solid state if they have more than 10 carbon atoms. The presence of double bonds in a fatty acid lowers its melting point compared to that of the corresponding saturated fatty acid.

The melting point increases with the number of carbon and the presence of double bonds lowers the melting temperature.

Example :

- **C14 : 0 = 53.9°C**
- **C 16 : 0 = 63.1°C**
- **C18 : 1 = 13.4°C**

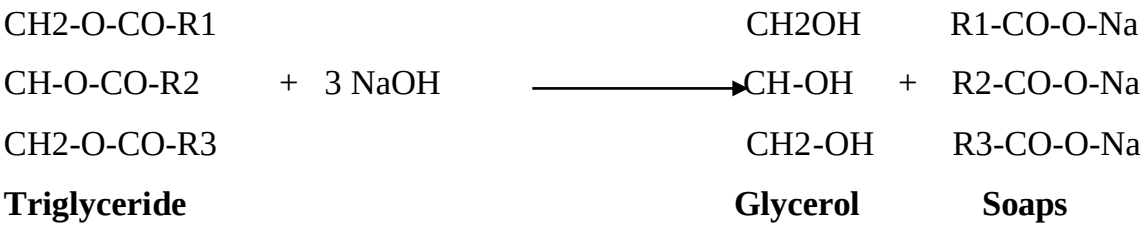
The boiling point of fatty acids is higher the longer the chain; the presence of double bonds is practically without influence.

II. Chemical properties

II.1 Properties Due to the presence of the carboxylic group (COOH)

a) Saponification (salt formation)

The hydrolysis of triglycerides by an alkali, a base (KOH, NaOH) provided with glycerol and salts of fatty acids called "soap".



- **Saponification Number**

This is the number of mg of potassium hydroxide or sodium hydroxide (KOH or NaOH) needed to saponify 1g of fat or fat. The higher the molecular weight of the lipid, the lower it will be.

b) Ester formation

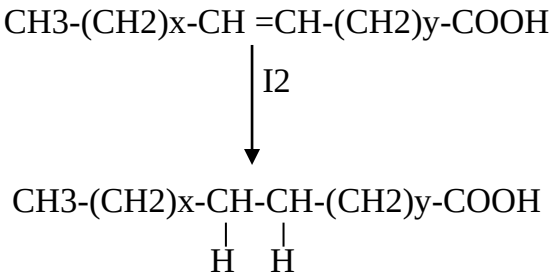
Fatty acids form esters with alcohols. The most important esters are: methyl esters used in gas chromatography (GPC).

II.2. Properties due to the presence of double bonds

a) Iodine number (degree of unsaturation) Halogenation

This is the amount in g of iodine fixed per 100g of fat. The higher the number of double bonds, the higher the iodine value.

The iodine value is constant for a pure fat. Its determination confirms (or not) the purity of a fat used in a food.



b) Hydrogenation (attachment of hydrogen to double bonds)

It converts the unsaturated guy acid into the corresponding fatty acid. Vegetable oils can be converted to solid fats by adding hydrogen to the double bonds of unsaturated fatty acids. This is the principle used in the manufacture of margarines from vegetable oils.

c) Lipid Oxidation

Lipid oxidation reactions lead to the formation of volatile compounds of unpleasant odor (rancidity) which limits the shelf life. These reactions can occur even in foods containing less than 1% lipids. The main substrates of oxidation are unsaturated (unsaturated) fatty acids; they usually oxidize faster in the free state than when they are part of triglyceride or phospholipid molecules.

Other unsaturated substrates may undergo oxidation reactions such as vitamin A, carotenoid pigments, and vitamin E.

Oxidation can lead to losses of vitamin activity and colour, just as oxidation of essential fatty acids causes a decrease in nutritional value.

Conclusion

The study of physicochemical properties shows that fats and oils exhibit complex behaviors influenced by their molecular structure. These properties play a key role in determining their functionality in food products. Proper control of these characteristics is essential to ensure product quality and stability.

Chapter V

Physico-chemical analysis of fatty substances

Chapter V. Physico-chemical analysis of fatty substances

Introduction

Often the first step in the analysis of fats will be to extract the fat from its matrix, whether it is an oleaginous raw material (seeds, fruits) or a food (meat, cheese, biscuit). Simple determinations by physico-chemical method (refractive index, acid index, iodine index, etc.) will give global and sometimes sufficient information. Generally, a deeper knowledge of the product is necessary and this will result from the combination of different methods often using sometimes sophisticated instrumental techniques such as gas and liquid chromatography.

I. Lipid extraction

The extraction of lipids is most often done directly with an apolar solvent (diethyl ether, petroleum ether, hexane) using the soxhlet apparatus (figure 20), after evaporation of the extraction solvent, the residue is dried and weighed.

This direct extraction is not complete when lipids are mechanically retained (cell walls) or chemically bound to other compounds such as proteins; in these cases, disaggregation is required prior to extraction. The latter can be done:

- by means of hydrochloric acid according to Weibull-Stoldt. Disaggregation by hot acid of all compounds other than lipids, which are then separated from the mixture by filtration and then extracted with a soxhlet. This technique is applied to foods cheese, seafood, sauces, meat
- using ammonia and ethanol according to the Röse-Gottlieb method for milks. After disintegration (or rather dissolution of the proteins and destruction of the envelope of the fat globules), the fat is extracted with ether and petroleum ether.
- enzymatic (amylases, protease) then extraction of lipids using the mixture methanol-chloroform (probably the most universal method).

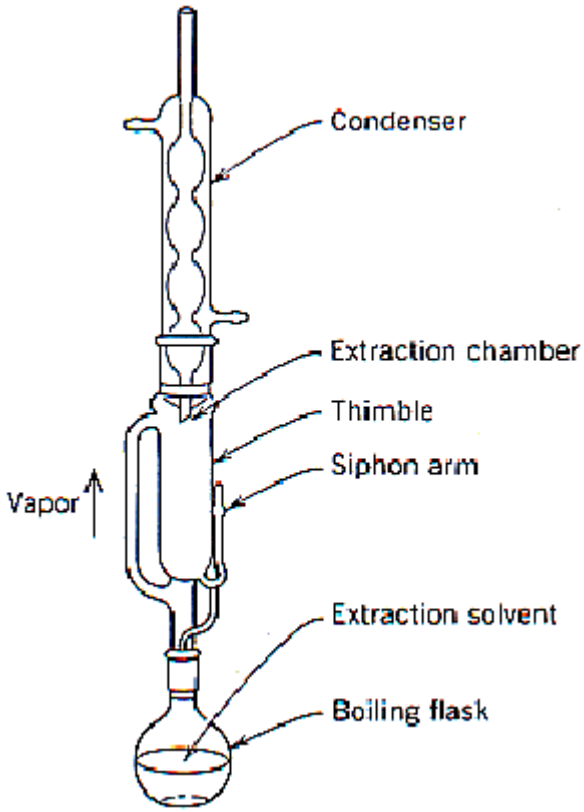


Figure 20: Soxhlet apparatus

II. Physicochemical characteristics of lipids

II.1. Refractive index

The refractive index is the refractive index of a substance is the ratio of the speed of light at a wavelength defined in vacuum to its speed in the substance. It is determined using a refractometer (figure 21). The value of the refractive index is related to the iodine index; it increases with the degree of establishment of the fatty acids contained in the fat. It is 1.468 – 1.472 for peanut oil, 1.472 - 1.478 for soybean oil, 1.467 – 1.469 for olive oil. For butter, the refractive index is between 1.453 and 1.456

It makes it possible to differentiate whether the fat belongs to the following two groups: vegetable lauric fats (R= 1.448 to 1.458) or animal lauric fats (R= 1.457 to 1.463) on the one hand and vegetable oil (R=1.468 to 1.490) or animal lauric fats (R= 1.471 to 1.485) on the other. However, it allows the monitoring of the operations of hydrogenation and fractionation of fats.

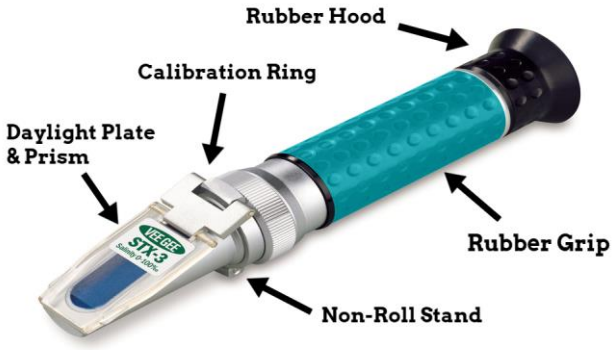


Figure 21: A refractometer

II.2. The acid number

This is the measurement of the amount of free fatty acids in a dietary fat. It is expressed by the number of mg of potassium hydroxide necessary to neutralize the fatty acidity present in a g of lipids. Depending on the nature of the fat, three modes of expression are used: in equivalent amount of oleic acid for the vast majority of fats, or palmitic for palm oil, or lauric for lauric fats (copra, palm kernel).

The determination of acidity is based on the neutralization of the free fatty acids present in the oil by a solution of sodium hydroxide (NaOH) or potassium hydroxide (KOH) in the presence of a colored phenolphthalein indicator according to the following reaction:

$$\underset{\text{Acide gras}}{\text{R-COOH}} + \underset{\text{soude}}{\text{NaOH}} \rightleftharpoons \underset{\text{savon}}{\text{R-COONa}} + \underset{\text{eau}}{H_2O}$$

The free acidity of lipids mainly provides information on the alteration of triglycerides following chemical or enzymatic hydrolysis when they are under favourable conditions.

II.3. Peroxide value (PV)

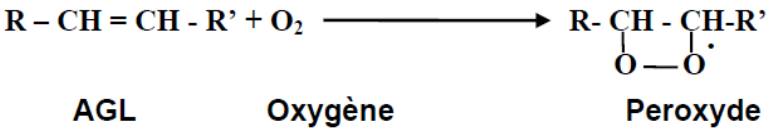
The peroxide number is the number of milliequivalents of active oxygen of the peroxide contained in one kilogram of fat and capable of oxidizing potassium iodide with release of iodine.

It is a very useful and satisfactorily sensitive criterion for assessing the first

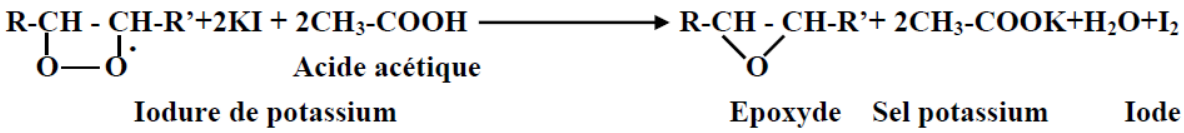
stages of oxidative deterioration. It gives an assessment of the amount of peroxides present in a fatty substance. This is what actually indicates the amount of GA already rancid.

The principle of this determination is based on dissolving the fat in a chloroform/acetic acid mixture, and a potassium iodide solution is added. The released iodine is titrated with a sodium thiosulfate solution in the presence of starch poisons as an indicator.

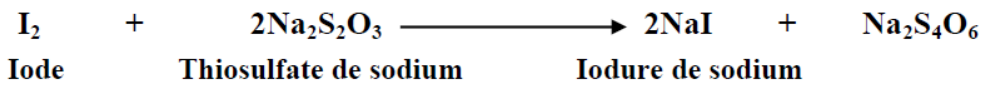
The unsaturated fatty acids used in the composition of the fatty substance oxidize partially in the presence of oxygen in the air to give peroxides.



Réaction d'iodure de potassium au milieu acide :



L'iode libéré est titré par le thiosulfate de sodium :



- **The iodine number**

It globally measures the degree of establishment of a fat by determining the number of g of iodine binding to the double bonds present in 100 g of lipids.

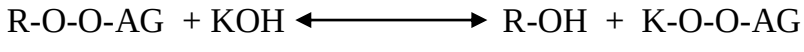
The determination of the iodine index consists of dissolving the fat in an anhydrous solvent, then this solution is brought into contact, protected from light, with the WIJS reagent (iodine monochloride). After 1 hour, the unfixed iodine is titrated with a sodium thiosulfate solution in the presence of starch poisons as a colored indicator.

This indicator makes it possible to know the number of double bonds present on an unsaturated fatty acid. Animal fats, which are highly saturated, have iodine values of around 45; in vegetable oils, this value reaches 150.

During hydrogenation, the iodine value is used to determine the amount of double bonds remaining within an oil sample. From this result, hydrogenation is stopped or continued (depending on the desired degree of establishment).

II.4. The saponification index

This analysis consists of transforming into soluble soaps (sodium or potassium) all the fatty acids present in the esterified state in a fat and regenerating glycerol in the case of triglycerides. The total lipid sample is treated in the presence of alcoholic potash, at boiling point to obtain the following reaction:



R-OH represents one of the alcohol functions of glycerol.

The excess potassium hydroxide not fixed to the fatty acids is dosed in return with a solution of hydrochloric acid in the presence of phenolphthalein.

The saponification index represents the amount of potash, expressed in mg, required to saponify one g of fat. This index reflects the average languor of the chain of fatty acids constituting the extract since its value is all the higher the lower the molecular weight of the fatty acids.

Exp:

Sunflower oil (majority linoleic and oleic acid) IS= 190

Copra oil (majority lauric acid) IS = 260

In addition to the determination of this index, the interest of saponification is to make it possible to extract from the alkaline solution by a neutral solvent, the fraction of unsaponifiable compounds. If acid hydrolysis is carried out, the glycerol and fatty acids are collected in the free state.

II.5. Measurement of unsaponifiable content

The unsaponifiable content is generally low: 0.3 to 1.5% in natural fats. Depending on the nature of the sample, it includes cholesterol, polyphenols, ergosterol, pigments,

fat-soluble vitamins, hydrocarbons, etc. Some lipids of plant (wheat germ oil) or animal (cod oil) origin contain significantly higher unsaponifiable content (up to 10 or 20%).

The principle of this determination is based on the saponification of the fat by boiling treatment with an ethanoic solution of KOH, followed by extraction of the unsaponifiable from the soap solution by means of a specific solvent and finally evaporation of the solvent and weighing of the residue after drying at 103°C.

II.6. Ultraviolet spectrophotometric examination

UV absorbances are indicative of self-oxidation and the degree of stability of the oil during storage. Hydroperoxides absorb in the vicinity of 232 nm, and by-products such as aldehydes and ketones are quantified at 270 nm. The E232 / E270 ratio is all the lower the more oxidation by-products the oil contains, therefore the more advanced the oxidation.

II.7. Fractionation of lipid constituents

When the extraction of total lipids has been carried out using a non-destructive technique (without acid hydrolysis), it is possible to identify the main categories of these lipids (neutral lipids or triglycerides, hydrolyzed lipids or partial glycerides, more or less polar complex lipids such as phospho and glycolipids).

One of the fractionation techniques is thin layer chromatography (TLC). This technique offers the possibility of separating the different classes of lipids that have differences in polarity. There are several variants in the mixtures of solvents used to carry out their fractionation and of reagents used for their identification.

II.7.1. Example of non-destructive TLC process

a. Separation

This step consists in placing the lipid extract in chloroform and depositing it on a silica gel plate (silica gel G). The mono-, di-, triglycerides, total polar lipids and free fatty acids are separated according to their functional groups by means of a mobile

phase consisting of a mixture of solvents according to the nature of the lipids to be extracted.

Example:

- chloroform/ methanol/ water; 60:30:4

-Petrol ether/ethyl ether/acetic acid; 90 :10 :1

- Chloroform/ methanol/acetic acid/ water . 80 :12 :18 :5

The more polar compounds remain near the deposition zone while the triglycerides are driven by the mobile phase. Their relative mobility is measured by their Rt (Retention Factor: ratio between the distances traveled by the solute and the solvent during chromatography (figure 22).

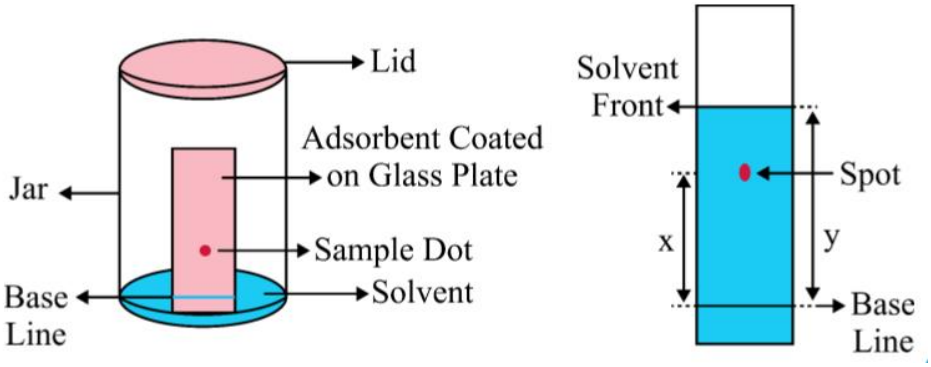


Figure 22: TLC working

b. Lipid disclosure

It can be done by spraying the plate with a dichlofluorecein solution, then observing under UV light (270 nm). Lipids are visible as fluorescent green spots on a dark background. Similarly, stains can be visualized by spraying 50% V/V sulfuric acid (or a mixture of sulfuric acid and acetic anhydride) and heating to 100°C for 10 minutes. Similarly, spots can be located by iodine (neutral lipid). The mixture of ninhidrin and molubdenum can be used to visualize lipids with amine functions.

The different fractions thus revealed can be recovered by scraping the silica to be quantified (GPC).

c. Fatty acids identification

This step is crucial in the analysis of a fat, because it explains both its origin, its physical properties (melting temperature) and its nutritional characteristics. The analysis is conventionally done by gas chromatography (GPC); more recent high-performance liquid chromatography (HPLC) techniques are also available.

II.8. Gas chromatography (GC)

II.8.1. Definition and principle

Gas chromatography (GPC) is, like all chromatography techniques, a technique that makes it possible to separate molecules from a possibly very complex mixture of very diverse nature. It applies mainly to gaseous compounds or compounds that can be vaporized by heating without decomposition.

The mixture to be analyzed is vaporized at the inlet of a column, which contains a solid or liquid active substance called stationary phase, and is then transported through it using a carrier gas (or carrier gas). The different molecules of the mixture will separate and leave the column one after the other after a certain period of time which is a function of the affinity of the stationary phase with these molecules. When they arrive at the exit of the column, they are detected by a detector which transmits an electrical signal to a recorder. The results then appear on a chromatogram as peaks (Figure 23).

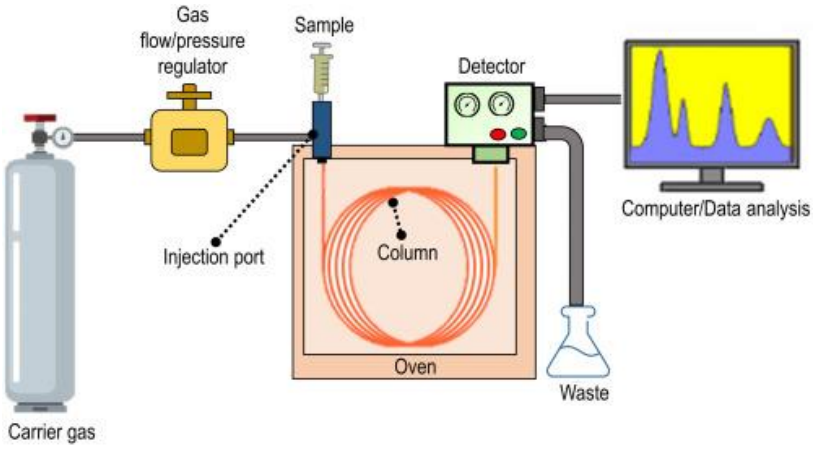


Figure 23: Gas chromatography (GC).

II.8.2. Apparatus and materials

Regardless of the gas chromatograph, we always find the following main components:

- **The mobile phase**

The mobile phase entraining the compounds in the column are chemically inert gases. The main ones are helium, argon and carbon dioxide. They are delivered in drums branched from a pressure regulator. These gases must be of analytical purity, as these impurities are responsible for background noise on the chromatogram.

- **Direct injection chamber**

The injection chamber is a compartment placed just before the main furnace containing the column. It is equipped with elements that can heat the compartment to very high temperatures.

The sample is injected using a syringe graduated in microliters which is introduced into the chamber through a rubber washer. Because of the very high temperature of this compartment, the compounds instantly change to the vapour state and are pushed by the carrier gas towards the chromatographic column.

- **The main oven**

The main furnace contains the chromatographic column and is equipped with heating elements that can control the temperature of the furnace with very high precision.

- **The Funnel**

It is the main organ of the device. The columns are tubes 4-6 mm in diameter, made of stainless steel, glass or copper. Their length varies from 1 to 4 m. They are folded in a U or helix to reduce the space requirement in the oven. The column can be of the filled type (containing granules impregnated with stationary phase) or of the capillary type (open tubular) (Figure 24)

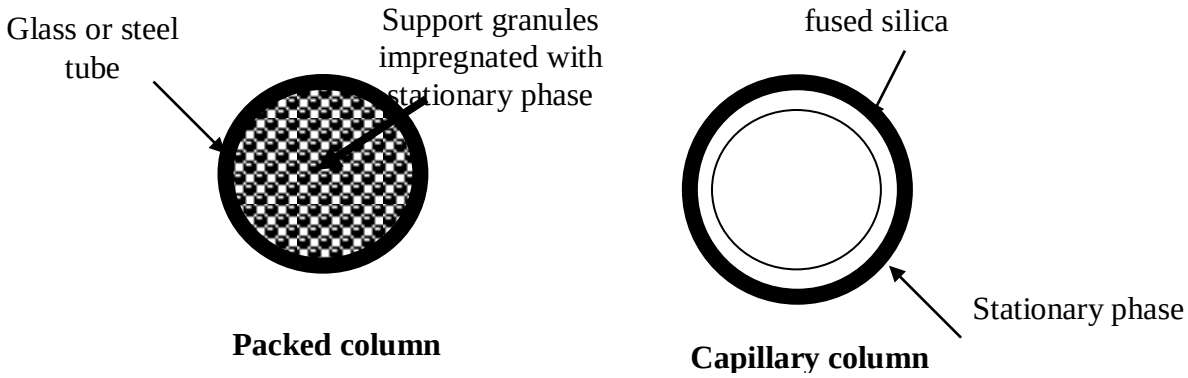


Figure 24: Filled column and capillary

- **The detector**

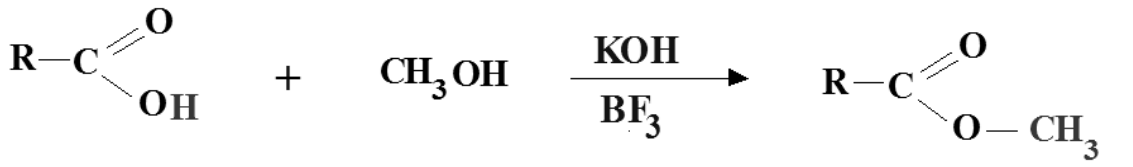
It makes it possible to highlight the passage of the different gases separated by the column. The gas chromatograph detector is located in the compartment immediately at the column outlet. Like the injection chamber, the detection chamber can be heated to very high temperatures. Its role is to detect the compounds at the exit of the column and to transmit the information in the form of an electrical signal to the recorder.

II.8.3. Experimental technique

The main steps of a fatty acid analysis in gas chromatography are:

- **Preparation of methyl esters**

GPC analysis of free fatty acids requires their methylation by esterification of their carboxyl groups to make them more volatile by lowering their boiling point and also very stable at high temperature. The esterification is carried out with methanol, either in the presence of acid catalysts (HCl, H2SO4, BF3), or in the presence of basic catalysts (NaOH, KOH) according to the reaction below



Acide gras **Ester méthylique**

The methylation of fatty acids characterizing glycerides requires their isolation by saponification and their conversion into derivatives whose boiling temperatures are lowered.

- Adjustment of parameters (gas flow, temperature, etc.) for optimal separation of compounds from the unknown mixture.
- Injection of unknown samples and standards.

- **Results and interpretation**

In gas chromatography, the results appear on the chromatogram as peaks

- **Qualitative Analysis**

Qualitative analysis consists of identifying one or more compounds of the unknown mixture injected. To do this, it is necessary to have standards for the suspected compounds in the mixture.

The retention time of a compound represents the time it takes for the compound to pass through the column. The distance traveled by the compound is calculated from the moment of injection until it appears at the detector.

When it is desired to identify a peak on the chromatogram, the suspected standard is injected under the same experimental conditions as the unknown mixture. If the retention time of the standard corresponds to the retention time of a peak of the mixture, it can be concluded that it is the same compound.

- **Quantitative analysis**

Quantitative analysis consists in determining the concentration of one or more compounds of the unknown mixture. The method is essentially based on determining

the surface area of the peaks. Then, the concentration of a compound in the mixture can be determined by the calibration curve method.

Conclusion

This chapter has presented the main physico-chemical methods used in the analysis of fatty substances, highlighting their importance in evaluating the quality, purity, and stability of fats and oils. Key parameters such as acidity value, peroxide value, iodine value, saponification value, and melting behavior were discussed as essential indicators for characterizing lipid materials.

The analysis shows that these physico-chemical indices provide valuable information about the chemical structure, degree of unsaturation, and oxidative state of fatty substances. They also play a crucial role in determining the suitability of fats and oils for different industrial and nutritional applications.

Chapter VI

Sensory evaluation of fatty substance

Chapter VI. Sensory evaluation of fatty substances

Introduction

This chapter focuses on the sensory evaluation of fatty substances, which plays a crucial role in determining their overall quality and consumer acceptability. Unlike physico-chemical analyses, sensory evaluation is based on human perception and involves the assessment of attributes such as appearance, color, odor, taste, and texture.

Sensory properties are particularly important for fats and oils, as they directly influence consumer preference and market value. These characteristics can be affected by factors such as raw material quality, processing conditions, storage, and oxidative degradation. Therefore, sensory analysis is widely used as a complementary method to instrumental techniques in quality control.

The objective of this chapter is to present the main principles, methods, and evaluation criteria used in the sensory analysis of fatty substances, as well as their importance in food quality assessment.

I. Definition

AFNOR defines sensory evaluation as the implementation of techniques that use the human senses to measure the sensory quality or hedonic quality of a product. Indeed, it is the study of human responses to the physicochemical properties of food.

II. Organoleptic properties

Sensory evaluation uses the human sensory organs as a measuring instrument. It is irreplaceable in all cases where there are no physical sensors capable of competing with the sensory organs.

Controlling food quality involves taking into account the sensations generated by the appearance, texture, flavour and flavour of food.

II.1. Appearance

All the organoleptic characters perceived by the organ of sight: size, shape, color, conformation, turbidity, clarity, fluidity and foam.

II.2. Flavour

Complex set of olfactory and gustatory properties perceptible during tasting, and which can be influenced by tactile, kinesthetic and thermal properties. The flavour is broken down into five components:

- **Aroma**

Sensations perceived by the olfactory organ indirectly during the tasting of a food product that are due to volatile molecules.

- **Flavor**

Sensations perceived when the gustatory papillae are stimulated by some soluble substances.

- **Consistency**

It is determined by the contact of the food with the walls of the oral cavity, the surface of the tongue and throat

- **Odor**

The set of sensations perceived by the olfactory organ when inhaling certain volatile substances.

- **Texture**

The set of characteristics of the solid or rheological state of a food product capable of stimulating mechanoreceptors during tasting, particularly those located in the oral region.

III. Sensitivities involved in sensory evaluation

III.1. Visual sensitivity

It is the sensory system which comes into play first and which will be at the origin of a certain expectation with regard to the product.

III.2. Hearing Sensitivity

It has a significant role in the perception of crunchiness, crunchiness and crispiness in particular, the movements of the jaw allow the transmission of sound vibrations

III.3. Olfactory sensitivity

It allows the olfactory mucosa to sense volatile molecules by two routes (direct and indirect)

III.4. Somesthesic sensitivity

It brings together a set of sensations of mechanical or thermal origin perceived at the level of the skin, mucous membranes, muscles and joints, we find:

- Touch sensation, for the evaluation of roughness and astringency
- Kinesthetic sensation, for the evaluation of hardness, elasticity and plasticity;
- Thermal sensation (hot / cold)
- The general chemical sensation, allowing the detection of spiciness, burning and irritant.
-

IV. The different sensory thresholds

IV.1. Absolute threshold

Minimum value of a sensory stimulus which gives rise to:

- the appearance of a sensation (stimulus threshold or detection threshold) , or
- the identification of the sensation (recognition threshold) .

IV.2. Differ Threshold

Minimum value of a sensory stimulus which gives rise to a perceptible difference in the intensity of the sensation.

IV.3. Terminal threshold

Maximum value of a stimulus above which an increase in intensity is not perceived.

IV.4. Preference threshold

Minimum quantitative value of a stimulus or supra-threshold critical value of this stimulus corresponding to the appearance of an attraction or rejection response compared to a neutral stimulus, for example, in the choice between a sugar solution and water.

V. Practical organisation of sensory analysis of fats (e.g. olive oil)

V.1.The personal

The sensory evaluation of fatty substances requires the establishment of a group of motivated subjects, trained to recognize the different characteristic flavors of oils and to measure their intensity. Tasters should not show any aversion to this product to be evaluated.

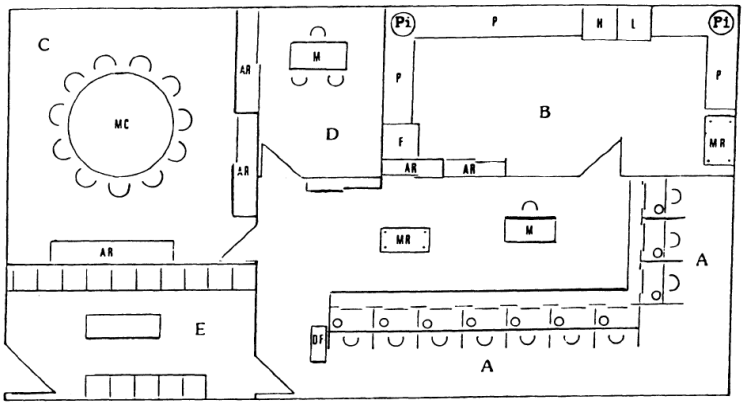
V. 2. Sensory evaluation room

The room must be pleasant and suitably lit, while maintaining a neutral appearance. It must be easy to clean. In addition, it must be away from any source of noise, any abnormal odors, and the temperature must be maintained at 20- 25°C using air conditioning

The room must be sufficiently spacious to allow the installation of about 10 cabins, as well as an area for sample preparation (Figure 16).

V. 3. Description of the cabins

The cabins must be identical and separated from each other by partitions high and wide enough to isolate the tasters once seated. Seats must be comfortable and adjustable in height and each cabin must be provided with individual adjustable lighting. It would be desirable to equip the cabins with a warning light, allowing the taster to communicate with the organizer of the tasting session. (Figure 25 et 26)



A - Cabine
B - Salle de nettoyage du matériel et de préparation des échantillons
C - Salle pour un essai en jury ouvert
D - Bureau
E - Salle d'attente
F - Réfrigérateur
H - Étuve-four
L - Lave-vaisselle
Pi - Évier
Ar - Armoire ou placard
Mr - Table roulante auxiliaire
Df - Distribution d'imprimés
Mc - Table ronde
M - Table
P - Paillasse

Figure 25: Example of a tasting room

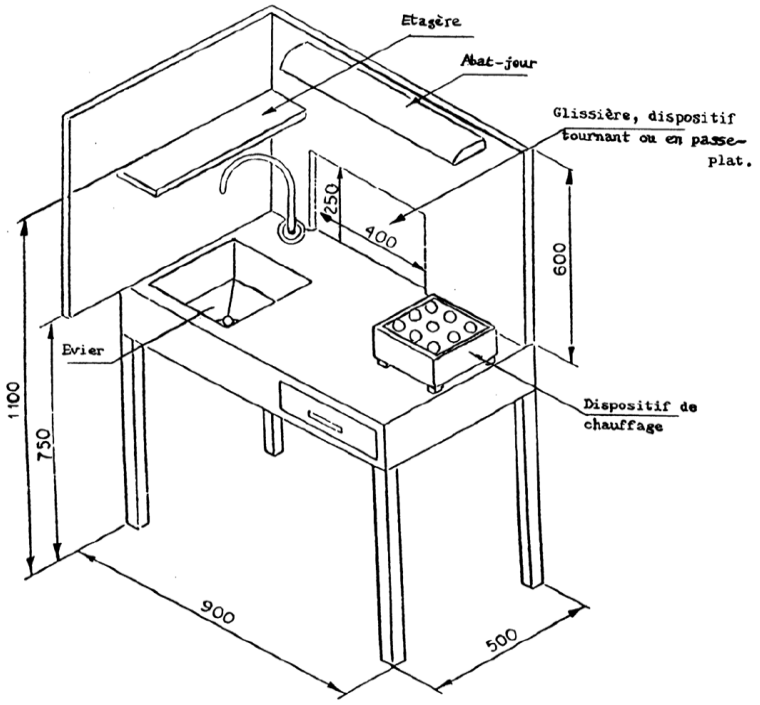


Figure 26: Sensory analysis cabin.

V. 5. Samples presentation

Samples must be coded, presented homogeneously (temperature, quantity, container). For the tasting of refined oils and olive oils, the optimal conditions for highlighting the differences between products are as follows:

i) use of coloured balloon glasses (Figure 27),

ii) Sample volume = 20 mL

iii) closing the opening of the glass with aluminium foil or a watch glass in order to concentrate volatile products

iv) tasting of refined oils at 45°C ± 2°C and olive oils at 28°C ± 2°C.

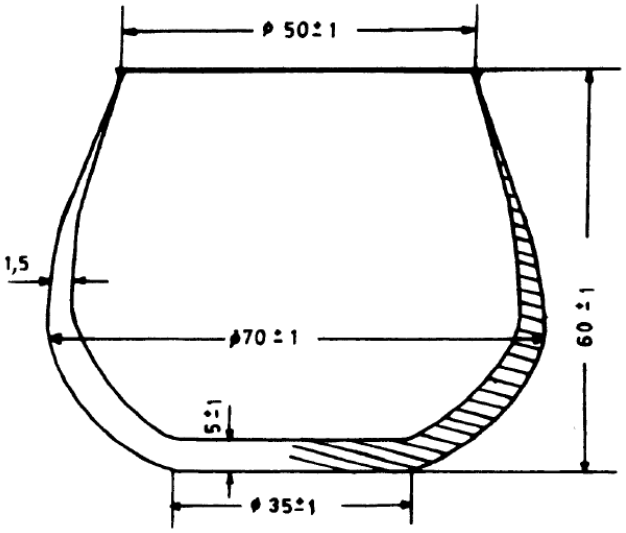


Figure 27: Balloon glass
(Dimensions in ml)

V.6. The tasting

- The tasters shall pick up the glass, keeping it covered with the watch-glass, and shall bend it gently; they shall then rotate the glass fully in this position so as to wet the inside as much as possible. Once this stage is completed, they shall remove the watch-glass and smell the sample, taking slow deep breaths to evaluate the oil. The duration of the olfaction should not exceed 30 seconds. If no conclusion has been reached during this time, they shall take a short rest before trying again.

- Once the olfactory test has been completed, the oral sensations must be evaluated. To do so, they shall take a small sip of approximately 3 ml of oil. It is very important to distribute the oil throughout the oral cavity,

- Brief and successive aspirations, by making air penetrate through the mouth, not only make it possible to perceive the volatile aromatic compounds retro-nasally.
- The tactile sensation of pungency should be taken into consideration. For this purpose it is advisable to ingest the oil.

V.7. Use of the taster's profile sheet

After tasting, each taster must indicate on the 10 cm scales of the profile sheet at his disposal the intensity at which he perceives each of the negative and positive attributes (Figure 1). At the end, as part of the hedonic evaluation, the taster must assign an overall score between 0 and 9 for each sample according to the intensity of the major defect and the presence or absence of the "olive fruity" attribute.

a. Positive attributes

- **Fruity**

The set of olfactory sensations characteristic of the oil, depending on the variety of olives, coming from healthy and fresh fruits, green or ripe, perceived by direct and/or retronasal inhalation.

- **Bitter**

Basic taste characteristic of oil obtained from green olives or at the veraison stage, perceived by the circumvallate papillae forming the lingual V.

- **Spiciness**

Pungent tingling sensation characteristic of oil made at the beginning of the season mainly from olives that are still green. It can be perceived throughout the mouth cavity, particularly in the throat.

b. Negative attributes

- **Fusty/muddy sediment**

Characteristic flavor of oil from olives piled or stored under conditions such that they are in an advanced state of anaerobic fermentation.

- **mustiness**

Musty/humid characteristic flavour of oil from olives in which large numbers of fungi and yeasts have developed as a result of storage for several days in humid conditions.

- **winey-vinegary**

Characteristic flavor of certain oils reminiscent of wine or vinegar.

- **acid/sour**

This flavour is basically due to a process of aerobic fermentation of olives or leftover olive paste in scourtins that have not been washed properly, which gives rise to the formation of acetic acid, ethyl acetate and ethanol.

- **Rance river**

Rancid flavour of oil that has undergone an intense process of oxidation.

V. 8. Collect and the treatment of the result

The results can be collected in two ways: on paper, sheets with data processing using statistical software or using a computerized system specially designed for sensory analysis. In this case, individual terminals located in the booths allow the responses to be entered, which are then processed by the central computer.

The head of the jury must control the intensities assigned to the different attributes. In the event of an anomaly, he will ask the taster to revise his profile sheet and, if necessary, to repeat the test.

V.9. Oil grading

The ranking is carried out by comparing the value of the median (the median represents the central value of an ordered series of odd numbers, or the average of two

central values of an ordered series of even numbers) of the fruity attribute and the majority defect at reference intervals defined experimentally for each denomination.
Olive oil is classified in the category:

- extra virgin olive oil the median of the defects is 0 and the median for "fruity" is above 0;
- virgin olive oil the median of the defects is above 0 but not above 3,5 and the median for "fruity" is above 0;
- Current blank when the median of the defects is greater than 3.5 and less than or equal to 6.0 or when the median of the defects is less than or equal to 3.5 and the median of the fruity is equal to 0;
- Virgin lampant when the median of defects is greater than 6.0.

(*) Median of defects means median of the defect perceived with the strongest intensity.
Regarding the hedonic evaluation, the results will be submitted to a STUDENT TES in order to preferably which oil is the best appreciated.

Conclusion

This chapter has highlighted the importance of sensory evaluation in the quality assessment of fatty substances. The different sensory attributes, including odor, taste, color, and texture, are key indicators of freshness, stability, and overall product quality.

The analysis shows that sensory evaluation is closely linked to the chemical and physico-chemical changes occurring in fats and oils, particularly oxidation and degradation processes. It therefore serves as an essential tool for detecting defects that may not always be identified through instrumental analysis alone.

In conclusion, sensory evaluation is a fundamental complement to physico-chemical methods, ensuring a comprehensive assessment of fatty substances in both industrial quality control and consumer-oriented evaluation.

Chapter VII.

Fatty substance technology

Chapter VII. Fatty substance technology

Introduction

This chapter presents the technological processes involved in the extraction and processing of fats and oils. It covers methods such as mechanical pressing, solvent extraction, refining, bleaching, and deodorization. These processes are essential to obtain high-quality edible oils that meet industrial and nutritional standards.

I. Preparation of the Raw Materials

The preparation of raw materials is an essential step in fat technology, as it directly conditions the yield and quality of the extracted oil. Its objective is to transform oleaginous seeds or fruits into a homogeneous, clean material capable of easily releasing lipids during extraction. This step also aims to remove impurities, reduce particle size and adjust physical parameters (humidity, temperature) in order to optimize subsequent processes.

Cleaning is the first operation performed after receiving the raw materials. It consists of removing all impurities that may alter the quality of the oil or damage the equipment.

These impurities can be of various types: dust, sand, metal fragments, shells, leaves or foreign seeds. Their removal is based on several combined techniques such as screening (size separation), aspiration (removal of light particles) and magnetic separation (removal of metals).

Effective cleaning not only improves the quality of the final product, but also reduces machine wear and the risk of contamination.

I.1. Decortication (or peeling)

Hulling involves removing the outer husk of the seeds, called the husk or integument. This operation is particularly important for certain seeds such as sunflower, soya or peanut.

The shells are generally low in oil but high in fibre, which can adversely affect the efficiency of extraction and the quality of the meal. Their removal therefore makes it possible to increase the lipid concentration of the treated material and to improve the overall yield.

Hulling is carried out mechanically, often by abrasion or percussion, followed by separation of the shells by ventilation or sieving.

I.2. Grinding

Grinding, also called crushing, aims to reduce the size of the seeds in order to release the cells containing the oil. This operation increases the contact area and facilitates the diffusion of lipids during extraction.

Depending on the process used, the grinding may be more or less fine. In some cases, it is followed by flaking, which consists of transforming the particles into fine lamellae. This treatment improves solvent penetration and extraction efficiency.

Well-controlled grinding is essential to avoid the formation of compact pastes that could impede the flow of oil.

I.3.Thermal conditioning

Thermal conditioning involves heating the crushed seeds to a controlled temperature, usually using steam. This step makes it possible to modify the physico-chemical properties of the raw material in order to facilitate extraction.

Heat causes proteins to clot, cell membranes to rupture and the viscosity of the oil to decrease. It also promotes particle agglomeration, which improves the permeability of the material during pressing or solvent extraction.

However, an excess of temperature can lead to degradation of the oil and alteration of its nutritional qualities. It is therefore essential to precisely control the heating conditions.

1.4. Humidity adjustment

The moisture of the raw materials plays a crucial role in the extraction process. Too high a moisture content can reduce the efficiency of solvent extraction, while too low a content can make the material too hard and difficult to process.

Thus, an adjustment is often necessary in order to obtain an optimal level, generally between 8 and 12% depending on the type of seed. This adjustment can be made by drying or by adding water, depending on the initial state of the raw material.

1.5. Importance of preparation

All the preparation operations make it possible to optimize the performance of the subsequent stages, in particular extraction and refining. Proper preparation improves oil yield, reduces losses and ensures better quality of the final product.

It is therefore a strategic step in the recovery of oilseed raw materials and in the control of industrial processes of fats.

II. Oil extraction

The extraction of vegetable oils is a fundamental step in the processing of oilseed raw materials such as soya, sunflower, rapeseed or peanut. It consists of releasing and recovering the oil contained in plant cells, usually in the form of triglycerides, by breaking down cell structures. This operation requires prior preparation of the seeds in order to optimize the yield and quality of the oil obtained. Indeed, the oil is located in the lipid vacuoles of the cells, and its extraction depends strongly on the size of the particles, the water content and the structure of the plant tissue.

II.1. Mechanical extraction (pressure)

II.1.1. Principle of pressure

Mechanical extraction is based on the application of physical force to compress oilseeds or pastes to extract oil. This method is usually carried out using screw presses (expellers), where the material is subjected to increasing pressure along a worm. The oil is then expelled through orifices, while the solid residue, called cake, is recovered at the outlet (figure 28) .

Cold pressing is carried out at low temperature (generally below 50°C), which preserves the nutritional and organoleptic qualities of the oil, especially vitamins and aromatic compounds. However, this method has a relatively low yield.

Conversely, hot pressing involves pre-heating the seeds, which improves the fluidity of the oil and increases the extraction yield. However, this technique may result in partial degradation of some heat-sensitive compounds.

II.1.2 Advantages and limitations

Mechanical extraction is appreciated for its natural character and the absence of chemical solvents. It is particularly used for high quality oils such as olive oil. Nevertheless, it leaves a significant amount of residual oil in the meal, which limits its industrial efficiency.

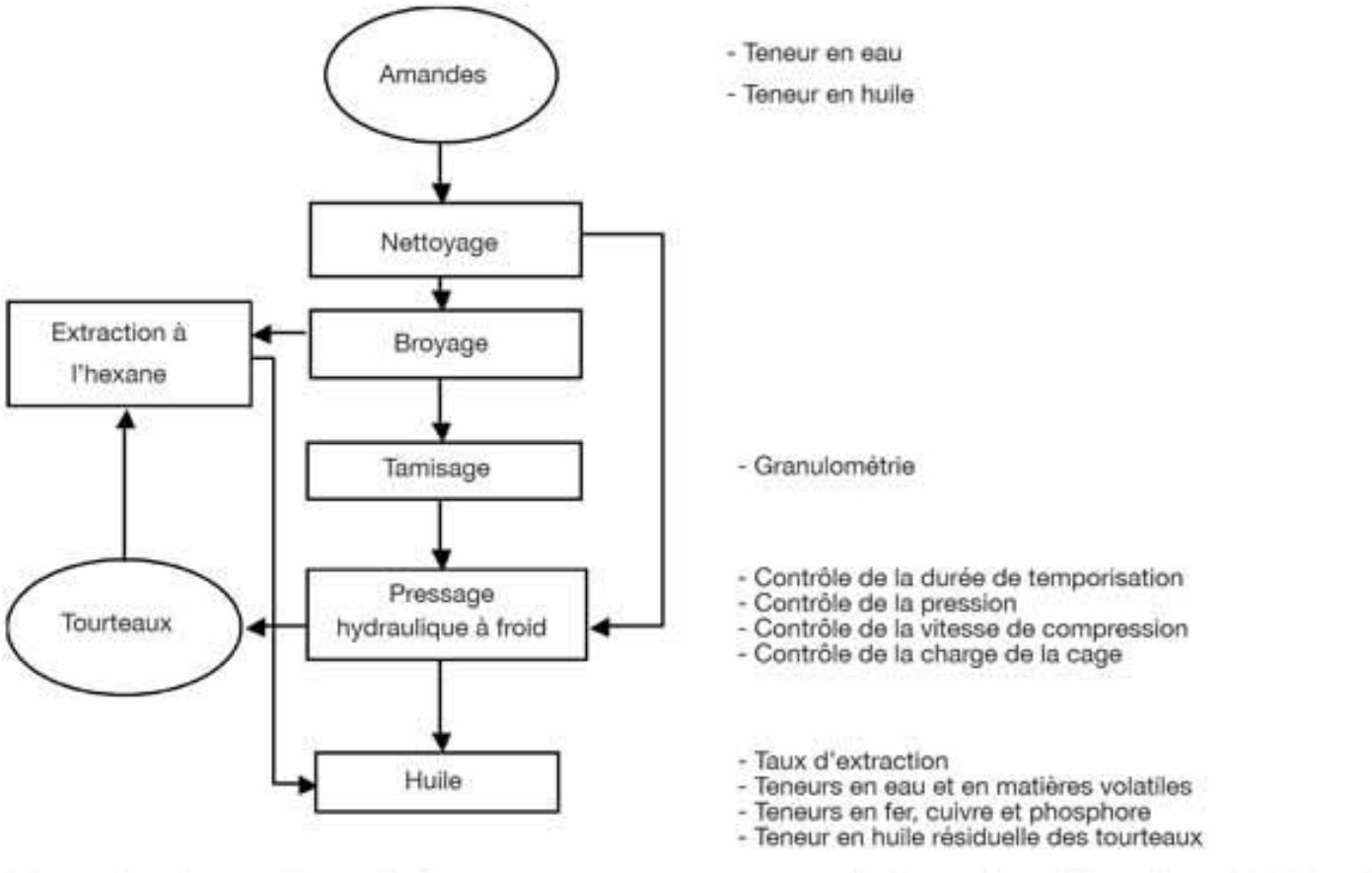


Figure 28: Mechanical extraction

II.2. Solvent extraction

II.2.1. Principle of chemical extraction

Solvent extraction is a technique widely used in industry to maximize yield. It is based on the use of an organic solvent, usually hexane, capable of dissolving the oil contained in the seeds. The raw material is brought into contact with the solvent in an extractor, which allows the formation of a mixture called miscella (oil + solvent).

II.2.2. Process steps

The method comprises several steps. First, the extraction itself, during which the solvent dissolves the lipids. Then, the separation of the miscella is carried out, followed by distillation to recover the solvent by evaporation. Finally, the meal is subjected to desolventization in order to remove the remaining traces of solvent.

II.2.3. Advantages and drawbacks

This method offers a very high yield, making it possible to extract almost all of the oil contained in the raw material. It is therefore favoured on a large scale. However, it has drawbacks related to the use of flammable and potentially toxic solvents, requiring strict safety and control measures.

II.3. Modern and alternative techniques

Faced with environmental and health concerns, new extraction techniques have been developed. Supercritical CO_2 extraction uses carbon dioxide under high pressure and controlled temperature to solubilize lipids. This method has the advantage of being clean, without toxic residues, and preserving the quality of the oils.

Other techniques, such as ultrasound-assisted or microwave-assisted extraction, improve plant cell rupture and increase yield while reducing extraction time. While promising, these technologies are still limited to specific applications due to their high cost.

II.4. Comparison of extraction processes

Mechanical extraction and solvent extraction have complementary characteristics. The first focuses on the quality and naturalness of the product, while the second aims for maximum efficiency in terms of yield. The choice of process therefore depends on industrial objectives, the type of raw material and final quality requirements.

II.5. Conclusion

Oil extraction is a key step in the development of oilseed resources. It is based on various processes ranging from traditional techniques such as pressing to advanced industrial methods using solvents or innovative technologies. The development of more sustainable processes is now a major challenge to meet environmental and health requirements.

III. Oil Refining

III.1. Objectives of refining

Refining oils is an essential step to improve their organoleptic, nutritional and health quality. The crude oils obtained after extraction contain various impurities such as

phospholipids, free fatty acids, pigments, odorous compounds as well as traces of metals and contaminants (Figure 29).

The main objective of refining is therefore to eliminate these undesirable substances while retaining as many beneficial constituents as possible, in particular essential fatty acids and fat-soluble vitamins. This operation makes it possible to obtain a stable, clear, odourless oil suitable for consumption or industrial use.

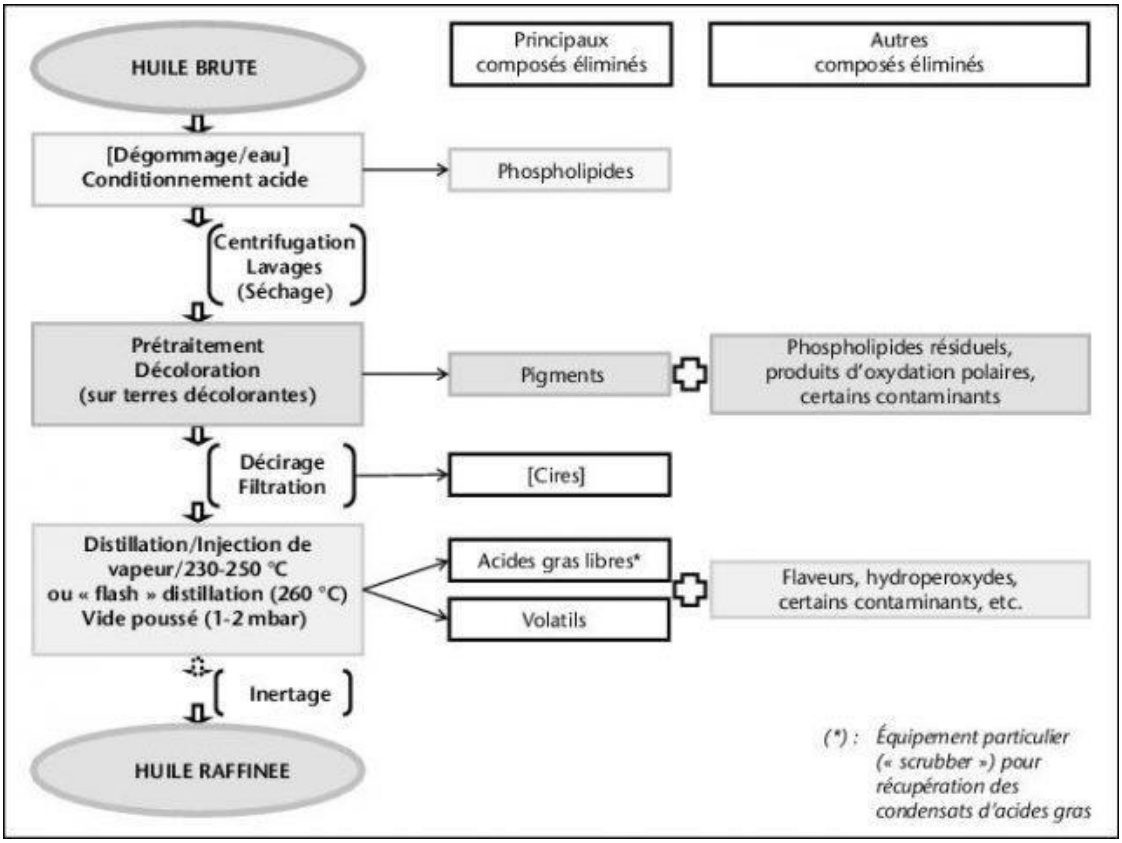


Figure 29: Oil Refining

III.2. Refining stages

III.2.1. Degumming

Degumming is the first step in refining. It consists of removing the phospholipids, also called “gums”, present in the crude oil. These compounds can cause disorders (cloudiness, instability) and affect storage.

The process is usually based on the addition of water or an acidic solution, which hydrates the phospholipids and makes them insoluble in oil. These are then separated by centrifugation. This step improves the stability of the oil and prepares the next phases of refining.

III.2.2. Neutralisation

Neutralisation aims to remove the free fatty acids responsible for the acidity of the oil. This operation is generally carried out by treatment with a base, most often sodium hydroxide (NaOH).

The free fatty acids react with the soda to form soaps (soapstock), which are then separated from the oil by decantation or centrifugation. This step improves the taste quality and stability of the oil.

III.2.3. Discolouration (or bleaching)

The purpose of discoloration is to remove unwanted pigments such as carotenoids and chlorophyll, which are responsible for the colour of the oil. It also reduces the content of certain contaminants (trace metals, oxidation products).

This step is based on the use of adsorbents, especially bleaching earths or activated carbon, which fix the pigments. After stirring, the oil is filtered to remove the impurity-laden adsorbents.

III.2.4. Deodorization

Deodorization is the last step in refining. It consists of removing the volatile compounds responsible for undesirable smells and tastes.

This operation is carried out by high-temperature vacuum steam distillation. The odorous compounds are entrained by the steam and separated from the oil. This step gives the oil a neutral taste and greater consumer acceptability.

III.2.5. Importance of refining

Refining makes it possible to obtain an oil that meets food and industrial quality standards. It improves the oxidative stability, health safety and sensory properties of the final product, while ensuring its preservation.

IV. Modification of fatty substances

IV.1. Objectives

The modifications of fatty substances aim to adapt their physico-chemical properties (texture, melting point, plasticity) to industrial and food needs. They make it possible to

produce specific fats used in the manufacture of margarines, baked goods or confectionery.

IV.2. Hydrogenation

Hydrogenation involves adding hydrogen to the double bonds of unsaturated fatty acids in the presence of a catalyst (often nickel). This reaction converts unsaturated fatty acids into saturated fatty acids.

It increases the melting point and makes the oil more solid at room temperature. However, partial hydrogenation can lead to the formation of trans fatty acids, which are associated with negative health effects.

IV.3. Inter-esterification

Interesterification consists of redistributing fatty acids on triglyceride molecules without changing their degree of saturation. It can be carried out chemically or enzymatically (Figure 30).

This technique makes it possible to obtain fats with specific properties (texture, fusion) without the formation of trans fatty acids, which is an important nutritional advantage

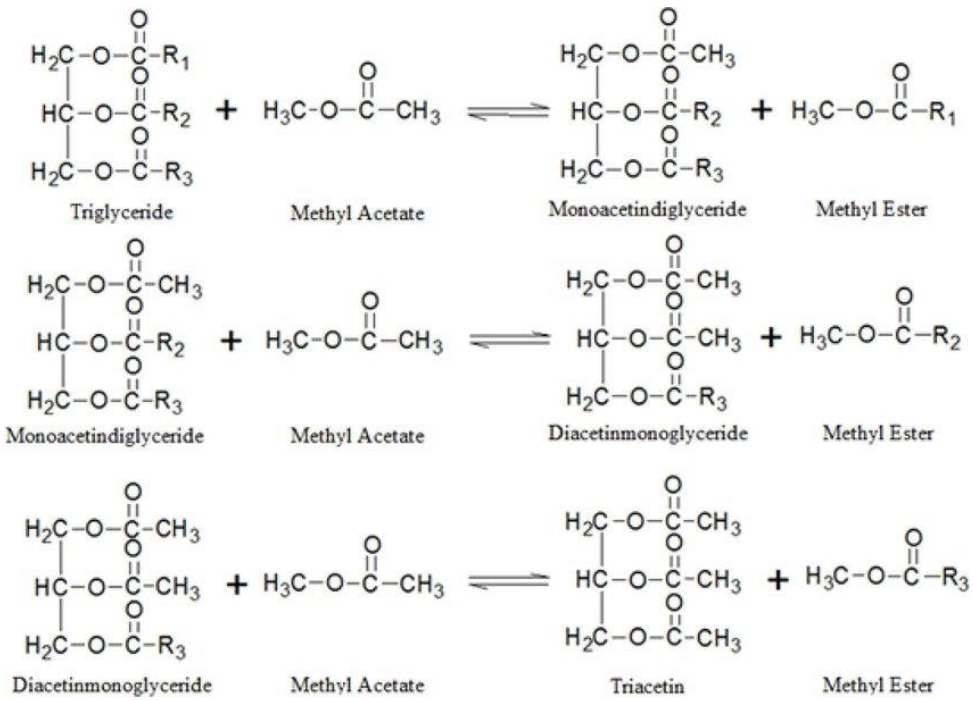


Figure 30: Inter-esterification reaction

IV.4. Splitting

Fractionation is a physical technique based on the melting point difference of triglycerides. It involves cooling the oil to cause the solid fractions to crystallize, which are then separated from the liquid fractions.

This method is widely used for palm oil, making it possible to obtain a solid fraction (stearin) and a liquid fraction (olein), each having specific applications.

IV.5. Significance of changes

These processes make it possible to diversify fat-based products and adapt their properties to technological and nutritional requirements. They play a key role in the modern agri-food industry.

V. Products derived from fatty substances

Fats, of plant or animal origin, are an essential raw material for many industries. After extraction, refining and possible modification, they give rise to a wide variety of derived products intended for food, cosmetic, pharmaceutical and industrial uses.

The valorization of fats is based on their richness in triglycerides and their ability to undergo various chemical and physical transformations. These properties make it possible to adapt their characteristics (texture, stability, melting point, functionality) according to the targeted applications. Thus, products derived from fats occupy a strategic place in the agri-food and chemical economy.

V.1. Dietary Oil

Edible oils represent the most direct and widespread form of fat recovery. They are obtained from seeds (sunflower, soya, rapeseed) or fruits (olive, palm) and generally undergo refining to improve their quality.

These oils are used in human food for cooking, frying and seasoning. Their fatty acid composition (saturated, monounsaturated, polyunsaturated) determines their nutritional value. For example, oils rich in unsaturated fatty acids are particularly sought after for their beneficial effects on cardiovascular health.

In addition, some oils, such as virgin olive oil, can be consumed without refining, which preserves their bioactive compounds (antioxidants, vitamins). Packaging also plays an important role in preservation, including limiting exposure to light and oxygen.

V.2. Margarine

The formulation of a margarine involves several essential components. The fatty phase forms the base of the product and is generally composed of vegetable oils (sunflower, soya, palm, rapeseed) that can be modified (hydrogenation, interesterification, fractionation) to adjust their melting point and plasticity.

The aqueous phase consists of water or milk, sometimes enriched with salts, preservatives or milk proteins. Emulsifiers (lecithin, mono- and diglycerides) are added to stabilize the water-in-oil emulsion. Finally, dyes (such as β-carotene) and flavors (such as butter) are incorporated to improve appearance and taste.

V.2.1. Principle of manufacture

- **Phase preparation**

The fats are first refined and then blended to obtain a suitable lipid profile. At the same time, the aqueous phase is prepared by dissolving the water-soluble ingredients.

- **Emulsification**

The water-in-oil emulsion is formed by finely dispersing the aqueous phase in the fatty phase with intense stirring. This step is crucial to ensure the stability of the final product.
After emulsification, the mixture is subjected to rapid cooling in heat exchangers (scraped surface heat exchangers). This step allows the formation of β'-type lipid crystals, which give the margarine its fine, plastic and spreadable texture.

Crystallization control is essential: poor crystallization can lead to defects like granular texture or phase separation.

Mechanical work (kneading)

Once cooled, the margarine is kneaded to evenly distribute the fat crystals and improve consistency. This process contributes to a homogeneous and stable structure.

Storage

The margarine is then packaged (trays, blisters, jars) under strict hygienic conditions. It is stored at low temperatures to preserve its texture and avoid lipid oxidation **(Figure 31).**

- **Types of margarines**

Depending on their composition and use, there are several categories:

-Table margarines (spreadable)

-Industrial margarines (pastry, bakery)

-Fat reduction

-Fortified margarines (vitamins, omega-3)

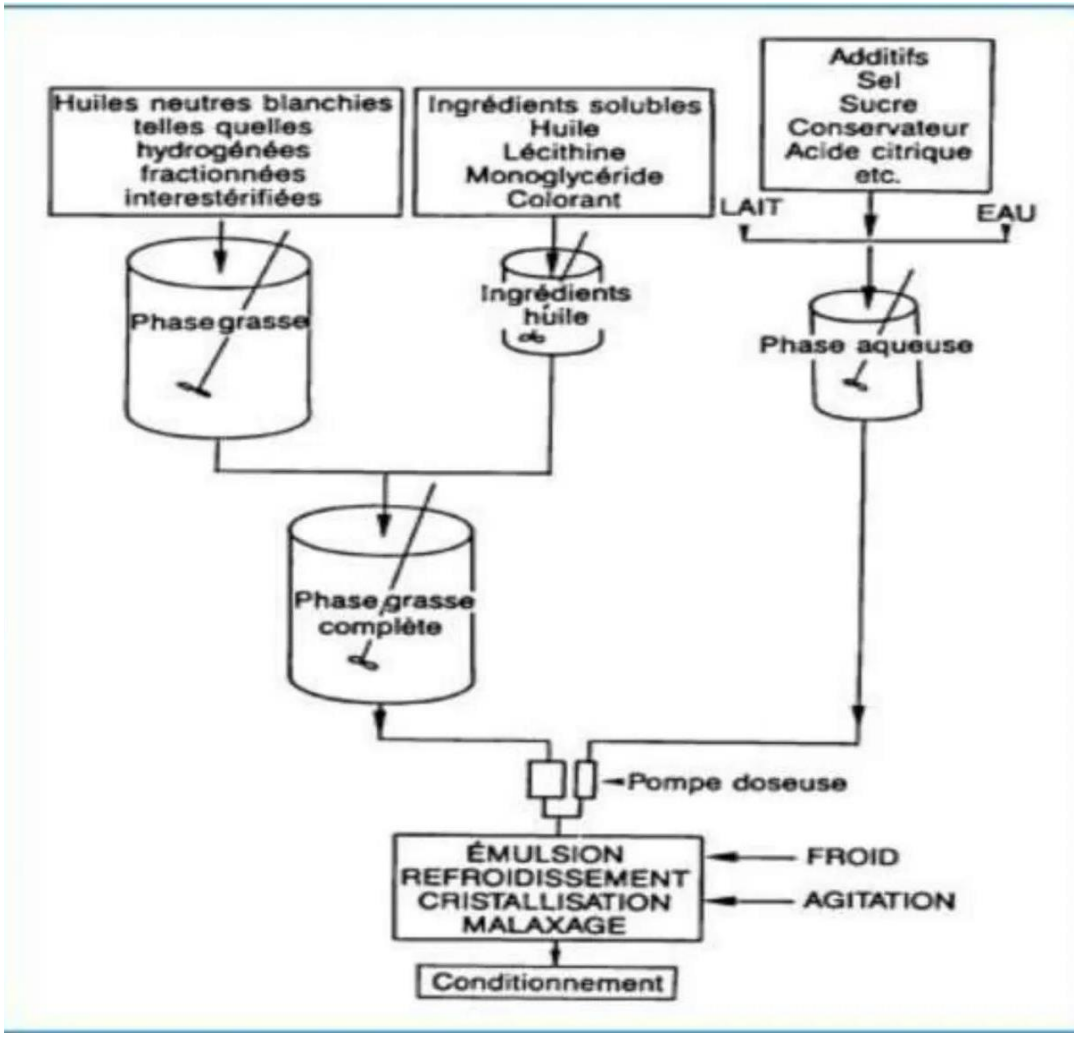


Figure 31: Formulation of a margarine

V.3. Saponification products: soaps and detergents

Soap is a product obtained by the chemical transformation of fats in the presence of an alkaline base. This process is based on the saponification reaction, which converts triglycerides into fatty acid salts (soap) and glycerol.

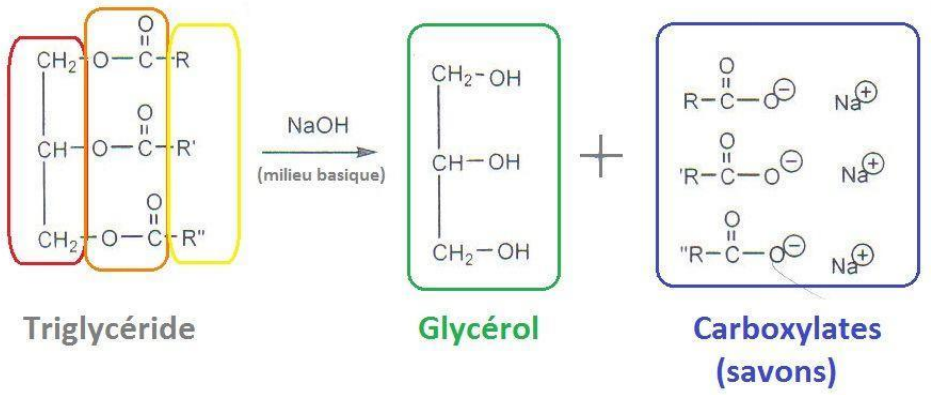
5.3.1. Raw Materials

The main raw materials used are fatty substances (vegetable oils such as olive, palm or coconut oil, or animal fats) and alkaline bases such as sodium hydroxide (NaOH) for solid soaps or potassium hydroxide (KOH) for liquid soaps.

Water is required to dissolve the alkali, and various additives can be incorporated: fragrances, dyes, overgreasing agents, preservatives or specific active ingredients (antibacterials, moisturizers).

V.3.2. Saponification reaction

Saponification is a chemical reaction between a triglyceride and a strong base. It produces soap (fatty acid salt) and glycerol. This reaction can be carried out hot or cold depending on the method chosen.



V.3.3. Manufacturing procedures.

- **Cold-Process Adhesives**

In this artisanal method, the oils are mixed with a soda solution at moderate temperature. The reaction proceeds slowly and the soap is poured into molds and then left to dry for several weeks (cure). This method preserves the oils and produces soaps that are mild and rich in glycerine.

- **Hot Process**

The mixture is heated to accelerate saponification. The soap is then purified, often by washing and salting out (adding salt), to remove impurities and glycerin. This method is used on an industrial scale.

V.3.4. Technological steps

The industrial manufacture of soap involves several steps:

- **Preparation of raw materials** (refining and dosing of oils)
- **Saponification** in reactors
- **Release** to separate soap from glycerin
- **Drying** to reduce water content
- **Moulding and extrusion** to give the final shape
- **Packaging**

V.3.5. Types of soaps

Different types of soaps can be distinguished according to their composition and use:

- Toilet soaps
- Industrial soaps
- Liquid soaps
- Medical or antiseptic soaps
- Overgreased soaps (rich in moisturizing agents)

5.4. Cosmetic products

Fats play a fundamental role in the cosmetic industry due to their moisturizing, emollient and protective properties. They are used in the formulation of many products such as creams, lotions, balms and body oils.

Lipids help restore the skin barrier, limit water loss and improve the texture of cosmetic products. Certain vegetable oils, such as argan or coconut oil, are particularly appreciated for their nourishing properties and their richness in bioactive compounds.

In addition, fatty substance derivatives, such as fatty acid esters, are used as texturing and emulsifying agents in cosmetic formulations.

V.5. pharmaceutical products

Fats and their derivatives are also used in the pharmaceutical field. In particular, they serve as carriers for fat-soluble active principles, facilitating their absorption by the body.

Lipids are used in many dosage forms such as ointments, soft capsules and emulsions. Their role is to improve the bioavailability of drugs and protect active substances from degradation.

In addition, some essential fatty acids play a therapeutic role and are used as dietary supplements.

V.6. Biofuels (biodiesel)

Fats are an important source of biofuels, especially in the form of biodiesel. This is obtained by a transesterification reaction between triglycerides and an alcohol (usually methanol), producing fatty acid methyl esters.

Biodiesel is used as an alternative to fossil fuels, contributing to the reduction of greenhouse gas emissions. It has the advantage of being biodegradable and renewable.

V.7. Other industry applications

Fat derivatives also find applications in various industrial sectors. They are used in the manufacture of lubricants, paints, varnishes and plasticizers. Their natural origin and biodegradability make them interesting alternatives to petrochemical products.

V.8. Economic and technological importance

The diversity of products derived from fats testifies to their strategic importance in many areas. Their transformation makes it possible to efficiently develop natural resources and meet the growing needs of the food, cosmetic and energy industries.

Thus, fats are not limited to their nutritional role, but also constitute an essential basis for the development of many industrial innovations.

Conclusion

This chapter has highlighted the importance of technological processes in transforming raw materials into refined fats and oils. Each stage of processing plays a crucial role in improving purity, stability, and sensory quality. However, these processes must be carefully controlled to preserve nutritional value.

Chapter VIII
Alteration of fatty substances

Chapter VIII. Alteration of fatty substances

Introduction

Fats are essential compounds in the food and agri-food industry. However, they are particularly sensitive to weathering phenomena that affect their physico-chemical, nutritional and organoleptic quality. These degradations can lead to the formation of undesirable, even toxic compounds, thus altering food safety.

The alteration of fats is mainly related to chemical reactions involving oxygen, water, heat and light. These reactions lead to profound changes in the structure of lipids, especially unsaturated fatty acids.

I. Oxidation of fatty substances

Fatty acids tend to oxidize on contact with atmospheric air. It is the double bond that attracts the oxygen molecule. All lipids can oxidize, but only unsaturated lipids can oxidize at low temperatures. The more unsaturated the fatty acid, the more easily it will oxidize. Other unsaturated substrates may undergo oxidation reactions such as Vit A and carotenoid pigments.

I.1. Definition of free radicals

A free radical is a molecule or atom with one or more unpaired electrons, making them extremely reactive. The set of free radicals is often referred to as reactive oxygen species (ROS). These include the oxygen free radicals themselves, the superoxide radical (O2 .-), the hydroxyl radical (OH.), nitric oxide (NO.),but also certain reactive non-radical oxygenated derivatives, whose toxicity is significant, such as hydrogen peroxide (H_2O_2) and peroxynitrite (ONOO-)

I.2. Mechanism of oxidation reactions (Figures 32 and 33)

In the oxidation of lipids, there are 3 types of reaction:

I.2.1. Initiation

It corresponds to the formation of free radicals from lipids, they are produced by the departure of a proton and according to the following reaction:

$$R\text{-}H \longrightarrow R^{\cdot} + H^{\cdot}$$

Fatty acid Fatty acid free radical

I.2.2. Propagation phase

It is an amplification phase developing in the presence of oxygen. A peroxyl radical (ROO°) is formed by combining a lipid radical with an oxygen molecule. The peroxyl radical in turn reacts with a new molecule of unsaturated fatty acid to form a hydroperoxide (ROOH) and a new free lipid radical that ensures propagation of the propagation chain.

$$R^{\circ}_1 + O_2 \longrightarrow R_1OO^{\circ} \text{ (rapid reaction)}$$

$$R_1OO^{\circ} + R^{\circ}_2H \longrightarrow R^{\circ}_2 + R_1OOH \text{ (slow reaction)}$$

I.2.3. Termination phase

At the same time as the initiation and propagation reactions, stop reactions can occur and lead to the disappearance of some free radical propagation by association of 2 radical species. Or by splitting hydroperoxides into acid, alkane, aldehydes and ketones responsible for the smell of rancidity.

$$ROO^{\circ} + ROO^{\circ} \longrightarrow ROOR + O2$$

$$ROO^{\circ} + R^{\circ} \longrightarrow ROOR$$

$$ROO^{\circ} + {}^{\circ}OH \longrightarrow ROOH + 1/2O2$$

$$R^{\circ} + R^{\circ} \longrightarrow RR \text{ (dimer)}$$

I.3. The consequences of oxidation reactions

Oxidation reactions give rise to many compounds:

-Formation of volatile compounds such as aldehydes and ketones, of low molecular weight, which are responsible for the smell of rancid

-loss of colour due to oxidation of pigments

-loss of vitamin activity

-Oxidation of essential fatty acids causes a decrease in nutritional value.

I.4. Oxidation indicators

I.4.1. Acid value

Gives an assessment on the amount of free fatty acids. These acids are responsible for greater ease of rancidity

I.4.2. Iodine Number

It makes it possible to know the degree of unsaturation of a fatty acid. This is an assessment of how easy it is to get rancid.

I.4.3. Peroxide value (PV)

It gives an assessment of the quality of peroxides present in a fatty substance. This is what actually indicates the amount of GA already rancid.

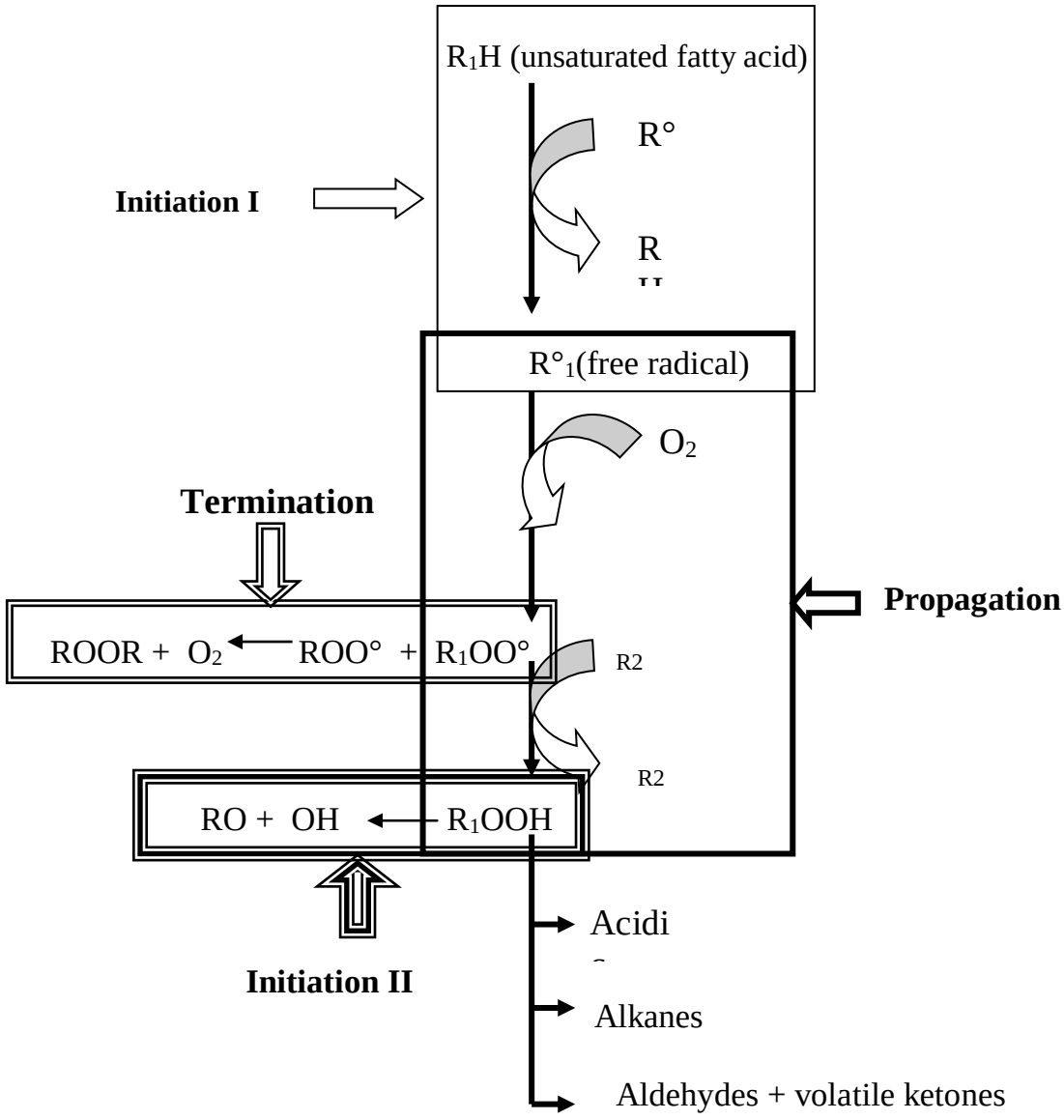
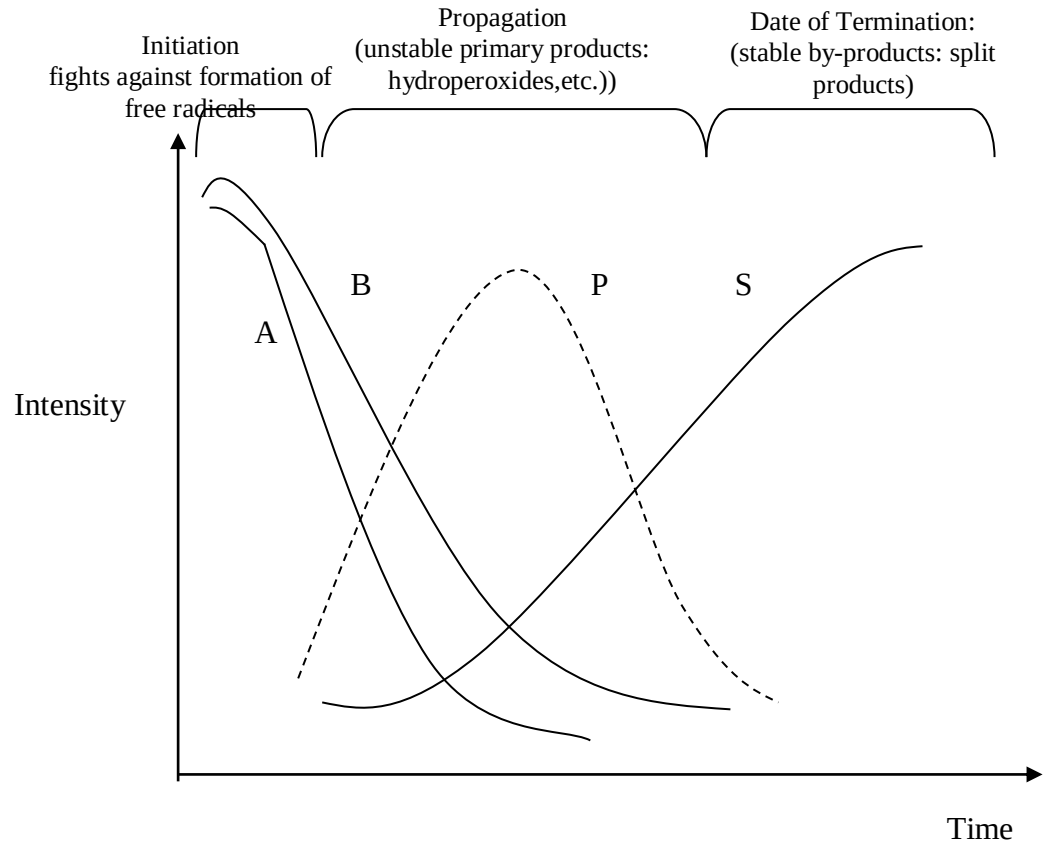


Figure 32: Mechanism of oxidation reactions



A: Oxygen disappearance
B: disappearance of polyunsaturated fatty acids
P: primary oxidation products
S: oxidation by-products

Figure9: Lipid oxidation kinetics

I.5. Parameters influencing oxidation

I.5.1. Action of light: the presence of light promotes the primary phase of oxidation, hence the interest of protecting sensitive fats with opaque packaging.

I.5.2. Temperature: Oxidation is markedly accelerated with heating. At very high temperatures, even saturated GAs are oxidized.

I.5.3. Action of metals: heavy metals such as Iron, Cu, Co, Mn accelerate oxidation reactions.

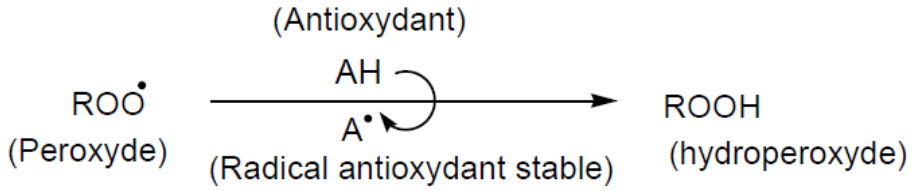
I.5.4. Degree of establishment of GAs: the more double bonds a GA has, the more sensitive it will be to oxidation.

II. Means of prevention and stabilization of oxydation (Antioxidants)

II.1. Definition

Antioxidants are molecules capable of neutralizing (or stopping) free radicals, thus slowing the rancidity of unsaturated oils.

The antioxidant reacts with a lipid free radical by converting the latter to hydroperoxide ROOH, simultaneously a radical A from the antioxidant is formed.



II.2. Classification of antioxidants

Antioxidants are classified according to different criteria:

II.2.1.Classification according to mode of action :

- **Antioxidants**

They encompass components that interfere with lipid autooxidation by converting lipid oxidation products (L°, LOO°) into more stable radicals through their proton donor property. The radical (A°) derived from the antioxidant is more stable than the lipid radical

$L° + AH \longrightarrow LH + A°$

$LOO° + AH \longrightarrow LOOH + A°$

- **Antioxidants**

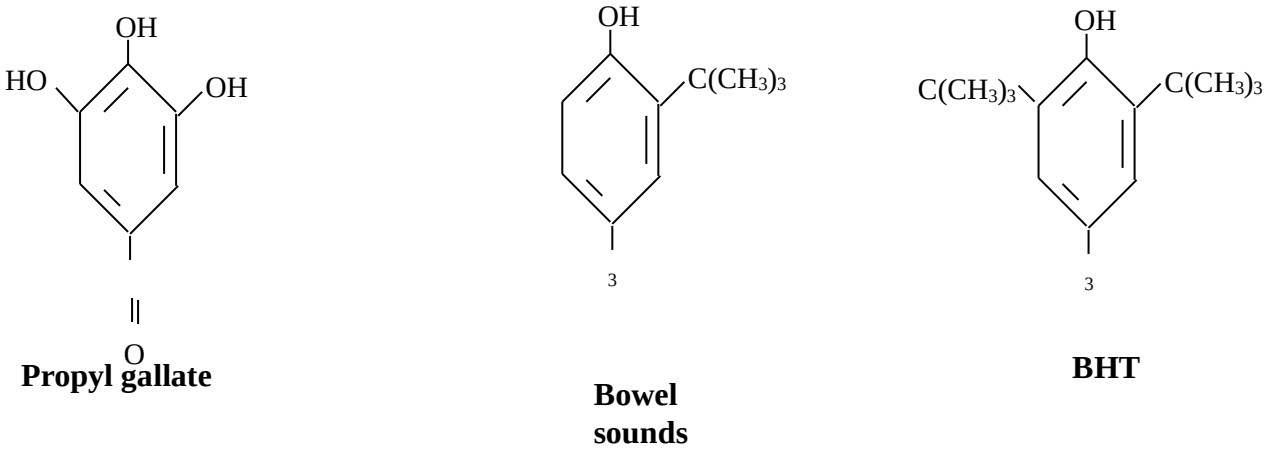
These are compounds that delay lipid auto-oxidation according to different modes of action:

- high absorption of radiation
- Heavy metal test
- Hydroperoxide reduction

II.2.2.Classification by origin

- **Synthetic Antioxidants**

The most used in the agri-food industry are: hydroxyanisol butylate (BHA); hydroxytoluene butylate (BHT), gallate propyl but their use is regulated because of suspicions about their toxicity (Figure 34)



Propyl gallate **Bowel sounds** **BHT**

Figure104: Some examples of synthetic antioxidants

- **Natural Antioxidants**

They include different chemical species such as phenolic compounds, pigments and vitamins that are of plant origin

II.3. Olive oil antioxidants

Olive oil contains a large amount of natural antioxidants such as phenolic compounds, tocopherols and carotenoids.

II.3.1.Phenolic compounds

Phenolic or polyphenol compounds are benzene ring substances with one or more hydroxyl groups. This gives them antioxidant properties through hydrogen transfer and metal chelation.

Among the polyphenols in olive oil are:

- **Simple phenols** (caffeic acid, cinnamic acid and oleuropein)
- **Flavonoids (**Luteolin 7-O-glucoside, Luteolin 5-O-rutin and Quercetin)

The best described antioxidant property of polyphenols is their ability to scavenge free radicals (hydroxyl radicals (OH°), superoxide anion ($O_2^{\circ -}$) and peroxylipid radicals). Polyphenols inactivate and stabilize free radicals thanks to their highly reactive hydroxyl (C_3-OH) group according to the following reaction:

$$\text{Polyphenol (OH)} + R^\circ \longrightarrow \text{Polyphenol (O°)} + RH$$

Polyphenols also inhibit the formation of free radicals by the chelation of transition metals such as copper, iron and aluminium which, in the free state, can be at the origin of the production of free radicals.

- **Carotenoids**

Olive oil is rich in carotenoids, but these pigments tend to degrade during maturation just like chlorophylls.

Olive carotenoids include carotenes (β-carotene) and xanthophyls (lutein, zeaxanthin, violaxanthin, neoxanthin and antheraxanthin). Carotenoids are effective inhibitors of chlorophyll-induced photo-oxidation of olive lipids

Carotenoids **(Car-H**) neutralize free radicals (R°) by hydrogen transfer according to the following reaction:

$$R^\circ + \text{Car-H} \longrightarrow RH + \text{Car}^\circ$$

- **Tocopherols (vitamin E)**

Olive oil is an important source of tocopherols, antioxidants whose content increases during maturation

In the olive, α-tocopherol predominates; the other stereoisomers (β, γ and δ) are present in trace amounts.

Tocopherols have an important antioxidant activity by preventing the action of singlet oxygen, initiator of lipid peroxidation. Due to its hydrophobic nature, α-tocopherol can be inserted into biological membranes and neutralize peroxyl radicals (LOO°). In addition, this tocopherol has a synergistic effect with β-carotene by protecting it against oxidation.

II.4. Methods for assessing antioxidant activity.

The tests can be divided into two groups: tests measuring the ability to inhibit the oxidation of a substrate (often a lipid) under accelerated conditions and tests evaluating the "scavenger" effect on free radicals.

II.4.1. Tests measuring inhibition of lipid oxidation

The simplest test for antioxidant activity involves the addition of the antioxidant to an oil, lipid, or substrate model such as linoleic acid. After incubation of linoleic acid and antioxidant for 7 days at 40-50°C, the antioxidant activity is expressed as the rate of inhibition of the formation of primary products (peroxides and hydroperoxides) or secondary products such as hexanal, the rate of which is measured by GC

II.4.2. Tests evaluating the "scavenger" effect on free radicals (exp: DPPH)

This test is based on measuring the ability of an antioxidant to exert a scavenger effect on the stable radical DPPH$^{\bullet}$ (2,2-diphenyl-1-picrylhydrazyl). The DPPH$^{\bullet}$ free radical is reduced when reacting with a hydrogen donor. This power is evaluated by electron resonance spectroscopy, based on the emission of a signal by the DPPH$^{\bullet}$ whose intensity is inversely related to the concentration of the antioxidant and the reaction time. However, the most used technique is a discoloration test, which evaluates the decrease in the absorbance of the DPPH$^{\bullet}$ $^{\text{solution at 515-528nm}}$, due to the addition of an antioxidant (Du Toit *et al*., 2001; Sanchez-Moreno, 2002; Xiao-Dong *et al*., 2002).

II.4.3. Other methods of measuring antioxidant activity

There are methods that cannot be classified into the previous two groups; these methods evaluate antioxidant activity by measuring reducing power. It is measured with another method based on the reduction of $FeCl_3$ to $FeCl_2$ in an acidic medium and in the presence of a chromogenic agent, potassium ferricyanide. In this test, the absorbance at 700 nm is proportional to the reducing power of the sample tested.

II.4.4. Estimation of fatty acid oxidation

Due to the complexity of the reactions and the multiplicity of products that can be formed, there are a large number of methods for assessing the oxidation of fatty acids. The different parameters used to measure their oxidation are based on:

1- primary changes due to oxygen consumption, loss of polyunsaturated fatty acids, formation of hydroperoxides and peroxides.

2- secondary changes resulting from the partial decomposition of oxides with formation of:

- Split product, resulting from the cleavage of the fatty acid at the double bond and giving volatile short-chain products (aldehyde, ketones, etc.).
- Oxidized products with the same chain length as the starting fatty acid. These "oxidized acids" are conjugated dienes or unsaturated ketones.

a. Measurement of primary products

- **iodometric method**

The peroxide number is established by the amount of iodide oxidized to elemental iodine by the peroxides. By definition, it is expressed as the number of micrograms of active oxygen contained in one gram of fat.

The fat dissolved in a solvent (acetic acid/ chloroform) is deaerated and then brought into contact with an excess of potassium iodide for 5 min in the dark. The iodine released by the peroxides is determined by a titrated solution of thiosulfate, in the presence of starch as an indicator.

This method is not totally specific given that, as it is released, iodine may bind to all the unsaturated bonds present in fats and thus escape the assay. It is therefore essential to respect the incubation time.

- **Colorimetric method**

These methods are based on the property of peroxides to oxidize ferrous ions to ferric ions. Commonly, the sample (10 to 300 mg of fat) is mixed with 9.8 ml of chloroform/ methanol (7 :3, V/v); it is stirred in the presence of 50 ul of ammonium thiocyanate and then 50 ul of ferrous chloride. After 5 min, the absorbance is read at 500nm.

This method is simple, fast and sensitive and it applies to meat, dairy and oils products.

b. Measurement of secondary products

Under no circumstances is the determination of peroxides sufficient to estimate the degree of oxidation of a lipid phase. If the peroxides are abundant, the oxidation is indisputable, but its degree of progress must be specified by the search for stable by-products (split products, oxidized products). If the amount of peroxides is small, this means either that we are in the first stage of oxidation, or that it is so developed that the hydroperoxides are already decomposed and transformed into second generation molecules.

In any case, the search for secondary products of oxidation is necessary to specify the state of the fat. A first estimate results from the measurement of absorbance at 268 nm; at this wavelength molecules such as unsaturated ketoses, molecules characteristic of the cleavage products of polyunsaturated fatty acids, are detected. However, this reading does not offer absolute specificity; it provides an indication that requires commentary assays on split products to conclude formally.

- **Para-anisidine index**

The principle is based on the reaction, in acetic solution, between aldehyde dienes and p-anisidine to give a complex coloured yellow, the absorbance of which is measured at 350 nm. It makes it possible to assess the rancid state of lipids.

By convention, this index is 100 times the value of the absorbance of a solution of 1 g of fat in 100 ml of the mixture of solvent and reagent, placed in a tank with an optical path of 1 cm.

Its value, often associated with that of the peroxide index, gives the overall oxidation value, called TOTOX (total oxidation value) which consists of twice the value of the peroxide index plus once the value of para-anisidine.

Conclusion

Lipid oxidation is one of the main causes of quality deterioration in fats and oils. Understanding the mechanisms and controlling factors is essential to improve stability and extend shelf life. The use of antioxidants and proper storage conditions is therefore crucial in lipid preservation.

Chapter IX

Frying: Driving and Control

Chapter IX: Frying: Driving and Control

Introduction

This chapter deals with the frying process, one of the most widely used thermal treatments in the food industry, particularly for products rich in fats and oils. Frying involves the immersion of food in hot oil, where complex heat and mass transfer phenomena occur simultaneously, leading to significant changes in both the food matrix and the frying medium.

During frying, fats and oils act not only as a heat transfer medium but also as a component that influences the final sensory and nutritional quality of the product. However, repeated use of frying oils can lead to chemical and physical degradation, including oxidation, polymerization, and hydrolysis, which affect oil quality and food safety.

The objective of this chapter is to describe the mechanisms involved in frying, the factors influencing the process, and the methods used to control oil quality during frying operations.

I. Frying procedure

I.1. Basic principle

The frying process is one of the oldest food processing processes. It can be carried out in the pan in the presence of a little fat (flat frying) or in a large volume of oil or fat (deep frying)

The oil is used to transfer heat to the material until almost complete vaporization of the water continues in the material. The latter occurs at a temperature generally close to the boiling temperature of pure water for water-rich materials and at a higher temperature for materials with intermediate humidity and from which water is strongly adsorbed.

The water escapes in the form of a jet of steam bubbles characteristic of the "explosive" behaviour of frying. The steam may eventually carry with it volatile or hydrophilic constituents (flavourings or solutes).

The surface layers of the material are the first to be subjected to higher temperatures where pore water vaporizes, and are therefore the most rapidly dehydrated. They are the site of the main macroscopically visible reactions and transformations (browning, crusting, etc.).

I. 2. Application of the frying process

Frying is mainly used to achieve transformations that increase:

- The digestibility of food by facilitating its crushing and assimilation in the tract (coagulation of proteins and starch);
- Palatability of food through the development of textures, colours and flavours;
- The stabilization of raw materials by lowering the water content of the material and inactivating microorganisms.

II. Main fried food products

Fried products can be classified into three categories or according to three physical models according to the surface in contact with the oil, in relation to their total volume.

- The "fries, chicken legs, donuts" model is characterized by a large internal volume whose water content is little affected by frying. Dehydration and fat impregnation are then only superficial. In this case, frying is essentially used to cook the material.
- The <<chips>> model is characterized by a very low residual water content and a continuous crust. After cooling, only the porous matrix of the initial material is retained, the voids left by the water leaving being partially filled by the frying oil.
- The <<pelotes>> model consists of a honeycomb product that exposes itself to the flow of frying and whose structure freezes during cooling. The best known products are Indonesian keropoks or krupuks made from pasta made from cassava flour used alone or mixed with other root and tuber flours or fishmeal.

III. Thermal deterioration of the oil

III.1. Overview

The degradation of fats during frying depends on the composition of the starting oil, the nature of the food, as well as the frying conditions: temperature, duration of use, surface of the oil exposed to air relative to the volume, periodic uses, frying capacity (Kg fried food/hour) and heat transformation mode (gas or electric).

The use of refined fats as heat transfer fluids is particularly frequent in the case of successive reuse of frying baths, accompanied by thermo-oxidative attacks that lead to significant chemical and physical changes. These transformations, the most obvious manifestations of which are the increase in coloration, appearance of smoke and foam,

and increase in viscosity, which results from complex reactions such as oxidation, hydrolysis and polymerization. On the other hand, defects in smell and taste.

At high temperatures (160°C and 180°C), in the presence of water and oxygen, triglycerides undergo a large number of complex reactions that can be classified into three main families: **oxidation, polymerization and hydrolysis.**

III. 2. Oxidation reactions

The action of oxygen on unsaturated fatty acids is at the origin of their deterioration. It causes the appearance of aromas and color changes, often undesirable, in fried oils and/or fried products.

III.2.1. Polymerization reactions

They produce inter and intra-molecular rearrangements that sensitize the frying oil to oxidation and lead to an increase in the apparent viscosity of the oils. Resin-like compounds can then foam on the bath surface and walls.

III.2.2. Hydrolysis reactions

They are by far the most numerous under normal fried conditions. They lead to the formation, the contact of water vapour, of free fatty acids, mono-glycerides, diglycerides and glycerol. These compounds are then very sensitive to the reactions mentioned above and their products will be responsible for the main taste or odour defects.

As they degrade, the fats in the bath become more and more volatile and the oil bath begins to smoke. Usual fatty substances have smoke points initially between 180° and 230° C. The degradation of fatty substances leads to a significant lowering of the smoke point (≤170° C), increases the content of surfactants (soap) (responsible for the formation of foams on the surface of the bath and the lowering of the surface tension between essentially aqueous foods and oils), and increases the viscosity of oils.

III.3. Formed compounds

During heating of the oil, chemical changes resulting from the combined action of heat and oxygen from the air on triglycerides and fatty acids occur. These occur in two ways, on the one hand there is the appearance of light volatile products (responsible for the

smell of frying), and on the other hand the formation of heavy products remaining in the oil bath.

III.3.1. Volatile light products

They mainly come from the oxidation of unsaturated fatty acids. The volatile fraction consists mainly of aldehydes, ketones, alcohols, short-chain fatty acids (C_1 to C_9), esters, hydrocarbons and furan derivatives, etc. Almost all of these products leave the atmosphere due to their low molecular weight.

III.3.2. Non-volatile (heavy) products

These are high molecular weight products, remaining in the frying bath, and some of which impregnate food.

Nutritionists are interested in the nature and toxicity of these products. These compounds are referred to as ECN (New Chemical Species). Their quantities depend on the nature of the oil, the temperature, the duration and the heating cycles. Many of these compounds have been described. Among the compounds characterized, mention may be made of:

III.4. Choice of frying oils

The choice of frying fats results from a compromise between sensitivity to thermooxidation (high in the presence of polyunsaturated systems) and nutritional benefit.

The choice of the type or mixture of oil used will also depend on the perception and acceptability of the fried product by the consumer (smell, texture, mouthfeel, aftertaste, stability of the oil during storage before use or in the final product).

Fatty substances with a fresh smoke point above 200°C are generally considered too unstable for use in industrial frying processes at atmospheric pressure.

Conclusion

This chapter has outlined the main principles governing the frying process and its impact on both food products and frying oils. It has been shown that frying is a complex process influenced by temperature, frying time, food composition, and oil type.

The study also highlights that the quality of frying oils progressively deteriorates due to thermal and oxidative reactions, which can negatively affect both nutritional value and

sensory properties of fried foods. Therefore, proper control of frying conditions is essential to ensure product quality and consumer safety.

In conclusion, effective monitoring and management of frying operations are crucial to maintaining oil stability, improving food quality, and extending the usability of frying fats in industrial applications.

Chapter X: Sustainability and Future Perspectives in Lipid Science and Technology

Introduction

The growing global demand for fats and oils has raised major concerns regarding environmental sustainability, resource depletion, and public health. Lipid production and consumption are no longer viewed solely from a nutritional or technological perspective but also through the lens of sustainability and innovation. This chapter explores emerging trends in lipid science, focusing on sustainable sources, green processing technologies, and future challenges in the field of fats and oils.

I. Environmental impact of lipid production

The production of lipid-rich foods, particularly vegetable oils and animal fats, has significant environmental implications. Large-scale cultivation of oil crops such as palm, soybean, and sunflower requires extensive land use, often leading to deforestation and biodiversity loss. In addition, intensive agricultural practices involve high water consumption and the use of fertilizers and pesticides, which contribute to soil degradation and water pollution. Animal fat production is also associated with greenhouse gas emissions, particularly methane, as well as high feed and water requirements. These environmental pressures highlight the need for more sustainable approaches to lipid production.

II. Sustainable sources of lipids

In response to environmental concerns, research has increasingly focused on alternative and sustainable lipid sources. Microalgae have emerged as a promising option due to their rapid growth rate and high lipid content, particularly in omega-3 fatty acids. Unlike traditional crops, microalgae do not require arable land and can be cultivated using wastewater or saline water. Insects also represent an innovative lipid source, offering high efficiency in converting feed into biomass with a lower environmental footprint compared to conventional livestock. Additionally, the valorization of food industry by-products, such as oilseed cakes and fish processing residues, allows the recovery of valuable lipids

while reducing waste. These alternative sources are expected to play a key role in future food systems.

III. Green technologies in lipid processing

Traditional methods of lipid extraction and processing often rely on high energy inputs and the use of chemical solvents, which can have negative environmental and health impacts. Green technologies aim to minimize these effects by developing more sustainable and efficient processes. Mechanical extraction methods, such as cold pressing, preserve the nutritional quality of oils while reducing chemical use. Emerging techniques, including supercritical fluid extraction using carbon dioxide, offer high efficiency and selectivity without leaving harmful residues. Enzymatic processes are also gaining attention as environmentally friendly alternatives for lipid modification. These technologies contribute to reducing the ecological footprint of lipid production while improving product quality.

IV. Lipids and functional foods

The role of lipids in human health has led to the development of functional foods enriched with specific fatty acids and bioactive compounds. Omega-3 fatty acids, phytosterols, and structured lipids are increasingly incorporated into food products to provide health benefits beyond basic nutrition. These functional lipids can help reduce the risk of cardiovascular diseases, improve cognitive function, and support immune health. The design of such foods requires a deep understanding of lipid chemistry, stability, and bioavailability, making this field a dynamic area of research and innovation.

V. Future challenges in lipid science

Despite significant advances, several challenges remain in the field of lipid science and technology. Ensuring the stability of lipids during processing and storage is a major concern, particularly for polyunsaturated fatty acids that are highly susceptible to oxidation. Another challenge lies in balancing technological functionality with nutritional quality, as some industrial processes may negatively affect lipid composition. In addition, consumer demand for natural, healthy, and sustainable products is driving the need for transparency and innovation in the food industry. Addressing these challenges requires

interdisciplinary approaches that integrate chemistry, nutrition, engineering, and environmental science.

VI. Perspectives and Innovations

The future of lipid science is closely linked to advances in biotechnology and food engineering. Genetic modification and metabolic engineering of plants and microorganisms offer new opportunities to produce tailored lipid profiles with enhanced nutritional properties. Nanotechnology is also being explored for the encapsulation and delivery of lipophilic compounds, improving their stability and bioavailability. Furthermore, the development of plant-based alternatives to animal fats is gaining importance in response to changing dietary patterns and sustainability concerns. These innovations are expected to reshape the role of lipids in food systems in the coming decades.

Conclusion

Sustainability and innovation are becoming central themes in the study and application of lipids. As the global population continues to grow, the demand for high-quality, safe, and environmentally friendly lipid sources will increase. Integrating sustainable practices, developing alternative sources, and advancing green technologies are essential for meeting these challenges. This chapter highlights the importance of adopting a holistic approach to lipid science, combining nutritional, technological, and environmental considerations to ensure a sustainable future.

Chapter XI

Applications of Lipids in Food Products and Industry

Chapter XI: Applications of Lipids in Food Products and Industry

Introduction

Lipids are not only essential nutrients but also key functional ingredients widely used in the food industry. Their physicochemical properties, such as melting behavior, texture, and oxidative stability, make them indispensable in the formulation and processing of a wide range of food products. From bakery goods to dairy products and fried foods, lipids contribute to sensory quality, technological performance, and shelf life. This chapter focuses on the diverse applications of lipids in food systems, highlighting their functional roles and industrial importance

I. Functional Roles of Lipids in Food Systems

In food products, lipids perform multiple technological and sensory functions that go beyond their nutritional value. They play a crucial role in determining texture by contributing to softness, creaminess, and mouthfeel. In baked goods, lipids interact with flour components to limit gluten development, resulting in tender and crumbly textures. In addition, lipids act as carriers of flavors and aroma compounds, enhancing the overall sensory perception of foods.

Lipids also influence the physical stability of food systems, particularly in emulsions such as mayonnaise, sauces, and dairy products. Their ability to form and stabilize emulsions depends on the presence of emulsifiers and the interaction between lipid and aqueous phases. Furthermore, lipids contribute to heat transfer during cooking processes such as frying, ensuring uniform cooking and the development of characteristic flavors and textures.

II. Applications in Major Food Products

Bakery and Pastry Products

In bakery products, lipids such as butter, margarine, and vegetable oils are essential ingredients that affect dough properties and final product quality. They improve dough handling, increase volume, and contribute to the softness and shelf life of products such as

bread, cakes, and biscuits. In pastry, the plasticity of fats is particularly important for creating layered structures, as seen in croissants and puff pastry.

Dairy Products

Lipids are fundamental components of dairy products, where they contribute to texture, flavor, and nutritional value. In products such as cheese and cream, milk fat plays a key role in determining consistency and mouthfeel. The distribution and crystallization of fat globules influence the structure and stability of these products. In ice cream, lipids are essential for creating a smooth texture and preventing the formation of large ice crystals.

Fried Foods

Frying is one of the most common applications of lipids in food processing. Oils are used as heat transfer media, allowing rapid cooking and the development of desirable sensory properties such as crispiness and flavor. However, repeated use of frying oils can lead to lipid degradation, resulting in the formation of undesirable compounds. Therefore, the selection and management of frying oils are critical for ensuring product quality and safety.

Meat and Processed Foods

In meat products, lipids contribute to juiciness, flavor, and texture. They are also involved in the formation of emulsified products such as sausages and pâtés. The type and distribution of fat within the product influence its technological properties and consumer acceptance. In processed foods, lipids are often used to improve palatability and extend shelf life.

III. Lipid-Based Food Ingredients

The food industry uses a wide range of lipid-based ingredients designed to meet specific technological and nutritional requirements. Margarine and shortening are widely used as alternatives to butter, offering controlled melting properties and improved stability. Structured lipids, obtained through processes such as interesterification, allow the modification of fatty acid composition to achieve desired functionalities. Emulsifiers derived from lipids, such as lecithin, are essential for stabilizing complex food systems and improving texture and consistency.

IV. Role of Lipids in Sensory Quality

Lipids have a major impact on the sensory attributes of food products. They contribute to flavor perception by acting as solvents for aromatic compounds and by participating in chemical reactions that generate flavor during cooking. The texture of foods, including attributes such as creaminess, smoothness, and crispiness, is also strongly influenced by lipid content and structure. In addition, lipids affect the visual appearance of foods by contributing to gloss, color, and overall attractiveness.

V. Challenges in Industrial Use of Lipids

Despite their importance, the use of lipids in the food industry presents several challenges. One of the main issues is oxidative stability, as lipids are prone to oxidation, leading to quality deterioration and reduced shelf life. Another challenge is the need to reduce saturated and trans fats in response to public health concerns, while maintaining the functional properties required for food processing. The development of healthier alternatives that do not compromise quality remains a key objective for the food industry.

VI. Future Trends in Lipid Applications

The future of lipid applications in food systems is shaped by innovation and changing consumer demands. There is a growing interest in plant-based and sustainable lipid sources, as well as in the development of functional foods enriched with beneficial fatty acids. Advances in food technology are enabling the design of lipids with tailored properties, improving both nutritional quality and technological performance. These developments are expected to expand the role of lipids in modern food systems.

Conclusion

Lipids play a central role in the formulation, processing, and quality of food products. Their multifunctional properties make them indispensable in the food industry, where they contribute to texture, flavor, stability, and nutritional value. Understanding the applications and challenges associated with lipids is essential for developing innovative and high-quality food products. As the field continues to evolve, the integration of health, technology, and sustainability will remain a key priority.

Conclusion

General conclusion

The study of fats and oils highlights their central role in both human nutrition and food processing industries. They are not only essential energy sources but also key functional ingredients that determine the quality and performance of numerous food products.

Throughout this work, it has been demonstrated that the structure and composition of lipids strongly influence their physical, chemical, and nutritional properties. The balance between saturated, monounsaturated, and polyunsaturated fatty acids is particularly important in determining their health impact and technological suitability.

The different industrial processes applied to fats and oils, including extraction, refining, and modification techniques, allow manufacturers to tailor lipid characteristics to specific applications. However, these processes must be carefully controlled to preserve nutritional quality while ensuring safety, stability, and consumer acceptability.

Moreover, the increasing awareness of health-related issues associated with dietary fats has led to significant developments in the lipid industry, including the production of trans-fat-free formulations, interesterified fats, and functional lipid-based products enriched in essential fatty acids.

In conclusion, fats and oils remain complex and versatile components that require a multidisciplinary approach involving food science, chemistry, nutrition, and technology. Their study is essential for the development of healthier, more stable, and more functional food products that meet modern consumer expectations and nutritional guidelines.

List of references

List of References

Alves, V., et al. (2024). *Chemical and Enzymatic Interesterification for Food Lipid Production*. Springer.

Belitz, H.-D., Grosch, W., & Schieberle, P. (2009). *Food Chemistry*. Springer.

Bender, D. A., & Bender, A. E. (1996). *Nutrition: A Reference Handbook*. Oxford University Press.

Calder, P. C. (2004). n-3 fatty acids and inflammation. *American Journal of Clinical Nutrition*.

Calder, P. C. (2015). Functional roles of fatty acids. *Journal of Clinical Nutrition*.

Coultate, T. (2009). *Food: The Chemistry of Its Components*. Royal Society of Chemistry.

Covas, M. I. (2007). Olive oil and health. *Pharmacological Research*.

Damodaran, S., Parkin, K. L., & Fennema, O. R. (2008). *Fennema's Food Chemistry*. CRC Press.

Erickson, D. R. (1995). *Practical Handbook of Soybean Processing*. AOCS Press.

FAO. (2010). *Fats and Fatty Acids in Human Nutrition*. FAO Food and Nutrition Paper.

Gunstone, F. D. (1996). *Fatty Acid and Lipid Chemistry*. Springer.

Gunstone, F. D., & Norris, F. A. (1983). *Lipids in Foods: Chemistry, Biochemistry and Technology*. Elsevier.

Gurr, M. I., Harwood, J. L., & Frayn, K. N. (2002). *Lipid Biochemistry: An Introduction*. Blackwell Science.

Hamm, W., & Hamilton, R. J. (2013). *Edible Oil Processing*. Wiley-Blackwell.

Hamilton, R. J. (1998). *Lipid Analysis in Oils and Fats*. Springer.

Hu, F. B., et al. (2001). Dietary fat intake and coronary heart disease. *Journal of Nutrition*.

Kris-Etherton, P. M., et al. (2002). Nuts and heart health. *Circulation*.

Kris-Etherton, P. M., et al. (2003). Fish consumption and cardiovascular health. *Circulation*.

Lawson, H. (1995). *Food Oils and Fats: Technology, Utilization and Nutrition*. Springer.

Mead, J. F., Alfin-Slater, R. B., Howton, D. R., & Popják, G. (1986). *Lipids: Chemistry, Biochemistry, and Nutrition*. Springer.

Mozaffarian, D., et al. (2010). Effects of dietary fats. *New England Journal of Medicine*.

Nielsen, S. S. (2017). *Food Analysis*. Springer.

Ros, E. (2010). Health benefits of nut consumption. *Nutrients*.

Ruxton, C. H. S., et al. (2004). Fish consumption and health benefits. *Nutrition Research Reviews*.

Sanders, T. A. B. (2015). *Functional Dietary Lipids*. Elsevier.

Schwingshackl, L., & Hoffmann, G. (2014). Olive oil consumption and health. *Lipids in Health and Disease*.

Shahidi, F. (2005). *Bailey's Industrial Oil and Fat Products*. Wiley.

Sharma, S. K., et al. (2022). *Chemistry of Food Fats, Oils, and Other Lipids*. Springer.

Simopoulos, A. P. (2002). The importance of omega-3 fatty acids. *Biomedicine & Pharmacotherapy*.

WHO. (2018). *Healthy Diet Guidelines*. World Health Organization.

Exercises and Assessment

Exercises and Assessment – Lipids and Fats Analysis

Multiple Choice Questions (MCQs)

1. Which solvent is most commonly used for lipid extraction in the Soxhlet method?

A. Water

B. Ethanol

C. Hexane

D. Acetic acid

2. The iodine value is an indicator of:

A. Free fatty acids

B. Degree of unsaturation

C. Water content

D. Protein content

3. A high acid value indicates:

A. High purity of oil

B. High oxidation stability

C. Hydrolysis of triglycerides

D. Low moisture content

4. Saponification value is inversely related to:

A. Molecular weight of fatty acids

B. Degree of unsaturation

C. Color of oil

D. Density of oil

5. Which of the following compounds belongs to unsaponifiable matter?

A. Triglycerides

B. Fatty acids

C. Sterols

D. Glycerol

6. The main purpose of converting fatty acids into methyl esters is:

A. Increase solubility in water

B. Facilitate chromatographic analysis

C. Improve taste

D. Reduce acidity

7. Refractive index increases with:

A. Decrease in temperature

B. Increase in saturation

C. Increase in unsaturation

D. Decrease in chain length

8. Soap traces in oil indicate:

A. Good refining

B. Incomplete refining

C. High oxidation

D. Low viscosity

9. Lipids are primarily composed of:

A. Amino acids

B. Fatty acids and glycerol

C. Monosaccharides

D. Nucleotides

10. Triglycerides are formed by:

A. 1 fatty acid + glycerol

B. 2 fatty acids + glycerol

C. 3 fatty acids + glycerol

D. 4 fatty acids + glycerol

11. Which fatty acid is saturated?

A. Oleic acid

B. Linoleic acid

C. Stearic acid

D. Linolenic acid

12. Unsaturated fatty acids contain:

A. Only single bonds

B. Double bonds

C. Triple bonds

D. Ionic bonds

13. Primary oxidation products are:

A. Aldehydes

B. Ketones

C. Peroxides

D. Alcohols

14. Which factor accelerates lipid oxidation the most?

A. Low temperature

B. Absence of oxygen

C. Light exposure

D. Vacuum conditions

15.Rancidity leads to:

A. Improved taste

B. Off-flavors

C. Increased stability

D. Decreased acidity

16. Antioxidants act by:

A. Increasing oxygen

B. Breaking oxidation chain reactions

C. Raising temperature

D. Increasing moisture

17.The first step in oil refining is:

A. Deodorization

B. Neutralization

C. Extraction

D. Hydrogenation

18.Neutralization removes:

A. Pigments

B. Free fatty acids

C. Water

D. Proteins

19.Hydrogenation results in:

A. Increased unsaturation

B. Formation of trans fats

C. Decrease in melting point

D. Increased oxidation

20.Deodorization removes:

A. Free fatty acids

B. Odor compounds

C. Water

D. Minerals

Corection:
1.C 2B 3.C 4.A 5.C 6.B 7.C 8.B 9.B 10.C 11.C 12.B 13.C 14.C 15.B 16.B 17.C 18.B 19.B 20.B