Lipids: Functions, Applications in Food Industry and Oxidation

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Abstract

Lipids are a group of naturally occurring molecules that includes fats, waxes, monoglycerides, diglycerides, triglycerides, phospholipids, sterols, fat-soluble vitamins (such as vitamins A, D, E, and K), and others. The basic biological roles of lipids include energy storage, signaling, and acting as structural components of cell membranes. Lipids have many applications in the cosmetic and food industries as well as in nanotechnology. Lipids are very different in both their individual compositions and functions. These diverse compounds that make up the lipid family are so grouped because they are insoluble in water. They are however soluble in other organic solvents such as ether, acetone, and other lipids. This review is focused on some basic points of lipids such as the difference between docosahexaenoic acid (DHA) and eicosapentaenoic acid (EPA), the role and function of lipids and their applications in food industry. Moreover, it presents the mechanism of lipids oxidation, and how to measure and prevent the oxidation of lipids.

Keywords: Lipids, Functions, Applications, Oxidation, Antioxidants

Introduction

Lipids are defined on the basis of their solubility characteristics, not primarily their chemical composition. The term "lipids" is defined as those organic molecules that are insoluble in water, soluble in organic solvents (e.g., chloroform, methanol, ether), contain hydrocarbon groups as primary parts of the molecule, and are exist in or derived from living organisms [1]. Compound classes covered in this definition or classification include fatty acids (FAs), acylglycerols, fatty acids esters, and isoprenoid hydrocarbons. Further compounds also included are regularly considered as belonging to different classes, such as carotenoids, sterols, and the vitamins A, D, E, and K. Lipids tend to be categorized as "simple" or "complex," referring to the size or structural detail of the molecule. The group of simple lipids includes fatty acids, hydrocarbons, and alcohols, all of which are comparatively "neutral" in terms of charge. While complex lipids, for instance glycolipids and phospholipids, are relatively more charged and are also referred to as "polar."

Fats and oils are fractions of lipids, mainly composed of triglycerides with great importance in food systems, and they are formed through the esterification of fatty acids molecules with one molecule of glycerol [2-5]. Lipid oxidation is one of the major reasons of quality retrogradation in natural and processed food products. Oxidative retrogradation is a large economic issue in the food industry because it affects many quality parameters such as flavor (rancidity), texture, color, and the nutritive value of foods. Furthermore, it results in the production of potentially poisonous compounds.

Lipid oxidation is one of the major factors that limit the shelf life of foods. In addition, the oxidative instability of the polyunsaturated fatty acids frequently limits their applications as nutritionally beneficial lipids in functional foods production.

Types and Functions of Lipids

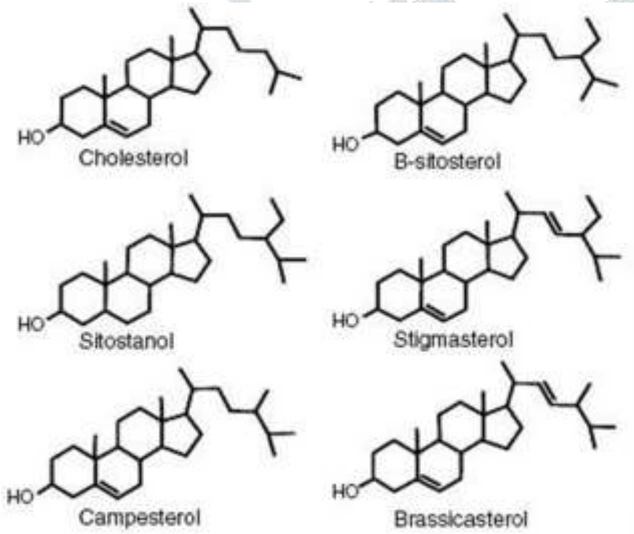
Functional lipids for instance, omega-3 and omega-6 fatty acids, conjugated linoleic acids, medium chain triglycerides, and phytosterols have numerous positive influences on human health such as in obesity, blood pressure, cardiovascular diseases, bone health, and in treating and managing depression [6]. There is some misunderstanding between lipids and fats, since not all lipids are fats, but all fats are lipids. There are numerous types of lipids to discover before completely understanding their functions, these types include the following:

1.1. Triglycerides

Triglyceride molecules are composed of three of fatty acids and one molecule of glycerol. The fatty acids may be either saturated or unsaturated. Triglycerides have the ability to float in a cell's cytoplasm since they have a lower density compared to water and are non-soluble, as is the case with all lipids. A triglyceride can be categorized as a fat if it converts to a solid at a temperature of 20°C, otherwise that are classified as oils. They are fundamental in the body for energy storage.

1.2. Steroids

Steroids are these organic compounds mainly composed of four rings arranged in a specific configuration. A few categories of common steroids are cholesterol, vitamin D2, estrogen and testosterone. These fractions of lipids have two main biological roles: certain steroids (such as cholesterol) are substantial constituents of cell membranes which change the fluidity of membranes, and many steroids are signaling molecules which stimulate steroid hormone receptors.



1.3. Phospholipids

Phospholipids can be defined as lipids containing phosphorus. They received their name as their constitution is primarily phosphate groups. They contain molecules that both attract and repel water, playing a key role in the organization of cell membranes structure. There are two major groups of phospholipids; glycerophospholipids and sphingolipids.

1.4. Glycolipids

Glycolipids are lipids with a carbohydrate attached by a glycosidic bond [7]. Short sugar chains form glycolipids, which can be found in a cellular membrane's exoplasmic surface. They play an important role in enhancing the body's immune system, as well as helping to maintain the stability of the membrane and attaching cells to one another to form tissues.

2. Applications of Lipids in Food Industry

2.1. Role and Changes of Plant Lipids in Processed Foods

- Plant lipids have the ability to increase the nutritional values of foods. They also contain tocopherols and tocotrienols, which are the major essential sources of vitamin E.

  Lipids affect the functional properties of foods; for example, they help to retain carbon dioxide in dough, thus increasing the final volume of bakery products.
- The main importance of lipids is their influence on the sensory properties. They affect the texture and increase the viscosity of the morsel after mixing with saliva; high viscosity is appreciated by many consumers.
- The most desirable influence of lipids is their effects on the odor and flavor of food products. Plant lipids, being more unsaturated than animal lipids, produce different flavor notes as a result of culinary operations. Flavors originating at roasting or frying temperatures are particularly appreciated.

2.2. Frying Oils and Fats

The using of oils and fats as a frying medium in both shallow and in deep frying mode is an important component in the overall picture of food applications. Recently, it has been reported that 20 million tons of oils and fats is used in this way. This represents a major share of the 90 million tones used for dietary purposes. Of course, it should be taken in mind that while some of the frying oil is consumed along with the fried foods, much is thrown away (shallow pan frying) or ultimately finds other uses as spent frying oil.

2.3. Spreads: Butter, Ghee

Butter. For many centuries, butter from cow’s milk fat has been mainly used as a spread, but also for baking and frying purposes. Butter has become less widespread with the continuous development of good-quality margarine and other spreads. The are some disadvantages associated with butter such as, its comparatively high price, its poor spread-ability (especially from the refrigerator), and its poor health profile resulting from its high fat content, its high content of saturated fatty acids and cholesterol, and the presence of trans unsaturated fatty acids. Butter has the advantages of its completely natural profile and its splendid flavor.

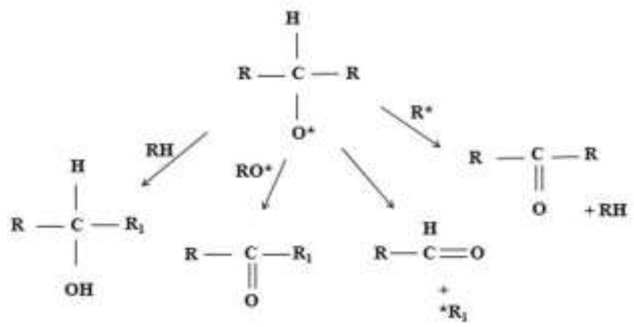
Ghee. Milk fat can be consumed partly as butter but also as ghee, however the latter is declining and is now probably below one-quarter of the combined total. Ghee is a concentrate of butterfat with more than 99% of milk fat and less than 0.2% moisture. It has a shelf life of 6- 8 months even at ambient tropical temperatures. Butter or cream is converted to ghee by controlled heating to reduce the content of water to below 0.2%. In other procedures the aqueous fraction is allowed to separate and some of it is run off before residual moisture is removed by heating. Ghee is distinguished by a cooked caramelized flavor varying slightly with the method of preparation.

2.4. Baking Fats, Dough and Shortening

The application of oils and fats in baking processes ranks with frying and spreads as a major food use of these materials. The products range from breads and layered dough to cakes, biscuits (cookies) and biscuit fillings, pie crusts, short pastry, and puff pastry. The fats used to produce this wide range of baked goods vary in their properties and particularly in their melting behavior and plasticity. It is possible to achieve these properties with different blends of oils, and preferred mixtures vary in different areas of the world.

3. Lipids Oxidation

The mechanism of lipids oxidation is shown in Fig. Lipid oxidation or rancidity is clearly the major challenge for stabilizing specialty oils, particularly since oils with special nutraceutical properties have predominantly polyunsaturated fatty acids. While there is relatively little data yet available regarding oxidation of specialty oils per se, all oils follow the same fundamental processes, modified by endogenous pro- and antioxidants and innate variances in fatty acid composition. What has been learned about lipids oxidation in conventional food oils can be applied to predict the stability of specialty oils and to explain the observed behaviors.



3.1. Applied Methods to Evaluate Lipids Oxidation

The analysis and examination of lipid oxidation in different food samples is a significant issue since the compounds produced in the process are associated with the undesirable sensory and biological influences. Suitable measurement of lipid oxidation considered a challenging mission since the process of oxidation is complicated and depends on the category of lipid substrate, the oxidation causes and the environmental influences. A great number of procedures have been developed and applied so far, in order to determine both primary and secondary products of lipids oxidation. The most common techniques and classical methods include, peroxide value, TBARS analysis and chromatographic tests.

Estimating the status of lipid oxidation is a challenging mission because of a number of evidences such as the diverse compounds which are produced depending on the time, the extent of oxidation and the involved mechanism. Consequently, selecting only one parameter to analyze the oxidative status is rather tough and it is often more appropriate to combine different procedures. In addition, as indicated by Eymard, Baron [8], not only nature and composition of lipid as the substrate of the reaction have an influence on lipid oxidation process, but also proteins kind and the concentration, antioxidants and prooxidants existing in the food matrix, as well as its physicochemical properties are parameters worthwhile to take in account.

4.1.1 Volumetric Methods

Amongst the different suggested methods for peroxides analysis, iodometry has been the most conventional and common technique mostly because of the simplicity of the experimental process. Though the procedure involves prior extraction of lipids, rapid and clear results are provided. In acidic medium, hydroperoxides and other peroxides react with the iodide ion to produce iodine, which is titred with a sodium thiosulfate solution, in the existence of starch. The AOAC provides an approved manner since 1965 [9]. According to this technique, peroxide value is considered to represent the quantity of active oxygen (in meq) contained in 1 kg of lipid and which could oxidize the potassium iodide.

4.1.2 Ferrous Oxidation Method

The ferrous oxidation technique for the quantification of peroxide content is easy and simple to use compared to iodometry. The chief reason is the lower sensitivity of ferrous ion towards the spontaneous oxidation by the oxygen existing in the air, when compared to the high susceptibility to oxidation of the iodide solutions. It involves the oxidation of Fe (II) to Fe (III), mediated by hydroperoxide reduction in acidic conditions and in the presence of either thiocyanate or xylenol orange.

4.1.3 Iodide Oxidation Method

A spectrophotometric iodidedependant technique has similarly been set for the determination of hydroperoxide content. In this not so regularly applied methodology [10], the lipid sample is placed in an acidic solution, which is then combined with iodide. The lipid hydroperoxide oxidizes iodide to iodine. Then, the produced iodine and iodide in excess react to give triiodide anion, which is identified spectrophotometrically at 350 nm. Bloomfield [11] used Fe(II) as a catalyst in this reaction. The closed conditions prevent interference from atmospheric oxygen, and the short reaction time reduces the interference from side reactions.

3.2. Reasons for Lipids Oxidation

As shown in Fig, the overall reaction mechanism of lipid oxidation consists of three phases:

(1) Initiation, the formation of free radicals.

(2) Propagation, the free radical chain reactions.

(3) Termination, the formation of non-radical products.

The important lipids involved in oxidation are the unsaturated fatty acid moieties, oleic, linoleic, and linolenic. The rate of oxidation of these fatty acids increases with the degree of unsaturation, as oleic acid has 1 times rate, linoleic acid has 10 times and linolenic acid has 100 times.

Initiation	$ROOH \leftrightarrow ROO\cdot + H$	
	$ROOH \leftrightarrow RO\cdot + OH\cdot$	
	$2ROOH \leftrightarrow RO\cdot + H_2O + ROO\cdot$	----------1.1
Propagation	$R\cdot + O2 \leftrightarrow ROO\cdot$	
	$ROO\cdot + RH \leftrightarrow ROOH + R\cdot$	----------1.2
Termination	$ROO\cdot + ROO\cdot \leftrightarrow ROOR + O_2$	
	$RO\cdot + R\cdot \leftrightarrow ROR$	----------1.3

3.3. Prevention of Lipids Oxidation

Lipid oxidation in foods considered a serious dilemma, difficult to overcome often and leads to loss of shelf life, palatability, functionality, and nutritional quality. Loss of palatability is due to the generation of off-flavors that arise primarily from the breakdown of unsaturated fatty acids during autoxidation. The high reactivity of the carbon double bonds in unsaturated fatty acids makes these substances primary targets for free radical reactions. Autoxidation is the oxidative deterioration of unsaturated fatty acids via an autocatalytic process consisting of a free radical chain mechanism.

3.4. Antioxidants

In foods containing lipids, antioxidants can delay the beginning of oxidation or slow the rate at which it proceeds. These substances can occur as natural components of foods, but also they can be deliberately added to products or formed during processing. Their role is not to enhance or improve the quality of foods, but they do maintain food quality and extend their shelf-life. Antioxidants used in food processing should be distinguished by their low-cost, nontoxic, influential at low concentrations, stable, and capable of surviving processing (carry-through effect); color, flavor, and odor must be negligible. The choice of the type of antioxidant which will be used depends mostly on the compatibility of the product and regulatory guidelines.

Antioxidants can slow lipids oxidation through inactivating or scavenging free radicals, consequently preventing initiation and propagation reactions. Free radical scavengers (FRS) or chain - breaking antioxidants are able to accept a radical from oxidizing lipids species such as peroxyl (LOO•) and alkoxyl (LO•) radicals by the following reaction:

$$LOO\bullet \text{ or } LO\bullet + FRS \longrightarrow LOOH \text{ or } LOPH + FRS\bullet$$

Conclusion

Lipids have a functional and significant role in foods because of their contribution to palatability, satiety, and nutrition. Consequently, lipid quality is a very important issue to consumers and may show a relation to numerous health problems. Lipid oxidation is a major problem in many areas of the food industry. Delaying lipid oxidation not only prolongs the shelf-life of the products but also decreases raw material waste, nutritional loss, and widens the range of lipids that can be used in specific product. Therefore, by controlling lipid oxidation, food processors can use more available, less costly and/ more nutritionally favorable oils for product preparations. Further studies and investigations might be valuable in view of practical and economic limitations on the production and effective utilization of novel antioxidants.

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