Feature

Getting the fat out

Researchers seek substitutes for full-fat fat

Researchers have pursued many ways to impart the functional and organoleptic properties of fats and oils into food without the nine calories per gram that fats and oils provide. In this article, JAOCS *News Editor Barbara Fitch Haumann reviews some of the approaches tried, the results and the outlook for future developments.*

As many Americans seek to reduce their caloric intake for medical or health reasons, food technologists continue to explore ways to produce food substances that provide the same functional and organoleptic properties as fats but not the calories.

Because fats contribute nine calories per gram compared to the four calories per gram provided by protein or carbohydrates, they are a primary target in efforts to cut calories in food. Any company able to develop a low-calorie material with the mouthfeel, culinary properties and feeling of satiety of fat should reap substantial financial returns.

The search for fat substitutes, or low-calorie fats, has covered many substances. Some already are used in relatively small quantities. Consumers now can buy reduced calorie salad dressings with ingredients replacing traditional oils, or table spreads with less fat than the 80% fat content provided by butter and margarine. Still other potential replacements are being studied in the laboratory. One of the most publicized of these has been Procter & Gamble's sucrose polyester (SPE). Procter & Gamble-financed studies of SPE have been the subject of articles in several publications including the *Wall Street Journal*, a recognition of the potential financial rewards for an approved low-calorie fat or fat substitute.

Fat Replacements

Calories have been reduced in some salad dressing formulations by eliminating oil and using a gum system to suspend flavorings and spices and to provide emulsion stability. A tapioca dextrin and a maltodextrin are among the ingredients used as partial replacements for fats and oils in margarine-type spreads, chocolate drinks, frozen desserts and salad dressings. Polydextrose is used to partially replace sucrose and fats in other foods.

Polydextrose—Polydextrose, patented and produced by Pfizer Inc., is a water-soluble, reduced-calorie polymer of dextrose with small amounts of sorbitol and citric acid. It provides one calorie per gram, as it is only partially metabolized in the human body. Although it is not a fat, it has been used as a replacement for sucrose and a partial replacement for fats to produce low-calorie and reduced-calorie foods.

Polydextrose functions as a bulking agent, texturizing agent and humectant in a variety of foods. It has been approved by the Food and Drug Administration (FDA) for use in specific baked goods and baking mixes, chewing gum, confections, frostings, salad dressings, frozen desserts and mixes, gelatins, puddings, and hard and soft candies. Pfizer is working with food processors to further develop reduced-calorie baked products and frozen desserts, including using polydextrose with aspartame to produce sugar-free products. According to Pfizer, polydextrose provides the texture and mouthfeel of sugar and fat.

Pfizer has two facilities to manufacture polydextrose—a pilot plant in Groton, Connecticut, and a new commercial plant, which went on line in the spring of 1985, in Terre Haute, Indiana.

Polydextrose was deliberately developed as a bulking agent that could be used with synthetic sweeteners. Work on the ingredient began in 1965. Final acceptance by FDA was issued in June 1981, 11 years after a patent for the ingredient had been granted. The company now is seeking approval for its use in other countries.

N-Oil—N-Oil, a tapioca dextrin marketed by National Starch and Chemical Corp., was designed to partially or totally replace fat in food products as well as augment the fat properties of foods. According to the National Starch and Chemical Corp., manufacturers can replace 30–50% of the oil in a salad dressing by using N-Oil. "It has the mouthfeel of a fat," a company spokeswoman said, explaining that the company usually recommends replacing four parts of fat or oil with one part N-Oil plus three parts water. N-Oil, a carbohydrate with four calories per gram, is used usually at 25% concentration, thus providing one calorie per gram in the final product.

Some applications recommended by National Starch and Chemical Corp. are pourable and spoonable dressings and ice cream. In ice cream, N-Oil's role is one of mouthfeel and texture enhancement. "A manufacturer can use 10% butterfat to meet the minimum standards of identity and add N-Oil on top to produce a better quality, richer, creamier, smoother ice cream," the company spokeswoman said.

N-Oil is sold in dry form for food applications. It then has to be heated to act like a fat. However, the company has designed instant N-Oil, which can be used in a dry mix, that doesn't require heat. "Instant N-Oil and N-Oil both are fat replacements and agents for enhanced mouthfeel and texture," the spokeswoman said. They have been used in vegetable fat frozen desserts containing tofu. In Europe, they are being used to replace fats in breakfast sausage. N-Oil has been marketed since January 1984.

Maltrin M-040 Maltodextrin—Maltrin M-040 maltodextrin made from corn starch is a spray-dried carbohydrate that can partially replace the oil in salad dressings, margarines and frozen desserts. Grain Processing Corp., the manufacturer, suggests it can be used to provide formulations with one-half the calories and one-quarter the oil level of a standard formulation while still providing a creamy, fat-like texture. Company officials say it is a unique carbohydrate in that a 25% solids solution produces a soft white gel similar to shortening at room temperature. When heated, this same gel will soften and melt to a clear solution. In salad dressings, they say, it produces a short texture much like oil as opposed to the stringy texture of some gums. The M-040 maltodextrin is completely digestible, thus containing four calories per gram. A 25% or 50% solution will contain one or two calories per gram, respectively, and depending on the application, will replace oil or fats on a gram-for-gram basis. Because it is digestible, it does not produce any laxative effects.

Maltodextrins are generally recognized as safe (GRAS) as direct food ingredients. Grain Processing Corp. suggests this product also can be used in oil and flavor encapsulation, in spray-drying hygroscopic materials, in pan coating and soup and gravy mixes, as a nonbrowning carrier for drying sensitive products and as a film forming agent for certain foodstuffs.

Gums—While gums are not used to replace fat per se in formulations, they do help fulfill some of the functions of oils in reduced-calorie salad dressings in which the oil content has been reduced. Xanthan gum, for instance, a high molecular weight natural carbohydrate or polysaccharide, is used as a suspension stabilizer in pourable salad dressings. Algins from kelp, meanwhile, also can be added to act as emulsifiers and emulsion stabilizers. Formulations may be varied, with oil content ranging from 0–50%, xanthan gum content from 0.20–0.50% and algins from 0.1–0.50%. "The primary function of

Jury still out on fat consumption

Although fats provide essential nutrients important for good health, how much fat should be consumed and what role dietary fats play in disease are questions still being debated.

Americans have been urged to lower their dietary cholesterol and fat intake as a result of a number of studies. Organizations including the American Heart Association, American Cancer Society, National Cancer Institute, U.S. Department of Agriculture and the Department of Health and Human Services have advocated decreasing total fat consumption for diverse health reasons. Backing up this recommendation, a National Institutes of Health expert panel in late 1984 recommended limiting cholesterol intake to less than 300 mg per day, fat intake to 30% of the calories in the diet, saturated fat intake to less than 10% of calories and polyunsaturated fat intake to a maximum of 10% of calories.

Some in the health field suggest that further research will be needed to prove whether such diet modification is needed for healthy, active people. Also, as pointed out by J. Edward Hunter of Procter & Gamble at the 1985 AOCS annual meeting held in Philadelphia, "Making significant long-term dietary changes, such as substantially reducing fat intake, is difficult for many people." Hunter facetiously suggested that a "fastity belt" (a device worn over the mouth) could help people control their eating behavior to reduce consumption of calories from all sources.

Hunter and others in the industry say that the role of dietary fat in the development of certain chronic diseases currently is controversial. Noting that the factors causing atherosclerosis, cancer, heart disease and obesity are not completely known, researchers say the role of polyunsaturated fatty acids and their optimum ratio to saturated fatty acids in the diet are still unknown. Nor is there an easy solution to the problems of overeating or faddish diets and weight control plans. "In the meantime, controlling caloric intake has become the suggested way to lose weight if one can only have the willpower to discipline oneself," Vigen Babayan of New England Deaconess Hospital has written.

Areas of controversy center on dietary fat's role in such diseases as heart disease and cancer and on the influence of dietary fat and cholesterol on serum cholesterol. David Kritchevsky and associates at the Wistar Institute have reported a connection between high caloric intake and tumor development. Michael Pariza and associates at the Food Research Institute, University of Wisconsin, also have reported similar findings. Total calories, Kritchevsky has suggested, may be a more important factor in tumor promotion than the amount of fat consumed. "When you look at dietary treatments, you have to look at dietary interactions. You should look at all the interactions, not just one thing," Kritchevsky said.

Despite recommendations during the past 20 years to decrease fats and oils consumption, disappearance and sales data indicate that actual per capita consumption has increased. During that time, however, mortality rates from heart attacks have decreased in the U.S. Although specific reasons for the decreasing mortality from heart attacks are not known, recognition and increased public awareness of the major risk factors—cigarette smoking, high blood pressure and elevated serum cholesterol—and also more effective treatment of heart disease probably have played a role.

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xanthan gum as an emulsion stabilizer is to give the pourable salad dressing a long shelf-life of up to a year," Kris Jackman of Kelco, division of Merck and Co. Inc., said. Xanthan is used in low-calorie and reduced-calorie dressings to increase viscosity and stability, she said, explaining, "We don't use it to replace fats, but in low calorie dressings where the oil is reduced and more water is added, we need it to stabilize the oil phase."

Lower-calorie "Fats"

Research to formulate food products with specially engineered fat ingredients has been under way for three decades. Such ingredients, because they are less digestible, provide fewer calories.

Work during the 1960s at USDA's Western and Southern regional research laboratories, for example, included research on new type fats with low digestibility. These included amylose esters, succinostearin and adipostearin. Other compounds have been mentioned in a number of patents. In 1960, a patent was granted to A. Minich for dietetic compositions produced from the complete esterification of a polyhydric alcohol with fatty acids. In 1971, F. H. Mattson and R. A. Volpenhein were granted a patent on sugar fatty acid esters and sugar alcohol fatty acid esters (sucrose polyesters) having at least four fatty acid ester groups. These displayed the same physical properties as normal triglycerides but were not absorbed during digestion, which classified them as low-calorie, fat-containing food compositions. Also in 1971, D. D. Whyte was granted a patent on glycerol esters of certain branched carboxylic acids with the same physical properties as triglyceride fats but not digested or absorbed to the same extent. In 1972, Vigen K. Babayan was granted a patent on a process for preparing and purifying polyglycerols and polyglycerol esters. Vernon W. Trost, for work done when at Swift and Co., in 1981 was granted a Canadian patent on low-calorie fat substitutes consisting of partly esterified glyceryl ether compounds with functional properties similar to those of conventional fats but not completely absorbed. Perhaps the most recent patent granted in this area was issued in April 1985 to Donald J. Hamm of CPC International Inc. on low-calorie edible oil substitutes based on thermally stable polycarboxylic acids esterified with saturated or unsaturated alcohols.

Reach Associates Inc., a consulting firm in New Jersey, has coined the terms "CALO fats" and "CAL fats" for low-calorie and modified fats and oils. According to Robert Aries, a chemical engineer and publishing director and editor of *Biotechnology Chemonomics*, CALO fats "must be functionally analogous to the fat they substitute, nontoxic, do not drain the organism of vitamins, and their metabolites must be completely excreted." He added, "Critical factors which influence the ultimate

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USDA data on per capita disappearance of fats and oils show total availability of fats and oils, including fats in meat, was 141 grams per person per day during 1947–49, 162 grams per person per day in 1982 and 166.3 grams per person per day in 1983. These and other USDA data indicate that about 43% of calories available in the American diet comes from fats, up about 16% from that available in the diet in the late 1940s.

However, Hunter and others are quick to add, such data do not take into consideration the amount of fat discarded and not actually eaten. Also, because dietary fat may be in the form of visible (in butter, margarine, cooking oils) or invisible (in meats, nuts, fish, eggs) fats, accurate dietary fat consumption figures are difficult to compile. Disappearance figures do indicate, however, that in recent years Americans have decreased their consumption of fat from animal sources and increased their consumption of vegetable fats and oils. According to USDA's Economic Research Service, the share of fats from vegetable sources, versus from animal fats, increased from 28% in 1950 to 43% in 1982.

According to the Summer/Fall 1985 issue of *Calorie Control Commentary* published by the Calorie Control Council (CCC), its 1984 national consumer survey revealed that more than 68 million Americans are using low-calorie foods and beverages, a 60% increase since a similar CCC survey in 1978. The council noted that results of a *Better Homes and Gardens* survey released in April 1985 also showed more Americans using low-calorie foods than two years ago. The surveys did not specifically mention low-fat foods.

Fred Mattson, currently with the Department of Medicine and Lipid Research Clinic at the University of California, San Diego, at La Jolla, California, said at the 1981 AOCS Dietary Fats and Health conference in Chicago, "Based on our knowledge of nutritional value, physiological functions and metabolic pathways, fat can be assigned its appropriate role in our diet. It is not the perfect food, nor should it be removed from the diet entirely. Rather, as in all things, moderation should be the guide."

Despite recommendations by health advisory organizations that people decrease fat consumption, disappearance and sales data indicate that total fat consumption of many Americans probably has not decreased during the past 20 years. Certainly there has been a shift from saturated animal fats to polyunsaturated vegetable fats and oils, probably the result of educational efforts by health organizations as well as economic factors. For those individuals desiring to reduce their fat intake, the availability of specially engineered low-fat products might be helpful to accomplish this. However, until such products are available, perhaps the most practical way for people to meet recommended guidelines will be to eat less.

energy value of fat products are the heat of combustion, coefficient of digestibility and the degree of utilization in the body."

Jon J. Kabara, in an article in the November 1979 issue of *JAOCS*, wrote, "The short to medium chain (6 to 10 carbons) and unsaturated fatty acids are more readily absorbed than the long chain saturated fatty acids (12 to 18 carbons). Also, the short chain fatty acids appear to enhance the absorption of fats in general, whereas long chain fatty acids tend to impair the process. Furthermore, the monoglycerides of the less well absorbed, long chain fatty acids (i.e., stearic) are better absorbed than the corresponding free fatty acids." He added, "Differences in the rates of digestion and absorption of the individual fatty acids are reflected in the overall rates of digestion and absorption of the dietary fats from which they are derived. Fats and oils with lower melting points (i.e., below 50 C) are more rapidly and completely digested and absorbed than are those with higher melting points."

Vigen Babayan of New England Deaconess Hospital and S. A. Hashim have suggested that high melting point stearines such as tristearine are only partially absorbed when used in food products.

Differences in absorbability relate to the activity and specificity of the lipolytic enzymes in the lumen of the intestinal tract. The intestinal enzymes which normally break down triglycerides are unable to metabolize the higher esters of such substances as sucrose polyester, for instance. The important determinant is the number of ester groups; triesters are essentially completely digested, tetraesters are partially digested and pentaesters are digested even less, while the hexa- and higher esters are not digested at all. Absorption, Mattson points out, is a direct reflection of the extent of hydrolysis.

Reach Associates lists the following substances as possible low-calorie fats or fat substitutes: sugar polyesters, polyglycerol esters, sucrose esters (mono-, di- and triesters), neopentyl-type alcohols, other sugar and sugar alcohol derivatives such as sorbitol and mannitol, glycerol dialkyl ethers, triglyceride esters of alpha branched carboxylic acids, diglyceride esters of short chain dibasic acids, trialkoxytricarballyate, polydextrose, palatinose, polygalactose, N-oil (tapioca dextrin), microbiologically derived products, nonabsorbable synthetic polymers with properties similar to edible oils, tree-derived products, low metabolized natural fats and oils, biopolymers, branched polysaccharides and jojoba oil.

A foot race is on to see which products will be first . . .

It is difficult to determine how many companies currently are investigating possible low-calorie fat substitutes or fat replacements, as company representatives are reticent to discuss their research. However, there is considerable interest in the topic and many companies have work going on in this area.

"Any agent developed to replace fats will offer food manufacturers some advantage, particularly with the current emphasis on calorie-reduced products," Gilbert Leveille, past president of the Institute of Food Technologists and currently General Foods' director of nutrition and health sciences, said. He added, "There are more of these carbohydrate or carbohydrate-like materials being scrutinized by companies to replace fats. It will be a real foot race to see which products get there first. There is no question these materials will be marketed. You will see competition intensifying within the next few years."

Ralph L. Wilkinson of Grain Processing Corp., however, says that the carbohydrate-based fat substitutes such as polydextrose, dextrin, maltodextrins and gums are useful only in "wet" or high moisture food systems kept below 100 C. "They are not suitable for frying," he said. Also, he added, "The laxative effects of many of these compounds appear to be a major problem." He said gums and polydextrose, for instance, can have a laxative effect if consumed in sufficient quantities. "Only the digestible maltodextrins and dextrins appear to avoid this problem," Wilkinson said.

Some of the research under way focuses on the following materials:

Sucrose Polyester

Sucrose polyester (SPE) is a fat-like material consisting of a mixture of octa-, hepta- and hexaesters formed by the reaction of sucrose with long chain fatty acids. Preparation of SPE is accomplished by the esterification of six to eight of the hydroxyl groups of sucrose with long chain fatty acids. SPE has the appearance and physical properties of usual dietary fats but, as it is resistant to hydrolysis by pancreatic and microbial enzymes, is neither digested nor absorbed. Consequently, it supplies no calories.

The use of SPE was patented by Procter & Gamble in 1971. Fred H. Mattson, who left P&G in the late 1970s to join the Department of Medicine and Lipid Research Clinic, School of Medicine at the University of California, San Diego, and R. A. Volpenhein of Procter & Gamble were the researchers who recognized that SPE, containing more than five ester groups, was not digested and thus was not absorbed. P&G research on SPE during the 1970s revealed it had the potential to be used in foodstuffs along with or in place of conventional dietary fats to lower cholesterol or reduce caloric intake.

"It was an odd situation. We were working on the problem of finding a fat that was easy to digest and absorb for premature infants who cannot absorb fats very well," Mattson recalled. In examining differences in digestibility, he said, "We discovered fats that were less, rather than more, digestible.

"Working with these materials, we found sucrose polyester to interfere with the absorption of cholesterol in animals. Subsequently, a drop in blood cholesterol levels was observed in humans." An article published by Mattson, C. J. Glueck and R. J. Jandacek in the *American Journal of Clinical Nutrition* (Vol. 32:1636) in 1979, for instance, noted significant lowering of total and low density lipoprotein plasma cholesterol in controlled human studies.

An early version of SPE was made with some relatively high-melting fatty acids from soybean oil, but tasters complained of a waxy or greasy taste and mouthfeel. A subsequent form was developed using the low-melting fatty acids from safflower oil to esterify sucrose, with the resulting oil then being mixed with hydrogenated palm oil. According to Mattson, the hydrogenated palm oil was introduced to control anal leakage, which can occur if the amount of SPE eaten exceeds gastrointestinal tolerance.

According to medical researcher Charles J. Glueck, there is considerable evidence that SPE produces a persistent oil phase in the gut, thus dissolving cholesterol in the digestive tract and reducing its absorption into the bloodstream. Additional research will determine whether SPE has any undesirable side effects. For instance, there is evidence it may do the same to substances other than cholesterol, including fat-soluble vitamins (see Mattson, Hollenbach and Kuehlthau, *Journal of Nutrition* 109:1688, 1979) and may cause anal leakage in some individuals at large dosages (see Mellies, Jandacek et al., *American Journal of Clinical Nutrition* 37:339, 1983).

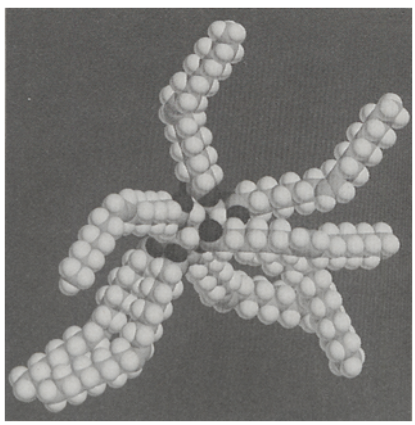
Despite such possible problems, Mattson sees much potential for SPE. "First, it offers a fat with zero calories. You can enjoy the benefits of eating fats without the calories. Secondly, it brings about the lowering of cholesterol. When people have a high cholesterol level, they are told to lose weight to lower cholesterol levels and also to lower cholesterol intake. Sucrose polyester can lower the body weight and help directly to lower the cholesterol level.

"In the experiences we had, particularly in human studies, the material can be used any place where fat can be, in margarines, frying, ice cream and other desserts. And you can't tell the difference when it is placed alongside a regular fat."

Most of Procter & Gamble's human studies with sucrose polyesters have been conducted in conjunction with the Lipid Research Clinic and General Clinical Research Center, University of Cincinnati, under the direction of Dr. Charles J. Glueck.

Sucrose polyester still undergoes substantial testing and must yet gain approval by the Food and Drug Administration (FDA) before it can appear on the market. According to P&G spokesman Don Tassone, "Much of our work in the safety area has been satisfactorily completed. Clinical testing is still in progress." Currently, this testing is being done under the investigational new drug procedure.

Richard W. St. Clair of the Department of Pathology, Wake Forest University Medical Center, Winston-Salem, North Carolina, has studied cholesterol absorption and SPE in African green monkeys. "SPE decreases the [cholesterol] absorption by 15–20%," St. Clair said, explaining that the SPE remains in an oil phase in the intestine; when the cholesterol enters the digestive tract, it dissolves into the oil and is excreted



A computer-generated structure of sucrose octaoleate.

along with the SPE. "SPE reduces cholesterol absorption in the monkeys, whether they are hypo- or hyper-responsive to cholesterol, but it reduces blood plasma cholesterol only in the hyper-responsive monkeys," St. Clair said, adding that as this same phenomenon exists in humans, "The only people who would benefit by using SPE as a cholesterol-lowering drug would be the ones who are hyper-responsive." The question then is what proportion of the population is "hyper-responsive." Since most people show a reduction of plasma cholesterol when they decrease their cholesterol intake and thus the amount available for absorption, one could assume that SPE would have the same effect, Mattson said.

St. Clair said that if problems occur with absorption of fat-soluble vitamins, such problems could be solved by supplements, while anal leakage complications seem to be mostly resolved by mixing the liquid SPE with hydrogenated palm oil. The use of supplements is covered in a U.S. patent issued in 1977 to Jandacek and Mattson and assigned to Procter & Gamble.

Even so, sucrose polyesters may have a limited level of tolerance in humans. One technical question yet to be answered is what dosage levels are safe. A marketing question to be answered is whether Procter & Gamble will seek approvals for SPE as a drug, as a food ingredient, or for both uses. According to Mattson, questions regarding safety and consumer acceptance should be answered before the direction of SPE's marketing can be settled.

While no official announcement has been made, many persons believe P&G has filed a new drug application for SPE. P&G officials are reluctant to comment on the status other than to say they are continuing to work closely with FDA. FDA can officially verify the filing of a new drug application only with consent of the filing company.

Sucrose polyesters already are GRAS as food additives in Japan although they are used for their functional characteristics, not for low-calorie applications. According to an official for Mitsubishi International Corp., Mitsubishi-Kasei Food Corp. of Tokyo, Japan, commercially introduced sucrose polyesters to the Japanese market in 1984. The main uses are as a lubricating agent in pharmaceutical tablets, as an anticaking agent in powdered products such as spices and as an oil-in-water emulsifier for processed fat products; sucrose polyesters also are used in chocolate enrobing to prevent blooming, to prevent foaming in tofu production and to improve heat stability in coffee whiteners. While there are no restrictions preventing their use in the major European Economic Community countries, sucrose polyesters have not been introduced commercially there yet.

Safe dosage levels still need to be determined...

Although sucrose polyesters are not GRAS in the U.S., Mitsubishi has received inquiries from U.S. companies interested in the potential applications for these materials. Mitsubishi is studying use of sucrose polyesters as a low-calorie fat, but reports this work is still only experimental.

Polyglycerol Esters

Polyglycerol esters on the market are used as emulsifiers and dietetic aids. They look and taste like conventional fats and oils but contribute fewer calories. In the European Economic Community, polyglycerol esters are used as emulsifiers in cakes and biscuits and as a gloss enhancer and retardant in chocolates. In the U.S., one product incorporating polyglycerol esters is Weight Watcher's ice cream. "They take out fat and replace it with 3.5% polyglycerol esters, making a product with 57% less calories," Babayan said.

According to Babayan, polyglycerol esters are hybrid fats with fatty acid side chains and a polyglycerol backbone. For fat and caloric reduction, Babayan said, the partial esters are of interest. "The mono- and diesters of such polyglycerols range from 6 to 6.5 calories per gram. These partial esters also have the unique characteristic where the use of a small amount in an aqueous emulsion gives one the palatable satisfaction of eating rich, creamy foods."

Babayan said there is some uncertainty over the metabolic fate of the polyglycerol moiety of the polyglycerol esters. "If the polyglycerol moiety is metabolized, then the hybrid fat figures prevail. If the polyglycerol backbone is not metabolized, a polyglycerol ester such as a decaglycerol monoester becomes less than two calories per gram. Either way, there are many possibilities for this class of compounds since there is no question about their safety and nontoxic nature. This is a very important consideration in selecting the polyglycerol esters for food use. The other consideration is that the polyglycerol esters are multifunctional. They can be an emulsifier, fat replacer, vitamin and flavor solventor carrier, moisturizer or clouding agent. Also, a little goes a long way. Consequently, although initially more expensive per pound than traditional emulsifiers, the polyglycerol esters end up being cost effective and even cheaper in some cases."

Babayan said polyglycerol esters have been found suitable for use in edible products such as ice creams, margarines, shortenings, peanut butter, confectionery coatings, frozen desserts, whipped toppings, vegetable fat coffee cream and bakery products.

Jojoba

Jojoba oil, a free-flowing liquid at temperatures above 10 C, is a mixture of linear esters of monounsaturated long chain fatty acids and fatty alcohols. Both the acid and alcohol components of jojoba oil contain principally 20 to 22 carbon atoms; each has one double bond. Because of its structure, jojoba oil is

being investigated for possible use as a low-calorie food ingredient or cholesterol-reducing agent.

"The use of jojoba in these applications will require approval by the Food and Drug Administration or similar agencies and therefore additional time and financing before products can be marketed to the consumer," Carole Ann Whittaker, president of the Jojoba Growers Association, told attendees at the 1985 AOCS annual meeting in Philadelphia.

Research on jojoba is under way at Nestec Ltd. of Switzerland, a research department for the Nestle group. According to Nestec scientists Krishna Anantharaman and Umberto Bracco, Nestec's research on jojoba oil which began in 1979 showed that jojoba oil was not hydrolyzed in vitro by pancreatic lipase because of its structure, yet the oil performed similarly to other vegetable oils. After the first in vitro trials, Nestec undertook in vivo trials with rats. In these studies, only 40% of the oil was absorbed.

"Now we need to determine safe dosage levels," Anantharaman said. In preliminary tolerance tests, Nestec experimented with different doses of jojoba oil. "At 16% by weight basis, animals don't grow," Anantharaman noted, explaining that all other nutrients were adequate in the diet. Above 16% by weight basis, the rats developed diarrhea and died within several days. At 12%, there were no adverse symptoms in rats although the growth rate was reduced slightly. To compensate, rats had to eat more calories.

"We need to be prudent in interpreting results from the animal studies," Anantharaman said, adding, "For instance, we do not know whether jojoba diminishes the availability of fat-soluble vitamins. When human studies are undertaken, we need to pay particular attention to jojoba oil's effect on other dietary nutrients."

So far, no adverse effects on the liver, kidneys, reproductive organs or heart have been seen, although Nestec scientists have observed some serum transaminases, marker enzymes which could indicate liver damage. "We are not sure what is causing this," Anantharaman said. Nestec studies also have shown a small amount of jojoba fatty acids is stored in the liver but this clears very quickly when jojoba is not used in the diet, Bracco said.

"One of our objectives is to see if you can offer an individual the food of his choice yet maintain his weight," he added, predicting that the jojoba products tested will not be marketed in the foreseeable future for general consumption because of high costs and limited availability. "Instead, if and when it does become practical, its use is more likely to be directed in special dietary situations, for calorie control regimens and under medical or clinical supervision," Bracco said.

Possible uses being considered by Nestec are obesity control or treatment of related disorders. "Jojoba oil is very attractive. It doesn't have an undesirable taste, its physical characteristics are good and it is a natural product," Bracco said, adding that Nestec will approach FDA when it has sufficient evidence of jojoba's safety.

Meanwhile, Nestec also has conducted rat studies on orange roughy (fish) oil but has tabled research for now. "Orange roughy has more or less the composition of jojoba and is 45% digested. However, jojoba oil has some organoleptic advantages, in that it has no odor reversal problems and is more stable. We feel it is the more promising," Bracco said.

CPC Patent

Meanwhile, research at CPC International has resulted in a 1985 patent for low-calorie edible oil substitutes. The substances, invented by Donald J. Hamm, are comprised of thermally stable polycarboxylic acids having two to four carboxylic acid groups esterified with saturated or unsaturated alcohols having straight or branched carbon chains consisting of eight to 30 carbon atoms.

As spelled out by the patent, the objective was to provide a low-calorie substitute for edible oil in oil-based food compositions. This could include use as a low-calorie cooking oil or, combined with other ingredients, use in margarine or mayonnaise.

Noting that the low-calorie substitutes derived exhibit physical and functional properties similar to triglyceride vegetable oils, the patent document said the fatty alcohol analogues of similar fatty acids are esterified onto a polycarboxylic acid backbone. It noted that because the ester units are reversed from the corresponding esters present in triglyceride oils, the esters in the low-calorie substitutes are not susceptible to enzymatic hydrolysis with lipases. "Therefore, these low-calorie substitutes are not seen to represent absorbable calories in the diet," the document states.

The document noted that one example of such a low-calorie substitute, and one of the most preferred, is trioleyltricarballylate. Animal feeding studies conducted revealed poor tolerance and deaths of rats at higher doses of the substitute oils, but CPC attributed these to secondary metabolic disturbances caused by the laxative effects of the oils rather than to direct toxicity.

Other CPC Research

CPC, in cooperation with Battelle Memorial Laboratory, also looked at five other substances—trialkoxytricarballylate (TATCA), trialkoxycitrate (TAC), trialkoxyglyceryl ether (TGE), sucrose polyester and refined jojoba oil—as possible low-calorie replacements for conventional edible fats and oils. Their findings were reported by Hamm in the March-April 1984 issue of the *Journal of Food Science*.

The study reported that TATCA and jojoba oil, when fed to rats at moderate to high dose levels, caused problems including anal leakage, depression, weakness and death. Noting that the toxicological safety of both TATCA and jojoba remain open to question, Hamm suggested that the deaths of the rats might be attributed to starvation as a result of interference with nutrient absorption rather than to toxicity. Hamm concluded that TATCA, due to its close structural resemblance to a triglyceride, appeared to be the most flexible candidate as a direct

substitute low-calorie replacement for edible fats and oils in food use. SPE and TGE, he said, appeared to show sufficient functional properties for broad applications although the difficulty in synthesizing TGE might severely limit its commercial viability. TAC, the study showed, did not have the thermal stability for use in frying, while jojoba oil solidified well above refrigerator temperatures. Hamm wrote that any of these substances still need to be proven safe for food use and their defects overcome.

Obstacles

Questions remain on the potential for dietary fat substitutes. One industry research leader told *JAOCS*, "Frankly, I'm not too optimistic about the commercial success of dietary fat substitutes. In my opinion, you are better off eating less fat."

Certainly a key question facing researchers is determining what level is safe for using nonabsorbable fats in the diet. Also, anal leakage seems to be a common problem with all of the specially engineered fats, David Kritchevsky of Wistar Institute said, adding, "I don't believe anyone has solved that yet."

Other concerns center on the problem of obtaining regulatory clearance for such substances. "The amount of testing required is astounding. The government requires a lot of tests and rightfully so. But it means substantial investment by companies," another researcher noted.

"The problem of clearance of such materials for dietary use is possibly an insurmountable one, since food additives are typically approved at no more than 1% of the 'no effect' level in the diet," Thomas Donnelly of Loyola University of Chicago said. He added, "It may well be that the 'over-the-counter' availability of nonmetabolizable lipids for use as general calorie control agents will not be forthcoming, and that our use of such materials for the reduction of caloric intake, or even as pharmacodynamic lipids, will begin as prescription drugs under a physician's supervision."

Donnelly, who worked with Trost at Swift and Co. in the research leading to Trost's Canadian patent in 1981 on partly esterified glyceryl ether compounds, said the questions of clearance and possible use remain major problems. "Using nonabsorbable fats may be a pipe dream unless there is a major change in the food law," he said.

Raj Aneja, director of research for Nutrimed Biotech at Cornell University Research Park, in Ithaca, New York, disagrees. "I don't believe that the existing legislation is the primary hurdle; rather, the obstacle is the properties of the lipid materials which have been proposed so far. Whatever the law, it would be essential, and rightly so, to require an appropriate amount of biological safety studies to gain approval either as a food ingredient or as a drug application." He added, "For an application as a food ingredient, the side effects such as anal leakage, loss of fat-soluble vitamins and other pharmacodynamic effects have been recognized widely. In my view, important additional aspects are potential metabolism of unabsorbed fats by the gut microflora and the toxicological effects of the metabolites. Nothing is known about these aspects. These technological shortcomings unhappily are perceived as an uncompromising law."

Aneja believes the main obstacle to gaining approval for such substances as food ingredients has been the pharmacological effects noted. "As soon as the word 'drug' appeared, the drug aspect has become more prominent in the approach to the Food and Drug Administration and the use as a possible food ingredient has become dimmer," Aneja said.

According to Aneja, any company able to successfully study a material and determine safe doses for human consumption will find a ready market for the product. He said that Nutrimed Biotech is in "an early stage" of designing nonabsorbable lipids, with the goal of developing a material that doesn't remove essential fatty acids or fat-soluble vitamins from the body. However, the company does not anticipate doing studies with animals for some time.

Nestec scientists, noting that the amount of testing required is an obstacle, question whether the type of testing sought is always appropriate. "The law should ensure safety for the consumer, but there should be a difference in the application of the law depending on the substance. It should ask an applicable set of questions, versus the same list of questions for all substances. For instance, jojoba oil is a natural material, while sucrose polyester is synthetic," Anantharaman said.

"The amount of testing required is astounding . . ."

Anthony Brunetti of FDA's Division of Food and Color Additives said that while existing regulations might allow a substance such as sucrose polyester to become a food additive or a drug, such substances also might fall into the category of a medical food.

"The issue of medical foods is an area where we don't have regulations established. We're talking about something used as a food but that has a medical implication. FDA currently is working on how this would fit within the provisions of the Federal Food, Drug and Cosmetic Act," Brunetti said. He added, "Any regulation of these substances all comes back to the questions of intended effect and use level."

Others in the industry wonder if FDA approval is obtained, will consumers want to use products containing synthetic nonabsorbable fats? "That will be one obstacle for their marketing," one industrial spokesman said, adding that the strategy to create low-calorie foods

by substituting water or air instead of a nonabsorbable fat for some of the oil avoids this problem. However, some point out that substituting water for fat can result in a less desirable product, such as a diet margarine which doesn't spread well.

A 1984 Frost & Sullivan report, "Diet Foods and Beverages," predicted reduced-fat foods will have an annual growth rate of 2.6% through 1990. The report predicted long-term stable trends, such as moves to tuna packed in water rather than oil, less fattening salad dressings and butter/margarine combinations. Also, the firm predicted, low-fat frozen desserts will grow by several hundred million dollars. It added that the bulking agent polydextrose will have an impact on the market.

Meanwhile, the industry searches for a substance to be developed sufficiently to apply for possible food use.

"The recommendation to eat less is laudable in a puritanical sort of way but ignores a part of the spectrum of innate biochemical and psychophysical needs which are satisfied by eating in general and eating fatty foods in particular. So there has been and remains a tremendous interest in nonabsorbable lipids," Aneja said. He added, "Somehow a successful product has always been just around the corner. It hasn't been seen yet, but there is hope."