FAT SUBSTITUTES: A SYSTEMATIC REVIEW

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ABSTRACT

Fat replacer is substance that takes the place of all or some of the fat in a food and yet gives the food a taste, texture, and mouth-feel similar to the original full-fat food. Fat replacers serve two purposes. They reduced the amount of fat in food product, and they usually reduce the calorie content of the food. Fat replacers are carbohydrate based, protein based, fat based. Consumers have directed their interest towards reduced or low-fat food products as they associate them with a reduced risk of obesity and CHD. Weight conscious people are adopting these fat replacers very quickly. As a result, more and more consumers are making it their goal to reduce overall dietary fat in their diet. The health risks are no longer challenged.
Key Factor: Fat replacer, Fat reducer, Low fat

INTRODUCTION

The development of new food products remains challenging, as it must fulfill the customers requirement for products that are simultaneously delicious and healthy (Cruz et al., 2009). Fat replacers, also called fat substitutes, gives mouth feel like to the original full-fat food. Fat replacers have two purposes. They reduce the amount of fat in food, and they usually reduce the calorie content of the food. Other fat-based fat replacers such as olestra, caprenin and benefat are partially absorbed by the body. Emulsifiers can also be used as fat replacers. They contain the same number of calories per gram as fat, but fewer grams of emulsifier are needed to achieve the same taste, texture, and mouth feel as fat.

Fat is the body's most important energy source. Body need fat for normal growth and development similarly for the supply of essential fatty acids and fat soluble vitamins A, D, E, and K. Fatty acids are either saturated, monounsaturated, or polyunsaturated. These can be characterized by their origin. Saturated fats are found mainly in foods of animal origin. These include whole milk, butter, and cheese. Some vegetable products such as coconut and palm oil also are mainly saturated fat. Monounsaturated fats are found mostly in plants but also in animal sources. Olive, peanut, and canola oil are high in monounsaturated fat. Most margarine and hydrogenated vegetable shortenings are also high in monounsaturated fatty acids. Polyunsaturated fats are found primarily in plants and fish. Corn, soybean, and safflower oils contain high amounts of polyunsaturated fats (Sundra Bastin., 1994).

Fat is a major food component and plays important role in sensory and physiological benefits. It is important in developing flavor, mouth feel, taste, and aroma (Mistry, 2001; Sampaio *et. al.*,

2004). It is also responsible for creaminess, appearance; palatability, texture, and lubricity of foods and during meal enhance the satiety. Due to lipophilic flavor it act as originator of flavor development (*e.g.,* by lipolysis or frying), and stabilize flavor (Romeih *et al.*, 2002). Fat-soluble vitamins and essential fatty acids are derived from fat and it is also a carrier for lipophilic drugs (Cooper *et al.*, 1997). In diet provides more energy as compared to other nutrients and supplying 9 kcal/g of energy as compared to the 4 kcal/g for proteins and carbohydrates. Fat soluble vitamins and other phytochemicals are absorbed by the aid of fat in adipose tissues that helps the body to maintain its temperature and serve as energy reserve (Stretch, 2006).

During cooking fat have different purposes *i.e*. its heat transfer quality enable speedy heating and achievement of very high temperatures. Due to its high temperature during frying many desirable sensory properties develop which produce taste and flavor. Sharpness of acid ingredient can be reduced with the help of fat. In a choice of meat, fat provides the flavor and help in the juiciness and tenderness (Sandrou and Arvanitoyannis, 2000).

Health conscious people look for ways to improve nutritional habits without sacrificing psychological satisfaction (Kostias, 1997, O'Brien,2003,Plug,1993).Health conscious peoples are interested in low fat diet since they associate them with a reduced risk of CHD and obesity (Akalin et al., 2008). This behavior has incited the development of "healthier" products. Such products must possess at least one of the following characteristics: a modified composition to avoid or limit the presence of potentially harmful compounds, such as fat, or the possibility of including certain substances, such as fibers, with subsequent added health benefits (Jimenez Colmenero et al., 2001). Low-fat and high-fiber foods can help reduce the risk of cardiovascular diseases, obesity, colon cancer, and other disorders (Mansour & Khalil, 1997). Dietetic fibers have been used in products as potential fat replacers (Mendoza et al., 2001). The carbohydrate based fat replacers rely on their ability to form gels, to increase viscosity, to provide texture and mouth-feel, and to increase water holding capacity (Voragen, 1998). Low fat a product must contain 3 g of fat or less per serving. To be labeled 'reduced fat' or 'reduced calorie,' a product must contain 25% less fat or 25% fewer calories than the regular version of the product. Light foods contain half the fat or one-third the calories of the regular product. Fat-free means the food has less than 0.5 g of fat per serving. Fat enhances food flavor, adds volume, and gives food a particular texture and mouth feel.

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 product (Hsu, 2005), skim milk instead of whole milk (Zalazar, 2002) in frozen desserts (Specter, 1994), and baking instead of frying (Haumann, 1986) for preparing snack foods; Some lipids may be replaced in diet 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). Fat replacers are generally divided into two groups: fat substitutes and fat mimetics. Fat substitutes are ingredients that have a chemical structure somewhat close to fats and have similar physiochemical properties (Lipp, 1998; Kosmark, 1996; & Peters 1997). They are indigestible or contribute lower calories on a per gram basis. Fat mimetics are substance that has distinctly different chemical structures from fat. They are usually carbohydrate or protein-based. They have diverse functional properties that mimic some of the specific physiochemical attributes and

desirable eating qualities of fat: viscosity, mouth feel and appearance (Johnson, 2000; Duflot, 1996; Harrigan, 1989).

Table 1. Classification of fat replacer by nutrient source, energy density, specific application and functional properties.

Type of fat replacer				Nutrient source	Energy density	Specific application	Functional properties
Fat substitutes (derived from fat)	**Olestra/ Olean**			Sucrose polyester of 6-8 fatty acids	noncaloric (not absorbed)	Savory snacks	Texturize, provide flavor and crispiness, conduct heat
	Caprenin			Caprocaprylobehenic triacylglyceride	5 kcal/g	Soft candy, confectionary coatings	Simulating properties of cocoa butter (emulsify, texturize)
	Salatrim			Short and long acyl trigliceryde molecule	5 kcal/g	Chocolate-flavored coatings, deposited chips, caramels and toffees, fillings and inclusions for confectionary, peanut spread	range melting points, hardness, appearance
						baked goods, fillings and inclusions for baked goods;	Emulsify, provide cohesiveness, tenderize carry flavor, replace shortening, prevent staling, prevent starch retrogradation, condition dough
						savory dressings, dips, sauces	Emulsify, provide mouthfeel and lubricity, hold flavorants
						dairy desserts, cheese	provide flavor, body, mouthfeel, and texture, stabilize, increse overrun
Fat mimetics	Derived from protein	**Simplesse**		White egg protein, milk protein	4 kcal/g	Yogurt, cheese, sour cream	stabilize, emulsify
		Simplesse100		Whey protein		baked goods	texturize
						frozen dessert products	texturize stabilize
						frostings	provide mouthfeel, texturize
						salad dressing, dips, mayonnaise	Texturize, provide mouthfeel
						margarine	texturize
						Sauces, soups	texturize
		LITA		zein	1-4 kcal/g	baked goods	texturize
		Trailblazer		White egg protein, serum protein mixed with xanthan gum		dairy products	Stabilize, emulsify
						Soups, sauces	texturize
Fat mimetics	Derived from protein	**N-Flate**		Non fat milk, gums, emulsifiers and modified starch		salad dressing	Texturize, provide mouthfeel
						Icings, glazes, desserts, ice cream	Texturize, stabilize
						ground beef	Texturize, provide mouthfeel, water holding
	Derived from carbohydrate	GUMS	Guar	Galactomannan extracted from leguminous seed	noncaloric	baked goods	retain moisture, retard staling
			Xanthan	Microbial polisaccharide produced by aerobic fermentation of *Xantomonas campestris*			
			Locust bean	Extracted from seeds of the tree *Ceratonia silique*			
			Carrageenan	Sulphated polysaccharides extracted from red seaweed (marine algae of the class *Rhodophyta*)		salad dressings	increase viscosity, provide mouthfeel, texturize,
			Gum arabic	Dry exude from *Accacia* tree			
			Pectins	Cell wall polysaccharides extracted from apple pomace, citrus peel, sugar beet pulp, sunflowers heads		sauces	Thicken, provide mouthfeel, texturize

		Starch: native, modified by acid or enzymatic hydro-lysis, oxidation, dextrinization, crosslinking, or mono-substitution; available in pregelatinized or instant forms	Common corn, high amylose corn, waxy maize, wheat, potato, tapioca, rice, waxy rice	4 kcal/g	Margarine, spreads, dressings, sauces, baked goods, frostings, fillings, meat emulsions	modifying texture, gelling, thickening, stabilizing, water holding
		CELLULOSE **microcrystalline cellulose**	Obtained by mechanical grinding from various plant sources	noncaloric	salad dressings frozen desserts sauces dairy products	contributes body, consistency and mouthfeel, stabilizes emulsions and foams, controls syneresis, adds viscosity, gloss and opacity to foods
		powdered cellulose	Obtained by chemical depolymerization from various plant sources		frying	reducing the fat in fried batter coatings and fried cake donuts
					baked goods	increasing the volume of baked goods because it can stabilize air bubbles and minimize after baking shrinkage
		methyl cellulose	Obtained by chemical derivitization from various plant sources	noncaloric	baked goods frozen desserts dry mix sauces	impart creaminess, lubricity, air entrapment and moisture retention
		hydroxypropyl methyl cellulose	Obtained by chemical derivitization from various plant sources		Sauces, dressings	impart pouring and spooning qualities
		maltodextrins	Produced by partial hydrolysis of starch (corn, potato, oat, rice, wheat, tapioca,)	4 kcal/g	table spreads, margarine imitation sour cream, salad dressings, baked goods, frostings, fillings sauces, processed meat, frozen desserts	build solids and viscosity, bind/control water, contribute smooth mouthfeel
		polydextrose	Randomly-bonded polymer of glucose, sorbitol, and citric or phosphoric acid	1 kcal/g	baking goods and baking mixes, chewing gum, confections, frostings salad dressing, frozen dairy desserts and mixes gelatins, puddings and fillings, hard and soft candy, peanut spreads, fruit spreads, sweet sauces, toppings and syrups	bulking agent, formulation aid, humectant, texturizer smoothness in high-moisture formulation, fat-sparing effect
		β-glucan	Soluble fiber extracted from oats (sometime barley)	1-4 kcal/g	baked goods and a variety of other food products	adding body and texture

TYPES OF FAT REPLACERS

Fat replacers chemically resemble fats, proteins, or carbohydrates are generally categorized into two groups-fat substitutes and fat mimetics. Fat substitutes are macromolecules that physically and chemically resemble triglycerides (conventional fats and oils) and which can replace the fat in foods on a one-to-one, gram-for-gram basis. Often referred to as lipid or fat-based fat replacers, fat substitutes are either chemically synthesized or derived from conventional fats and oils by enzymatic modification. Many fat substitutes are stable at cooking and frying temperatures. *Fat mimetics* are substances that imitate organoleptic or physical properties of triglycerides but which cannot replace fat on a one-to-one, gram-for-gram basis. Fat mimetics, often called protein or carbohydrate based fat replacers, are common food constituents, e.g., starch and cellulose, but may be chemically or physically modified to mimic the function of fat. The caloric value of fat mimetics ranges from 0-4 kcal/g. Fat mimetics generally adsorb a substantial amount of water. Fat mimetics are not suitable for frying because they bind excessive water and denature or caramelize at high temperatures. Many fat mimetics, however, are suitable for baking and retorting. Fat mimetics are generally less flavorful than the fats that the mimetics are intended to replace; they carry water- soluble flavors but not lipid-soluble flavor compounds. Successful incorporation of lipophilic flavors into foods that are formulated with fat mimetics may, therefore, require emulsifiers.

CARBOHYDRATE-BASED FAT REPLACERS

Carrageenan (marketed as carrageenan) is an extract of red seaweed. It gained FDA approved in 1961 for use as an emulsifier, stabilizer and as a thickener. Carrageenan came into popular use as a fat replacer in the early 1990s, 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. Carrageenan has been consumed by humans for hundreds of years, with no adverse effects reported.

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

Powdered cellulose (marketed as Solka-Floc) is an insoluble, non-digestible 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% reduction in fat uptake in fried batter coatings and up to a 20% fat reduction in fried cake donuts. Powdered cellulose is also used in reduced fat sauces products in which the ability of the cellulose to retain relatively large amounts of water is also critically important.

Dextrins (marketed as N-OIL, instant N-OIL, and Stadex) are made from the starches extracted from tapioca, corn, potato, and rice. Dextrins are known for their ability to mimic several fat sensations, including mouth coating, 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 a heat-stable gel, which makes them acceptable for use in some cooked foods. Dextrins are 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.

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

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. Xanthan gum may be found in beverages, in frozen fruit-pie fillings, and in some canned foods.

Pectin (marketed as Splendid and under other brand names) is made from citrus peel and table sugar. Pectin forms a gel that can replace up to 100 % 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.

Z-Trim is a recently developed fat replacer. Its availability was announced in late August 1996 by the USDA. Z-trim is made from the processed hulls of oats, soybeans, peas, and rice or from the bran of corn or wheat. The hulls or bran are processed into microscopic fragments, which are then purified, dried, and milled into a powder. Because the fragments absorb water, they swell to provide the smooth mouthfeel of fat. Z-trim also replaces the moistness and density that fat gives

to foods. Z-trim passes virtually unmetabolized through the human body, so it contributes no calories. No adverse gastrointestinal side effects have been noted from the consumption of Z-trim containing products. Z-trim has already been added successfully to brownies, to ground beef patties, and to cheeses. Z-trim can cut the fat calories in a brownie from 25 % to just 15.5 % of total calories. It can replace up to 15 % 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.

PROTEIN-BASED FAT REPLACERS

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.

Microparticulated protein (marketed under the brand names Simplesse and Trailblazer) is made from microparticulated milk 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.

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. Its ability to prevent shrinkage and iciness in frozen foods makes it especially desirable as a fat replacer in those products.

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

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 now, one type of product meets one of the greatest challenges to fat replacers: It is thermally stable enough to be used in frying. Fat-based fat replacers are made from some of the same ingredients found in natural fats. But because these ingredients are formulated in such a way that the body cannot absorb them completely in some cases, not at all they contribute either fewer calories than their ordinary counterparts or no calories.

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

Salatrim (marketed as Benefat) is the name for a family of reduced-calorie fats typically made from soybean or canola oil. (The name "salatrim" stands for short and long chain acid triglyceride molecules) 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.

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

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