Position of The American Dietetic Association: Fat replacers

POSITION STATEMENT

It is the position of The American Dietetic Association that the fat content of foods may be safely reduced or replaced using approved processing methods and constituents. Individuals who choose such foods should do so within the context of a diet consistent with the Dietary Guidelines for Americans.

The percent of total daily energy consumed as fat by the US population declined from about 40% to 42% in the late 1950s and early 1960s to approximately 34% in 1994 (1,2). Saturated fat intake also declined and now constitutes about 12% of total energy consumption. However, these downward trends in percent of total intake are somewhat misleading. Actual fat consumption rose from approximately 81 g/day in late 1970s to about 83 g/day in the early 1990s. Fat contributes proportionately less energy to the American diet, in part, because total energy intake increased from a mean of 1,989 kcal/day in the late 1970s to 2,095 kcal/day in the early 1990s. This increment was composed of a fuel mix that was relatively lower in fat. At the same time, the prevalence of overweight and obesity increased (3). Thus, progress toward meeting recommendations to reduce the percent of energy derived from fat has come, in part, from a failure to meet another recommendation; that is, to adjust energy intake and physical activity to maintain desirable body weight (4-7).

The principle sources of fat in the US diet are fats and oils; red meats, poultry, and fish; and dairy products. Combined, they account for about 90% of total fat intake. The most recent US Department of Agriculture (USDA) figures (8) indicate that use of fats and oils has increased from about 60 to 64 lb per capita during 1987 through 1991 to 66 to 68 lb per capita during 1992 through 1994. Preliminary figures for 1995 are approximately 64 lb per capita. Whether this represents a true reversal of the trend for increased use of fats and oils cannot be determined at this time. Consumption of red meats has remained relatively stable, ranging from roughly 117 lb per capita in 1987 to a projected 115 lb per capita in 1995. Little variation in fish consumption occurred between 1987 and 1995; levels varied between approximately 15 and 16 lb per capita. Poultry use increased from 51 lb per capita in 1987 to about 63 lb per capita during the years 1993 through 1995. As a result, total consumption of red meats, fish, and poultry has risen sharply, from a level of 184 to 186 lb per capita during the years 1987 through 1991 to about 190 to 193 lb per capita since 1992. The trend for reduced use of dairy products during the early 1990s (566 to 569 lb per capita) has been reversed and higher levels were reported for 1994 (574 lb per capita) and 1995 (585 lb per capita). Indeed, the preliminary value for 1995 is comparable to that of 1988. Although there was a marked consistent reduction in consumption of whole milk and a partially offsetting increase in the use of reduced-fat and no-fat milk, there has also been an increase in cheese intake and stable use of cream, half and half, sour cream, and ice cream. Thus, from 1992 to 1995, use of the principle sources of dietary fat has been stable or higher relative to the previous 5-year period. This is consistent with a 1997 study (9) indicating that the percentage of persons cautious about the amount of fat in their diet declined between 1992 and 1996. Consequently, additional efforts are required to achieve further reductions in fat consumption. Fat replacers may facilitate this aim.

DIETARY RECOMMENDATIONS

Consumption of a diet high in fat is associated with an increased incidence of obesity, coronary heart disease, hypertension, insulin resistance, certain cancers (eg, breast, colon, or prostate), and gallbladder disease. Marked reduction of total fat intake typically results in lower total energy consumption and weight loss, thereby ameliorating problems of obesity, hypertension, and insulin resistance. Reductions of total and low-density cholesterol and, as a consequence, coronary heart disease risk, are noted when saturated fat intake is restricted. These observations have prompted government, professional, and scientific bodies, including the US Surgeon General, US Department of Health and Human Services, USDA, Nutrition Research Council of the National Academy of Sciences, American Cancer Society, American Diabetes Association, and American Heart Association, to recommend reduced intake of total and saturated fat. Generally, the guidelines suggest that for persons older than 2 years, total fat intake should be limited to no more than 30% of total energy and that saturated fat should account for no more than 10% of daily energy consumption averaged over a 1-week period. The degree to which a diet meeting these guidelines will result in health benefits for an individual is difficult to predict because the outcome will depend on the influence of other factors such as a person's genetic constitution, level of physical activity, and total diet composition. Evidence suggests that overall dietary adequacy can be maintained while complying with current guidelines for dietary fat (10). The feasibility, safety, and efficacy (in terms of reduced health risks) of more severe restrictions of total and saturated fat have not been established (11-17).

Findings from the Third Report on Nutrition Monitoring in the United States (18) reveal that only 18.2%, 14.0%, and 20.9% of males aged 6 to 11, 12 to 19, and ≥20 years, respectively, are consuming ≤30% of energy from fat. The figures for females are 17.7%, 17.9%, and 25.2%, respectively. Adherence to the recommendations is only slightly better among whites (males, 20.6%; females, 25.3%) than among African-Americans (males, 17.0%; females, 21.3%) (18). There is little difference across income strata. Thus, a majority of the population continues to consume a diet higher in fat than current recommendations

ROLES OF DIETARY FAT

Dietary fats serve multiple purposes. Linoleic, α-linolenic, and, when linoleic acid is not available, arachidonic acid are essential fatty acids that play a functional role in all tissues. Adequate intakes of essential fatty acids are thought to range between 5% and 10% of total energy intake. Deficiency symptoms can be prevented when 1% to 2% of dietary energy is derived from n-6 fatty acids and 1% comes from n-3 fatty acids. Fat is also an important source of energy. It helps to meet daily energy needs under normal circumstances and, when stored in adipose tissue, provides a vital reserve to meet demands when other energy sources are unavailable (eg, starvation), unusable (eg, diabetes), or inadequate (eg, during stress of illness). These stores also help maintain body temperature and protect body organs from trauma. Fats serve as a vehicle for the delivery and absorption of fat-soluble nutrients, and although researchers (19-21) now question the historical view that fat is especially satiating because of its high energy density (9 kcal/g) and slow clearance from the stomach, fat clearly contributes to the satiety value of foods. Perhaps most importantly from the perspective of food selection, fat contributes to the sensory appeal of foods. Fats are a principle determinant of a food's texture. They also emulsify, absorb moisture, stabilize foams, aerate batters, transfer heat, and carry pigments and flavor compounds.

Fats have such a wide array of functions because the family of dietary fatty acids in the food supply is diverse and has a range of properties. Subtle differences in the particular mixture of fatty acids, which vary in chain length and degree of saturation, can markedly alter the sensory properties and nutritional implications of a food. Because these attributes generally reflect the collective influences of multiple fatty acids in a product, it is unlikely they will ever be replicated with a single natural or synthetic compound. Indeed, there is increasing awareness that product optimization will often require blends of the more than 100 compounds identified during the past decade as contributing specific "fat-like" functional properties to reduced-fat foods (22).

WHAT ARE FAT REPLACERS?

Consumer concern about the amount of fat in foods has recently waned, but remains extremely high. One method persons use to reduce fat intake is consumption of fat-modified foods. A 1996 national survey (23) revealed that 88% of the US population (90% of women and 87% of men) consume low-fat, reduced-fat, or fat-free foods and beverages. Eighty percent of respondents indicated they used such products to stay in better overall health and as a means to reduce total fat and energy intake. Yet the question remains whether most consumers can adhere to a reduced-fat diet for the extended period required to realize any health benefits. Adherence may be improved with the availability of palatable low-fat foods. With that in mind, one objective of the Healthy People 2000 project was to increase the availability of foods reduced in fat to 5,000 items by the year 2000. With more than 1,000 such items introduced per year since 1990, this goal has been far surpassed. However, there is still strong consumer demand for an expanded array of fat-modified foods; 56% of the US population indicate that there is a need for additional ingredients to replace fat in foods (5).

To meet this demand, food manufacturers have developed approaches for fat replacement that provide a variety of options for combining ingredients to yield products with characteristics like their full-fat counterparts. One set of ingredients is termed "fat substitutes" or "analogs." These compounds are designed to replicate the functional and sensory properties of fats, but are not chemically classified as fat and contain less energy than fats. They may be used to replace all or a portion of the fat normally present in a product. A second class of ingredients is referred to as "fat mimetics." These compounds replicate only a subset of the properties of the fats they are designed to replace. They are typically used for partial fat replacement. Fat "barriers" constitute a third type of replacement system. This entails adding compounds that reduce the absorption of fats during the frying process. The number and variety of fat replacers continues to increase (23-27). The Table provides a partial list of types and applications of currently available fat replacers. Because of rapid advances in the field, such information is quickly outdated.

Fat replacers may be classified by their macronutrient base. The largest number are carbohydrate-based. These ingredients are plant polysaccharides and include cellulose, gums, dextrins, fiber, maltodextrins, starches, and polydextrose. When added to foods, they thicken and add bulk, thereby producing a mouthfeel similar to that provided by fat. They also contribute emulsification and structural properties. Some of these compounds (eg, dextrins, modified starches) can be digested and provide 4 kcal/g, although in the hydrated form the value may drop to 1 to 2 kcal/g. Others are not digested to an appreciable extent (eg, cellulose) and have little energy value. Although these types of fat replacers cannot be used for frying, many can withstand heat (hence their common use in meat products). Polyols, which help to absorb moisture in foods, also are found naturally occurring in foods such as fruits. Because they are not fully absorbed and metabolized, they contribute less than 4 kcal/g. If used in high concentrations, polyols may have a laxative effect.

Table
Examples of fat replacers and their functions and properties

Class of fat replacers	Trade names	Applications	Functional properties
Carbohydrate-based			
Polydextrose	Litesse[a], Sta-Lite[b]	Dairy products, sauces, frozen desserts, salad dressings, baked goods, confections, gelatins, puddings, meat products, chewing gum, dry cake and cookie mixes, frostings and icings	Moisture retention, bulking agent, texturizer
Starch (modified food starch)	Amalean I & II[c], N-Lite[d], Instant Stellar[e], Sta-Slim[b], OptaGrade[e], Pure-gel[f]	Processed meats, salad dressings, baked goods, fillings and frostings, condiments, frozen desserts, dairy products	Gelling, thickening, stabilizing, texturizer
Maltodextrins	CrystaLean[e], Maltrin[f], Lycadex[g], Star-Dri[b], Paselli Excell[h], Rice-Trim[i]	Baked goods, dairy products, salad dressings, spreads, sauces, fillings and frostings, processed meat, frozen desserts, extruded products	Gelling, thickening, stabilizing, texturizer
Grain-based (fiber)	Betatrim[j], Opta[e], Oat Fiber[ek], Snowite[k], TrimChoice[b], Fibrim[l]	Baked goods, meats, extruded products, spreads	Gelling, thickening, stabilizing, texturizer
Dextrins	N-Oil[d], Stadex[b]	Salad dressings, puddings, spreads, dairy products, frozen desserts, chips, baked goods, meat products, frostings, soups	Gelling, thickening, stabilizing, texturizer
Gums (xanthan, guar, locust bean carrageenan, alginates)	Kelcogel[m] Keltrol[n], Viscarin[o], Gelcarin[o], Fibrex[p], Novagel[q], Rohodigel[j], Jaguar[r]	Salad dressings, processed meats, formulated foods (eg, desserts and processed meats)	Water retention, texturizer, thickener, mouthfeel, stabilizer
Pectin	Grindsted[s], Slendid[t], Splendid[t]	Baked goods, soups, sauces, dressings	Gelling, thickening, mouthfeel
Cellulose (carboxy-methyl cellulose, microcrystalline cellulose)	Avicel[q], cellulose gel, Methocel[u], Solka-Floc[v], Just Fiber[w]	Dairy products, sauces, frozen desserts, salad dressings	Water retention, texturizer, stabilizer, mouthfeel
Fruit-based (Fiber)	Prune paste, dried plum paste, Lighter Bake[x], WonderSlim[y], fruit powder	Baked goods, candy, dairy products	Moisturizer, mouthfeel
Protein-based	Simplesse[z], K-Blazer[aa], Dairy-lo[bb], Veri-lo[bb], Ultra-Bake[b], Powerpro[cc], Proplus[dd], Supro[dd]	Cheese, mayonnaise, butter, salad dressing, sour cream, spreads, bakery products	Mouthfeel
Fat-based	Caprenin[ee], Olean[ee], Benefat[bb], Dur-Em[ff] Dur-Lo[ff]	Chocolate, confections, bakery products, savory snacks	Mouthfeel
Combinations	Prolestra[gg], Nutrifat[gg], Finesse[gg]	Ice cream, salad oils, mayonnaise, spreads, sauces, bakery products	Mouthfeel

[a]Cultor Food Science, Inc, Milwaukee, Wis.
[b]AE Staley Manufacturing Co, Decatur, Ill.
[c]Cerestar USA, Inc, Hammond, Ind.
[d]National Starch and Chemical Co, Bridgewater, NJ.
[e]Opta Food Ingredients, Bedford, Mass.
[f]Grain Processing Corp, Muscatine, Iowa.
[g]Roquette America, Inc, Keokuk, Iowa.
[h]AVEBE America Inc, Princeton, NJ.
[k]Zumbro, Inc, Hayfield, Minn.
[j]Rhone-Poulenc, Inc, Cranbury, NJ.
[k]Canadian Harvest USA, Cambridge, Minn.
[l]Protein Technologies International, Pryor, Okla.
[m]Monsanto, Chicago, Ill.
[n]Kelco, Division of Merk, Clark, NJ.
[o]FMC Corp, Rockland, Me.
[p]Purity Foods, Okemos, Mich.
[q]FMC Corp, Philadelphia, Pa.
[r]Aston Chemicals, Aylesbury, Buckinghamshire, England.
[s]Danisco, New Century, Kan.
[t]Hercules Inc, Wilmington, Del.
[u]Dow Chemical, Midland, Mich.
[v]Fiber Sales and Development Corp, Green Brook, NJ.
[w]Quest International, Hoffman Estates, Ill.
[x]Sunsweet Growers, Yuba City, Calif.
[y]The Heart Garden Corporation, Los Angeles, Calif.
[z]Nutrasweet, San Diego, Calif.
[aa]Kraft Food Ingredients, Memphis, Ind.
[bb]Cultor Food Science, Groton, Conn.
[cc]Land O'Lakes Food Division, Arden Hill, Minn.
[dd]Protein Technologies International, St Louis, Mo.
[ee]Procter and Gamble, Cincinnati, Ohio.
[ff]Quest International, Owings Mills, Mo.
[gg]Reach Associates, South Orange, NJ.

Proteins can be used as fat replacers in several ways. When blended with gums, they form gels that provide structure and functionality similar to that of fat. Proteins of low molecular weight may act like fats to alter the texture of a product (eg, cheese) normally composed of proteins of higher molecular weight. Microparticulated proteins (1 to 1.5 µm in diameter) reportedly act as small ball bearings that provide fat-like lubricity and mouthfeel. Most protein-based replacers cannot be used at high temperatures because the protein coagulates and loses its functionality. However, the heat stability of some newer formulations has been improved. Protein replacers contribute 1.3 to 4 kcal/g and have the biological value of the component amino acids. They also carry the antigenic properties of the protein.

Fat-based fat replacers are not new to the food supply, although only recently has a truly noncaloric, heat-stable formulation been introduced. Monoacylglycerols and diacylglycerols have long been used as emulsifiers and contribute sensory properties comparable to fats. By using specific fatty acids in the formulation of these compounds, it is possible to achieve desired functionality at reduced energy (eg, 5 kcal/g vs 9 kcal/g). Triacylglycerols comprised of selected short- and long-chain fatty acids can also provide the sensory characteristics of fat with reduced energy content because they are not efficiently absorbed. They contribute about 5 kcal/g. Salatrim, which stands for short- and long-chain acid triglyceride molecules, is representative of this class of replacers. Another type of fat-based fat replacer binds fatty acids to nontraditional backbones (eg, sugar) so that enzymes in the human gut are not able to cleave the fatty acids. Thus, they are not absorbed and do not contribute energy. The principle advantage of this latter approach is that such compounds are heat stable and will retain their functional properties in baked and fried foods. Because they are not absorbed (not unlike constituents in high-fiber foods), they may pose a risk for gastrointestinal distress and reduce absorption of fat-soluble nutrients (28,29). Products containing sucrose polyester, the only approved product of this type (approved January 30, 1996) (30), are fortified with fat-soluble vitamins.

It should be noted that the fat content of foods can also be reduced by simply decreasing the amount of fat present. Fluid dairy products, cheese, and baked chips exemplify this approach. Because of the varied roles fat plays in foods, this is not feasible in all products. Replacement of fat with other foods (eg, fruit purees, nonfat yogurt) possessing sensory characteristics that resemble those contributed by fat (eg, creaminess, moistness, lubricity) can also yield an acceptable product.

SAFETY OF FAT REPLACERS

The safety of fat replacers has been, and will continue to be, based on a consideration of each compound's toxicologic profile, effect on overall diet (eg, likelihood of promoting nutrient deficiencies, excesses, or imbalances) and expected level of use by various segments of the population. Decisions about safety are made by the Food and Drug Administration (FDA) via 2 principle routes (26,31). The first, by which the majority of fat replacers have obtained approval, involves a manufacturer either claiming that an ingredient qualifies as Generally Recognized As Safe (GRAS) or petitioning FDA to grant the ingredient such status. Ingredients that FDA determines are derived from common food components and are generally recognized by scientific experts to be safe for specific applications based on a long-standing history of use or extensive scientific evidence can be approved for inclusion in foods under GRAS status. Examples of fat replacers approved as GRAS include various carbohydrate polymers, gums, gels, and starches; microparticulated proteins; whey proteins; and fat emulsifiers. The second approach entails a manufacturer's request for a new ingredient's approval as a food additive. A food additive is defined as an ingredient not previously found in food whose intended use results, or may reasonably be expected to result, directly or indirectly, in its becoming a component or otherwise affecting the characteristics of any food (32). Such a request requires submission of extensive data on the ingredient's safety and intended use. Once approved, FDA establishes recommended limits on consumption and may require monitoring of use and safety over a period of time. This latter route was followed for sucrose polyester.

DIETARY RESPONSES TO MODIFICATIONS OF FAT INTAKE

Fat replacers may be used for multiple purposes. One motivation is to facilitate a reduction in total and saturated fat consumption by maintaining the appeal of foods reduced in fat content. The goal of fat reduction is to decrease the incidence of obesity and certain chronic diseases. A second purpose may be to reduce total energy consumption to improve health and enhance physical appearance and self-concept. A third option entails using fat replacers to increase the volume of palatable foods that may be consumed without increasing fat or energy intake. Such an approach may facilitate adherence to a diet that maintains a given level of fat and/or energy content. Success in achieving any of these or other aims is difficult to predict because numerous factors (eg, genetic, neural, metabolic, sensory, cognitive, cultural, economic) influence the selection and consumption of foods containing fat. Furthermore, their relative importance will vary between persons and within a person over time.

Successful reduction of fat intake through the use of fat replacers will be determined, in part, by whether fat balance is tightly regulated. That is, to what degree will products containing fat replacers stimulate mechanisms to compensate for the reduction in fat? Short-term studies (ie, over hours) isolating potential physiologic mechanisms through covert manipulations of the fat content of foods, demonstrate that fat reduction does not elicit a fat-specific dietary compensation in children or adults (33,34). Longer-term (ie, over days) studies of similar design have yielded comparable results. Free-living persons or those residing in residential units do not spontaneously alter their consumptive behavior to replace eliminated fat (29,35,36). These findings do not support the existence of a physiologic mechanism tightly regulating fat intake. However, nonphysiologic factors (eg, health beliefs, cultural cuisine) may lead to ingestive behaviors that can offset reductions achieved through the use of fat-modified products (ie, increased intake of fat at other times). Controlled studies indicate that when persons are informed about their actual or presumed use of reduced-fat foods (as will likely be the case in free-living persons) and are not restricted in total energy intake, food intake increases, partially or completely offsetting the true or presumed reduction in fat consumption (37,38). In contrast, with unlimited access to reduced-fat foods only, total fat intake is reduced (39,40). The limited number of more naturalistic and modeling studies suggest that incorporation of reduced-fat products into the diet will result in a net reduction in fat consumption (41-47), but this work is based on study samples not representative of the US population and numerous assumptions (eg, reduced-fat products will replace full-fat items rather than supplement the diet) that leave open questions about their predictions. Nevertheless, the preponderance of evidence indicates that use of reduced-fat products will result in a net reduction of fat intake. Further, replacement of dietary fat with the fat replacer sucrose polyester results in reductions of total and low-density cholesterol (48,49). The influence of fat replacers on the preferred concentration of fat in foods is problematic. Although they can enhance the sensory appeal of reduced-fat products, they may impede acquisition of liking for foods naturally lower in fat content by maintaining a high level of exposure to the mouthfeel normally contributed by fats (50).

Products containing fat replacers may also be used to reduce energy intake. Common experience indicates there is a strong dietary defense against energy dilution or deficit. In most short- and longer-term studies involving manipulation of the macronutrient and energy content of the diet, a marked, albeit often incomplete, energy compensation is observed when the availability of full-fat foods is not restricted (33-35,51-53). A sharper increase in total energy intake is noted with more extreme dietary manipulations (ie, reduction of fat to 20% of energy vs 30% [54] or a change of greater than 10% of energy [29]). When only reduced-fat foods are available, intake is not increased to fully offset the energy reduction and weight loss is common (39,40). Naturalistic and modeling studies indicate that diets reduced in fat may not result in a reduction in total energy consumption (42,43). Thus, unless used as part of a controlled diet, reduced-fat foods may not result in energy or weight reduction. This may be especially true if reduction of fat is extreme and exceeds currently recommended guidelines (ie, 30% of energy).

Reduced-fat products can also be used to expand the diversity and volume of foods that can be consumed while maintaining a given level of fat and energy consumption. To our knowledge, no studies addressing the outcome of this dietary strategy have been undertaken. However, experience with high-intensity sweeteners suggests this is likely to be the most common pattern of use.

USES OF FAT REPLACERS TO ACHIEVE SPECIFIC OUTCOMES

Given that The American Dietetic Association:

- believes there is compelling evidence linking a high-fat diet with the incidence of certain chronic diseases;
- endorses current dietary guidelines regarding moderation of fat intake and maintenance of appropriate body weight;
- recognizes that the majority of the US population does not adhere to a diet consistent with current dietary guidelines;
- notes that trends for reduced consumption of fat from the primary dietary sources have attenuated;
- understands that maintenance of diet palatability is vital to the long-term success of dietary change and contributes to quality of life;
- accepts FDA conclusions regarding the safety of currently approved fat replacers;
- maintains that there is widespread consumer acceptance of and demand for reduced-fat, low-fat, and fat-free products;
- concludes that there is reasonable evidence that the substitution of products containing fat replacers for items higher in fat can result in reductions in dietary fat consumption;
- considers the evidence that the substitution of products containing fat replacers for items higher in energy content to be supportive of a beneficial effect on energy balance if the total diet is restricted in fat and/or energy; and
- acknowledges that use of products containing fat replacers may permit consumption of an increased volume and diversity of foods constituting diets of specified fat and energy content,

the Association affirms that fat replacers may offer a safe, feasible, and effective means to maintain the palatability of diets with controlled amounts of fat and/or energy. The successful use of such products to meet dietary objectives will ultimately be determined by whether they are added to the diet or used to replace a proportion of the fat or energy that would normally have been consumed. Intense sweeteners, which were introduced into the diet for many of the same reasons as fat replacers, are now used largely as additions to the diet. Consumption of intense sweeteners has tripled over the past decade without a concomitant reduction in carbohydrate sweeteners. Further, although there is no evidence for a causal relationship, the proportion of the population that is overweight increased by about 8% during the same time period (3). Thus, their mere use does not guarantee a reduction in body weight or in consumption of the macronutrient they were expected to replace. Similarly, if fat replacers are added to the diet rather than used as replacements for dietary fat, it is unlikely that a reduction of fat and energy intake will ensue.

Safe and effective use of products containing fat replacers should be facilitated through efforts to improve consumer understanding of labeling information, the importance of food preparation practices, portion size and eating frequency control, and the relationship between energy expenditure and total energy balance. This will permit determination of a sensible level of fat replacement for a person in the context of his or her total diet. Use by small children, especially those under 2 years of age, may not be compatible with their high energy needs. Because moderation of fat consumption may be achieved through selection of low-fat, high- (preferably complex) carbohydrate foods, there is no lower or optimal level of recommended use. Scientific evidence addressing upper limits is lacking, although there are reports that attempts to achieve extreme reductions in fat and energy intake through the use of fat replacers will likely lead to strong compensatory behaviors that compromise attainment of dietary aims (29,53). Further, at high levels of consumption, these products may pose a risk for depletion of fat-soluble nutrients and gastric distress (28,29). The best guideline for persons who choose to use fat replacers is that they be incorporated as one component of a total diet that meets current dietary guidelines at a concentration that is well tolerated.

References

1. Stephen AM, Wald NJ. Trends in individual consumption of dietary fat in the United States, 1920-1984. *Am J Clin Nutr.* 1990;52:457-469.

2. McDowell MA, Briefel RR, Alaimo K, Bischof AM, Caughman CR, Carroll MD, Loria CM, Johnson CL. *Energy and Macronutrient Intakes of Persons Ages 2 Months and Over in the United States: Third National Health and Nutrition Examination Survey, Phase 1, 1988-1991.* Hyattsville, Md: National Center for Health Statistics; 1994. Advance Data From Vital and Health Statistics No. 255.

3. Kuczmarski RJ, Flegal KM, Campbell SM, Johnson CL. Increasing prevalence of overweight among US adults: the National Health and Nutrition Examination Surveys, 1960-1991. *JAMA.* 1994;272:205-211.

4. *Nutrition and Your Health: Dietary Guidelines for Americans.* 4th ed. Washington, DC: US Depts of Agriculture and Health and Human Services; 1995. Home and Garden Bulletin No. 232.

5. *Healthy People 2000: National Health Promotion and Disease Prevention Objectives.* Washington, DC: US Dept of Health and Human Services, Public Health Service; 1991. DHHS (PHS) publication No. 91-50213.

6. National Research Council, Committee on Diet and Health. *Diet and Health: Implications for Reducing Chronic Disease Risk.* Washington, DC: National Academy Press; 1989.

7. *US Surgeon General's Report on Nutrition and Health.* Washington, DC: US Dept of Health and Human Services; 1988. DHHS (PHS) publication No. 88-50210.

8. *Per Capita Consumption of Major Food Commodities.* Washington, DC: US Dept of Agriculture; 1997.

9. LaBell F, O'Donnell C. (Lowfat) Food for thought and marketplace realities. *Prepared Foods.* 1997;February:47-52.

10. The Writing Group for the DISC Collaborative Research Group.

Efficacy and safety of lowering dietary intake of fat and cholesterol in children with elevated low-density lipoprotein cholesterol. *JAMA*. 1995;273:1429-1535.
11. Vobecky JS, Vobecky J, Normand L. Risk and benefit of low fat intake of childhood. *Ann Nutr Metab*. 1995;39:124-133.
12. Nicklas TA, Webber LS, Koschak ML, Berenson GS. Nutrient adequacy of low fat intakes for children: the Bogalusa Heart Study. *Pediatrics*. 1992;89:221-228.
13. Sigman-Grant M, Zimmerman S, Kris-Etherton PM. Dietary approaches for reducing fat intake of preschool-age children. *Pediatrics*. 1993;91:955-960.
14. Hampl JS, Betts NM. Comparisons of dietary intake and sources of fat in low- and high-fat diets of 18- to 24-year-olds. *J Am Diet Assoc*. 1995;95:893-897.
15. Mendola P, Marshall J, Graham S, Laughlin RH, Freudenheim JL. Dietary correlates of fat intake. *Nut Cancer*. 1995;23:161-169.
16. Klawansky S, Chalmers TC. Fat content of very low-calorie diets and gallstone formation. *JAMA*. 1992;268:873.
17. Jeppesen J, Schaaf P, Jones C, Zhou M-Y, Chen Y-DI, Reaven GM. Effects of low-fat, high-carbohydrate diets on risk factors for ischemic heart disease in postmenopausal women. *Am J Clin Nutr*. 1997;65:1027-1033.
18. Federation of American Societies for Experimental Biology, Life Sciences Research Office. *Third Report on Nutrition Monitoring in the United States: Executive Summary*. Washington, DC: US Government Printing Office; 1995.
19. Johnson J, Vickers Z. Effects of flavor and macronutrient composition of food servings on liking, hunger and subsequent intake. *Appetite*. 1993;21:25-39.
20. Stubbs RJ, van Wyk MCW, Johnstone AM, Harbron CG. Breakfasts high in protein, fat or carbohydrate: effect on within-day appetite and energy balance. *Eur J Clin Nutr*.1996;50:409-417.
21. de Castro JM. Macronutrient relationships with meal patterns and mood in the spontaneous feeding behavior of humans. *Physiol Behav*. 1987;39:561-569.
22. Kuntz LA. Where is fat reduction going? *Food Product Design*. 1996;March:24-47.
23. Calorie Control Council. Fat reduction in foods. *Calorie Control Council Commentary*. August 1996.
24. Calorie Control Council. Fat replacers. *Calorie Control Council Commentary*. August 1995.
25. Lucca PA, Tepper BJ. Fat replacers and the functionality of fat in foods. *Trends Food Sci Technol*. 1994;51:12-19.
26. Warshaw H, Powers MA, Franz M, Wheeler M. Fat replacers: their use in foods and role in diabetes medical nutrition therapy. *Diabetes Care*. 1996;199:1294-1303.
27. Gershoff SN. Nutrition evaluation of dietary fat substitutes. *Nutr Rev*. 1995;53:305-313.
28. Weststrate JA, van het Hof KH. Sucrose polyester and plasma carotenoid concentrations in healthy subjects. *Am J Clin Nutr*. 1995; 62:591-597.
29. deGraaf C, Hulshof T, Weststrate JA, Hautvast JG. Nonabsorbable fat (sucrose polyester) and the regulation of energy intake and body weight. *Am J Physiol*. 1996;270:R1389-R1393.
30. Food additives permitted for direct addition to food for human consumption: olestra: final rule (21 CFR 172). *Federal Register*. January 30, 1996.
31. Clydesdale FM. Olestra: the approval process in letter and spirit. *Food Technol*. 1997;51:104,185.
32. Midddlekauff RD. Legalities concerning food additives. *Food Technol*. 1974:42-48.
33. Rolls BJ, Pirraglia PA, Jones MB, Peters JC. Effects of olestra, a noncaloric fat substitute, on daily energy and fat intakes in lean men. *Am J Clin Nutr*. 1992;56:84-92.
34. Birch LL, Johnson SL, Jones MB, Peters JC. Effects of a nonenergy fat substitute on children's energy and macronutrient intake. *Am J Clin Nutr*. 1993;58:326-333.
35. Foltin RW, Rolls BJ, Moran TH, Kelly TH, McNeils AL, Fischman MW. Caloric, but not macronutrient, compensation by humans for required-eating occasions with meals and snack varying in fat and carbohydrate. *Am J Clin Nutr*. 1992;55:331-342.
36. Caputo FA, Mattes RD. Human dietary responses to covert manipulations of energy, fat and carbohydrate in a midday meal. *Am J Clin Nutr*. 1992;56:36-43.
37. Caputo FA, Mattes RD. Human dietary responses to perceived fat content of a midday meal. *Intl J Obesity*. 1993;17:237-240.
38. Rolls B, Shide D, Hoeymans N, Jas P, Nicols A. Information about the fat content of preloads, influences energy intake in women. *Appetite*. 1992;19:213.
39. Lissner L, Levitsky DA, Strupp BJ, Kalkwarf HJ, Roe DA. Dietary fat and the regulation of energy intake in human subjects. *Am J Clin Nutr*. 1987;46:886-892.
40. Kendall A, Levitsky DA, Strupp BJ, Lissner L. Weight loss on a low-fat diet: consequence of the imprecision of the control of food intake in humans. *Am J Clin Nutr*. 1991;53:1124-1129.
41. Gatenby SJ, Aaron JL, Morton GM, Mela DJ. Nutritional implications of reduced-fat food use by free-living consumers. *Appetite*. 1995;25:241-252.
42. Whatley JE, Donnelly JE, Jacobsen DJ, Hill JO, Carlson MK. Energy and macronutrient consumption of elementary school children served modified lower fat and sodium lunches or standard higher fat and sodium lunches. *J Am Coll Nutr*. 1996;15:602-607.
43. Beaton GH, Tarasuk V, Anderson GH. Estimation of possible impact of non-caloric fat and carbohydrate substitutes on macronutrient intake in the human. *Appetite*. 1992;19:87-103.
44. Lyle BJ, McMahon KE, Kreutler PA. Assessing the potential dietary impact of replacing dietary fat with other macronutrients. *J Nutr*. 1992;122:211-216.
45. Young VR, Fukagawa MD, Peller PL. Nutritional implications of microparticulated protein. *J Am Coll Nutr*. 1990;9:418-426.
46. *Fat Free Choices: A Guide for Professionals*. Glenview, Ill: Kraft General Foods Technology Center; 1990.
47. Velthuis-te Wierik EJ, Kluft C, van den Berg H, Weststrate JA. Consumption of reduced-fat products, haemostatic parameters and oral glucose tolerance test. *Fibrinolysis*. 1996;10:159-166.
48. Crouse JR, Grundy SM. Effects of sucrose polyester on cholesterol metabolism in men. *Metabolism*. 1979;28:994-1000.
49. Glueck CJ, Hastings MM, Allen C, Hogg E, Bachler L, Gartside PS, Phillips D, Jones M, Hollenbach EJ, Braun B, Anastasia JV. Sucrose polyester and covert caloric dilution. *Am J Clin Nutr*. 1982;35:1352-1359.
50. Mattes RD. Fat preference and compliance with a reduced fat diet. *Am J Clin Nutr*. 1993;57:373-381.
51. Louis-Sylvestre J, Tournier A, Chapelot D, Chabert M. Effects of a fat-reduced dish in a meal on 24-h energy and macronutrient intake. *Appetite*. 1994;22:165-172.
52. Prewitt TE, Schmeisser D, Bowen PE, Aye P, Dolecek TA, Langenberg P, Cole T, Brace L. Changes in body weight, body composition, and energy intake in women fed high- and low-fat diets. *Am J Clin Nutr*. 1990;54:304-310.
53. Gatenby SJ, Arron JI, Jack VA, Mela DJ. Extended use of foods modified in fat and sugar content: nutritional implications in a free-living female population. *Am J Clin Nutr*. 1997;65:1867-1873.
54. Cotton JR, Weststrate JA, Blundell JE. Replacement of dietary fat with sucrose polyester: effects on energy intake and appetite control in nonobese males. *Am J Clin Nutr*. 1996;63:891-896.

■ Recognition is given to the following for their contributions:
Author:
Richard D. Mattes, PhD, MPH, RD
Reviewers:
Dietitians in Business and Communications dietetic practice group (Rita J. Storey, MS, RD); American Society of Nutritional Sciences (Penny M. Kris-Etherton, PhD, RD; Rachel B. Shireman, PhD); Sonja L. Connor, MS, RD; Carol A. Defrancesco, RD; Diabetes Care and Education dietetic practice group (Margaret A. Powers, MS, RD); Institute of Food Technologists (Barry G. Swanson, PhD); Kathleen E. McMahon, PhD, RD; Sandra A. Schlicker, PhD; Susan K. Taylor, MS, RD