The purpose of this Advisory is to review potential effects of fat substitutes on achieving the American Heart Association (AHA) dietary recommendations for fat intake and to examine the potential effects of fat substitutes on health. Fat substitutes are compounds incorporated into food products to provide them with some of the qualities of fat. Trends in dietary fat intake and the composition and labeling of fat substitutes also will be reviewed.

Background
The AHA recommends limiting total fat intake to ≤30% of calories and saturated fats to <10% of total energy intake for the population as a whole. The AHA also recommends that those with elevated LDL cholesterol levels or cardiovascular disease restrict saturated fats to <7% of calories. To achieve a more healthful dietary pattern in the United States, current dietary guidelines recommend increasing the intake of fruits, vegetables, and grains and modifying the type and amount of fat consumed. The emphasis is on achieving an overall healthful pattern of eating rather than on limiting the focus to merely achieving goals for macronutrient composition.

Americans are responding to the dietary recommendations. The proportion of calories derived from fat in the United States is decreasing. Data from part one of the National Health and Nutrition Examination Survey (NHANES) III conducted from 1988 to 1991 indicated that in the American diet, 34% of calories were from fat, which is lower than previous estimates of 40% to 42% in the 1950s. Data from the National Food Consumption Survey and the Continuing Survey of Food Intake of Individuals (CSFII) are more mixed, with a downward trend between 1965 and 1988 and a shift upward by 1994 to 1995. Nonetheless, efforts to reduce or modify fat intake seem to continue.

In the food supply, 30% of the total fat comes from meat, poultry, and fish, and 25% comes from baked goods and other processed grain products. Milk products and fats/oils account for 18% and 11% of the total fat, respectively. Collectively, these food categories account for 84% of the fat in the food supply. Although the type of fat in these contributors to fat intake varies, the effort to reduce total fat and calorie intake has focused largely on reducing the fat content of foods in these categories.

Industry surpassed the Healthy People 2000 goal of having >5000 reduced-fat processed food products by 1998 with the introduction of >1000 reduced- or low-fat products per year during the 1990s. The most popular reduced-fat products include (1) fat-free or low-fat milk products, (2) salad dressing, sauces, or mayonnaise, and (3) cheese/dairy products. A 1998 Calorie Control Council National Survey indicated that all of these product categories are consumed by ≥50% of individuals who report selecting low-fat products. Consumpation of fat-reduced or fat-free margarine, chip/snack foods, meat products, and ice cream/frozen desserts also was reported by more than one third of these consumers who use fat-modified products. Furthermore, >90% of the adult population had consumed low- or reduced-fat foods and beverages. Thus, the vast majority of the population chooses lower-fat options and demonstrates high interest in foods that are promoted as being low in fat. Although low- and nonfat milks are the most commonly selected options, consumers face a growing variety of other products that contain ingredients added to replace the properties of fat. Survey data from the Calorie Council indicated that two thirds of adults believe a need exists for food ingredients that can replace the fat in food products, and more than half find “reduced in both fat and calories” an appealing descriptor. However, consumers can find the low-fat food options confusing.

In addition to the modification of fat intake, the dietary guidelines from the AHA and the federal government emphasize the rationale for achieving nutritional balance as illustrated in the food pyramid. Advocates who favor total fat reduction and those who recommend replacement of satu-
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Carbohydrate-based fat substitutes use plant polysaccharides such as fibers and starches to retain moisture and to provide textural qualities that usually are provided by fat. The specific fat substitute used in a food product may be the result of its functional properties, but federal regulation also may restrict the foods in which specific fat substitutes may be used. Fat substitutes are designed to mimic one or more of the roles of fat in foods.

### Classification of Fat Substitutes by Nutrient Source, Functional Properties, and Use in Food

<table>
<thead>
<tr>
<th>Type of Fat Substitute</th>
<th>Nutrient Source (Energy Density)</th>
<th>Functional Properties</th>
<th>Use in Food</th>
</tr>
</thead>
<tbody>
<tr>
<td>Derived from carbohydrate</td>
<td>Water-soluble polymer of dextrose (1 cal/g)</td>
<td>Bulking and retaining moisture</td>
<td>A wide range of foods, including baked goods, confections, frozen desserts, and salad dressings</td>
</tr>
<tr>
<td>Derived from starch</td>
<td>A variety of starch sources (1–4 cal/g)</td>
<td>Modifying texture, gelling, thickening, and stabilizing</td>
<td>Processed meats, salad dressing, baked goods, frozen desserts, etc</td>
</tr>
<tr>
<td>Derived from protein</td>
<td>A variety of starch sources (4 cal/g)</td>
<td>Modifying texture and bulking</td>
<td>Baked goods, dairy products, salad dressing, sauces, spreads, and other products</td>
</tr>
<tr>
<td>Gums and pectin</td>
<td>Zanthan, guar, locust bean, carrageenan, alginites, and fruit (virtually noncaloric)</td>
<td>Retaining moisture and modifying texture and mouth feel</td>
<td>Wide range of products, including baked goods, sauces, and salad dressings</td>
</tr>
<tr>
<td>Cellulose</td>
<td>Various plant sources (virtually noncaloric)</td>
<td>Modifying mouth feel, texture, and pouring qualities</td>
<td>Dairy products</td>
</tr>
<tr>
<td>β-Glucan</td>
<td>Soluble fiber extracted from oats (sometimes barley) (1–4 cal/g)</td>
<td>Adding body and texture</td>
<td>Baked goods and a variety of other food products</td>
</tr>
<tr>
<td>Derived from protein</td>
<td>Denatured or microparticulated protein from egg or milk (1–4 cal/g)</td>
<td>Modifying mouth feel</td>
<td>Dairy products, spreads, and bakery products</td>
</tr>
<tr>
<td>Derived from fat</td>
<td>Sucrose poly ester with triglycerides (not absorbed) (noncaloric)</td>
<td>Modifying texture and mouth feel</td>
<td>Savory snacks (stable for fried foods)</td>
</tr>
<tr>
<td>Caprenin and salatrim</td>
<td>Caprylic, capric, and behenic acid and glycerine, or triglyceride of short- and long-chain fatty acids (5 cal/g)</td>
<td>Simulating properties of cocoa butter</td>
<td>Confections, baked goods, and dairy foods</td>
</tr>
<tr>
<td>Mono-diglycerides</td>
<td>Derived from vegetable oil and emulsified with water (9 cal/g; reduces quantity of fat needed)</td>
<td>Adding moisture and modifying texture and mouth feel</td>
<td>Baked goods, vegetable dairy replacers</td>
</tr>
</tbody>
</table>

Adapted from Reference 7.

rated and trans-fatty acids with monounsaturated fatty acids share the concern that “The plethora of ‘fat-free’ products has offered people the opportunity to consume more sugar in, for example, sweet rolls, cookies, and frozen yogurt.” Data from the CSFII (1989 to 1991) indicate that people who used either low or high quantities of low-fat products and whose total fat intake was <30% of calories reported rice and pasta as major energy sources, whereas those who did not use low-fat products consumed more sugar. The increased availability of low-fat and nonfat dessert products and confections during the 1990s could shift intake toward higher sugar consumption. In a controlled randomized trial, when provided free access to fat-modified and regular food products, individuals ate less fat, saturated fat, and cholesterol but did not substantially reduce energy intake. Consumer survey data from the Food Marketing Institute indicate that buying food products labeled as “low fat” was reported as the most common action used to improve diet.

### Composition, Labeling, and Uses of Fat Substitutes

Fat substitutes can be categorized on the basis of nutrient sources, functional properties, and use in food, which have been reviewed as indicated in the Table. Fat substitutes are designed to mimic one or more of the roles of fat in foods.

#### Nutrient Source

- **Derived from carbohydrate**
- **Derived from starch**
- **Derived from protein**
- **β-Glucan**

#### Functional Properties

- Bulking and retaining moisture
- Modifying texture, gelling, thickening, and stabilizing
- Modifying texture and bulking
- Retaining moisture and modifying texture and mouth feel
- Modifying mouth feel, texture, and pouring qualities
- Adding body and texture
- Modifying mouth feel
- Modifying texture and mouth feel
- Adding moisture and modifying texture and mouth feel

#### Use in Food

- A wide range of foods, including baked goods, confections, frozen desserts, and salad dressings
- Processed meats, salad dressing, baked goods, frozen desserts, etc
- Baked goods, dairy products, salad dressing, sauces, spreads, and other products
- Wide range of products, including baked goods, sauces, and salad dressings
- Dairy products
- Baked goods and a variety of other food products
- Savory snacks (stable for fried foods)
- Confections, baked goods, and dairy foods
- Baked goods, vegetable dairy replacers

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Carbohydrate-based fat substitutes use plant polysaccharides such as fibers and starches to retain moisture and to provide textural qualities that usually are provided by fat. The currently available fat-based substitutes are chemically modified to affect absorption or to achieve the physical properties of fat with a reduced amount of fat. Olestra is a fat-based substitute comprised of sucrose esterified with 6 to 8 long-chain fatty acids. As such, olestra cannot be absorbed because it is not hydrolyzed by pancreatic lipase. Other fat-based substitutes

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Potential Effects of Fat Substitutes on Overall Dietary Intake and Body Weight

Data from the CSFII from 1989 to 1991 and 1994 to 1995 indicate that adults who used fat-reduction strategies had lower intake of total fat, saturated fat, cholesterol, and energy and were more likely to meet the dietary guidelines than those who did not use fat-reduction strategies. The micronutrient intake of persons who used several strategies to reduce fat intake was comparable to that of individuals who used only full-fat products. Data from the children participating in the CSFII suggest that the use of fat-modified products could help children reach dietary recommendations, but concomitant reductions in total energy and vitamin E intake may occur. However, these data were obtained from dietary intake data and were collected before olestra became available in 1998. Use of fat substitutes may facilitate reduction of the proportion of calories derived from fat, but the effects on total energy intake and body weight are less certain. The motivation for using fat-modified food products seems to be health and weight related. Short-term data suggest that use of fat substitutes has few adverse or positive effects. Longer-term studies will determine the potential impact of fat substitutes on preventing or treating obesity.

Data obtained in the Olestra Post-Marketing Surveillance Study suggest that the early adopters of the product, who responded to the marketing of olestra, held positive health beliefs about the potential benefits of lowering fat intake and about the link between diet and disease. Individuals with a higher education level and a perception of a strong relationship between diet and disease reported higher rates of olestra use. Overweight and obese individuals were more likely to be olestra users than were normal-weight individuals, but having diabetes was negatively associated with olestra use. In a double-blind, placebo-controlled, within-subject crossover study, 20 to 35 g of olestra was covertly substituted for conventional fat, and subjects had ad libitum access to additional fat, which allowed the investigators to determine if the replacement of conventional fat with a substitute would reduce fat and energy intake.

During the 2 weeks of olestra feeding, subjects consumed 8% less total energy and had an 11% lower intake of fat than during the 2-week conventional fat feeding period. The total deficit achieved with the substitution was only 2616 kcal over the 14-day study period. In a single-meal feeding study, substituting olestra for regular fat reduced intake by 450 kcal, but neither the participants’ subjective ratings of postmeal hunger nor the amount of food consumed during the subsequent meal changed. One-year follow-up data from the Olestra Post-Marketing Surveillance Study indicate that individuals in the highest consumption category (≥2 g/d) did not significantly reduce total energy intake, although they reduced the percentage of calories from fat by 2.7% and that from saturated fatty acids by 1.1%. Analysis of the dietary intake data indicated that higher intake of olestra-containing products was associated with higher intake of vegetables, fiber, protein, and sodium.

Potential Effects of Fat Substitutes on Health Status

The potential physiological effects of fat substitutes on health and nutrient status vary. Literature reviews indicate that few if any health issues have been raised about adverse impact of the carbohydrate-based or protein-based fat substitutes, which seem to have little or no effect on digestion, absorption, or metabolism of other nutrients. Fat-based substitutes derived from modifying length or number of fatty acids also seem to have no effect. These substitutes include caprein and salatrim, as well as mono- and di-glycerides.

Within the fat-based group, the safety research has focused primarily on olestra, which may affect nutritional status by its effects on absorption of fat-soluble nutrients. In the gastrointestinal tract, fat-soluble nutrients can partially partition into olestra and be excreted. Factors that affect the level of partitioning include (1) the degree of fat solubility (the more fat soluble the nutrient, the more it will be partitioned into olestra), (2) the relative amount of olestra to nutrient (partitioning increases as the amount of olestra per measure of nutrient increases), and (3) the timing of olestra and nutrient consumption (partitioning can occur when olestra and the fat-soluble nutrients are in the gut at the same time). The manufacturer has compiled partitioning coefficients for fat-soluble nutrients in 382 foods. The affected nutrients include phytosterol and carotenoids, with reduced absorption rates of <10% and 6% to 10%, respectively. Little is known about potential interactions with pharmacological...
agents and ingredients in food products that can affect fat-soluble nutrient motility and absorption rates in the gastrointestinal tract.

In an 8-week, randomized, controlled parallel study, olestra reduced serum concentrations of carotenoids, α tocopherol, 25-hydroxy-ergocalciferol, and phylloquinones in a dose-response manner. However, olestra did not affect other nutrients, lipids, or prothrombin time or concentration. Specified amounts of fat-soluble vitamins A, D, E, and K must be added by the manufacturer to offset the effects of olestra.

The results of several studies indicate that olestra intake affects the composition of the stool and its softness. Intake of olestra did not increase objective measures of diarrhea (stool output of >250 g/d, liquid or water stool, or >3 bowel movements per day). However, consumption of 40 g of olestra in ~5 oz of chips (15 chips are ~1 oz) can increase fecal fat excretion and result in a misdiagnosis of malabsorption. Consumption of olestra does not seem to exacerbate quiescent inflammatory bowel disease. Preliminary evidence from case reports of 3 individuals suggests that olestra can double the excretion of lipophilic environmental contaminants such as polychlorinated biphenyls (PCBs) and hexachlorobenzene (HCB). The long-term (lifetime) estimated daily intake (EDI) of olestra is estimated to be 3.1 g/d, which is considerably below the short-term (single-day) EDI of 10.3 g/d. For 13- to 27-year-olds, the short-term EDI rose to 24 g/d, which approximates 3 oz of olestra-containing potato chips. Continued monitoring of consumption patterns and health biomarkers is needed to determine the longer-term effects of olestra.

Summary and Recommendations

Fat substitutes can mimic one or more roles of fat in food products. Classification of fat substitutes usually is based on the nutrient source. Protein- and carbohydrate-based fat substitutes, as well as some fat-based products, provide the functional and sensory qualities of fats in foods and are absorbed and metabolized normally. The introduction of olestra, which is a nonabsorbable fat substitute that can affect nutrient absorption, raises questions about its potential effect on overall health. Some research suggests that individuals who consume a diet that is reduced in fat and calories and includes use of fat-modified products have a better overall nutrient profile than do individuals who do not use any fat-modified products. The recent increase in the availability of fat substitutes in the market raises questions about the cumulative impact of using fat substitutes in multiple food products and the potential interaction with medications and food ingredients. Within the context of a healthy dietary pattern, fat substitutes, when used judiciously, may provide some flexibility in dietary planning, although additional research is needed to fully determine the longer-term health effects.

References


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