Essential Polyunsaturated Fatty Acids: Bioactivities of Omega 3 and Omega 6 Fatty Acids

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Abstract

Fatty acids (FA) are organic compounds composed by lineal monocarboxylic carbon chains that usually have an even number of carbons and might contain a variable number of double bonds, whose positions on the molecule are used to classify unsaturated fatty acids. ω-6 and ω-3 fatty acids families have the first doble bond at C6 and C3 respectively, starting from de methyl end. These families are considered as essential since humans do not possess the enzymes necessary to synthesize them and in consequence, must be taken from the diet. The main sources of ω-6 fatty acids are vegetable oils and animal meat, while ω-3 fatty acids are predominantly found in marine organisms and some vegetable oils as well. They are functionally distinct and have important physiological functions and a high impact on health. In consequence, dietary recommendations regarding the intake and equilibrium between essential fatty acids families are of outmost importance.

Keywords: PUFA; Omega-3; Omega-6; Essential fatty acids; Nutrition and health

Cite this Article as: Barroso-Hernández, Alejandra, Angulo-Guerrero, Jesús Ofelia, Sánchez-Otero, María Guadalupe, Ramírez-Higuera, Abril, Rosas-Vásquez, Maritza, Arroyo-Vásquez Lydia Yahaira, Bravo-Ramos, José Luis, Oliart-Ros, Rosa María, 2025. Essential polyunsaturated fatty acids: bioactivities of Omega 3 and Omega 6 fatty acids. In: Ismael SS, Nisa QU, Nisa ZU and Aziz S (eds), Diseases Across Life: From Humans to Land and Sea. Unique Scientific Publishers, Faisalabad, Pakistan, pp: 115-124. https://doi.org/10.47278/book.HH/2025.88

A Publication of Unique Scientific Publishers	Chapter No: 25-017	Received: 07-Feb-2025 Revised: 25-March-2025 Accepted: 09-Apr-2025

Introduction

Lifestyle habits have drastically changed in the last decades, going towards a more sedentary life and industrialized dietary food pattern, characterized by being rich in carbohydrates, lipids and salt. These changes have led to the expansion of diet related diseases such as overweight, obesity, diabetes, cardiovascular diseases, hypertension, and nervous system illness, among others. In fact, ischemic heart disease, a noncommunicable disease, accounts for almost 15% of total deaths globally. Besides, the global prevalence projections to 2050 reports an increase of ischemic heart disease not only because of the population ageing but also due to the lifestyles changes that include more refined, fat rich and less whole grain foods. Diabetes is another non communicable disease, related to sedentary and industrialized diets that include not only snacks, beverages and animal fats but also reduced in vegetable-based foods. A study published in the Lancet (2024) (NCD-RisC) about the worldwide trends (1990-2022) in diabetes mellitus prevalence and treatment, relates an increase of 630 million adults with diabetes, mainly in low- and middle-income countries. The main factor attributed to this rise in prevalence of diabetes and other non-communicable diseases is the increase in obesity, accompanied by a high consumption of fat and refined carbohydrates rich foods. As a matter of fact, the excess of dietary carbohydrates and lipids are stored in the body as adipose tissue. As known, dietary fat is constituted mainly of triacylglycerides, composed by esterified fatty acids, which vary in length and degree of carbon saturation. Over 50% of dietary lipids is applied to produce body energy. Up to the 1930´s, fats were thought to be non-essential, until it was demonstrated that the lack of dietary fat led to different growth abnormalities that could eventually produce death. Indeed, phospholipids, another dietary type of fat, is important to support cell membrane's structure and function as source of vitamin D, prostaglandins and other types of eicosanoids. Dietary cholesterol as well as endogenous produced cholesterol is transported by lipoproteins and is imbedded into the cell membrane, however, when consumed or produced more than needed, cholesterol becomes a risk factor for ischemic heart disease. Since then, it is well known that essential fatty acids play very important roles at the cellular, molecular and physiological level in human health.

In this chapter, essential fatty acids will be presented, their different families, the recommended family balance, their dietary sources, their specific bioactivity, as well as their relationship with human health.

Essential Fatty Acids

Fatty acids (FA) are compounds of organic nature composed by lineal monocarboxylic carbon chains that usually have an even number of carbons. Although there are some dietary odd-chain FA, they are only present in trace levels in some types of fish and plants such as the pentadecanoic acid (C15:0), or a member of the omega-3 family, the C21:5n3. There are other “rare” FA with an odd molecular formula such as the cyclopropenoid fatty acids: sterculic (C19) and dihydrosterculic (C19) acids (Sánchez-Otero et al., 2024).

All fatty acids possess polar and non-polar regions; the carboxylic group (-COOH) is hydrophilic and more reactive than the rest of the molecule, and the carboxyl carbon is considered the “alpha” position of the chain. The opposite side of the chain is the methyl end (-CH3), the “omega” end, and is less reactive and hydrophobic (Lempke et al., 2024).

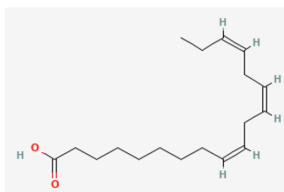
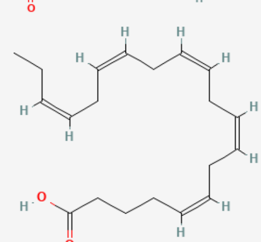
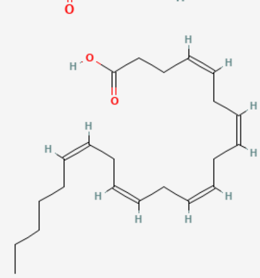
FA are classified according to the carbon chain length, the degree of carbon saturation (mono, and polyunsaturated), and the location of the first double bond on the carbon chain, counting from the methyl (omega) end of the carbon chain: ω-9, ω-6, and ω-3. The ω-9 family is represented by oleic acid (C18:1), obtained both from the diet and by the endogenous synthesis from carbohydrates, considered therefore as non-essential. On the other hand, in the ω-6 family the first double bond is located between the sixth and seventh carbon from the methyl end. The family is represented by linoleic acid (LA, C18:2) and since it is not produced by the body it must be taken in the diet; because of that they are considered as essential (Mori & Hodgson, 2013). The ω-3 family is another essential fatty acid family, where the position of the first double bond is located between the third and fourth carbon atoms form the methyl end (Cholewski et al., 2018); its precursor is α-linolenic acid (ALA, C18:3), with three double bonds.

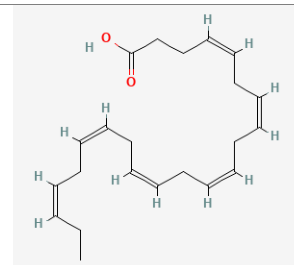
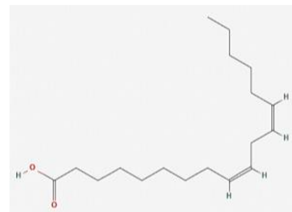
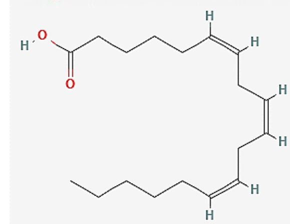
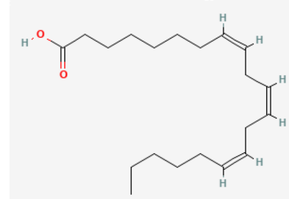
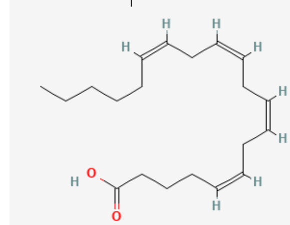
The double bond location in FAs, their geometry and the methyl branching are the chemical characteristics that determine their biological role (Wang et al., 2024). Both ω-3 and ω-6 fatty acids show geometric (cis-trans) isomerism, due to the presence of two carbon atoms with sp2 hybridization that form a double bond, which are methylene-interrupted when two or more are present in a conjugated arrangement; these carbons are also connected to a hydrogen atom and another carbon linked to the rest of the chain. The isomerism in FA plays an important role in their biological activity since the 3D molecular shape of the FA might vary between isomers, affecting the possible interactions with other molecules and resulting in different biological properties (Cholewski et al., 2018). Since the physicochemical characteristics of isomers are similar but their bioactivities might be dramatically different, the identification and quantification of each isomer is crucial in understanding their functions; the most popular method for this determination is gas chromatography coupled with mass spectrometry (GC/MS) analysis after their derivatization to fatty acid methyl esters (FAMEs) (Wang et al., 2024).

The ω-6 and ω-3 FAs are functionally distinct and many of them have opposing physiological functions compared with their molecular formula isomer counterpart. For example, ALA (C18:3 ω-3) and Ɣ-linolenic acid (LA) (C18:3 ω-6) share the same molecular formula $C_{18}H_{30}O_2$. However, their metabolic origin and biological activities are different. ALA has neuroprotective, anti-depressant and some anti-inflammatory effects in humans while LA is an inflammatory agent and platelet aggregation inhibitor (Djuricic & Calder, 2021).

Arachidonic acid, AA (20:4 ω-6), with 20 carbons and four double bonds is the main bioactive fatty acid of the ω-6 family. Eicosapentaeonic acid, EPA (22:5 ω-3), and docosahexaenoic, DHA (22:6 ω-3), are the main bioactive fatty acids of ω-3 family. AA, EPA and DHA are called long chain polyunsaturated fatty acids (PUFA) to differentiate them from their precursors LA and ALA. The chemical characteristics and structure of ω-3 and ω-6 FA are shown in Table 1.

Table 1: Chemical characteristics and structure of ω-3 and ω-6 fatty acids.

Common name	IUPAC name	Molecular formula	Simplified notation	Molecular weight (g/mol)	Structure	PubChem Identifier (Kim et al., 2025)
Omega-3						
Alpha-Linolenic acid	(9Z,12Z,15Z)-octadeca-9,12,15-trienoic acid	C18H30O2	C18:3n3	278.4		CID 5280934
Eicosapentaenoic acid	(5Z,8Z,11Z,14Z,17Z)-icosa-5,8,11,14,17-pentaenoic acid	C20H3O2	C20:5n-3	302.5		CID 446284
Docosapentaenoic acid	(4Z,7Z,10Z,13Z,16Z)-docosa-4,7,10,13,16-pentaenoic acid	C22H34O2	C22:5n-3	330.5		CID 6441454

Docosahexaenoic acid	(4Z,7Z,10Z,13Z,16Z, 19Z)-docosa-4,7,10,13,16,19-hexaenoic acid	$C_{22}H_{32}O_2$	C22:6n-3	328.5		CID 44ci5580
Omega-6						
Linoleic acid	(9Z,12Z)-octadeca-9,12-dienoic acid	$C_{18}H_{32}O_2$	C18:2n-6	280.4		CID 5280450
Gamma-linolenic acid	(6Z,9Z,12Z)-octadeca-6,9,12-trienoic acid	$C_{18}H_{30}O_2$	C18:3n-6	278.4		CID 5280581
Dihomo-gamma-linolenic acid	(8Z,11Z,14Z)-icosa-8,11,14-trienoic acid	$C_{20}H_{34}O_2$	C20:3n-6	306.5		CID 5280581
Arachidonic acid	(5Z,8Z,11Z,14Z)-icosa-5,8,11,14-tetraenoic acid	$C_{20}H_{32}O_2$	C2:4n-6	304.5		CID 444899

Biosynthesis and Metabolism of ω-6 And ω-3 Fatty Acids

In humans, the endogenous FA synthesis in the liver starts from acetyl Co-A and, with the participation of the acetyl-CoA carboxylase and the fatty acid synthase complex enzymes, goes up to saturated palmitic acid (C16:0) that can be desaturated to palmitoleic acid (C16:1) and elongated to stearic acid (C18:0), which by desaturation gives rise to the monounsaturated oleic acid (C18:1 ω-9). Only plants, microalgae and fungi can desaturate oleic acid to synthetize LA and ALA, the precursors of ω-6 and ω-3 polyunsaturated fatty acids (PUFA) (Fig. 1).

However, mammals do not possess the delta desaturases required to introduce a second double bond at the adjacent C6 of the carbon chain (Δ9,12) to produce linoleic acid (C18:2, ω-6), nor to introduce a third double bond at C3 (Δ9,12,15) to produce α-linolenic acid (C18:3, ω-3). Thus, both precursors of ω-6 and ω-3 PUFA families ought to be taken through dietary sources and because of that are considered as essential FA. Then, the synthesis of PUFAs can continue by increasing the chain length and degree of unsaturation through the incorporation of other double bonds at the carboxyl end of the FA molecule (Simopoulos, 2016). The metabolic pathways of the synthesis of ω-3 and ω-6 PUFAs from ALA and LA, requires the participation of the enzymes Δ6- and Δ5-desaturases and elongases of the microsomal system, and β-oxidation to shorten chains in the peroxisomes (Figure 2).

The desaturation of ALA is carried out by FADS2 Δ6-desaturase, responsible for inserting a double bond to give way to stearidonic acid (18:4 ω-3), then an elongase and another desaturation is introduced by FADS1 Δ5-desaturase to obtain eicosapentaenoic acid (EPA); finally, Δ6-desaturase gives way to the formation of tetracosahexaenoic acid that, through β-oxidation, produces docosahexaenoic acid (DHA). LA undergoes a desaturation by FADS2 Δ6-desaturase and an elongation that gives way to dihomo ϒ-linolenic acid (DHGLA), that undergoes desaturation by the FADS1 Δ5-desaturase for the formation of arachidonic acid (AA) (Figure 2) (Simopoulos, 2016).

Plants, microalgae and fungi possess the enzymatic machinery to sinthesize LA and ALA, so they are good sources for these essential FA, that are then incorporated into the lipids of fish, marine and terrestrial animals by the food chain and used as precursors for the synthesis of long chain PUFA. Microalgae and some fungi can also synthesize ω-3 PUFA; it has been suggested that marine algae are the major producers of long chain ω-3 PUFAs (e.g., DHA) in the biosphere (Sahidi & Ambigaipalan 2018).

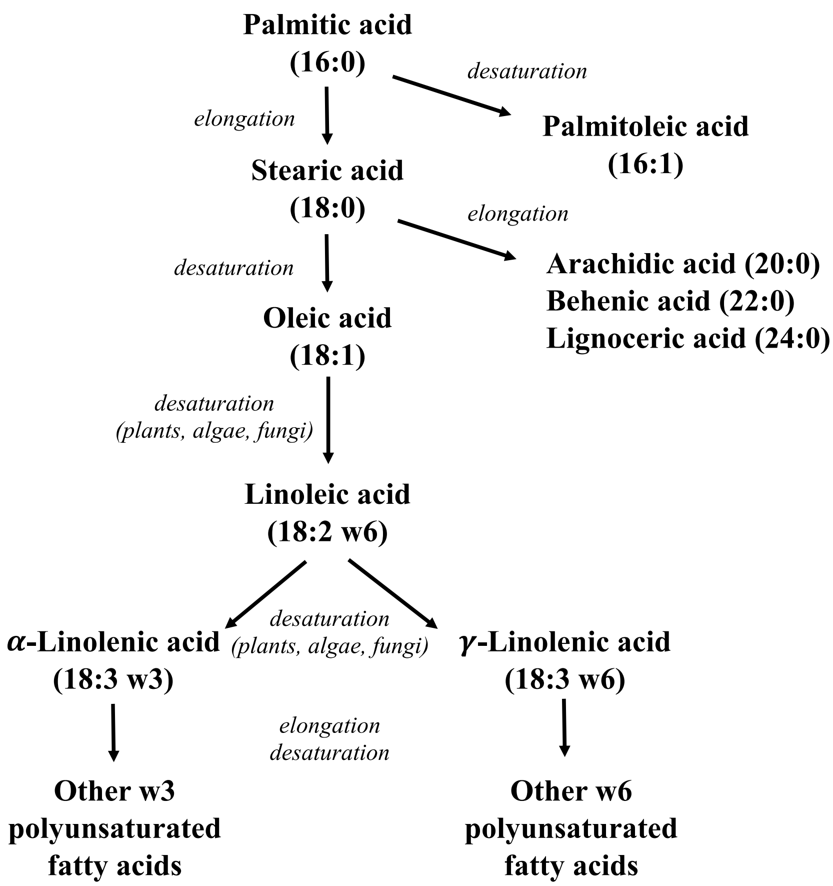


Fig. 1: Biosynthesis of PUFAS (Lehninger and Cox, 2017).

Food Sources of ω-3 and ω-6 fatty acids

Since humans cannot synthesize *de novo* the essential ω-3 and ω-6 fatty acids, they have to be ingested through dietary foods (Figure 3 and Table 2). Plants seeds, nuts and oils are good sources of ALA and LA. High concentrations of ALA (ω-3) are found in flaxseed, chia and echium seeds, walnut, hemp, canola and soybean oils, as well as in fish such as salmon, trout, and tuna; LA (ω-6) is found in sunflower, corn, soybean, safflower, and canola seed oils (Djuricic & Calder, 2021; Mititelu, et al., 2024).

Long chain PUFA, particularly EPA and DHA, can be obtained from the meat of fatty fish such as salmon, mackerel and menhaden, from the liver of white fish such as sardine, cod, halibut and herring, and from the blubber of marine mammals such as seals and whales. Marine algal species are also a good source of ω-3 PUFA, such as *Crypthecodinium cohnii* and *Schizochytrium spp.*, that contain DHA levels of 55% and 40% of total fatty acids, respectively (Sahidi & Ambigaipalan 2018).

Once ingested from dietary sources, pharmaceutic capsules or supplements, LA and ALA can be used by the human body to synthesize longer and more unsaturated ω-6 and ω-3 fatty acids. However, the bioconversion of ALA to ω-3 PUFAs has a low efficiency due to the inequality in the content of ω-3 vs ω-6 fatty acids in the cells. This imbalance is a result of a higher dietary intake of foods and oils rich in LA and its derivatives, such as edible oils than contain more than 50% of linoleic acid, and grain and feedlot cattle-based diets enriched in ω-6 PUFA due to high production farming, along with a lower consumption of foods rich in ALA. Since the same delta desaturases and elongases are needed to introduce double bonds and extend the carbon chains of both LA and ALA, there is a competition for the substrates that results in a greater conversion of LA due to its higher relative abundance, even though the Δ6-desaturase has a greater affinity for ALA (Ponnampalam et al., 2021). In consequence, the body produces much more AA, and much less EPA and DHA. Therefore, it is highly recommended to consume ω-3 PUFA from leafy vegetables and seeds' oils rich in ALA, and marine fish that, as stated before, are the major dietary sources of long chain ω-3 PUFA that are then incorporated mainly into phospholipids and have very important cellular, molecular and physiological functions in human health.

ω-3 AND ω-6 Fatty Acids Bioactivities and its Participation in Health and Disease

In the 1970s, the health benefits of ω-3PUFAs were first described, following the observation of Bang and Dyberg who detected a low mortality rate due to cardiovascular diseases in the Eskimo population in Greenland despite consuming a high-fat diet. They proposed that their marine-based diet (fish, seals and whales) could reduce mortality, while other populations that did not consume them presented certain types of pathologies, and that an excessive intake of ω-6 PUFA without ω-3PUFAs could promote various pathologies (Bang et al., 1971). Since then, a great number of investigations have documented the bioactivities of these essential PUFAs and their relationship with human health, particularly on cardiovascular, metabolic and inflammatory diseases. Bioactivities are mainly involved in the regulation of cell membranes' structure and function, of intracellular signaling pathways, transcription factors' activity, and gene expression, and in the production of bioactive lipids mediators (Calder, 2015).

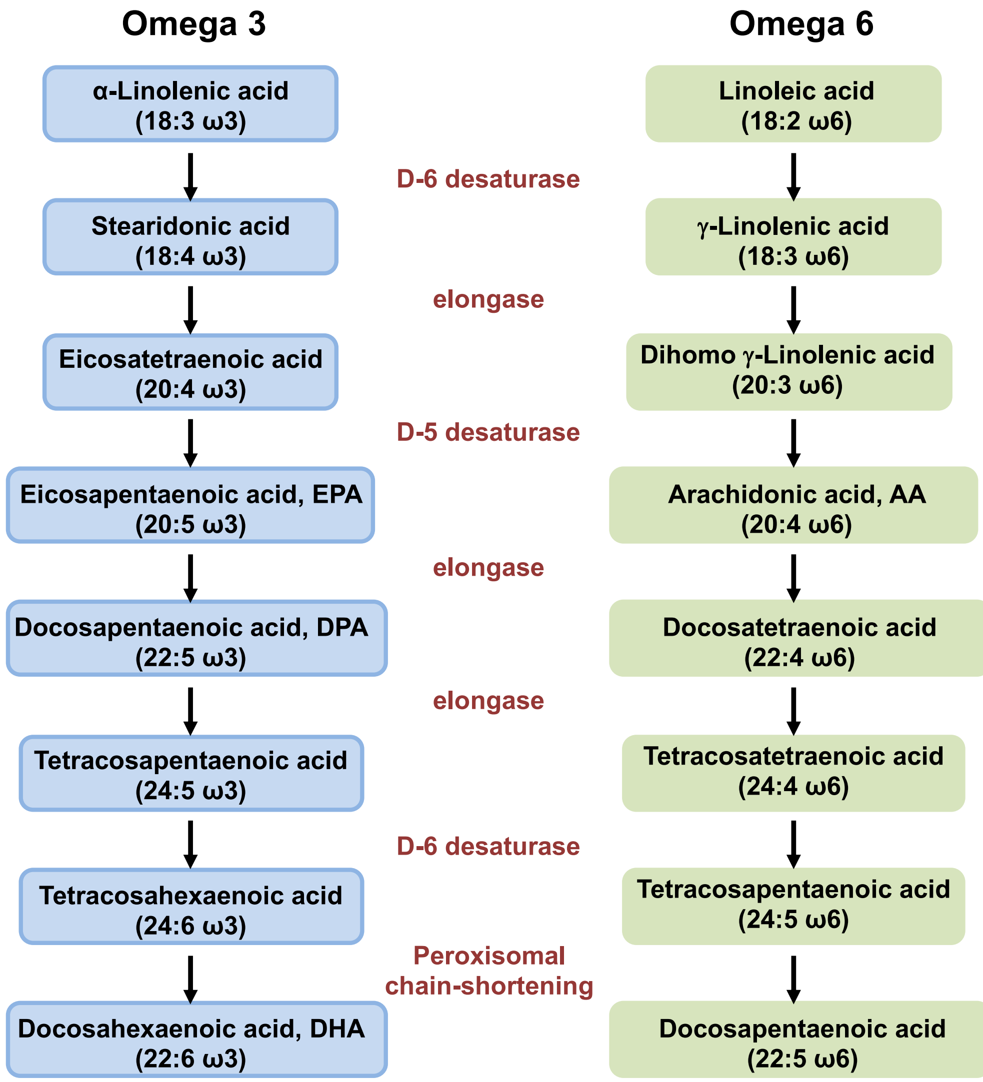


Fig. 2: Biosynthesis of ω-3 and ω-6 fatty acids (Simopoulos, 2016).

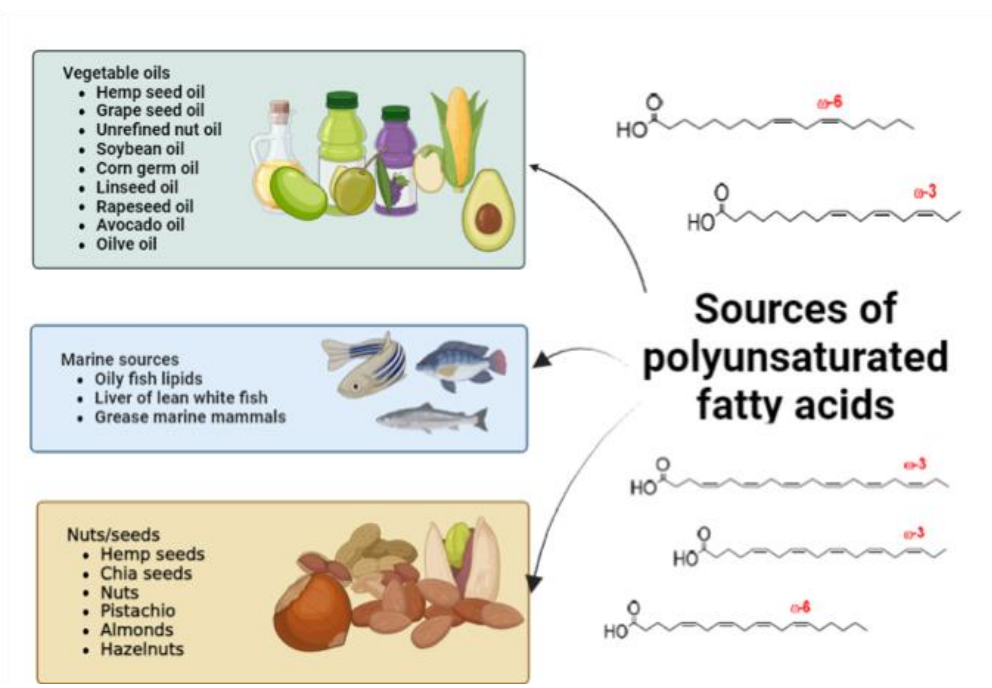


Fig. 3: Food sources of ω-3 and ω-6 fatty acids.

Table 2: Percentage of ω-3 and ω-6 fatty acids in diverse foods from plant and animal origin.

Food	ω-3				ω-6	
	ALA	EPA	DHA	DPA	LA	ARA
Edible oils (Popa et al., 2012; Dorni et al., 2018)						
Coconut	--	--	--		1.90	--
Corn	0.76	--	--		48.97	--
Cotton seed	0.35	--	--		51.81	--
Groundnut	--	--	--		26.96	--
Soybean	6.79				50.42	
Linseed	53.21				17.25	
Seeds (Saini et al., 2021)						
Rapeseed/canola	8.7-9.5	--	--		--	--
Garden cress	30.34	--	--		--	--
Flax	53.4	--	--		--	--
Chía	54.5-64.7	--	--		--	
Fish oil (Shahidi and Ambigaipalan, 2018)						
Menhaden	--	18.3	9.6	1.8		
Salmon	--	6.2	9.1	1.8		
Herring	--	7.5	6.8	0.75		
Cod flesh	--	19.1	32.6	2.0		
Sardine	--	13.20	18.23	2.99		
Crustaceans (Budge et al., 2002)						
Shrimp	--	15.26	11.37	0.74	--	--
Red carb	--	12.13	11.93	2.25	--	--
Lobster	--	17.04	7.69	1.29	--	--
Other marine species (Shahidi and Ambigaipalan, 2018)						
Common octopus	--	16.1	20.6	1.8		
Squid	--	13.9	16.9	1.3	--	--
Surf clam	--	22.9	14.3	--	--	--
Scallop	--	26.9	25.9	--	--	--
Meat. Adipose tissue (loin chops or steaks) (Wood et al., 2008)						
Pig	1.4	--	--	--	14.3	0.2
Sheep	1.0	--	--	--	1.3	--
Cattle	0.5	--	--	--	1.1	--
Meat. Muscle (loin chops or steaks) (Wood et al., 2008)						
Pig	0.95	0.31	--	--	14.2	2.21
Sheep	1.37	0.45	--	--	2.7	0.64
Cattle	0.70	0.28	--	--	2.4	0.63

In cells, ω-3 and ω-6 PUFAs are incorporated into membrane's phospholipids and play fundamental roles in their structure, fluidity and functionality, as well as of the proteins embedded within the membrane (Calder 2015; Feliu et al., 2021). In addition, they are precursors of molecules that participate in cell signaling processes that have different activities depending on the nature of their fatty acid composition. They might be used also for the synthesis of eicosanoids (prostaglandins, thromboxanes and leukotrienes), that are regulatory molecules whose bioactivities differ depending on the precursor fatty acid, and for the synthesis of proresolving mediators (protectins and resolvins), that participate in the resolution of inflammation (Djuricic *et al.*, 2021). The participation of fatty acids on the regulation of gene expression directly or by modifying the activity of transcription factors is another activity that has profound effects on cell function and metabolism and that differ depending on the fatty acid involved in gene expression regulation (Calder, 2015). In consequence, the impact on health and disease must be analyzed according to the fatty acid family in question (Fig. 4).

Omega-3 Fatty Acids

Numerous studies have documented the beneficial impacts of ω-3 PUFAs, particularly EPA and DHA, for the treatment and risk reduction of cardiovascular diseases (CVD), diabetes mellitus, and metabolic syndrome. The effects are mediated by the reduction of blood pressure and serum levels of triacylglycerol, LDL- and VLDL-cholesterol, TNF-α, the inhibition of platelet aggregation, an increase in HLD cholesterol levels and CD36 expression, and by ameliorating inflammation (Alexander et al., 2004; Calder, 2004; Alexander et al., 2006; Saravanan et al., 2010). They are therapeutic in other clinical conditions such as psoriasis, atherosclerosis, cancer, rheumatoid arthritis, atopic dermatitis, coronary heart disease, collagen vascular diseases, autoimmune and neurodegenerative diseases (Das, 2006; DeFilippis et al., 2006; Djuricic et al., 2021).

ω-3 PUFAs have also important roles in nervous system development and function. DHA is present in higher amounts than other fatty acids in different tissues, organs and systems such as retina and central nervous system; this is due to its important role in neurotransmission, neuroplasticity and signal transduction (Lauritzen et al., 2016; Mallick et al., 2019). In infancy and childhood, ω-3 PUFAs are fundamental for a good behavioral, visual and neural development. In addition, the positive effects of EPA and DHA in treating and preventing dementia, Alzheimer's disease and schizophrenia have been extensively documented (Feliu *et al*., 2021). It has also been observed that the administration of EPA + DHA improves depressive symptoms (Das, 2006; Tian et al., 2025) and has beneficial effects in a parkinsonism rat model by restoring locomotor alterations and by exerting neuroprotective and neurorestorative activities (Barroso et al., 2022).

EPA and DHA have also anti-inflammatory actions by mean of the increased synthesis of resolvins, protectins and maresins, considered as pro-resolving mediators (SPMs) along with the reduced synthesis of eicosanoids from arachidonic acid (Knochel et al., 2015) (Figure 4). Diminutions in inflammatory markers (cytokines, chemokines, adhesion molecules, and acute phase proteins) after the administration of EPA and DHA have been observed in diseases such as rheumatoid arthritis (Miles and Calder, 2012). Anti-inflammatory beneficial actions have also been observed in cancer studies, enhancing the effectiveness of anticancer treatments. Cell apoptosis, reduction of prostaglandin E2 and the induction of oxidative stress are also documented effects of ω-3 PUFAs in cancerous cells (Merendino et al., 2013). An antioxidant role has been given to ω-3PUFAs since they regulate antioxidant signaling pathways (Djuricic et al., 2021). Beneficial effects on atopic dermatitis, collagen vascular diseases, and autoimmune diseases have also been reported (Das, 2006; DeFilippis et al., 2006; Djuricic et al., 2021).

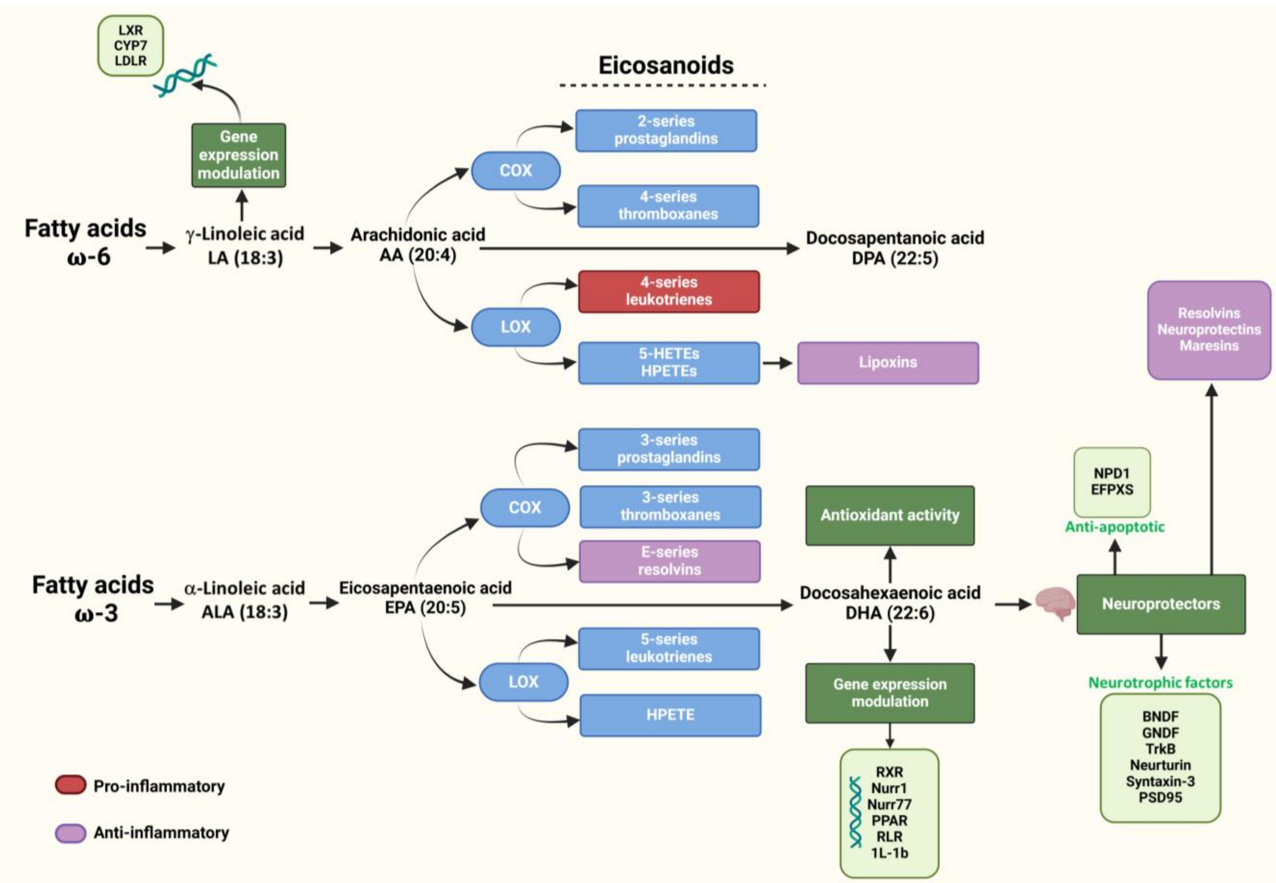


Fig. 4: Bioactivities of the molecules synthesized from ω-3 and ω-6 fatty acids. COX: cyclooxygenases; HETEs: hydroxyeicosatetraenoic acids; HPETE: hydroperoxyeicosatetraenoic acids; LOX: lipoxygenases; LTB4: leukotriene B4 (Knochel et al., 2015).

Recent research suggests that ω-3 PUFAs, especially EPA and DHA, are useful for COVID-19 therapies, due to their actions on inflammation and thrombosis, although more confirmative studies need to be undertaken (Djuricic et al., 2021).

Omega-6 Fatty Acids

ω-6 PUFAs are known for their generally proinflammatory properties and have been involved in several pathological processes. However, linoleic and arachidonic acid, which are the principal ω-6 fatty acids, usually have different biological roles, and their pathological implications derive from the fact that a greater concentration of these fatty acids are found in cells, in comparison to ω-3 fatty acids, mainly due to the higher intake of ω-6 PUFAs that characterizes western diets. In consequence, the eicosanoid products of arachidonic acid (AA), including prostaglandins, thromboxanes, and leukotrienes (Figure 4), are produced in greater amounts than those synthesized from ω-3 PUFAs. AA derived eicosanoids participate in important processes such as the immune response, the regulation inflammatory responses and pain, bone turnover, smooth muscle contraction, renal function, the proliferation of tumor cells and cancer progression, and might have opposing effects depending on the producer cell and it's physiological situation; for example, in some circumstances AA metabolites alleviates inflammation by means of the production of the pro-resolving mediator lipoxin A4 (Vachier et al., 2002).

Linoleic acid (LA) has a specific and unique function in skin structure and barrier function, as this fatty acid is a basic component of ceramides; LA also participates by modulating the fluidity of the stratum corneum that functions as a permeability barrier of the skin. The combined treatment with ω-6 and ω-3 PUFA of atopic dermatitis and other skin inflammatory disorders can ameliorate skin inflammation by acting as precursors of pro- and anti-inflammatory eicosanoids (Honda and Kabashima, 2019; Calder, 2020).

With respect to CVD, it has been reported that a low to moderate intake of LA reduces cholesterol and LDL-cholesterol concentrations in blood by partially substituting saturated fatty acids, and as a result of the positive regulation of the gene expression of hepatic LDL receptor. In consequence, it has been related with a lower incidence and mortality of cardiovascular diseases (Djuricic et al., 2021). Eicosanoids derived from AA participate also in the regulation of platelet aggregation, thrombosis and vascular tone (Crescente et al., 2019).

From the above mentioned beneficial and detrimental effects of ω-3 and ω-6 PUFA on cell functioning and human health, it is mandatory to establish dietary recommendations for the proper consumption of these essential fatty acids, not only in their absolute amount but, most importantly, in the balanced percentage of both ω-3 and ω-6 families in order to prevent diseases and reach an optimal health.

The ω-3/ ω-6 Ratio and Dietary Recommendations

Studies on food and nutrition associated to human evolution show that there was a lower consumption of saturated and trans fatty acids, and comparable amounts of ω-3 and ω-6 PUFA (1-2:1 ratio) in the Paleolithic era compared to today's diet (Simmoupolus, 2016). Since early XX century, the important role of fats in human health was recognized considering them as essential nutrients, but nobody noticed the importance of the type of fatty acids present in fats and oils until the second half of XX century, when scientists and public health authorities recommended the use of vegetable oils (rich in the ω-6 fatty acid, LA) instead of saturated fats. However, this change impacted in all the food producing sector since animals in the farms were also feed with ω-6 rich plant oils, thus, ω-6 levels in foods of animal origin (livestock, poultry) also increased (Lembke, 2024). Consequently, modification of eating patterns, as well as modern agriculture technics and the spreading of western diets led to dramatic changes in the consumption of essential FA, having a high intake of ω-6 FA and a low consumption of ω-3 FA, resulting in a modification in the ω-6/ω-3 ratio from 1-2:1 to 17:1, 20:1 and higher (Simmoupolus, 2016; Lembke, 2024).

Having an adequate ω-6/ω-3 ratio is of nutritional importance because it plays a fundamental role for a balanced synthesis of eicosanoids and other important molecules in the body (Abedi & Sahari, 2014). Since ω-6 and ω-3 FA compete for the desaturases and elongases enzymes, the ratio of ingested ω-6/ω-3 defines the rate of synthesis from LA and ALA to their respective long chain PUFAs and their bioactive products (Saini & Keum, 2018).

Although it is difficult to establish an ideal ω-6/ω-3 ratio, some authors such as Simopoulos in 2016 stablished that a 4:1 ratio is adequate for the prevention and treatment of CVD, and that it has been related to a 70% reduction in mortality. In other diseases such as colon, prostate, and liver cancer it has been shown that the increase in ω-3 intake reduces the degree of inflammation, favors apoptosis and reduces anti-proliferative effects.

In general, adults' diets (aged 18 years and older) fail to provide the minimum requirements of ω-3 PUFA (ALA, EPA, DHA and DPA), therefore authorities and organizations from several countries have made recommendations to stablish the daily intakes of ω-3 and ω-6 PUFA and the total amount of long-chain PUFAs. For example, doses of 500mg/day have been recommended in France, and in Norway up to 1-2g/day; the World Health Organization (WHO) counsels an intake of 0.3-0.5g/day, while the International Society for the Study of Fatty Acids and Lipids (ISSFAL) recommends 500mg/day, the North Atlantic Treaty Organization (NATO) recommends 800mg/day, and the American Heart Association committee states that fats should provide no more than 30% of caloric intake, with less than 7% of total calories corresponding to saturated fats (Gomez & Canela, 2011; Ponnampalm et al., 2021).

The Food and Agricultural Organization (FAO 2010) stablishes for the purposes of food labelling, that the term PUFA refers to the major dietary polyunsaturated fatty acids: LA (ω-6), ALA (ω-3), and a variable quantity of long chain PUFA: AA, EPA, DPA and DHA. FAO recommends a daily consumption of 0.5–0.6% ALA to prevent deficiency symptoms in adults considering a daily intake of 0.5-2% ω-3 PUFA; the dietary intakes for total fat and fatty acids according to age are shown in Table 3.

Table 3: Dietary intakes for total fat (as acceptable macronutrient intake) and the adequate fatty acid intake recommended according to the age group (Adapted from FAO 2010).

Age group	Total fat (%)	Total PUFA (%)	ω-3			ω-6	
			ALA (%)	DHA (%)	EPA+DHA (mg)	AA (%)	LA (%)
Infants (0-6 months)	40-60	<15	0.2-0.3	0.1-0.18	100-150	0.2-0.3	--
Infants (6-24 months)	35	<15	0.4-0.6	10-12mg/kg	150-200	3.0-4.5	--
Children (2-18 years)	25-35	11	--	--	200-250	3.0-4.5	
Adults	20-35	2.5-3.5	>0.5		250-2000*	2.0-3.0	

*Recommended for secondary prevention of coronary heart disease

On the other side, the Dietitians of Canada (2013), indicate that a healthy diet should contain at least two servings of fish per week to provide 0.3-0.45g/day of EPA and DHA; this organization also recommends that the ALA level should vary between 1.1-1.6g/day depending on the gender and age, without upper limit established for ALA intake. It is relevant to notice that the recommendation and guidelines between organizations are variable, probably due to the differences in the basal diet of different countries and regions in the world (Ponnampalm et al., 2021).

Conclusion

ω-3 and ω-6 PUFAs are fundamental for human homeostasis since they are not only a source of energy or of membrane cell components but are substrates for the synthesis of bioactive molecules that mediate inflammation, cardio-protection, brain development and health, cell signaling, gene expression, amongst other. Due to their important physiological functions and high impact on health, and since they must be obtained from diet, determination of an adequate intake in quantity and balance of essential PUFAs is a paramount assignment for health authorities, who must adequate dietary recommendations to traditions, food availability and other factors to achieve a healthier society.

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