Fats and Oils Structure and Function Update

Lipid and lipid components provide sensory, nutritional and functional aspects to foods and beverages. Emerging information on changing technologies, uses and health benefits of this macronutrient is provided.

The types of fats and oils used in formulations have specific impacts on sensory, nutritional and functional aspects of finished products. Fats and oils, collectively called "lipids," impart lubricity, which improves food texture. The way cocoa butter melts on the tongue gives chocolate its unique sensual properties. Lipids are solvents for flavors; cream and butter are regaled not only for their textural qualities, but also for their ability to carry flavors people crave. The species-specific flavors of meats are carried in their lipids; the flavors of beef, lamb and pork are indistinguishable, if the lipids are stripped from the meats. The structure of lipids affects their nutritional and functional properties.

Partially-hydrogenated trans fats, now considered the bad boys of the nutrition world, were for many years extremely popular for their functionality in dough products. Trans fats largely have been replaced by combinations of saturated and unsaturated fats, which are modified to provide similar functional attributes with improved nutritional profiles. Lipid components, such as mono- and diglycerides and lecithin, are routinely used as emulsifiers in many food products. Lipids, such as omega-3 fatty acids and conjugated linoleic acid, also impart positive nutritional benefits. (See sidebar "Healthy Fats.") All in all, lipids are the components that can move food from mundane to memorable.

Function Follows Form

Lipids are produced in all living things as the components that make up the structure of cell membranes, as biochemical messenger compounds and as energy storage. The structure of the lipid determines its function in the cell. Most of the lipids that have value for food products are in the triglyceride, energy-storage form. Food fats and oils are extracted as triglycerides from plant and animal sources. Triglycerides (see illustration "A Triglyceride Structure") are composed of three fatty acids attached by an ester linkage to a glycerol backbone. Glycerol is water-soluble, while the fatty acids generally are oil-soluble. The order in which the fatty acids are attached to the glycerol backbone is highly structured in nature.

Triglycerides--Functional Fats/Shortenings

The difference between fats and oils is driven by their fatty acid composition and the arrangement of the fatty acids in the triglyceride molecule. Fatty acid chain length and the number and placement of double bonds in the fatty acid chain determine the melting profile of fats and oils. The melting profile determines the functionality and sensory characteristics of a fat. As an example, properly crystallized (conched) cocoa butter in chocolate has a sharp melting point slightly below body temperature, which gives chocolate its unique properties of melting and cooling on the tongue. The fatty acid composition of cocoa butter is about two thirds saturated fatty acids (palmitic and stearic acids) and one third unsaturated (oleic with a small amount of linoleic acid).

This is in contrast to commonly used liquid oils, such as soybean and canola, that are them more healthful, but also more susceptible to oxidation, which shortens shelflife. However, shelflife issues are becoming less of a concern with new strains of these oilseed crops that have greatly reduced the level of linolenic (18:3) acid, while maintaining or increasing the levels of oleic (18:1) acid.

Choosing solid shortenings for food applications is more complicated than liquid oils, as the shortening's structure impacts its function, such as flaky texture in pastry and smooth mouthfeel in breads. Solid shortenings range from very hard and highly saturated to very soft and plastic with a high degree of unsaturation. Lipid chemists manipulate the fatty acid composition and the triglyceride structure to provide desired functionality in the finished application. For many years, much of this functionality was achieved through the use of trans fats. Trans fats are unique, in that they are unsaturated lipids that function much like their saturated counterparts. While small amounts of trans fats are naturally occurring in some foods, such as butter, they primarily are produced through partial hydrogenation of unsaturated oils, such as soybean oil.

As the food industry rapidly moved away from using trans fats because of perceived health concerns, lipid scientists had to scramble to find replacements that provided the unique functionality that trans fats offered. Palm and palm kernel oils have become the primary sources for zero-trans alternative shortenings. This is because they have a high degree of shorter-chain saturated fatty acids, with lower melt points, that can be manipulated to provide crystalline structure with a range of melt profiles. The move to palm-based shortenings proved difficult for many food manufacturers, because the palm-based shortenings were not as adaptable in application as trans shortenings. However, fats and oils manufacturers now have built much of the functionality into palm-based shortenings, to the point that they are now comparable to their trans counterparts. This has been done through fractionation and recombination of the triglycerides, along with rearrangement of the fatty acids on the triglyceride molecules. Other fat sources, such as combinations of native and/or fully-hydrogenated soybean and canola fractions (no-trans), are also being used in shortenings. (See sidebar "The Next Frontier.")

While palm-based shortenings now are working well in foods, there continue to be concerns around their saturated fat content. However, fats and oils manufacturers are addressing this issue. According to Jan Helson, executive vice president of a shortening manufacturing company, palm-based shortenings are being transformed from containing as much as 64-69% saturated fat to as low as 24-46% saturated fat with equal functionality. This is being done by using unsaturated fractions of soybean and canola oils in combination with interesterified palm fats.

Emulsifiers

Many food products are emulsions or foams, which are stable mixtures of components that normally do not want to be mixed together (immiscibility). Emulsifiers allow stability by reducing the surface tension between the two immiscible components, such as oil and water in salad dressings and margarines. To begin to understand emulsifier functionality, one needs to become acquainted with general emulsifier nomenclature. The HLB scale of 1-14 is widely used to describe emulsifier functionality (i.e., an emulsifier used for water-in-oil emulsions has a low HLB value, and one that is used in an oil-in-water emulsion has a high HLB value). Those emulsifiers that are given a middle value of the scale sit on the fence, or literally "sit at the interface" between the two phases. There are numerous emulsifiers with a wide range of emulsification properties. Examples include fluid lecithin (low HLB), sodium stearoyl lactylate (high HLB) and DATEM (mid HLB).

However, emulsifiers go beyond salad dressing and margarine stabilization; they also have significant functionality in many food products that do not fit the conventional emulsification scenario. The baking industry, for example, makes extensive use of emulsifiers to build dough strength and to slow staling of baked products. Emulsifiers also can be used to reduce fat and calories in a food product, without compromising product quality.

The variety of emulsifiers available today offer so many options for the product developer's toolbox that it is worthwhile to become acquainted with the broad functional classes of emulsifiers. Professional assistance is available from vendors for application-specific emulsifier selection.

Here are some of the more prominently used emulsifiers.

* Lecithin. Lecithin is a naturally occurring emulsifier and belongs to a class of lipids called phospholipids. Every chef knows how to use egg yolk to thicken and stabilize hollandaise sauce; egg yolk is a rich source of lecithin. Found in every living cell, phospholipids form a lipid bilayer, which is the structure of the cell membrane. Phospholipids are amphiphilic: they have a hydrophilic (water-loving) component and a lipophilic (oil-loving) component. The lipophilic component is two fatty acids attached to the glycerol backbone. The hydrophilic component is attached to the third position of the glycerol molecule and is composed of a phosphate-containing group. The phosphate-containing group can vary, and this difference changes the polarity of the lecithin compounds.

While egg yolk still is used to stabilize mayonnaise and high-end restaurant sauces, the most common source for lecithin for the food industry is from soybean oil extraction. According to Karen Allen Seabolt, global lecithin research lead for a major soy processing company, standard fluid lecithin (refined from oil extraction) has very limited water dispersability and works well for water-in-oil emulsions (low HLB value), such as mayonnaise and margarines. Further processing of lecithin by enzymatic or chemical modification gives it broader emulsification properties and improved functionality in foods where a water-dispersible emulsifier is required. Enzymatically-modified lecithin is used to improve dough sheeting performance by reducing dough stickiness. Lecithin can allow fat reduction in cookies, while maintaining texture.

Lecithin is the ingredient of choice throughout the food industry as a pan-release agent. Because of lecithin's unique hydrophilic/lipophilic nature, it is used to keep food products from sticking together on a production line. The pan/product release attributes of lecithin have helped immensely in reducing the amount of oil used as a processing aid.

The oil (triglyceride fraction) associated with fluid lecithin can be removed, which concentrates the emulsifying phospholipids and increases water dispersability. De-oiled lecithin can be used as a stabilizer of oil in water (high HLB value) emulsions.

Lecithin is an extremely effective wetting agent. For hydrophobic powders, such as high-fat cheese powder or cocoa, a modified, high HLB lecithin is typically used. Protein- or starch-containing powders, such as instant sauces or soups, tend to wet too fast, causing the formation of "fish-eyes," which are lumps that are wet on the outside and dry on the inside. Lower HLB lecithins that are specially refined to have a low viscosity, and bland flavor can be used to instantize those types of powders, thereby controlling wetting and fish-eye formation.

* Mono- and Diglycerides. Triglycerides can be broken up into their component parts of fatty acids and glycerol. How they are broken up determines their functionality. Actually, mono- and diglycerides are formed by reacting triglycerides with glycerol under specific conditions. The resulting products can then be fractionated and processed to obtain distilled (purified) mono- and diglycerides. Monoglycerides and diglycerides have different degrees of oil- and water-solubility. Thus, they can be used as emulsifiers in a variety of food products.

Monoglycerides are not a single ingredient, but actually, a wide family of ingredients with different specifications and uses. Monoglycerides can have the fatty acid in the first or second position of the glycerol molecule. Different fatty acids can be attached to the glycerol, which affects emulsification properties and melt point. Monoglycerides are used as anti-sticking agents in pasta, instant mashed potatoes and cereals. Monoglycerides function well as emulsion stabilizers in many products, such as margarine, and also have been used as fat replacers. Distilled monoglycerides are used in the stabilization and dispersant for powdered coffee creamers. They form particulates around the fat droplets in the creamer, which impede the coalescence of the fat droplets, imparting smooth, creamy mouthfeel in hot beverages.

Monoglycerides are commonly used for anti-staling or starch complexing in bread. Fully saturated monoglycerides, such as glyceryl monostearate (GMS), form complexes with the amylose portion of starch, resulting in slowed starch retrogradation and slowed bread staling. The monoglyceride component complexes with starch substantially better than diglycerides. The reason for this is that the stearate (hydrophobic) tail on the monoglyceride can insert itself within the helix of the starch molecule, while the hydrophilic groups of the glycerol can bind with water. This prevents the starch molecule from cross-linking, as occurs during staling.

While GMS is the most efficient monoglyceride to slow starch retrogradation, it is not soluble in water. To make GMS functional in dough systems, emulsifier manufacturers pre-hydrate the distilled GMS by heating it to its melt point (140˚F), while mixing with water. This forms a hydrated monoglyceride gel that incorporates easily into dough systems.

Diglycerides generally are included in some monoglyceride applications, but have substantially less surface activity and corresponding functionality than the monoglycerides. However, diglycerides have their own benefits, particularly as crystal modifiers for fats and fat-based coatings. Diglycerides are used to impart structure to foods, such as peanut butter and processed imitation cheese.

* Stearoyl Lactylates. Calcium and sodium stearoyl lactylates are widely used in the food industry, and particularly in the baking industry, for their emulsification and dough strengthening. They are produced by reacting stearic acid, a fatty acid, with lactic acid and sodium or calcium hydroxide. According to Jim Doucet, of a U.S.-based emulsifier company, the resulting compound is a very polar (high HLB) lipid that works by cooperative adsorption with proteins at the oil/water interface of an emulsion. These emulsifiers work well to stabilize dairy emulsions, such as coffee creamers. The lactylates bond ionically to gluten proteins and, during baking, will agglomerate gluten and strengthen the dough structure. The stearoyl lactylate surfactant, when hydrated, also complexes with starch to slow starch retrogradation/staling. It is thought about 70% of the surfactant’s activity is attributed to the ionic bonding to the gluten and 30% to the hydration complex with the starch.

Neither calcium or sodium stearoyl lactylate, along with many other emulsifiers, are considered GRAS components. The US CFR (Title 21:172.844 and 846) lists specific applications and usage levels for these emulsifiers that can be used in food products. Both lactylates are limited to 0.5% of the weight of flour in bakery applications.

* DATEM (Diacetyl Tartaric Acid Esters of Monoglycerides). DATEM is another ionic emulsifier, similar to the lactylates, which functions similarly in stabilizing protein-rich dairy emulsions, such as coffee creamers, through a combination of electrostatic and hydrophobic interactions. DATEM is also used extensively in the baking industry, either alone or in combination with other emulsifiers, such as monoglycerides and the lactylates. DATEM's mid-HLB nature of sitting at the interface is thought to function cooperatively with gluten proteins and flour lipids at the air/water interface to improve gas-holding ability of dough.

The roles fats and oils play in food products and in human nutrition continue to grow and change. The convergence of the food manufacturer with food science and nutrition is resulting in more healthful, satisfying food products. **pf**

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Healthy Fats

Certain lipids and lipid components may have a major beneficial effect on health. The role of omega-3 unsaturated fatty acids (18:3, 20:5 and 22:6) have been discussed previously (Black, *Prepared Foods*, July 2009). Other lipids have demonstrated or are being studied for their positive health implications as well.

The primary fraction of lecithin, phosphatidyl choline, can be used as a bioavailable, time-release source of choline. Lecithin and choline may aid in memory and cognitive function, cardiovascular health, liver function, reproduction and fetal development, and physical and athletic performance (Zeissel, 2000). The U.S. Food and Nutrition Board recommends "adequate intakes" of choline for men, women, children and infants. "Good-source" (55mg choline) and "excellent source" (110mg choline) claims can be made for qualifying food products.

Medium-chain triglycerides (MCTs), primarily derived from coconut oil, may have benefits ranging from improved energy delivery for athletes to enhanced weight and appetite control for dieters. MCTs may also have a positive impact on atherosclerosis and immune function (Beerman, et al. 2003). While MCT's fatty acids are saturated, they are only 8-12 carbons in length and, thus, absorbed and metabolized in the body differently than triglycerides with 16 or more carbons. These lipids may be involved in accelerating fat metabolism, particularly when combined with long-chain omega-3 lipids (Beerman, et al. 2003).

Conjugated linoleic acid (CLA) was found in 1987 to have anti-carcinogenic properties. CLA is an 18-carbon fatty acid that contains one cis double-bond and one trans double-bond, so it actually is a trans fat. Two isomers (cis-9, trans-11, and trans-10 and cis-12 18:2) are thought to be bioactive. Since its anti-carcinogenic discovery, the cis-9, trans-11 isomer of CLA also has been associated with a reduction in cardiovascular disease and a reduction in inflammation (Burdge, et al. 2004; Zulet, et al. 2005). Numerous studies demonstrate that both CLA isomers may cause reduced body fat mass and increased lean body mass in normal and overweight individuals (Gaullier, et al. 2004). CLA is found naturally in products from grass-fed cattle and other ruminants. CLA is being produced commercially from safflower oil. The FDA recognized CLA as GRAS in 2008 and is allowing structure/function claims for CLA's effect on increased lean body mass.

Pinolenic acid (PLA) is another fatty acid associated with satiety and appetite suppression. PLA, found in pine nuts, is an 18-carbon omega-6 fatty acid with three double-bonds in the 5, 9 and 12 positions. Korean pine nuts are particularly rich in this fatty acid. PLA is thought to act by causing release of two satiety hormones in the gut, which signals the brain to slow food consumption. Research on PLA is just emerging; no large dietary studies have been conducted to date. One supplier has notified the FDA of the GRAS status of its pine nut oil (GRN No. 332).

Source: PrefaredFoodsNetwork 1 July