

Fat's Balancing Act

By Donna Berry, Contributing Editor

The fatty-acid composition of fats and oils controls their functionality and nutritional profile. Balancing the two can be difficult, because they are often diametrically opposed, with less-healthy fats often providing the most-desirable functionality. This challenges product designers in applications where fat directly influences product performance and shelf life.

The one attribute all fats and oils have in common is that they are concentrated sources of energy that deliver 9 calories per gram, explains Bob Wainwright, technical director, oils & shortenings, Cargill, Minneapolis. "Beyond that, it is difficult to generalize," he says. "For example, land-based animal fats and some vegetable fats, such as palm, are semisolid at room temperature. Other vegetable sources are liquid at room temperature, as are animal-based fish oils. Algal oils tend to be liquid and highly unsaturated; however, more-saturated derivatives are in development. Animal fats from ruminants contain naturally occurring trans fatty acids, while vegetable and non-ruminant derivatives do not. Animal fats and oils contain cholesterol, while plant-based derivatives do not. So, the source is especially relevant to performance, functionality and nutritional impact."

A quick review

Before one attempts to balance functionality and nutrition, it is essential to understand the chemical structure of fats and oils, which are almost always triacylglycerols (a glycerol backbone esterified to three fatty-acid chains consisting of carbon molecules connected to hydrogen molecules). Those three fatty acids are seldom the same, regardless of source. One fatty acid may be saturated (no double bonds), while the other two might be unsaturated. (One double bond is referred to as monounsaturated, or MUFA, while two or more double bonds is referred to as polyunsaturated, or PUFA.) If the triacylglycerol has undergone partial hydrogenation, one or both of the unsaturated fatty acids may be in the trans configuration, rather than in the traditional cis configuration. The trans orientation makes the fatty acid less flexible, with more solid-like properties.

Saturated fatty acids are typically solid at room temperature and are inherently the most-stable type of fatty acid. Stability refers to susceptibility to oxidation, which takes place when a double bond breaks and an oxygen molecule attaches. Saturated fatty acids have no double bonds, hence they are considered highly stable. Therefore, the least-stable fatty acids are those that have a long carbon chain with multiple double bonds.

The majority of unsaturated fatty acids in the human diet contain 18 carbons. However, they can contain as few as 10 carbons and as many as 22, with the former mostly found in animal fat and the latter in marine oils. The "omega" nomenclature system, which identifies the carbon that begins the first double bond counting from the methyl end of the fatty acid, helps categorize fatty acids in terms of function and nutrition.

For example, of the 18-carbon-chain fatty acids, oleic acid has one double bond starting on the ninth carbon from the methyl end, and is appropriately referred to as an omega-9 fatty acid. Linoleic acid and linolenic acid (also often referred to as alpha-linolenic acid, or simply ALA) are also 18-carbon-chain fatty acids. Linoleic has two double bonds, the first occurring at carbon six (from the methyl end) and is referred to as an omega-6, while ALA has three double bonds. It is classified as an omega-3, as the first double bond occurs at the third carbon.

Two other popular omega-3 fatty acids are eicosapentaenoic acid (EPA), which has a 20-carbon chain and five double bonds, and docosahexaenoic acid (DHA), which has a 22-carbon chain and six double bonds. As you can imagine, these long-chain fatty acids with numerous double bonds are highly unstable for certain food applications, in particular those that involve high heat, as frying and baking temperatures accelerate oxidation.

The nutrition angle

But the body appreciates this instability. This is where that diametrical opposition (functionality vs. nutrition) comes into play. "In general, trans and saturated fatty acids have been shown to raise total and low-density lipoprotein (LDL) serum cholesterol levels, the bad cholesterol, while most monounsaturated and polyunsaturated fatty acids have been shown to lower total and LDL serum cholesterol levels," says Tom Tiffany, senior technical manager, ADM, Decatur, IL. "Overall, the goal is to consume a greater proportion of unsaturated fatty acids compared to saturated and trans fatty acids within the context of a healthy balanced diet."

Gerald McNeill, vice president of R&D, Lodgers Croklaan North America, Channahon, IL, says it is important to recognize that, while fats and oils are crudely categorized as "saturated" or "unsaturated," they are actually composed of combinations of saturated and unsaturated fatty acids. In other words, it is not always fair to characterize a fat as "good" or "bad."

"For example, the fatty-acid composition of palm oil, which is a highly functional, natural, solid fat, is about half unsaturated and half saturated," McNeill says. "Clearly, the 'good' unsaturated fatty acids cancel out the 'bad' saturated fatty acids and palm oil should be considered neutral."

To clarify, it's the fatty acids that have the good and bad reputation, not the fat or oil ingredient. And when it comes to trans fatty acids, the National Academy of Sciences says: "Trans fatty acids are not essential and provide no known benefit to human health.... As with saturated fatty acids, there is a positive linear trend between trans-fatty-acid intake and LDL cholesterol concentration and, therefore, increased risk of coronary heart disease (CHD) ... any incremental increase in trans-fatty-acid intake increases CHD risk."

Further, Christine Bunting, director, product application & technical support, Martek, a division of DSM Nutritional Products, Columbia, MD, points out that some research shows that trans fatty acids are also believed to reduce high-density lipoprotein (HDL) serum cholesterol, a.k.a., good cholesterol, making them the unhealthiest of all fatty acids.

Good vs. bad

But Tiffany reminds us, "Fats and oils used in the food industry are mixtures of fatty acids, so simply focusing on one class of fatty acids doesn't reflect how a fat or oil will impact serum cholesterol levels."

Oleic acid is the most common omega-9 fatty acid. David Dzisiak, commercial leader, grains & oils, Dow AgroSciences, Indianapolis, says that research has shown that omega-9 fatty acids can help reduce the risk of cardiovascular disease and stroke by increasing HDL cholesterol and decreasing LDL cholesterol.

Oleic acid is naturally found in abundance in highly flavorful vegetable oils such as olive and peanut. The intense flavor profile of these oils, as well as price, limits their use in commercial baking. However, having only one double bond, oleic acid is the most stable of all unsaturated fatty acids. This knowledge has been the driving force behind advancements in oilseed breeding.

Creating new oils

According to Don Banks, edible oil chemist and consultant, United Soybean Board, oilseed breeders have been able to lower the linolenic fatty acids, increase the oleic fatty acids and decrease the saturated fatty acids in soybeans. "This, combined with the inherently high antioxidant content of soybeans in the form of tocopherols, reaffirms soybean oil as a viable option for commercially baked and fried foods," he says.

Traditional plant breeding is also responsible for sunflowers that yield oil with less than 3% saturated fatty acids, is void of trans fatty acids and is uniquely high (>92%) in oleic acid, making it very stable in heat applications, according to Dzisiak. It will be commercially available in 2013.

"We also market a high-oleic canola oil that contains more than 70% oleic acid and has application in cookies, crackers, tortillas, muffins, microwave popcorn and foodservice fryer applications," Dzisiak adds.

Many other vegetable oilseed breeders have made similar progress. For example, for more than 15 years, "scientists have been creating high-oleic canola oils with increased heat and oxidative stability," says Wainwright. "Unlike typical canola oil, which can develop grassy and painty off notes when oxidized, high-oleic oils have natural resistance to oxidation without going through hydrogenation, fractionation or other complex processing. The first generation was particularly suitable for frying applications. The most-recent generation has the highest level of oleic acid of all canola oils and the highest level of oxidative stability among all high-oleic oils, including sunflower, safflower, soybean and all other high-oleic canola oils. It delivers exceptional shelf life, low levels of saturated fatty acids and no trans fatty acids."

Manipulating fatty acids

Lipid scientists have made significant progress, too. "The role of the lipid scientist is to balance the nutritional contribution of fats and oils with the functional requirements of the food product developer," says Roger Daniels, director of R&D, Bunge Oils, St. Louis. "This is being accomplished by the use of structuring fats such as palm oil and various forms of palm kernel oil, specialized partial-hydrogenation techniques that reduce polyunsaturated fatty acids while minimizing trans-fatty-acid formation, enzymatic interesterification, and use of high-oleic vegetable oils. The result is that we now have lipid solutions that are balanced in terms of functionality and nutrition."

Interesterification is a process that shifts fatty acids within the oil molecule, redesigning its architecture. "This can improve melting properties and functionality," says Daniels. "Interesterification provides a means of conferring a desired melting profile to a blend of an oil and a fat, without the use of partial hydrogenation, which creates trans fatty acids.

"Specifically," Daniels continues, "a liquid oil is physically blended with a fully hydrogenated structuring agent, introduced to an oil-purification vessel, enzymatically rearranged at the 1- and 3-fatty-acid positions on the glycerol backbone, and placed into finished form through the use of a scraped-surface heat exchanger. These shortenings were developed as a drop-in replacement for traditional partially hydrogenated shortenings. The ingredient line is commercially employed in cakes, cookies, tortillas, pie crusts, prepared foods, doughnut frying applications and more."

According to Tiffany, ADM helped pioneer enzymatic interesterification of fats and oils in North America and "offers a variety of products using enzymatic rearrangement," he says. "Products such as enzymatically

interesterified hydrogenated palm kernel oil are lauric-based products used in confectionary applications, providing food manufacturers with a functional cocoa-butter substitute.

"We also enzymatically interesterify blends of soybean oil with fully hydrogenated soybean oil," Tiffany adds. "By varying the level of fully hydrogenated vegetable oil, which is a solid fat, we can tailor the melting and functional characteristics of the blend for the desired food application."

McNeill notes that Loders Croklaan, too, has developed a range of trans-fatty-acid-free products to replace partially hydrogenated vegetable oil. "Using the process of fractionation, an unlimited variety of shortenings and confectionary fats can be tailor made," he says. "Our approach has been to physically separate palm oil into fractions, which can be blended with each other or liquid vegetable oils, in the right ratio to achieve target fatty-acid profiles for a given application. Blending with high-oleic canola or cottonseed oils allows for a stable and low-saturated-fatty-acid ingredient.

"We also developed blended oils that include emulsifiers, which assists with usage levels," continues McNeill. "We recently received the IFT Innovation Award for this technology, as it provides both cost savings and a significant reduction in saturated-fatty-acid content in a wide range of baked goods. This addresses the recent rise in food commodity prices, as well as ongoing efforts to provide more healthful choices to consumers."

With so many options, product developers should be able to balance functionality with nutrition as it relates to fat and oil ingredient selection. "Fat consumption should become less of a concern for consumers as they become more aware of different types of fatty acids, and the role of moderate consumption of fats as part of an overall healthy diet," concludes Banks.

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