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Fat Replacers in Food Production

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Abstract

Dietary factors are implicated in the etiology of a number of chronic degenerative diseases. High fat intake is associated with increased risk for some types of cancer, and saturated fat intake is associated with high blood cholesterol and coronary heart disease. Also, consumption of a diet rich in fat has been identified as a risk factor for excess energy intake, positive energy balance, and the development of obesity. Consequently, health conscious individuals are modifying their dietary habits and eating less fat. Consumer acceptance of any food product depends upon taste—the most important sensory attribute. Although consumers want foods with minimal to no fat or calories, they also want the foods to taste good. Foods formulated with fat replacers are enjoyable alternative to familiar high-fat foods. By choosing these alternative foods, health conscious consumers are able to maintain basic food selection patterns and more easily adhere to low-fat diet.

Keywords: Fat Replacers; Fat Mimetics; Fat Substitutes; Low-Fat.

Introduction

As a food component, fat contributes key sensory and physiological benefits. Fat contributes to flavor, or the combined perception of mouthfeel, taste, and aroma/odor (Lucca, 1994; Mistry, 2001; Sampaio, 2004). Fat also contributes to creaminess, appearance, palatability, texture, and lubricity of foods and increases the feeling of satiety during meals (Romanchik-Cerpovicz, 2002; Sipahioglu, 1999). Fat can also carry lipophilic flavor compounds, act as a precursor for flavor development (e.g., by lipolysis or frying), and stabilize flavor (Romeih, 2002; Tamime, 1999). From a physiological standpoint, fat is a source of fat-soluble vitamins, essential fatty acids, precursors for prostaglandins, and is a carrier for lipophilic drugs (Trudell, 1996, Cooper, 1997, Harrigan, 1989). Fat is the most concentrated source of energy in the diet, providing 9 kcal/g compared to 4 kcal/g for proteins and carbohydrates.

Dietary factors are implicated in the etiology of a number of chronic degenerative diseases (Harrigan, 1989; Haumann, 1986). High fat intake is associated with increased risk for some types of cancer, and saturated fat intake is associated with high blood cholesterol and coronary heart disease (Krauss, 2001; Poppitt, 1995). Also, consumption of a diet rich in fat has been identified as a risk factor for excess energy intake, positive energy balance, and the development of obesity (Thomas, 1992; Wylie-Rosett, 2002; Siggaard,1996).

Overweight and obesity are the fifth leading risk for global deaths. At least 2.8 million adults die each year as a result of being overweight or obese (WHO, May 2012). In 2010, more than 40 million children under five were overweight. Close to 35 million overweight children are living in developing countries and 8 million in developed countries (WHO). In the Indian scenario, even with the growing awareness about health and fitness, more than 3 percent (3 crores) of the Indian population is obese. (Obesity Foindation of India, 2009).

CVDs are the number one cause of death globally: more people die annually from CVDs than from any other cause (WHO, Sept. 2012). An estimated 17.3 million people died from CVDs in 2008, representing 30% of all global deaths. Of these deaths, an estimated

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7.3 million were due to coronary heart disease and 6.2 million were due to stroke (WHO, 2012). In India, about 25 per cent of deaths in the age group of 25- 69 years occur because of heart diseases. The proportion of deaths caused by heart disease is the highest in south India (25 per cent) and lowest - 12 per cent - in the central region (India Today, 2010) .

The Surgeon General's Report on Nutrition and Health states: "High intake of total dietary fat is associated with increased risk for obesity, some types of cancer, and possibly gallbladder disease. Epidemiologic, clinical, and animal studies provide strong and consistent evidence for the relationship between saturated fat intake, high blood cholesterol, and increased risk for coronary heart disease. Excessive saturated fat consumption is the major dietary contributor to total blood cholesterol levels." In addition to the Surgeon General, the National Academy of Sciences, American Heart Association, National Cholesterol Education Program, American Cancer Society, American Dietetic Association, National Institutes of Health, USDA and the Department of Health and Human Services are among the many health and government authorities that advocate reduction of dietary fat for most consumers. Generally, these groups recommend that even healthy consumers would benefit from reducing fat to no more than 30 percent of total calories (Calorie Control Council, 2017).

Considering an average consumption of 34 percent of calories from fat, decreasing intake to 30 percent may not seem a monumental task. However, for many people it is exceedingly difficult. To meet this dietary goal, people need to significantly modify their diets—e.g., choose leaner meats, skin poultry and fish, select low-fat/non-fat dairy products and dressings, and limit fried foods. Of course, consumers' strong desire for high-fat foods makes this difficult. In fact, diet and obesity experts have found that consumers have difficulty maintaining diets once their fat consumption dips below 30 percent of total calories. Nevertheless, millions of consumers are trying to change their "high-fat" ways. A national survey conducted in 2000 by Booth Research Services for the Calorie Control Council revealed 188 million adult Americans (88 percent of the adult U.S. population) consume low- or reduced-fat foods and beverages. Another Council survey shows that two-thirds of adults believe there is a need for food ingredients which can replace the fat in food products. According to *Prepared Foods*, more than 2,000 new low- or reduced-fat products have been introduced since 1997 (Calorie Control Council, 2017). Foods formulated with fat replacers are enjoyable alternative to familiar high-fat foods. By choosing these alternative foods, health conscious consumers are able to maintain basic food selection patterns and more easily adhere to low-fat diet (Calorie Control Council, 1996).

Fat may be replaced in food products by traditional techniques such as substituting water (Chronakis, 1997) or air for fat, using lean meats in frozen entrées (Hsu, 2005), skim milk instead of whole milk (Zalazar, 2002) in frozen desserts (Specter, 1994), and baking instead of frying (Haumann, 1986) for manufacturing or preparing snack foods.Some lipids may be replaced in foods by reformulating with selected ingredients that provide some fat-like attributes (Tarr, 1995; Sipahioglu, 1999). These fat replacers can be lipid, protein or carbohydrate-based (Table 1) and can be used alone or in unique combinations (Akoh, 1998; Costin, 1999; Lucca, 1994; Crehan, 2000; Sandrou, 2000).

The term "fat replacer" is used to describe a wide variety of products that replace some or all of the fat in food. 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.

Types of Fat Replacers

According to Finley and Leveille (1996), 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(Finley et al., 1996).

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(Finely et al., 1996).

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 (Finely et al., 1996) 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 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 (Jones, 1995). 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 (Calorie Control Council,1996).

Classification of Fat Repalcers

Type of Fat Replacer	Type of Food Products	Commercial Names
Carbohydrate-Based		
Carrageenan	Ground beef, hot dogs, processed cheeses, low-fat desserts	Carrageenan
Cellulose (also called microcrystalline cellulose)	Salad dressings, mayonnaise, processed cheese, frozen desserts	Avicel
Powdered cellulose	Fried foods, sauces	Solka-Floc, JUST FIBER
Dextrins	Salad dressings, puddings, spreads, dairy desserts, meat products	N-OIL, instant N-OIL, Stadex
Gums	Bakery products, frozen desserts, yogurts, dairy products, sauces, soups, reduced-fat margarines, Jaguar, meats, soups, pie fillings, sauce mixes, salad dressings	RHODIGEL, Rhodigum, Dycol, Jaguar, Uniguar
Pectin	Dressings, spreads, frozen desserts, cakes, cookies, frostings, soups, sauces and gravies	Splendid
Polydextrose	Bakery products, bakery mixes, chewing gum, confections, frostings,salad dressings, frozen dairydesserts and mixes, gelatins, puddings, candies	Litesse, StaLite
Vegetable fibers	Frozen, reduced-fat bakery products	
Z-trim	Still experimental but has been used successfully in brownies, cheese, ground-beef patties	

Source: Napier K.(1997). Fat Replacers. The Cutting Edge of Cutting Calories.

Type of Fat Replacer	Type of Food Products	Commercial Names
Protein-Based		
Isolated soy protein	Ground meats, poultry products, beverages, weight-loss products	Supro, ProPlus, Supro Plus
Microparticulated protein	Frozen desserts, cheese, cheesecake, salad dressings, mayonnaise, cakes, pie crusts, pie fillings, pastries, spreads, yogurt, sour cream, pizza, cream soups, cheese sauces, casseroles	Simplesse, Trailblazer
Modified whey concentrate	Frozen dairy desserts, hard and processed cheeses, sour cream, dips, yogurt, sauces, baked goods	Dairy-Lo
Fat-Based		
caprenin	Chocolate-containing confections; not currently in any foods on the market	Caprenin
Mono- and diglycerides	Cake mixes, cookies, icings, select dairy products	Dur-Em, Dur-Lo
Salatrim	Confections, baked goods, dairy products	Benefat
Sucrose polyester (olestra)	Potato chips and other savory snacks	Olean

Source: Napier K.(1997). Fat Replacers. The Cutting Edge of Cutting Calories.

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(Calorie Control Council,1996).

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 (Kurtzweil,1996). 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 (International Food Information Council Foundation,1995). Carbohydrate-based fat replacers cannot be used to fry foods, however, as they break down at the high temperatures required for frying(International Food Information Council Foundation,1995).

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 (Napier,1997).

Some of the most popular carbohydrate-based fat replacers include the following (Napier, 1997)

Carrageenan (marketed as carrageenan) is an extract of red seaweed. It gained FDA approved 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 (Kurtzweil,1996), when manufacturers starting 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 (*The Wall Street Journal*,1996). Carrageenan has been consumed by humans for hundreds of years, with no adverse effects reported (Napier,1997).

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 (Calorie Control Council,1996). Cellulose gel is used widely in salad dressings, in mayonnaise, in processed cheeses, and in frozen desserts (Napier,1997).

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 (Calorie Control Council, 1996).

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 (Calorie Control Council, 1996).

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." (Calorie Control Council,1996).Typically, a 40-gram candy bar will contain 8 to 12 grams of polydextrose (*The Wall Street Journal,*1996).

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 (Calorie Control Council, 1996).

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 (Napier, 1997).

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 (Calorie Control Council, 1996).

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 (Napier, 1997).

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 (USDA,1996).

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. 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 (FDA, 1995).

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 (Gershoff, 1995).

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(Calorie Control Council, 1996). Its ability to prevent shrinkage and iciness in frozen foods makes it especially desirable as a fat replacer in those products (Napier, 1997).

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 inground meats and poultry products(Calorie Control Council, 1996).

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 (Calorie Control Council,1996). 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 (Napier, 1997).

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 (Mayo Clinic Health Letter, 1996). 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 (Napier, 1997).

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(Napier, 1997).

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 (Calorie Control Council, 1996).According to the FDA (1995), 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(Finley et al., 1996). The FDA is satisfied, however, that fortifying olestra-containing foods with fat-soluble vitamins adequately offsets this effect (FDA,1995; Cooper et al., 1997).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 (Schlagheck et al., 1994).

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 betacarotene (Napier, 1997).

A recent estimate of the magnitude of this effect is that betacarotene absorption would be reduced by 6.0 to 9.5 percent, depending on how much olestra was consumed along with the carotene-containing food(Cooper et al., 1997). 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 betacarotene *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 (Block et al., 1992; Ziegler,1991). 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 (The Alpha-Tocopherol, Beta Carotene Cancer Prevention Study Group,1994; Rowe,1996).

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 (Hassal,1994). 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 (U.S. Department of Health and Human Services, Food and Drug Administration, 1996).

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 (*FDA Consumer,* 1996).

And olestra appears to offer a benefit: It can inhibit cholesterol absorption and lower blood cholesterol levels (Finley et al., 1996). 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 (Jandacek et al., 1990).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(Crouse et al.,1979). 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 (Beaton et al., 1992).

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 *s*hort *a*nd *l*ong chain *a*cid *tri*glyceride *m*olecules.) 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 (Calorie Control Council.,1996).

Caprenin, like salatrim, provides only about five calories per gram. It is a good substitute for cocoa butter and can be used in confections.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(Calorie Control Council.,1996).

Conclusion

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—feelings of deprivation that can cause dieters to revert to the higher fat eating styles that keep them from achieving healthier body weights (Napier,1997).There is no "magic bullet" to achieving dietary goals. A prudent approach, however, is combining proper nutrition, dietary variety, with a healthy lifestyle, regular exercise, and a reduction of total dietary fat aided by choosing foods formulated with fat replacers (Akoh,1998).

References

1. Akoh, C.C. Synthesis of carbohydrate fatty acid polyesters. In "Carbohydrate Polyesters as Fat Substitutes," ed. 1994.p.9-35.
2. Akoh, C.C. Fat replacers. Food Technology. 1998;52:47-52.
3. Babayan, V.K. (Specialty lipids and their biofunctionality. Lipids. 1987;22:417-420.
4. Bastin S. Fat Replacers. The National Academy of Science's Diet and Health Report, Healthy People 2000: National Health Promotion and Disease Objectives and the Dietary Guidelines for Americans issued jointly by the U.S. Department of Agriculture and the U.S. Health and Human Services. 2000.
5. Beaton GH, Tarasuk V, Anderson GH. (1992). Estimation of possible impact of non-caloric fat and carbohydrate substitutes on macronutrient intake in the human. Appetite. 1992;19:87–103.
6. Cáceres, E., et al. The effect of fructooligosac-charides on the sensory characteristics of cooked sausages, Meat Science, 2004;68:87-96.
7. CCC. "Fat Reduction in Foods," Calorie Control Council, Atlanta, Ga. 1996.p.111.
8. Calorie Control Council. Light Products Survey by Booth Research Services Inc., Atlanta, March, 1996.
9. Calorie Control Council. Fat reduction in foods. Atlanta, January 1996.
10. Calorie Control Council. Fat reduction in foods. Atlanta, August, 1996.

11. Calorie Control Council. Fat Replacers. 2017.
12. Cengiz, E., Gokoglu, N. Changes in energy and cholesterol content of frankfurter-type sausages with fat reduction and fat replacer addition, Food Chemistry, 2005;91:443-447.
13. Chronakis, I.S. Structural-Functional and Water-holding Studies of Biopolymers in Low Fat Content Spreads, Lebensmittel-Wissenschaft und-Technologie, 1997;30:36-44.
14. Cooper, D.A., Webb, D.R., Peters, J.C. Evaluation of the potential for Olestra To Affect the Availability of Dietary Phytochemicals, J.Nutr. 1997;127:1699S-1709S.
15. Cooper, D.A., Berry, D.A., Jones, M.B., Kiorpes, A.L. Olestra's Effect on the Status of Vitamins A, D and E in the Pig Can Be Offset by Increasing Dietary Levels of These Vitamins, Journal of Nutrition, 1997;127:1589S-1608S.
16. Costin, G.M., Segal, R. Alimente funcþionale, Ed. Academica, Galaþi. 1999;188-202.
17. Crehan, C.M., et al. Effects of fat level and maltodextrin on the functional properties of frankfurters formulated with 5, 12, and 30% fat, Meat Sci. 2000;55:463-469.
18. Sharma D.C. India's no.1 killer: Heart disease. India Today. 2010 April 12.
19. Duflot, P. Starches and Sugars Glucose polymers as sugar/fat substitutes, Trends in Food Science & Technology, 1996;7:206.
20. Finley JW, Leveille GA. Macronutrient substitutes. In: EE Ziegler and LJ Filer, Jr., eds. Present Knowledge in Nutrition. 7th ed. Washington, DC: ILSI Press. 1996;581–595.
21. Gershoff SN. Nutrition evaluation of dietary fat substitutes. Nutrition Reviews. 1995;53:304–313.
22. Harrigan, K.A., Breene, W.M. Fat substitutes: Sucrose esters and simplesse, Cereal Foods World, 1989;34:261-267.
23. Haumann, B.F. Getting the fat out – researchers seek substitutes for full-fat fat, Journal of American Oil Chemistry Society, 1986;63:278-286.
24. International Food Information Council Foundation. Uses and nutritional Impact of fat reduction ingredients. IFIC Review, Washington, DC, November. 1995.
25. Jandacek, R.J., Ramirez, M.M., and Crouse, J.R. Effects of partial replacement of dietary fat by olestra on dietary cholesterol absorption in man. Metabolism. 1990;39:848-852.
26. Jones SA. Fat replacers: the broad perspective. The World of Ingredients. 1995 September;8–15.
27. Kennedy, J.P. Structured lipids: Fats of the future. Food Technol. 1991;45(11):76, 78, 80, 83.
28. Krauss, R.M., Eckel, R.H., Howard, B., et al. American Heart Association's (AHA): AHA Dietary Guidelines – Revision 2000: A statement for Healthcare Professionals From the Nutrition Committee of the American Heart Association, Journal of Nutrition, 2001;131:132-146.
29. Kurtzweil P. Taking the fat out of food. FDA Consumer. July–August (Internet edition: http://www.fda.gov). 1996.
30. Lucca, P.A., Tepper, B.J. Fat replacer and the functionality of fat in foods, Trends in Food Science and Technology, 1994;5:12-19.
31. Mayo Clinic Health Letter. Fat Substitutes. 1996;14(6):6.
32. Miller, G.D. and Groziak, S.M. Impact of fat substitutes on fat intake. Lipids 1996;31(S):293-296.
33. Mistry, V.V. Low fat cheese technology, Int.Dairy J. 2001;11:413-422.
34. Murray B.C., et.al. Starch Manufacturing-A Profile.Research Triangle Institute. 1994.
35. Napier Kristine. Fat Replacers.The Cutting Edge Of Cutting Calories. American Council On Science And Health. 1997.
36. Obesity Foundation India. Need for awareness in India. 2009.
37. Ognean C.F., et al. Fat Replacers – Review. Journal of Agroalimentary Processes and Technologies, 2006;12(2):433-442.
38. Hill, J., et al. Effects of a 14 d of covert substitution of olestra for conventional fat on spontaneous food intake, Am. J. Clin. Nutr. 1998;67:1178–1185.
39. Peters, J.C., Lawson, K.D., et al. Assessment of the Nutritional Effects of Olestra, a Nonabsorbed Fat Replacement: Introduction and Overview, Journal of Nutrition, 1997;127:1539S-1546S.
40. Poppitt, S.D. Energy density of diets and obesity, International Journal of Obesity, 1995;19:S20-S26.
41. Romanchik-Cerpovicz, J.E., et al. Moisture Retention and Consumer Acceptability of Chocolate Bar Cookies Prepared With Okra Gum as a Fat Ingredient Substitute, Journal of the American Dietetic Association, 2002;102:1301-1303.
42. Romeih, E.A., et al. Low-fat white-brined cheese made from bovine milk and two commercial fat mimetics: chemical, physical and sensory attributes, International Dairy Journal, 2002;12:525-540.
43. Sampaio, G.R., et al. Effect of fat replacers on the nutritive value and acceptability of beef frankfurters, J. Food Composition and Analysis, 2004;18:469-474.
44. Sandrou, D.K., Arvanitoyannis, I.S. Low-Fat/Calorie Foods: Curent State and Perspective, Critical Reviews in Food Science and Nutrition, 2000;40:427-447.
45. Siggaard, R., Raben, A., Astrup, A. Weight loss during 12 weeks' ad libitum carbohydrate-rich diet in

overweight and normal-weight subjects at a Danish work site, Obesity Research, 1996;4:347-356.

46. Sipahioglu, O., Alvarez, V.B., Solano-Lopez, C. Structure, physico-chemical and sensory properties of feta cheese made with tapioca starch and lecithin as fat mimetics, International Dairy Journal, 1999;9: 783-789.

47. Tamime, A.Y., et al. Processed Cheese Analogues Incorporating Fat-Substitutes 2. Rheology, Sensory Perception of Texture and Microstructure, Lebensmittel-Wissenschsft und Techologie, 1999;32:50-59.

48. Tarr, B.D., Bixby, S.H. Proteinaceous grain-based fat substitute Trends in Food Science & Technology, 1995;6:317-318.

49. B. Thomas, C.D., Peters, J.C., Reed, et al. Nutrient balance and energy expenditure during ad libitum feeding of high-fat and high-carbohydrate diets in humans, American Journal of Clinical Nutrition, 1996 Jul 31;55:934-942.

50. Trudell, M.S., Flansburgh, K.A., Gee, D.L. Carbohydrate-Based Fat Substitute is an Acceptable Replacement for margarine in Pumpkin Bar Recipe, Journal of the American Dietetic Association, 1996;96: A43-A44.

51. USDHHS. "The Surgeon General's Report on Nutrition and Health. Publ. No. 88-50210. U.S. Govt. Print. Office, Washington, D.C. 1988.

52. USDA and USDHHS. Nutrition and your health: Dietary guidelines for Americans. 4th ed., Home and Garden Bulletin, No. 232., U.S. Dept. Agriculture and U.S. Dept. Health and Human Services, Washington, D.C. 1995.

53. Unilever NV. Preparation of polyol fatty acid polyesters. Netherlands Patent 1998;8:601,904.

54. Wylie-Rosett, Judith. Fat Substitutes and Health – An Advisory From Nutrition Committee of the American Hearth Association, Circulation, 2002;105:2800-2804.

55. Zalazar, C.A., et al. Effect of moisture level and fat replacer on physicochemical, rheological and sensory properties of low fat soft cheeses, International Dairy Journal, 2002;12i:45-50.