Chapter 6

Low-Fat Foods

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Additional information is available at the end of the chapter

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Abstract

Fats are responsible for performing varied and important functions in the body, such as providing calories, essential fatty acids, and fat-soluble vitamins. They are considered very important among the ingredients and the sensory aspects of the functional properties of the food. They influence the melting point, consistency, and formation of crystals in the spreadability of many foods and are also responsible for flavor, aroma, creamy appearance, aeration, stability, and feeling of fullness after meals. However, the consumption of high amounts of fats and oils has often been associated with obesity and multiple chronic diseases. To reduce fat and caloric value of foods, we can reduce or eliminate fat from the formulation by increasing the amount of proteins, carbohydrates, fibers, and water. However, it is not so easy to treat with fat substitution in a food formulation. The crystallization behavior of lipids has important implications, especially in industrial processing of products whose physical characteristics (consistency and melting point) are affected by the crystal structure of fat, such as chocolate, margarine, and shortenings. Much of the knowledge about the crystal structure of the fat comes from studies performed on diffraction of x-rays. The crystal structure depends on the specific type of triacylglycerol (TAG) present, the composition and distribution of fatty acids, the purity of TAG, and the crystallization conditions (temperature, cooling rate, shear, and solvent). The ideal fat replacers should be a composite of recognized safety and health, which has all the functional and organoleptic properties with the benefit of significant calorie reduction. Fat food processors have been careful about developing and producing low-fat foods due to the problems it could generate in the production, such as an increased risk of unstable products and unconfident production parameters. Some fat foods can be considered as margarines, creams, chocolate products, ice creams, cakes, and some baked goods.

The substitution of *trans* and saturated fatty acids should be considered also when creating a low-fat food. Saturated and *trans* fats refer to a group of fatty acids, each with its own properties and characteristics. Despite saturated fats' potential health benefits, saturated fat has long been associated with increased risk of heart disease, stroke, and even cancer, as well *trans* fats. When designing a low-fat food as spread, for example, it is important to observe the fat composition, the quantity of liquid oil, because the oil phase needs to cover a higher amount of water droplets and the solid fats cause disappearance of smoothness. A combination of the right process parameters and fat composition can give a satisfactory fat food product. In this chapter, the possibilities of low-fat food creation are discussed.

Keywords: Fats and oils, food structure, food processing, food health

1. Introduction

The final characteristics of processed fat products depend on the physical and chemical properties of oils and fats present in their formulation. To obtain the required specifications for each product, different fatty bases have to be formulated. The knowledge of physical, rheological, chemical, and sensory characteristics, functionality, and fat interactions with other ingredients is essential for formulating these bases.

Vegetable oil and vegetable fats are products consisting primarily of glycerides of fatty acids found in different types of plants. They may also contain small amounts of other lipids, such as phospholipids, and unsaponificable constituents and free fatty acids naturally present in oil or fats. Vegetable oils are liquid at 25°C, and vegetable fats are solid or pasty at 25°C.

There are different types of vegetable oils used by the industry to formulate fat bases: soybean, cotton, peanut, sunflower, canola, sesame, corn, olive, palm, palm kernel, coconut, cocoa, linseed, and castor oil, as well as oils and fats obtained from fish, beef, pork, and poultry.

According to Brazilian laws and regulations [1], vegetable fats are derived from various sources and defined as products made primarily of glycerol of fatty acids found in plant species. Chemically, all oils and fats are considered triacylglicerols or esters of glycerol and fatty acids, which are responsible for the different properties observed in these molecules due to their size, saturation, and/or position. When comparing chains of the same length, saturated structures are less reactive than those with unsaturation [2].

The importance of fats for humans, animals, and plants is their energy content (9 kcal/g). It is a source of fat-soluble vitamins (A, D, E, and K) and of essential fatty acids (omegas 3 and 6); they act as heat transfer medium and contribute to texture, flavor, and color of foods.

Fat substitutes (fat replacers) can replace fat in food products; however, they often change texture and/or flavor of foods or beverages. Partial replacement of fat is generally a better approach in terms of consumer acceptance.

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It was in the 1980s that consumers became aware of impact of diet on health; it was then proposed a reduction to 30% (from 40% to 49%) of energy from fat in diet, which started to affect consumer attitudes. The challenge was to produce low-fat products with physical and sensory characteristics as close as possible to full-fat quality.

Protein-based fat substitutes came along with the introduction of a microparticulated protein product called *Simplesse.* Subsequent development efforts revealed consequences of removing fat from a product. Alternative ingredients or processes had to be developed as all the attributes of fat became recognized.

2. Functionality and crystallization of fats

Lipids are a family of organic compounds soluble in organic solvents but not in water. The lipid class can be divided into the following categories: triacylglicerols (95% of lipids in foods), phospholipids such as lecithin, and sterols such as phytosterol and cholesterol.

Sensory functions of fats in foods can be as follows: appearance (gloss, translucency, color, surface uniformity, and crystallinity), texture (viscosity, elasticity, and hardness), flavor and aroma (flavor release profile and development), and mouthfeel (meltability, creaminess, thickness, degree of mouthcoating, and mouth warming or cooling).

Unsaturated fatty acids may have *cis* and *trans* configurations with different physicochemical properties. Due to their structural characteristics, fatty acids in the *trans* configuration have higher melting point than its corresponding *cis* isomer but lower than the melting point of the saturated fatty acid with an even number of carbon atoms. Thus, the *trans* isomer can be considered as intermediate between an original unsaturated fatty acid and a completely saturated fatty acid [2].

The crystallization behavior of lipids has important implications, especially in industrial processing of products whose physical characteristics (consistency and melting point) are affected by the crystal structure of the fat, such as chocolate, margarine, and shortenings. Most of the knowledge about the crystal structure of the fat comes from studies done with X-ray diffraction. The structure of the crystal depends on the specific type of triacylglycerol (TAG) present, the composition and distribution of fatty acids, the purity of TAG, and the crystallization conditions (temperature, cooling rate, shear, and solvent) [3, 4].

The crystallization process consists of two events: nucleation and crystal growth. Nucleation involves the formation of aggregates of molecules that exceed a critical size and are therefore stable [5, 6]. The three polymorphic forms of fat crystals, in order of increasing thermodynamic stability, are alpha (α), beta press (β'), and beta (β); the choice of fat should be based on the polymorph β' to promote excellent creaminess properties [7].

Lipid crystallization behavior has important implications, especially in industrial processing of products whose physical characteristics depend largely of fat crystals, such as chocolates, margarine, and shortenings.

The crystal growth rate and the polymorphic transformations are important to determine the process and conditions of storage of oils and fats.

Plastic fats consist of a crystal network in the continuous oil matrix. The rheological behavior of these fats is the result of interactions between the crystals that are immersed in this liquid matrix.

The liquid portion, in conjunction with the solid fraction, is responsible for the viscoelastic behavior of a plastic fat. Thus, the amount of crystallized fat and the type of fat matrix crystals are of paramount importance in the rheological behavior of the fat.

The main objectives of fat crystallization are to increase the thermal stability and oxidative stability of the product, to increase plasticity, to promote creaminess and smoothness, to standardize of the physical and chemical characteristics of the product, and to guarantee performance.

The structure of fat crystals depends on the conditions of its formation, such as stirring, cooling rate, and fat quenching, leading to a specific consistency (plasticity).

Some important properties of acyl chains are providing flexibility that consequently leads to a molecular conformation that results in lateral packing and their aggregation state due to the solid and liquid crystalline states created. The physical properties of long-chain compounds in the solid state, such as melting point, heat competence, and plasticity, depend on the crystal structure and are very important to the industry. TAGs exhibit various crystalline forms. The solid states are related to the quality of industrial products. Heat treatment is used in the production processing of oil and fat products. Information about crystal structures of fats and complex lipids can be provided by X-ray diffraction analysis [8].

3. Fats versus health

More and more people are trying to lose weight. In general, people continue to understand that restrictive dieting (deprivation, short-term solutions) spells failure. Instead, it takes permanent lifestyle changes to lose weight and prevent weight gain. Fifty-four percent of U.S. adults are currently trying to reduce their weight. (Note: previous surveys asked about "dieting," but in 2010, the survey was modified to refer to weight reduction or "trying to lose weight" [9].)

However, the consumption of high amounts of oils and fats has often been associated with obesity and various types of chronic diseases. The reduction of fat and caloric value of foods can reduce or eliminate fat from the formulation increasing the protein, carbohydrate, fiber, and water content.

High-fat diets are associated with obesity and cardiovascular disease. There is an epidemic of overweight and obesity in some locations. Individuals with BMI ≥ 25 (BMI = weight (kg)/height ^{2} (m^2) are considered overweight, and with BMI ≥ 30 they are considered obese. The recom-

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mended dietary allowance (RDA) intake of fat is 30%, but the actual consumption is higher: calories, 9 kcal/gram; carbohydrates and protein, 4 kcal/g of.

4. Fat substitutes

An ideal fat substitute should be a compound of recognized as safe and which has all the functional and organoleptic properties and significantly less fat and calories. Due to the multiple roles played by fats in determining product properties (thermal stability, emulsification and aeration, lubrication, taste, and mouthfeel), it is usually necessary to use a combination of different fat substitutes in order to have products with these expected properties [10].

Fat replacers can be classified into two groups according to their mechanism of action: fat mimetics or derivatives. They can also be classified into three groups based on their chemical nature: carbohydrates, proteins, or fats.

According to the mechanism of action, the fat mimetics are a combination of water and lipids or nonlipids (modified proteins or carbohydrates) and emulsifying properties; they are capable of forming gels and thus normally serve as body agents, for example, cellulose, gum, inulin, maltodextrin, starches and modified starches, proteins, and microparticulate concentrated protein. Derivatives are noncaloric or low-calorie fat compounds with properties similar to those lipids, which ester bonds are modified.

According to the Calorie Control Council [9], fat replacers can be classified and exemplified as follows:

Type	Commercial name	Source	Calories	Application
Microparticulated protein	Simplesse®	Whey protein or milk and egg protein	1–2 kcal/g	Dairy products, salad dressing, margarine, mayonnaise-type products, bakery
Modified whey protein concentrate	Dairy-Lo®	Protein	Reduced calorie	Milk/dairy products, baked goods, salad dressing, mayonnaise-type products
Similar to microparticulated protein but made by a different process	K-Blazer® , ULTRA-BAKE™, ULTRA-FREEZE™, Lita®	Based on egg white and milk proteins or derived from a corn protein	Reduced calorie fat substitute and fat replacer	Frozen desserts, bakery

Table 1. Protein-based fat replacers

Type	Commercial name	Source	Calories	Application
Cellulose	Avicel® cellulose gel, Methocel™, Solka-Floc®	Purified form of cellulose ground to microparticles	Noncaloric	Dairy-type products, sauces, frozen desserts, salad dressings
Dextrins	Amylum, N-Oil®	Dextrins, tapioca	4 kcal/g	Salad dressings, puddings, spreads, dairy-type products, frozen desserts
Fiber	Opta™, Oat Fiber, Snowite, Ultracel™, Z-Trim	Fiber	Low caloric	Bakery, meats, spreads, extruded products
Gums	KELCOGEL®, KELTROL®, Slendid™	Guar gum, gum arabic, locust bean gum, xanthan gum, carrageenan, pectin	Noncaloric	Salad dressings, desserts, and processed meats
Inulin	Raftiline®, Fruitafit®, Fibruline®	Fiber and bulking agent extracted from chicory root	1–1.2 kcal/g	Yogurt, cheese, frozen desserts, bakery, icings, fillings, whipped cream, dairy products, processed meats
Maltodextrins	CrystaLean®, Lorelite, Lycadex®, MALTRIN®, Paselli®D-LITE, Paselli®EXCEL, Paselli®SA2, STAR-DRI®	Carbohydrate sources such as corn, potato, wheat, and tapioca	4 kcal/g	Bakery, dairy products, salad dressings, spreads, fillings, processed meat, frozen desserts, extruded products, beverages
Nu-Trim		From oat and barley	Reduced calorie	Bakery, milk, cheese, ice cream
Oatrim	Beta-Trim™, TrimChoice	Hydrolyzed oat flour	1–4 kcal/g	Bakery, fillings, frozen desserts, dairy beverages, cheese, salad dressings, processed meats and confectionery
Polydextrose	Litesse®, Sta-Lite™	From dextrose containing minor amounts of sorbitol and citric acid	1 kcal/g	Baked goods, chewing gums, confectionery, salad dressings, frozen dairy desserts, gelatins, puddings

Type	Commercial name	Source	Calories	Application
Polyols	Many brands available		1.6–3.0 kcal/g	Reduced fat and fat-free products
Starch and modified food starch	Amalean®I & II, Fairnex™VA15, & VA20, Instant Stellar™, N-Lite, OptaGrade®#, Perfectamyl™AC, AX-1, & AX-2, PURE-GEL®, STA-SLIM™	From potato, corn, oat, rice, wheat, or tapioca starches	1–4 kcal/g	Processed meats, salad dressings, bakery, fillings, sauces, condiments, frozen desserts, dairy products
Z-Trim	Appears as cornstarch on the ingredient statement, others appear as food starch modified	Made from insoluble fiber from oat, soybean, pea, and rice hulls or corn or wheat bran	Calorie free	Bakery, burgers, hot dogs, cheese, ice cream, yogurt

Table 2. Carbohydrate-based fat replacers

Type	Commercial name	Source	Calories	Application
Olestra	Olean®	Made from sucrose and edible fats and oils	Calorie-free	Salty snacks, crackers, frying
Sorbestrin	*May require FDA approval*	Liquid fat substitute composed of fatty acid esters of sorbitol and sorbitol anhydrides	Low-calorie (approximately 1.5 kcal/g)	Fried foods, salad dressing, mayonnaise, bakery
Esterified propoxylated glycerol (EPG)	*May require FDA approval*		Reduced-calorie	All typical consumer and commercial applications, bakery, frying

Table 3. Lipid (Fat/Oil) analogs

Type	Commercial name	Source	Calories	Application
Emulsifiers	Dur-Lo®, EC^T-25	Vegetable oil mono- and diglyceride + water, sucrose fatty acid esters, emulsion systems using soybean oil or milk fat	9 kcal/g	Mixes, cookies, icings, vegetable dairy products
Salatrim	Benefat^T	Structured lipid (Short And Long Acyl Triglicéride Molecule)	5 kcal/g	Bakery, confectionery

Table 4. Fat-based fat replacers

Using small amounts of inulin, it is possible to improve the flavor and texture of products with low fat content. Combinations with polyols or fructose give excellent results in chocolates.

Plum products can be used to replace fat in products with reduced fat content due to the presence of sorbitol and fiber, which can bind the water. These products have been used as fat substitute in bakery products and confectionery [11].

Organogels are mixtures with characteristics of gel, consisting of structuring agents and immobilized phase forming a thermoreversible self-sustaining network, in which the immobilized phase is an organic compound, which differs from other gels formed primarily of water-soluble compounds. The main structuring agents that have been studied for the formation of organogels are diacylglycerols, monoacylglycerols, fatty acids and alcohols and mixtures thereof, waxes and wax esters, phytosterol and oryzanol, lecithin, and sorbitan tristearate, among others. The use of organogels in food products has been the subject of several studies as an alternative to obtain products with appropriate technological properties without the use of *trans* fats and reduced saturated fatty acid content [12].

4.1. Hydrocolloids

Hydrocolloids are substances that form colloidal systems when dispersed in water. They are polymers of carbohydrates (also proteins) and are derived from a wide range of natural sources or are produced synthetically. Hydrocolloids are widely exploited in industry, not only in the food sector, for their ability to control important functional properties, including thickening and gelling, stabilization, dispersion, and emulsification.

In processed foods, hydrocolloids are responsible for texture control and stabilization of these products, and therefore they can prevent or retard a number of physical phenomena such as sedimentation of solid particles suspended in the medium (water) or the crystallization of the sugar or disaggregation and aggregation of dispersed particles [13]. In products with total or partial fat reduction, gums minimize texture changes and prevent phase separation in emulsions [14].

Gums can replace fats in certain formulations since they have the ability to swell or solubilize in aqueous systems providing viscosity characteristics similar to those of fats [15]. In addition, the substitution of fat for ingredients with low calorie content has revolutionized the food industry due to the demand of consumers concerned about health. This factor has allowed many technological advances, and improvements in the functionality and palatability of these products have been made. The addition of starch in foods can also provide nutritional benefits associated with dietary fiber intake [16, 17].

The use of natural gums in the food industry is considered safe, according to the Food and Drug Administration (FDA) [18]; the domestic production of some natural polysaccharides as an alternative to existing products or for the manufacture of new products is a possibility [15, 19].

It was possible the development of chocolate spread with the addition of gelatin in partial replacement of fat, as evaluation of control (with vegetable fat) and with addition of solution of gelatin (1.0%) from chicken feet to replace 50% of the fat [20].

Three conventional fat-based formulations for filling were prepared with low *trans* fat, at concentrations of 10%, 7.5%, and 5%, and six others with the addition of 0.3% (w/v) of guar gum and chichá gum individually. Rheological study showed the formulations made with guar and chichá gums pointed similar behavior and pronounced thixotropy by a decrease in apparent viscosity with time, followed by recovery of the structure of the system. Thus, it is concluded that the rheological properties of the fillings are significantly altered by the addition of the studied gums, substituting part of the fat, even at low concentrations [21].

Light mayonnaise was obtained, produced from 25.5% starch (+24.82% oil) and 25.5% hydrogel chitosan (+34.50% oil). Chitosan leads mayonnaise to a lighter texture. Mayonnaise, known to be as calorie sauce, had reduced oil content in addition the biological, nutritional, and chemical properties of the biopolymer chitosan [22].

Reduced fat and egg mayonnaise samples were produced with different fat replacers (xanthan, guar, and pregelatinized cornstarch) and egg/soy milk mixture as egg alternative, concluding that due to the capability of xanthan and pregel cornstarch in changing physicochemical parameters, they can be used in mayonnaise and other food formulations as fat replacer [23].

4.2. Structured lipids

Structured lipids are TAGs restructured or modified to change the fatty acid composition and/or their positional distribution in glycerol molecules by a chemical or enzymatic process. Salatrim is a typical example in this category.

They can be synthesized in order to improve or modify the physical (polymorphism, melting point, solid fat content, viscosity, and consistency) and/or chemical (oxidative stability) characteristics of triglycerides, as well as to modify one or more of their nutritional properties (presence or absence of saturated fatty acids or unsaturated fatty acids easily absorbed and digested).

Some benefits of specially formulated lipids are as follows: they can improve immune function, decrease risk of cancer, prevent stroke, and decrease blood cholesterol levels, and they have low calories.

4.3. Cocoa butter

Since the 1930s, there has been an increased interest in using fats other than cocoa butter in confectionery production due to the uncertainty of supply and costs of cocoa butter, which are dependent on the fluctuating cocoa bean market.

When a different fat composition is added to cocoa butter, the resulting crystalline form of the fat is typically altered, producing changes in the melting profile of the fat, called incompatibility.

To replace cocoa butter completely or partially, industry and researchers have attempted to develop substitutes by producing fats with features that meet consumer demands. These are classified as follows [24, 25]:

a. Substitutes (cocoa butter substitutes [CBS])—similar to cocoa butter in its physical properties, but not fully compatible for mixtures. Can be divided into lauric and nonlauric fats

b. Equivalent (cocoa butter equivalents [CBE])—similar in physical and chemical properties and can be used in mixtures in any proportion since they contain almost the same type of fatty acids and glycerides of cocoa butter

The stearic acid has a unique position within the saturated fatty acids of long chain. It is shown that, unlike other saturated fatty acids, it has a neutral cholesterolemic effect.

Cocoa butter contains lots of saturated fatty acids in the TAG positions, which are less easily absorbed and thus do not reduce the risk of atherosclerosis.

Some details, when cocoa butter is substituted, are its technological and nutritional characteristics. For example, the use of special oils in creamy fillings must be compatible with the fat coating and migration of the filling towards the coating may occur, or vice versa. This process can affect the integrity and appearance of the product.

4.4. Nutritional and functional shortenings

Industries produce fats for many applications, and some nutritional benefits are expected. Saturate All Purpose and Emulsified Shortening are products free of partially hydrogenated oil and have reduced content in saturated fat compared to traditional shortening, polyunsaturated, and monounsaturated fat products; they have zero grams *trans* fat per serving.

Saturated fats can cause cardiovascular diseases, hypertension, obesity, diabetes mellitus, inflammatory and autoimmune disorders, cancer, increased blood cholesterol levels, and gallbladder diseases.

Monounsaturated fats are considered good fats because they help protect the heart against cardiovascular diseases. A benefit of polyunsaturated fatty acids is that they reduce the triglyceride levels. It is recommended to substitute saturated fat in the diet for polyunsaturated fats. Polyunsaturated fats attach to and clear out unhealthy fats, such as saturated fat, cholesterol, and triglycerides. Higher intake of most dietary saturated fatty acids is associated with higher levels of total blood cholesterol and low-density lipoprotein (LDL) cholesterol. High total and LDL cholesterol levels and high intake of *trans* fatty acid are risk factors for cardiovascular disease.

It is suggested the selection of features and beneficial properties of lipids and exclusion (or decrease) of fats (or its components) that cause health problems.

4.5. *Trans* and low *trans* fats

The characteristics of a low *trans* fat are as follows: acceptable level of *trans* fatty acids, acceptable level of saturated fatty acids, palm oil use, application/performance, shelf life required. From a technological point of view, the best type of fat has fast crystallization and beta prime crystal form. Alternative low *trans* fats are palm, corn, and cotton oil (little or

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nonhydrogenated oils). Other alternatives are palm kernel, coconut, high oleic canola, medium-oleic sunflower, high oleic soybean, and low linolenic soybean oil and also animal fats.

There are a number of challenges faced by the food industry during the process of developing alternatives to low *trans* (LT)/low saturated (LS) fats such as the replacement of oils and fats seeking an alternative to LT/LS while keeping the same functionality in the final product. Another challenge is the availability of these oils and fats. The technologies to obtain LT and LS fats may be used alone or combined: mixtures of different sources of oils and fats, interesterification, hydrogenation, fractionation, and genetics. For example, high oleic canola oil + fully hydrogenated soybean oil (70°C) = interesterified fat (melting temperature, 35°C–40°C).

The change to zero *trans* fat can modify the product capability, performance, oxidative stability, flavor, and color.

Trans fats that contain *trans* fatty acids may be produced by either natural or industrial hydrogenation. Biohydrogenation occurs when fatty acids ingested by ruminants are partially hydrogenated by enzymatic systems of the intestinal tract of the animals. Industrial hydrogenation is the addition of nitrogen polyunsaturated vegetable oils using a catalyst under appropriate temperature and pressure. This process promotes the formation of fatty acids with high melting point due to the linear guidance molecules in *trans* fats and the increased saturation index and increased stability to lipid oxidation process [26].

The hydrogenated vegetable fat is responsible for most of the consumption of *trans* fatty acids in the diet. In Brazil, the commercial hydrogenation of vegetable oils date from the 1950s, and it aims at producing technical fats (shortenings), margarines, and fats for frying. With the development of selective hydrogenation techniques, processed vegetable oils quickly replaced animal fats in the diet of Brazilians. These fats have been widely used in the production of various foods such as margarine, chocolate icing, cookies, baked goods, ice cream, pasta, and potato chips, among others [27].

In the past, the formation of *trans* isomers was considered as a technological advantage since, due to its higher melting point compared to that of the corresponding *cis*, it facilitated the creation of solid desirable levels of hydrogenated fat [28, 29].

Scientific evidences related to the negative impact of *trans* fatty acids on health (heart disease risk, high LDL cholesterol levels, low HDL levels) have led to minimized consumption of partially hydrogenated fat, fact corroborated by progressive changes in law and regulations in several countries. The challenge of the food industry in terms of *trans* fat replacement in various products is to develop formulations with comparable economic viability and functionality, and which do not result, however, in a substantial increase in the saturated fatty acid content in foods [30].

The low *trans* fats that are free of *trans* fatty acids, for example, obtained by interesterification, have been used to replace hydrogenated vegetable fat. The interesterification of oils and fats may be chemical or enzymatic. In this process, the fatty acids are redistributed in ester bonds, creating new groups without the formation of *trans*-isomers. The chemical interesterification process has long been used for its ease and low cost, and it is usually carried out with mixtures of highly saturated fats and liquid oils [2]. In general, blends of coconut and palm oils, after modifications, have great potential in the development of healthier fat products. Enzymatic interesterification after a full hydrogenation is useful in the production of low *trans* fats.

The application of most oils and fats in their natural form in food products is very limited due to their physicochemical properties. However, by increasing their functionality and nutritional value, their behavior can be changed. Adaptation of the melting profile increases stability and shelf life.

The most difficult challenge is to replace *trans* fat in shortening. Solid fats are desirable in foods. Saturated fats have been replaced with hydrogenated (*trans*) fats due to health issues associated to fat, but now, saturated fat is also desirable again.

Trans fatty acids can be replaced, although it is very difficult to remove these fats from foods. However, success has been obtained with significant research efforts.

5. Fat and low-fat products

A food product contains two or more of the following ingredients: carbohydrates, proteins, fats, water, and additives (colorants, flavors). Each ingredient has a function in the product. Fat is the most abundant ingredient in fatty or high-fat products; it has some functions in foodstuff such as: aeration emulsifying properties, improving texture, flavor releasing, facilitating the mixing process, and staining.

The correct product structure is essential for making products with desirable properties. The product structure is then dependent on the type and the amount of fat present in its formulation. The chemical properties of oils and fats (carbon chain length, degree of unsaturation, distribution of fatty acids, *cis*–*trans* configuration, and crystalline state) are responsible for the physical properties of the food, i.e., their structure, properties, and rheological and thermal behavior during processing and post-processing, and stability during storage.

In many products, the outward appearance is defined by the macrostructure and determined by processing. The important factor in innovations of novel food products is the development of new process concepts dedicated to food structuring purposes. Particles of emulsions, foam bubbles, fat globules serve a microscale, which is related to the structure of the product (1–100 μm).

5.1. Low-fat products

According to the American Cancer Society [31], foods like margarine and mayonnaise with a high fat content must have half or less than half the fat of the regular version of the food to be called *light*. These foods do not usually meet the 30% cutoff for number of calories from fat to be considered low fat. Low-fat foods can be, for example, dairy and dairy-like products (low-fat (1%), fat-free (skim) yogurt, cottage cheese, milk, sorbet, sherbet, gelatin ices, and low-fat

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or fat-free frozen yogurt); fish, meat, and poultry (egg whites or egg substitutes, crab, white fish, shrimp, veggie burgers); grains, cereals (except granola types), and pastas (rice or noodles (watch out for fat in sauces you may add); bagels, pita bread, or English muffins; low-fat crackers, soft tortillas, toast, muffins, crackers, or plain breads); fruits and vegetables (fruit juices, vegetable juices); and sweets (gelatin, low-fat microwave popcorn, hard and jelly candies).

Diet chocolate is known to be a product rich in fat. Its caloric value can decrease with a decrease in the concentration of fat. However, when the fat content is less than 27% of its weight, the chocolate loses its softness and its melting in the mouth. The main ingredients of diet chocolate, in addition to the traditionally used ingredients (such as cocoa mass, cocoa butter, milk powder, and others), are monitol, maltitol, xylitol, sorbitol, and fructose. The use of anhydrous crystalline forms of polyols such as isomalt, maltitol, and lactitol facilitates the process [32].

5.2. Functionality of fat substitutes

Proteins are good substitutes for fat (structuring of the aqueous phase) function, for example, as a gelling agent or thickener. The properties of gels depend on the type and concentration of protein, pH, type, and concentration of salt and heat treatment. These also have the water and fat holding capacity, as well as air retention.

Polysaccharides also have water retention capacity (network formation), serving as a thickener (high molecular weight and high capacity to bind water), stabilizing and gelling.

Viscoelastic properties of dilute solutions of polymer materials such as carbohydrates and proteins can be used to characterize their three dimensional configuration in the solution, that can affect its functionality in many food products. It is possible to improve the food flow behavior by understanding how the polymer molecular structure affects its flow properties, for example, improving the consistency and stability of emulsions using polymers with increased surface area and increased viscosity and elasticity.

In a mayonnaise-like emulsion, which is a viscoelastic material, these features are associated with complex interactions between oil droplets and biopolymers present (egg protein and polysaccharide). The yolk lipoproteins influence the viscoelasticity.

In designing frozen food structure, there is a high dependence between product quality and structure of crystals, which is defined by size, number, shape, and arrangement of crystals. The structure of the crystals formed (ice, fat, and sugar crystals) is influenced by process parameters and ingredients. High variation of temperature during storage can change and increase the size of crystals. Proteins and hydrocolloids (as antifreeze agents) can be added to formulations to create rectangular and elongate ice crystals, which can lead to a high quality product.

Fats and sugars influence mechanical properties, melting resistance, and palatability of ice creams. There are technological effects on different sugars (fructose syrup in blends with sucrose instead glucose syrup) and fats (palm fat as an alternative to hydrogenated vegetable) on the structure of ice cream formulations. Hygroscopicity of fructose syrup increased the solids content in the formulations. Melting rate and overrun were higher in products added with fructose syrup. Palm fat caused changes in melting ranges of formulations, and higher melting rate was observed in the combination of palm fat and fructose syrup [33].

Rheological method was used by Su and Lannes [34] to predict the fat network formation in ice cream with three types of fats (hydrogenated, low *trans*, and palm fat), before and after the ageing process. The maximum compression force, overrun, and melting profile were determined in the prepared ice creams. The product with hydrogenated fat showed better response of the ageing process than the low *trans* fat product. Greater differences between the three were found. The distinction on structure formation of hydrogenated fat was presented by overrun, compression force and meltdown determinations.

Esteller et al. [35, 36] evaluated the substitution of hydrogenated fat and sucrose in hamburger buns formulas were replaced by polydextrose (Litesse II®), salatrim (Benefat™), and sucralose (Splenda®) and their effects on crust color. The results showed that these ingredients can be used as an option to produce low calories baked products.

In the sensorial analysis, the special chocolate filling confectionery, diet + light, produced with Benefat®, as a fat substitute, obtained high levels of purchase intention and thus can be considered as a great product from a market potential point of view [37].

The potential use of beta-glucans as hydrocolloids in the food industry is based mainly on their rheological characteristics, i.e., their gelling capacity and ability to increase the viscosity of aqueous solutions [38]. Oat extract to replace hydrogenated vegetable fat to prepare cakes was used by Rios and Lannes [39], and the structural quality characteristics and shelf life were evaluated; the characteristics of cakes increased without losses of quality.

Inulin was tested as a fat substituted by Richter and Lannes [37] and Laguna et al. [40] in fillings and biscuit, respectively. Fat replacement with inulin or hydroxypropyl methylcellulose provided acceptable biscuits until determined limit. In fillings a good acceptance was obtained also.

Vegetable fat was partially replaced by potato maltodextrin and specially derived waxy-maize maltodextrin aqueous gels in different proportions, in filling formulations. The increase in the amount of fat reduction resulted in an increase in hardness and change in color of the final product, but acceptable by consumers [41].

5.3. Characterizing fat components in emulsions

Water in oil (W/O) emulsions have continuous phase made up of combinations of fats and oils. Butter and margarines, for example, are solid in the refrigerator (around 5°C) and almost liquid above 40°C. Unfortunately, when butter is removed from the refrigerator, there are some problems. Temperature sweep tests at a fixed frequency and strain rate can allow these products to be characterized as a function of temperature and specific melting point. This can help determine the combination of fats and oils required or fat substitute to obtain optimized spreading and texture.

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Products containing more crystallizing fat melt a bit slower than products containing more oil. Softening of fresh cheese products rely on a larger extent on dispersion of the product in saliva, although the product consistency reduces considerably as a result of the melting of fat under mouth temperature. A completely molten fresh cheese will be has much more residual thickness in the mouth than margarine.

As for emulsions with plastic rheology, spreading does not tend to change the emulsion structure dramatically unless the volume fraction of the dispersed phase is very large and spreading induces coalescence of the emulsion droplets. Low-fat spreads may coalesce unless the water droplets are structured with biopolymers to retard re-coalescence under shear.

Processing in the mouth will result in more dramatic microstructural changes. First, consider the behavior of a food emulsion in the mouth during mastication when it is eaten pure, i.e., not on bread. In this situation, a typical food emulsion undergoes a chain of events, although some stages may occur simultaneously or may be unnecessary for a specific food emulsion.

The breakup of a food emulsion can be very important for flavor release. For soluble flavors, in both the lipid and the water phases, diffusion should be fast enough to allow the flavors to move from the product to the saliva within the typical residence time in the mouth.

For studying ice cream formulations using different types of fat, rheology provides information to analyze the effect of each fat studied in the ice cream structure [42, 43].

6. Final considerations

Despite of the calories, maybe of some undesirable triacylglicerols and fatty acids, fats and oils occur naturally in a wide variety of sources for providing distinguish material. Hundreds of seeds and oily fruits, animals, and marine sources supply oils. Many food products can be produced using these oils. However, the production of low-fat food is also of great interest due to the current consumer market. Healthiness and beauty are common interests between people nowadays. Nevertheless, the technology for production of low-fat products cannot be overlooked.

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