FAT REPLACERS

THE CUTTING EDGE
OF CUTTING CALORIES

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Executive Summary

- Substances that can replace some or all of the fat in food products have the potential to help consumers reduce their total fat consumption. Because fat replacers can improve both the taste and texture of lower-fat foods, they can help alleviate the sense of deprivation that can impede sticking with a reduced-fat, reduced-calorie dietary plan.

- Humans cannot survive on a diet that contains no fat. Dietary fat plays a number of essential roles in the human body. It is necessary for the absorption of vitamins A, D, E, and K and other fat-soluble substances; it provides the essential fatty acids required for the production of some hormones; and it is the source of the fatty acids that are integral parts of the membranes of all cells.

- Dietary fat strongly influences the taste and texture of many foods. It is responsible, for example, for the tenderness of meats and baked goods and for the smooth “mouthfeel” of avocados and premium ice creams.

- Of the three macronutrients in the diet—fat, protein, and carbohydrate—fat is the most calorically dense. Consequently, when people wish to decrease the caloric content of their diets, it makes sense for them to decrease the fat content. Because fat replacers have fewer than the 9 calories per gram of real dietary fat (one fat replacer—olestra—provides no calories at all), they can assist in this goal.

- The safety of some fat replacers (and of the products that contain them) has been questioned. The American Council on Science and Health emphasizes that all fat replacers currently in use are safe. Those that have been part of the American diet since before 1958 are considered “GRAS”—Generally Recognized as Safe.

- New ingredients, such as olestra, undergo extensive testing before they are approved for use in foods. The federal Food and Drug Administration currently requires ongoing surveillance of consumers’ use of— and reaction to—olestra-containing products. At present, the FDA has approved only some salty snacks to be made with olestra as
a replacement for the usual fat. Any new use of olestra will require prior approval by the FDA.

• Fat replacers may be categorized by the type of substances that constitute them. Carbohydrate-based fat replacers include cellulose, carrageenan, dextrins, gums, pectins, and vegetable fibers. Protein-based fat replacers include isolated soy protein, microparticulated protein, and modified whey protein. Fat-based fat replacers include mono- and di-glycerides, caprenin, salatrim, and olestra. But of all these substances, only olestra can be used in place of fat to fry foods.

• Fat replacers may be found in a wide variety of food products, including (but not limited to) baked goods, dairy and meat products, chocolate snacks, salty snacks, sauces and salad dressings, cream soups, gelatins, puddings, and candies.

• While fat replacers are a boon to Americans who wish to reduce dietary fat, ACSH emphasizes that reduced-fat or fat-free foods are not calorie-free. In order to reduce body weight, a person still must consume fewer calories than he or she burns. Fat replacers cannot replace the balance, variety, and moderation that are necessary to a health-promoting diet.
Introduction

Substances that replace some or all of the fat in food products offer many advantages to consumers. Most importantly, these substances have the potential to help Americans reduce total fat consumption—a significant dietary concern—by increasing the variety and number of lower-fat food products on the market. Furthermore, fat replacers can improve the taste and texture—both important yardsticks in consumers’ food selection—of those lower-fat foods.

Replacing full-fat foods with lower-fat variations can also help consumers reduce their total caloric consumption. It is necessary to keep in mind that reduced-fat, low-fat, and “fat-free” products are not necessarily noncaloric. It is possible to gain weight (or fail to lose it) on a diet of low-fat foods if total caloric intake is increased as lower-fat foods are substituted for their full-fat counterparts.

The safety of fat replacers and the products that contain them has been called into question. Some of these substances have been part of the American food supply for over 30 years. Newer products, such as olestra (trade named “Olean”), have undergone extensive testing before their release. It is certainly prudent to scrutinize all food products, but the American Council on Science and Health thinks it is unfortunate to carry this scrutiny to excess or to reject safe products out of unrealistic concern.

Even while dietary fat has become one of Americans’ key nutritional concerns, taste has remained the number-one factor influencing our food choices. And fat ranks at the top of Americans’ taste preferences, according to a 1995 Food Marketing Institute survey.1

Overconsumption of fat is one of the most important contributors to obesity,2 and Americans have never been fatter. Today, one third of the population has slipped into the ranks of the officially obese.3* Obesity, in turn, is associated with a number of serious health troubles, including hypertension, diabetes, cardiovascular disease, arthritis, and cancer.3,4

Finding a way to satisfy Americans’ desire for fatty-tasting foods while reducing fat intake could be a valuable weapon in the battle of the bulge. It could also go far toward solving a multitude of obesity-related health problems. Fat replacers can help in both of these areas. The American Council on Science and Health believes that the proper use of fat-replacing substances

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* Obesity is defined as having a Body Mass Index or BMI greater than 30.  
BMI = weight in kilograms/height in meters squared
offers consumers potential health benefits and gives them the taste attributes that so strongly influence their food choices. Once again, though, we remind consumers that the terms “low fat” and “fat free” do not translate to “calorie-free”; we emphasize the importance of using these products in responsible moderation.

Although there has been a good deal of recent press coverage of fat replacers—mostly in the form of stories on such products as olestra, Simplesse, and Z-trim—fat replacers as a class are not new. Some of the ingredients used today as fat replacers have been around since the 1960s, when they were first developed to thicken and stabilize foods or to replace some of those foods’ carbohydrate calories. By 1993 there were over 100 ingredients marketed as fat replacers; by 1995 that number had grown to about 200. And the variety of products containing fat replacers is also growing: They now range from reduced-fat sour cream and potato chips to low-fat and “fat-free” salad dressings and luncheon meats (2,600 new ones in 1996).

In this booklet we will examine dietary fat replacers. We will explain how they are made and will discuss their safety, their uses, and their limitations. We will start, however, with a brief review of dietary fat: what it is, why it is necessary in the human diet, and what functions it serves in food. We will also review the evidence that using fat replacers appears to be an effective way of reducing the fat and calorie content of the diet.

Fat as a Nutrient

Three substances—called macronutrients—contribute calories to food. These substances are carbohydrate, protein, and fat. Even the most fat-free–seeming foods (such as lettuce) contain traces of fat.

Fat is the most calorically dense of the macronutrients. While protein and carbohydrate each have just four calories per gram, fat has over twice that amount: nine calories per gram (a gram is about 1/30 of an ounce). To put this into perspective, half a skinless chicken breast contains about 130 calories overall. The half breast contains about 26 grams of protein, which contribute about 104 of the calories. It also has about three grams of fat.

* Alcohol also contributes calories, of course—7 per gram—but we are not including it in this discussion of fat replacers.
which contribute 27 additional calories. In contrast, four teaspoons of butter or margarine or vegetable oil, which have far less volume than the chicken, have about the same number of calories (135) in their 15 grams of fat.

Like protein and carbohydrate, fat is not just a source of calories. Fat has distinct and critical functions in the human body. In our rush to reduce dietary fat, we Americans tend to forget a crucial fact: It's the dose that makes the poison. Without fat, the body's millions of cells could neither form properly nor regulate the entry and exit of nutrients, hormones, and other essential chemicals. Dietary fat is necessary for the absorption of the fat-soluble vitamins—A, D, E, and K—and for their transport in the blood. And some dietary fats provide essential fatty acids—substances that, like vitamins, are necessary for life.

Americans consume fat to the tune of some 839 billion calories each year. This means that we eat 34 to 36 percent of our calories as fat. Nearly 20 years ago, however, the United States Senate's Select Committee on Nutrition and Human Needs issued a bulletin—Dietary Goals for the United States—that urged all Americans over the age of two to limit calories derived from fat to just 30 percent. This advice has since been echoed by the American Heart Association, the American Dietetic Association, and other reputable health groups.

People are more likely to overconsume fats than to overconsume carbohydrates and proteins. Because fats are more calorically dense than carbohydrates and proteins, it takes far less volume to derive excessive calories from fat. In other words, people's intake of calories from fat is often passive—eaters are often unaware of the caloric level of the food being consumed.

Also, although experts are not in total agreement, dietary fat seems less likely than either protein or carbohydrate to make a person feel full while eating. In a recent experiment, researchers added 400 calories of fat (the equivalent of about three tablespoons of butter) to a small meal of 440 calories. The researchers found that the added fat had no effect on whether or not the people in the study felt full sooner.

In other experiments—studies in which people were allowed to choose freely from a broad selection of high-fat foods—the subjects typically consumed from 50 percent to 100 percent more calories than they did when they were consuming high-carbohydrate foods. And, sad to say, fat may contribute even less to the feeling of fullness in an obese person than it does in a relatively slim person—which means that passive intake of calories from fat is likelier for an obese person.

Thus, fat is less likely to make a person feel full because of its volume:
It packs quite a few calories in a small serving. We humans seem to be fairly good at controlling the volume of the food we consume, but we are not very good at controlling the number of calories.\textsuperscript{2,7} A person is more likely to polish off a relatively small, 500-calorie piece of cheesecake than he or she is to finish a large, 200-calorie bowl of salad. And again, sadly, this tendency might be even more pronounced in an obese woman than in her normal-weight counterpart.\textsuperscript{2}

Another reason excess dietary fat is troublesome is that the body stores any excess calories it gets from fat more easily than it does excess calories from carbohydrate or protein. The body is simply more efficient at storing extra “fat calories”: By some estimates about 25 out of every 100 extra “carbohydrate calories” are needed to convert those calories into fat for storage\textsuperscript{3}; in contrast, it takes less than 10 out of every 100 extra “fat calories” to pack those away for storage. And, once again, those of us who are obese are hit especially hard: the obese are even more likely than their slimmer conferees to deposit excess fat.\textsuperscript{1,3,6}

And, finally, the obese are impacted more adversely by dietary fat for yet another reason: As a group they tend to prefer higher-fat foods to a greater degree than do their leaner peers.\textsuperscript{8}

**Fat as a Flavor Enhancer**

Although most consumers don’t think about it, fats impart many qualities to food beyond the tastes people love. Among those qualities are some that, when absent, cause many people to reject a food. One food quality for which dietary fat is a large determinant is texture. Texture is almost as important to a food’s palatability and acceptability as is its taste. Many people will reject a slice of roast beef that tastes all right but is “tough.” Similarly, many people will reject the texture of a low-fat or “fat-free” bakery product whose taste is fairly similar to its traditional counterpart but whose texture is quite different.

Put another way, fat is extremely important to the “mouthfeel” of food. Compare ice cream and light ice cream, for example. While regular ice cream imparts a creamy mouthfeel, the mouthfeel of a lighter or “fat-free” ice cream is often crisper and icier. Lower-fat versions of ice cream, unlike genuine ice cream, are more likely to form ice crystals—and ice crystals are objectionable to many consumers.

Fat is also essential for the smooth mouthfeel of many salad dressings;
for the moist, tender mouth sensations imparted by a piece of cake; for the richness of frosting and cheese; and for the crispness of potato chips. People often speak of “comfort foods”—soothing foods to which they turn during times of emotional stress, sadness, or even happiness. Comfort foods such as mashed potatoes (especially those made with butter and whole milk or cream) and ice cream have earned their reputation because their texture is just as appealing as their taste. And both mashed potatoes and ice cream get some of their comfort-inducing texture from the fat they contain.

Fat is critical to a food’s moisture content, to its melting point, and/or to its “susceptibility to preparation”—its suitability for frying, for example. Because of the multiple and critical roles that fat plays in food, processors can’t simply remove fat from food. If they did, most foods would taste—and look—unappealing. Indeed, research has shown that the majority of consumers, when given foods from which fat has been removed and to which an appropriate substitute has not been added, find such foods unacceptable. Consider, for example, some reduced-fat bakery products. Home bakers can successfully reduce the fat content of cakes and muffins by substituting applesauce or pureed prunes for some of the oil in the recipe, but total substitution often results in an unacceptable appearance, a tough texture, and an “off” taste.

Can Fat Replacers Decrease Intake of Fat and Calories?

Several studies have shown that when people consume diets with relatively low caloric densities, they spontaneously consume fewer calories. Thus, reducing fat intake may be a more effective strategy for weight loss than consuming reduced amounts of low-carbohydrate foods. But while changing to a lower-fat diet may be one of the most effective ways to lose weight, it is challenging for most people to stick with such a change over the long haul. For many people it is simply impossible. Most people can limit their fat intake temporarily, but few can do it permanently.

This inability to stick with a lower-fat diet is partly due to fat’s various functions in food. But permanent fat reduction may also require a person to change his or her basic food selection and preparation patterns. It may involve limiting intake of ethnic or favorite foods that happen to be high in fat.

The use of fat-modified foods can help solve such problems. Reduced-
fat foods that mimic their full-fat counterparts are designed to provide much of the pleasing taste, texture, and mouthfeel that people seek.\textsuperscript{1,6,8} Adding reduced-fat foods also increases the variety of foods in a reduced-calorie diet—another significant aid to people who want permanently to adopt a new, lower-fat style of eating. Overall, reduced-fat foods help prevent psychological and physical feelings of deprivation that often accompany a strictly limited diet. In addition, eating good-tasting foods made with fat replacers can promote the gradual acquisition of a preference for lower-fat foods.\textsuperscript{2}

Eating lower-fat versions of foods can also potentially prevent the passive intake of excess calories—particularly intake of “fat calories.”\textsuperscript{1,6} Some studies have shown that the availability of lower-fat versions of favorite foods reduces the number of foods that dieters crave.\textsuperscript{8}

Research on the ability of lower-fat foods to reduce dietary caloric level is also very encouraging. It has been shown that people who switch to a diet of good-tasting, fat-modified foods can maintain such a diet long term. Such long-term maintenance is an important strategy for following a lower-fat diet and reducing total caloric intake to achieve a lower, leaner, and healthier body weight.\textsuperscript{6}

Short-term studies have also suggested that people who use fat replacers decrease their fat intake. These dieters increase their protein and carbohydrate intake, but they do not always increase their intake of these substances enough to bring total calorie intake up to the level consumed on their old, higher-fat diets.\textsuperscript{3} What follows is a review of the results of several of these studies, all of which looked at the effect of low-fat diets—both with and without fat replacers—on overall caloric intake.

Dr. Lauren Lissner and associates tracked calorie intake in 24 healthy women aged 22 to 41. For two weeks the women were placed on diets providing 15- to 20-percent fat, 30- to 35-percent fat, or 40- to 45-percent fat. Fat replacers were not used. The women consuming the diet lowest in fat did compensate for the calories lost because of the fat reduction, but that compensation was only 37-percent complete. Consequently, the women on the lowest-fat diet lost weight, as did the women on the more moderate, lower-fat diet. Only the women consuming the highest-fat diet gained weight.\textsuperscript{9}

The same authors conducted a longer study in which 13 women ate either a 20- to 25-percent–fat diet or a 35- to 40–percent fat diet for 11 weeks.\textsuperscript{9} Again, while the women on the lower-fat diet compensated for the caloric deficit of their low-fat diet, they only added back about one third of the calories lost from fat.\textsuperscript{10}

When healthy, nondieting, lean, young-adult males were given low-fat
diets, over a two-day period they compensated enough, by increasing their food intake, to bring their calorie level up to that of higher-fat diets. Similarly, a study of children aged 2 to 5 years found that over two-day periods, replacement of 10 percent of the fat in the diet by the fat-replacer olestra did not result in a calorie deficit—the children compensated by increasing their carbohydrate intake.

The results of these short-term studies in healthy children or lean young adults are not necessarily applicable to other groups studied for longer time periods, however. In one 20-day study 10 obese men and women ate diets in which, for every 1,200 calories consumed, 40 grams of dietary fat were replaced with 40 grams of olestra, causing a 30-percent reduction in mealtime calorie intake. The people in the study compensated only minimally for this loss of calories, resulting in an overall caloric deficit of 23 percent. And eight Dutch studies involving a total of 298 adult subjects produced similar results: People who replaced some dietary fat with olestra compensated for only 14 percent of the lost calories over periods ranging from 1 to 12 days.

It's important to emphasize that these studies were all relatively short-term and that scientists still do not know if most people on reduced-fat diets will, over long time periods, fully compensate their calorie intake. However, most experts do agree that fat replacers and the lower-fat products they make possible could at least help prevent weight gain. With appropriate use, the experts add, such lower-fat products could help people lose weight.

The American Dietetic Association, acknowledging that the human body is not perfect at regulating food and fat intake, supports the use of fat replacers to “dilute” the amount of fat in the American diet. One of the objectives of the U.S. Department of Health and Human Services (DHHS) for the year 2000 is to “increase to at least 5,000 brand items the availability of processed food products that are reduced in fat, saturated fat and cholesterol.” In 1986 there were 2,500 such items on the market; by 1991 the total had reached 5,600.

In a 1995 survey by the Food Marketing Institute, more than 75 percent of consumers said they had stopped buying a specific food because of the amount of fat listed on the nutrition label. The Calorie Control Council’s 1996 national survey found that 88 percent of American adults use reduced-fat foods and beverages regularly.* In 1996 the most popular

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* For the purposes of this survey, “regularly” was defined as at least once in 14 days.
reduced-fat products were:

<table>
<thead>
<tr>
<th>Type of Product</th>
<th>Percentage of Adult Users</th>
</tr>
</thead>
<tbody>
<tr>
<td>low-fat or skim milk</td>
<td>66</td>
</tr>
<tr>
<td>salad dressings/sauces/mayonnaise</td>
<td>60</td>
</tr>
<tr>
<td>cheese/dairy products</td>
<td>53</td>
</tr>
<tr>
<td>margarine</td>
<td>50</td>
</tr>
<tr>
<td>chips/snack foods</td>
<td>43</td>
</tr>
<tr>
<td>ice cream/frozen desserts</td>
<td>43</td>
</tr>
<tr>
<td>meat products</td>
<td>41</td>
</tr>
<tr>
<td>cakes/baked goods</td>
<td>40</td>
</tr>
</tbody>
</table>

Overall, though, regular use of fat-modified products is not yet widespread. In a national survey, 70 percent of respondents used only one such product (typically a reduced-fat milk). No other reduced-fat product was used by more than 5 percent of those surveyed.14

The Potential Impact of Fat Replacers

How much fat can fat replacers replace? Can they help Americans meet the dietary goal of limiting fat to just 30 percent of calories? According to an analysis by Kraft General Foods, median fat intake could be reduced by up to 10 grams per day if equal amounts of “fat-free” alternatives were substituted for frozen desserts, dairy products (excluding milk, cream, natural cheese, yogurt, and butter), salad dressings, and sweet baked goods. This would decrease calories by 110 per day and would reduce the percentage of “fat calories” from 36 percent to about 30 percent.2 Kraft Foods also estimated that about 47 of the average 72 grams of fat in the typical American diet come from foods that could be modified with low-fat or nonfat alternatives.2

According to some research, the use of fat replacers in several items throughout the day might have the greatest impact on reducing overall fat and calories. In other words, using lower-fat dairy products at breakfast, eating lower-fat meats (such as hamburger cut with soy protein) at lunch, and having “light” cheeses at dinner might offer more benefit than cutting all the fat out of one meal.1,6
Safety

Unlike other food additives—those that color or flavor foods, for example—fat replacers can potentially account for a very significant portion of a food. While colorants and flavorings constitute no more than one to two percent of a food, a fat replacer can constitute 30 to 40 percent. Therefore, safety concerns have been a major issue with the newer fat replacers, such as olestra.

The amount of safety testing a fat replacer must undergo is based on how it is classified by the U.S. Food and Drug Administration (FDA). Some substances must undergo testing; others are classified as GRAS (Generally Recognized as Safe).

A “food additive” is any substance that directly or indirectly results in becoming a food component or otherwise affects the characteristics of a food. Some examples of fat replacers that are considered additives are polydextrose, carrageenan, and olestra.

Food additives are regulated by a 1958 amendment to the Federal Food, Drug, and Cosmetic (FD&C) Act of 1938, the basis of all food regulation in this country. The 1938 act grants the Food and Drug Administration authority over food and food ingredients. The 1958 amendment, in addition to regulating food additives, also defines requirements for the truthful labeling of ingredients.

The 1958 Food Additives Amendment to the FD&C Act of 1938 requires FDA approval of an additive prior to its inclusion in food. The amendment demands that a manufacturer prove an additive safe before it can be marketed and used in food. Substances determined safe by the U.S. Department of Agriculture (USDA) prior to the 1958 amendment have been “grandfathered”—designated as prior-sanctioned substances.

New food additives must undergo rigorous safety tests. A new additive is tested on animals before it is tested on humans. The tests are meant to uncover any toxic effects, as well as to determine if there is a maximum level of the substance in the diet that should be considered safe.

But fat replacers are more difficult to test than many other new ingredients. Because most other additives are present in foods in very small amounts, they can be tested in animals at levels hundreds of times higher than the levels at which they would be found in the human diet. In contrast, fat and fat replacers will be present in the human diet at levels much higher than the levels of most additives, so exaggerating animal doses to the same extent as is done with other additives is not possible. Fat replacers may therefore undergo many more tests than would a typical food additive.
In human studies, fat replacers are tested on healthy individuals as well as on special populations of people: those who are at risk of adverse reactions to special food products. Such people include people with gastrointestinal conditions that might be adversely affected by such products.3

Food manufacturers must also consider another safety factor when evaluating a fat replacer: They must determine if the product affects the absorption or utilization of other dietary factors. Olestra, for example, passes through the body unabsorbed, carrying with it some of the fat-soluble vitamins and carotenoids ingested with the olestra-containing food(s). The manufacturer of olestra—or of another fat replacer that could adversely affect nutrients—must determine whether such problems exist and then formulate solutions. Manufacturers of olestra-containing products handle the situation by fortifying their products with vitamins that could otherwise be lost because of malabsorption.3

Substances classified as GRAS do not have to undergo rigorous testing before they are used, usually because they have a long history of safe use in food. These substances are considered safe on one of two bases: either because they have been used safely and extensively in food products over many years (as is the case with salt, sugar, and many spices) or because of scientific evidence published before 1958. These substances may also have undergone safety testing in the past.

Several hundred substances fall into the GRAS category, including many carbohydrate-based fat replacers.15 Some of these items are natural food products, such as fiber or carbohydrates. Among the fat replacers considered to be GRAS are cellulose gel, dextrins, guar gum, and gum arabic.4 Manufacturers of such products need only notify the FDA of their intent to use GRAS ingredients in formulating a GRAS product or file a petition with the FDA requesting that such a product be declared GRAS.

The lower salt content of reduced-fat margarines raises another safety issue. The salt in traditional margarine helps protect it from microbiological overgrowth, even when the margarine is stored at room temperature. Reduced fat margarines, with their low salt content, lack this protective factor. To ensure their safety, reduced-fat margarines should be stored in the refrigerator.1,6
The term “fat replacer” is used to describe a wide variety of products that replace some or all of the fat in foods; the goal is to change the sensory qualities of a food as little as possible while reducing its fat and calorie content. One example of this is the addition of milk solids to reduced-fat or skim milk; another is the addition of ground turkey or other lean meat to processed meat products such as salami.

According to Finley and Leveille there are three categories of fat replacers: fat mimetics, low-calorie fats, and fat substitutes.

Fat mimetics provide the bulk and mouthfeel of fats but have fewer calories. Typical ingredients used to mimic fat are starch, cellulose, pectin, protein, and dextrins (substances related to sugar). Fat mimetics reduce calories not only because they are less calorically dense than fats, but also because they contain a lot of water, which itself replaces part of the fat. Typically, fat mimetics are used in products that have a lot of fluid in them, such as desserts, spreads, and salad dressings.

Low-calorie fats are actual fats whose structure ensures that they provide fewer calories to the body. For example, salatrim has very short fatty acids and very long ones. The short ones have fewer calories and the long ones are not well absorbed; the result is that the combination contributes only about five calories per gram. Similarly, caprenin is composed partly of a very long fatty acid called behenic acid, which is poorly absorbed, and partly of medium-length fatty acids that are processed differently by the body than are the longer ones. The result is that caprenin also contributes only about five calories per gram.

Fat substitutes are the substances most similar to fats functionally. They are heat stable, which is not true of all fat replacers. These substances generally contribute fewer calories than regular fats (or no calories at all) because of their molecular structure and/or because of the way the body handles them. One example of a fat substitute is olestra. Olestra is composed of the sugar sucrose (table sugar) and from six to eight fatty acids. Because of the way in which the fatty acids are attached to the sucrose, humans are unable to digest and absorb olestra; thus, it contributes no calories.

Fat replacers are also classified according to the substances from which they are derived: carbohydrate, protein, or fat. Generally, carbohydrate- and

* More detailed information about the structure of different fatty acids may be found in the ACSH publication Facts About Fats.
protein-based fat replacers are fat mimetics; fat-based fat replacers are low-calorie fats or fat substitutes. Manufacturers commonly use a combination of several fat replacers in one food. They do this because fat has more than one function in food, and a single fat replacer often cannot perform all of fat's functions.

**Carbohydrate-Based Fat Replacers**

Carbohydrate-based fat replacers are the most widely used fat-replacing ingredients. They are made primarily from grains, cereals, and other plant products. Some examples are starches, fibers, gums, and celluloses. On food labels they can be identified by such terms as dextrin, maltodextrin, modified food starch, polydextrose, cellulose, and gum. Some carbohydrate-based fat replacers are digestible, which means they contribute calories (up to four per gram). Others are indigestible and do not contribute calories.

The first of these carbohydrate-based fat replacers—cellulose gel—became available in the mid-1960s. Cellulose gel was introduced as a stabilizer, a substance added to a food to help make it resistant to changes in texture. Many of the other carbohydrate-based fat replacers were also initially developed to improve various qualities in food—qualities such as thickness, bulk, and moisture. These substances did not come to be used as calorie-reducing agents until nearly 30 years later, in the early 1990s.

Today's carbohydrate-based fat replacers still play multiple roles in foods. These roles range from improving qualities to reducing fat content in many categories of foods. Carbohydrate-based fat replacers are commonly used to reduce—and sometimes eliminate—“fat calories” in such foods as frozen desserts, puddings, salad dressings, gravies, sauces, baked goods, processed meats, cheeses, sour cream, and yogurt. Carbohydrate-based fat replacers cannot be used to fry foods, however, as they break down at the high temperatures required for frying.

Food manufacturers often replace part or all of the fat in a food with a carbohydrate-based fat replacer bound to water. This is possible because starches, celluloses, dextrins, and maltodextrins can hold at least three times their weight in water; some gums can hold as much as 100 times their weight. Typically, this translates into replacing nine “fat calories” with 0–1.33 “nonfat calories,” depending on whether a digestible or nondigestible carbohydrate-based fat replacer is used. Calorie and fat-gram savings can
be considerable with this type of fat-replacement system.

Some of the most popular carbohydrate-based fat replacers include the following:

Carrageenan (marketed as carrageenan) is an extract of red seaweed. It gained FDA approval in 1961 for use as an emulsifier (a substance that helps oily and watery ingredients stay mixed), as a stabilizer, and as a thickener. Carrageenan came into popular use as a fat replacer in the early 1990s, when manufacturers started using it to provide some of the gel-like mouth feel of fat in select foods. Typically, carrageenan is used to replace part of the fat in ground beef, in hot dogs, in processed cheeses, and in low-fat desserts. Some consumers complain that the taste of such products is compromised, but others find no fault. Carrageenan has been consumed by humans for hundreds of years, with no adverse effects reported.

Cellulose (marketed as Avicel) is also known as microcrystalline cellulose. It forms a gel in the presence of water and has been used traditionally in foods as a stabilizer. Cellulose has several properties that make it an excellent fat replacer: It acts like a fat in water; it supplies the mouthfeel of fat; it has the glossy, opaque appearance of fat; and it contributes no calories. Cellulose gel is used widely in salad dressings, in mayonnaise, in processed cheeses, and in frozen desserts.

Powdered cellulose (marketed as Solka-Floc and JUST FIBER) is an insoluble, nondigestible fiber. It is often used in fried foods and bakery products. Like most carbohydrate-based fat replacers, powdered cellulose binds water tightly. Thus, when powdered cellulose is used in the batter of foods to be fried, the cellulose preferentially binds to water instead of to the oil used in frying. The end result is that less of the oil is absorbed by the food as it is fried. Studies have shown that the use of powdered cellulose in fried foods can result in a 40-percent reduction in fat uptake in fried batter coatings and up to a 20-percent fat reduction in fried cake donuts. Powdered cellulose is also used in reduced-fat sauces—products in which the ability of the cellulose to retain relatively large amounts of water is also critically important.

Dextrins (marketed as N-OIL, instant N-OIL, and Stadex) are made from the starches extracted from tapioca, corn, potato, and rice. Dextrins are known for their ability to mimic several fat sensations, including mouthcoating, the melting sensation, and the richness of fat. They are also excellent at replacing some of the juiciness lost from meat products when fat is removed. In addition, dextrins can form heat-stable gels, which makes them acceptable for use in some cooked foods. Dextrins are commonly used in salad dressings, in puddings, in spreads, in dairy desserts, and in meat...
products. Naturally occurring carbohydrates, they have a long history of safe use.\(^{18}\)

Polydextrose (marketed as Litesse and StaLite) is made from citric acid, a sugar alcohol called sorbitol, and a sugar extracted from corn. Because human digestive enzymes cannot totally break down polydextrose, some of it passes through the body unabsorbed. Consequently, it contributes only one calorie per gram. Polydextrose was originally developed as a bulking agent—an ingredient added to puff up the volume of cakes and cookies after sugar was removed from the batter. It was subsequently discovered that polydextrose exhibits the mouthfeel characteristics of higher-fat products; as a result, it is also used today to replace some of the fat in bakery items. Eating too much polydextrose can have a laxative effect in some people, however, so products containing more than 17 grams of polydextrose must be labeled with the warning, “Sensitive individuals may experience a laxative effect from excessive consumption of this product.”\(^ {18}\) Typically, a 40-gram candy bar will contain 8 to 12 grams of polydextrose.\(^ {19}\)

Vegetable fibers (no trade names), because of their ability to absorb relatively large amounts of water and their ability to improve the body and texture of foods, are often used to replace some of the fat in various products. Soy, pea, wheat, and oat fibers are used as fat replacers in some baked goods, in meats and in spreads.\(^ {18}\)

Gums (marketed as RHODIGEL, Rhodigum, Dycol, Jaguar, and Uniguar) have been added to foods for many years as emulsifiers. Because gums have a creamy mouthfeel, they are excellent fat replacers. Most gums pass through the human body virtually unmetabolized; as a class, they have a long history of safe use. Some of the gum names consumers will find on food labels include gum arabic, guar gum, locust bean gum, xanthan, and modified carbohydrate or vegetable gum. Guar gum is commonly used to reduce fat in cakes, donuts, ice creams, sour cream, yogurts, cheese products, sauces, and soups. Gum arabic is often used to reduce the fat in bakery products, butter, margarine, toppings, spreads, and frozen desserts. Locust bean gum is used as a fat replacer in ice creams, sausages, salami, bologna, cheeses, canned meat and fish, sauces, syrups, soups, and pie fillings. Modified carbohydrate gum/vegetable gum is used in baked goods, in frozen desserts, in dry sauce mixes, in pourable/spoonable sauces, and in salad dressings. And xanthan gum may be found in beverages, in frozen fruit-pie fillings, and in some canned foods.

Pectin (marketed as Splendid and under other brand names) is made from citrus peel and table sugar. Pectin forms a gel that can replace up to 100 percent of the fat in select foods. Because pectin forms small particles that
mimic fat globules, it has the mouthfeel and melting sensation of fat. Pectin is commonly used as a fat replacer in foods that contain emulsified fats (fats suspended in a watery medium). Such foods include soups, sauces, and gravies; cakes and cookies; dressings and spreads; frozen desserts; and frostings.\textsuperscript{18}

Z-Trim is a recently developed fat replacer. Its availability was announced in late August 1996 by the USDA. Z-trim is made from the processed hulls of oats, soybeans, peas, and rice or from the bran of corn or wheat. The hulls or bran are processed into microscopic fragments, which are then purified, dried, and milled into a powder. Because the fragments absorb water, they swell to provide the smooth mouthfeel of fat. Z-trim also replaces the moistness and density that fat gives to foods. Z-trim passes virtually unmetabolized through the human body, so it contributes no calories. No adverse gastrointestinal side effects have been noted from the consumption of Z-trim containing products.

Z-trim has already been added successfully to brownies, to ground beef patties, and to cheeses. Z-trim can cut the fat calories in a brownie from 25 percent to just 15.5 percent of total calories. It can replace up to 15 percent of the fat in ground beef while boosting the meat's tenderness and juiciness. Z-trim was developed by a USDA researcher from GRAS ingredients. Once the patent has been received, the USDA will license the production process to private companies, enabling them to develop commercial products containing Z-trim.\textsuperscript{20}

\textbf{Protein-Based Fat Replacers}

Unlike carbohydrate-based fat replacers—many of which were initially developed to improve such qualities as thickness, bulk, and moisture in foods and which only secondarily came to be used as fat replacers—protein-based fat replacers were designed specifically to replace fat.\textsuperscript{4}

Protein-based fat replacers are typically made from milk, egg, and whey proteins modified by a process called microparticulation. As the name implies, this process produces tiny particles. In the mouth, the particles act like tiny ball bearings, rolling over one another easily. The end result is a food with the same creamy, slippery texture of its higher-fat counterparts.

Protein-based fat replacers are commonly used in butter, cheese, mayonnaise, salad dressings, frozen dairy desserts, sour cream, and baked goods. These fat substitutes generally give a better mouthfeel than do carbohydrate-
based substances; however, like their carbohydrate-based counterparts, protein-based fat replacers cannot be used for frying.\textsuperscript{21}

Microparticulated protein (marketed under the brand names Simplesse and Trailblazer) is made from microparticulated milk and/or egg-white proteins, sugar, pectin, and citric acid. When added to foods, these products successfully perform many of the functions of fat, and they impart a fatlike creaminess and richness. They are lacking in fat-type flavor, however.

Because microparticulated protein fat replacers are not heat-stable, they are used chiefly in cold products such as ice cream, butter, margarine, sour cream, and salad dressings. Microparticulated protein fat replacers provide 1.33 calories per gram, as compared with the nine calories per gram of regular fats. Used in ice cream, a single gram of Simplesse can replace three grams of fat, for a saving of 23 calories.\textsuperscript{3}

Modified whey protein (marketed as Dairy-Lo) is made from high-quality whey (or milk) protein concentrate. Modified whey protein does an excellent job of improving the texture, flavor, and stability of low-fat foods. It replaces fat at four calories per gram and is typically used in frozen dairy desserts; in hard and processed cheeses; in sour cream, dips, and yogurts; in sauces; and in baked goods.\textsuperscript{18} Its ability to prevent shrinkage and iciness in frozen foods makes it especially desirable as a fat replacer in those products.

Isolated soy protein (marketed as Supro, ProPlus, and Supro Plus) has been used in foods for 35 years. Isolated soy protein is not meant to replace the fat in foods functionally; manufacturers add it simply to reduce the fat content of foods—primarily meat products. Isolated soy protein is also used in some beverages and in weight-loss products. The USDA allows up to two percent isolated soy protein in cooked sausages; it allows higher levels in ground meats and poultry products.\textsuperscript{17}

**Fat-Based Fat Replacers**

Fat-based fat replacers are the newest category of fat replacers. They have the most acceptable taste of any of the fat substitutes and they provide a mouthfeel closest to that of fat. And now, one type of product meets one of the greatest challenges to fat replacers: It is thermally stable enough to be used in frying.\textsuperscript{17}

Fat-based fat replacers are made from some of the same ingredients found in natural fats. But because these ingredients are formulated in such a
way that the body cannot absorb them completely—in some cases, not at all—they contribute either fewer calories than their ordinary counterparts or no calories.

Sucrose Polyester, also known as olestra (marketed under the name Olean), is the first calorie-free fat substitute approved by the U.S. Food and Drug Administration. Most dietary fats are triglycerides: As the name indicates, they are composed of a carbohydrate (glycerol) with three fatty acids attached. Instead of having a glycerol at its core, olestra contains a larger sugar molecule (sucrose) and has six to eight instead of the usual three fatty acids. Olestra looks, tastes, and acts like real fat, but its formulation causes it to pass through the body totally unabsorbed, contributing no calories to the diet.

In January 1996 the FDA approved the use of olestra in potato chips and other savory snacks. Using olestra instead of real fat to fry these products reduces their calories substantially: A one-ounce serving of potato chips fried in olestra contains no fat and 70 calories; a one-ounce serving of ordinary chips contains 10 grams of fat and 160 calories.

Potentially, olestra could be used to replace fat in a wide variety of foods: oils, ice cream, salad dressings, and cheeses. But, as with every food additive, each new use of olestra must be approved by the FDA. To date, the only approved use of olestra is as a replacement for the fat used in the production of some salty snack foods such as potato and tortilla chips, crackers, and cheese curls. Currently, olestra is the only fat replacer approved and on the market that can be used for frying. So far, it has been approved only for commercial uses, but it would also potentially be suitable for home use.

Some vocal opponents have questioned olestra’s safety, but that safety has been documented in more than 100 animal studies and 98 human studies conducted over the past 20 years. According to the FDA, these studies included:

- animal and human studies which showed that olestra does not break down in the digestive tract;
- animal studies which showed that olestra is not absorbed into the body;
- animal studies which showed that olestra does not cause birth defects;
- animal studies which showed that a diet containing olestra is not associated with a higher incidence of cancer;
animal and human studies which showed that olestra's effects on the absorption of the four fat-soluble vitamins (vitamins A, D, E, and K) can be offset by supplementing olestra-containing foods with these vitamins;

animal and human studies which showed that olestra does not decrease the absorption of five key water-soluble nutrients (folate, vitamin B12, calcium, zinc, and iron) that are hard to absorb or that are limited in the U.S. diet;

human studies which showed that at usual snack-food consumption levels, olestra's potential to cause cramping, bloating, loose stools, diarrhea, and other gastrointestinal symptoms in healthy adults and children and in adults with inflammatory bowel disease is no different than that of the full-fat snack foods olestra-containing products can replace;

human studies which showed that olestra does not affect normal intestinal microflora functions; and

animal and human studies which showed that olestra does not affect the absorption of some commonly used drugs, especially drugs that attach to fat in the body, such as oral contraceptives.

Two main areas were investigated in these extensive studies. The most significant area of study focused on olestra's ability to decrease the absorption of fat-soluble vitamins (vitamins A, D, E, and K). Because olestra is an oil and passes through the body unabsorbed, it carries a certain amount of these fat-soluble substances with it.\textsuperscript{16} The FDA is satisfied, however, that fortifying olestra-containing foods with fat-soluble vitamins adequately offsets this effect.\textsuperscript{21,23} The rationale is that when these vitamins are dissolved in the olestra before it is eaten, the olestra no longer has "room" to pick up additional fat-soluble vitamins from foods as it passes through the body. Stated yet another way, with fortification there is no net loss of vitamins.\textsuperscript{24}

Another area investigated was the potential impact of olestra on the body's absorption of beta-carotene and other carotenoids from foods eaten at the same time as olestra-containing foods. (The carotenes are a group of yellow-red chemicals found in both plants and animals. Some can be converted to vitamin A in the body; some have antioxidant activity). The consumption of olestra products as part of a meal that also includes carotene-
rich items such as carrots can block the absorption of some of the beta-carotene. A recent estimate of the magnitude of this effect is that beta-carotene absorption would be reduced by 6.0 to 9.5 percent, depending on how much olestra was consumed along with the carotene-containing food.25

It is difficult to evaluate completely the potential health effects of the diminished absorption of carotenoids. Carotenoids are not known to be essential for human diets, but some scientists believe they protect us from cancer and other diseases. The only proven health role for beta-carotene and other carotenoids is as a precursor to vitamin A—and the potential effect of olestra on vitamin A has been addressed by fortification. When advocates argue that substantial ingestion of beta-carotene will decrease cancer risk, they are referring mostly to studies that do not link the intake of beta-carotene per se with lower cancer risk. Rather, the studies link the high intake of fruits and vegetables—with their vitamins, minerals, carotenoids, and other phytochemicals—with lower cancer risk.26,27 Indeed, recent epidemiological studies indicate that beta-carotene is ineffective at protecting people from lung cancer and may even increase the risk of lung cancer in smokers.28,29

While recognizing that additional data on the impact of small decreases in carotenoid uptake would be helpful, we must remember that foods often interact with each other to alter the absorption of some nutrients. In a balanced diet any losses that may occur in one meal are generally made up in another. Having a glass of milk can reduce iron absorption from a typical breakfast cereal by 50 percent. A high-fiber meal can reduce the absorption of beta-carotene by 50 percent.30 But neither of these examples of food–nutrient interaction has caused nutritionists to advise against drinking milk or eating fiber. This is because both instances cited involve only one meal, not an overall diet.

At a single meal olestra can lower carotenoid absorption just as fiber can. This decrease depends on the carotenoids and the olestra-containing foods' being eaten at the same time, however. For people eating olestra-containing savory snack foods, the effect on carotenoid absorption is less than 6 percent—well within the variability seen in people eating a normal mixed diet. Conceivably, olestra could be fortified with carotenoids; but at this time the FDA—basing its decision on input from the National Cancer Institute and the National Eye Institute—has recommended that, since there is no basis on which to do so, carotenes should not be added to olestra in snack foods.31

Some people experience loose stools after consuming olestra-containing foods. Because of this the FDA requires manufacturers of olestra-containing
foods to include a label statement telling consumers about this potential side effect.\textsuperscript{32}

And olestra appears to offer a benefit: It can inhibit cholesterol absorption and lower blood cholesterol levels.\textsuperscript{16} In one study 20 men with normal cholesterol levels were fed 750 milligrams (mg) of cholesterol per day along with either butter or a butter-olestra blend. The group receiving the olestra absorbed about 18 percent less cholesterol than the group receiving all butter.\textsuperscript{33}

In another study 24 healthy, normal-weight men with normal cholesterol levels were fed 300 or 800 mg of cholesterol in a typical American diet (a diet containing 20 percent of its calories as protein, 40 percent as fat and 40 percent as carbohydrate). Adding olestra to the diet lowered both total and LDL- (“bad”) cholesterol.\textsuperscript{34} The same authors later studied the effect of this type of dietary regimen on obese people: Again, they found that the subjects’ total and LDL-cholesterol levels both fell.\textsuperscript{10}

Salatrim (marketed as Benefat) is the name for a family of reduced-calorie fats typically made from soybean or canola oil. (The name “salatrim” stands for short and long chain acid triglyceride molecules.) As noted on page 13, salatrim provides just five calories per gram, rather than the typical nine of regular fats. Salatrim can be used to reduce the fat in a variety of products such as baked goods, confections and dairy products. Unlike olestra, salatrim cannot be used for frying.\textsuperscript{18}

Caprenin, like salatrim, provides only about five calories per gram. It is a good substitute for cocoa butter and can be used in confections.\textsuperscript{16} Caprenin cannot be used for frying foods, and it is not in any foods currently on the market.

Mono- and diglycerides (marketed as Dur-Em, Dur-Lo, etc.) were developed as emulsifiers—ingredients that help disperse fat in watery mediums. Mono- and diglycerides help stretch fats or spread them more widely throughout a food, thereby allowing less fat to be used in the product. So, although mono- and diglycerides have the same caloric value as other fats—nine calories per gram—their use can result in a substantial fat and calorie reduction. Mono- and diglycerides are used to replace all or part of the shortening in cake mixes, in cookies, in icings, and in select dairy products.\textsuperscript{18}
Fat replacers have a tremendous potential to decrease the fat content as well as the overall calorie content of the diet. Fat replacers can help consumers avoid both the physical and the psychological feelings of deprivation that may arise when they attempt to follow strict, low-fat eating plans—feeling of deprivation that can cause dieters to revert to the higher-fat eating styles that keep them from achieving healthier body weights.

Consumers must realize that the terms “low fat” and “fat free” are not synonymous with “calorie-free.” Unfortunately, consumer surveys indicate that some consumers believe that eating “fat-free” foods in any amounts will promote weight loss. A balanced approach is essential. Eating reduced-fat margarine, for example, cannot erase bad dietary habits such as eating too much high-fat meat or having too many high-fat desserts. Instead, moderation is the key: Using a reduced-fat margarine should be part of an eating plan that is healthier overall—a plan that includes moderate amounts of meat as well as the occasional high-fat dessert. Even more importantly, this healthy eating plan should include at least five servings of fruits and vegetables each day along with lots of naturally low-fat whole grains such as barley, rice, and whole-grain bread.

Increasing the amount of complex carbohydrate in the diet in this way not only adds essential vitamins and minerals to the diet, but also has the potential of helping to control weight. Indeed, sticking to a low-fat, high-carbohydrate diet may be helpful in maintaining lower body weight after a period of weight loss. Observing the guidelines in the USDA’s Food Guide Pyramid and the Dietary Guidelines for Americans is an excellent way to design a healthy eating plan.

Practicing moderation should also prevent any of the unpleasant side effects that can occur with over-consumption of some fat replacers. The fat-based fat replacer salatrim, for example, causes gastrointestinal side effects when it is used in excess. Substituting a single salatrim-containing chocolate bar for its regular-fat counterpart is a wise dietary maneuver, however. The same can be said of foods containing the carbohydrate-based fat replacer polydextrose.

In short, the American Council on Science and Health regards fat replacers not as cure-alls, but as safe and helpful aids in reducing the fat and calorie content of the American diet.
## Appendix: Summary of Fat Substitutes*

<table>
<thead>
<tr>
<th>Type of Fat Replacer</th>
<th>Type of Food Products</th>
<th>Commercial Names</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Carbohydrate-Based</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>carrageenan</td>
<td>ground beef, hot dogs, processed cheeses, low-fat desserts</td>
<td>carrageenan</td>
</tr>
<tr>
<td>cellulose (also called microcrystalline cellulose)</td>
<td>salad dressings, mayonnaise, processed cheese, frozen desserts</td>
<td>Avicel</td>
</tr>
<tr>
<td>powdered cellulose</td>
<td>fried foods, sauces</td>
<td>Solka-Floc, J UST FIBER</td>
</tr>
<tr>
<td>dextrins</td>
<td>salad dressings, puddings, spreads, dairy desserts, meat products</td>
<td>N-OIL, instant N-OIL, Stadex</td>
</tr>
<tr>
<td>gums</td>
<td>bakery products, frozen desserts, yogurts, dairy products, sauces, soups, reduced-fat margarines, meats, soups, pie fillings, sauce mixes, salad dressings</td>
<td>RHODIGEL, Rhodigum, Dycol, J aguar, Uniguar</td>
</tr>
<tr>
<td>pectin</td>
<td>dressings, spreads, frozen desserts, cakes, cookies, frostings, soups, sauces and gravies</td>
<td>Splendid</td>
</tr>
<tr>
<td>polydextrose</td>
<td>bakery products, bakery mixes, chewing gum, confections, frostings, salad dressings, frozen dairy desserts and mixes, gelatins, puddings, candies</td>
<td>Litesse, StaLite</td>
</tr>
<tr>
<td>vegetable fibers</td>
<td>frozen, reduced-fat bakery products</td>
<td></td>
</tr>
<tr>
<td>Z-trim</td>
<td>still experimental but has been used successfully in brownies, cheese, ground-beef patties</td>
<td></td>
</tr>
<tr>
<td>Type of Fat Replacer</td>
<td>Type of Food Products</td>
<td>Commercial Names</td>
</tr>
<tr>
<td>----------------------</td>
<td>-----------------------</td>
<td>------------------</td>
</tr>
<tr>
<td><strong>Protein-Based</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>isolated soy protein</td>
<td>ground meats, poultry products, beverages, weight-loss products</td>
<td>Supro, ProPlus, Supro Plus</td>
</tr>
<tr>
<td>microparticulated protein</td>
<td>frozen desserts, cheese, cheesecake, salad dressings, mayonnaise, cakes, pie crusts, pie fillings, pastries, spreads, yogurt, sour cream, pizza, cream soups, cheese sauces, casseroles</td>
<td>Simplesse, Trailblazer</td>
</tr>
<tr>
<td>modified whey protein concentrate</td>
<td>frozen dairy desserts, hard and processed cheeses, sour cream, dips, yogurt, sauces, baked goods</td>
<td>Dairy-Lo</td>
</tr>
<tr>
<td><strong>Fat-Based</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>caprenin</td>
<td>chocolate-containing confections; not currently in any foods on the market</td>
<td>Caprenin</td>
</tr>
<tr>
<td>mono- and diglycerides</td>
<td>cake mixes, cookies, icings, select dairy products</td>
<td>Dur-Em, Dur-Lo</td>
</tr>
<tr>
<td>salatrim</td>
<td>confections, baked goods, dairy products</td>
<td>Benefat</td>
</tr>
<tr>
<td>sucrose polyester (olestra)</td>
<td>potato chips and other savory snacks</td>
<td>Olean</td>
</tr>
</tbody>
</table>

*Except as indicated, these fat replacers are currently in use or available to manufacturers.*
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